



ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๒๔ (พ.ศ. ๒๕๕๗)

เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป

อาศัยอำนาจตามความในมาตรา ๓๒ และมาตรา ๓๔ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ อันเป็นพระราชบัญญัติที่มีบทบัญญัติบางประการเกี่ยวกับการจำกัดสิทธิและเสรีภาพของบุคคล ซึ่งมาตรา ๒๙ ประกอบกับมาตรา ๓๕ มาตรา ๔๔ มาตรา ๕๐ และมาตรา ๕๑ ของรัฐธรรมนูญแห่งราชอาณาจักรไทยบัญญัติให้กระทำได้โดยอาศัยอำนาจตามบทบัญญัติแห่งกฎหมาย คณะกรรมการสิ่งแวดล้อมแห่งชาติ จึงได้มีมติในคราวการประชุมครั้งที่ ๒/๒๕๕๗ เมื่อวันที่ ๒๔ กุมภาพันธ์ ๒๕๕๗ ให้ปรับปรุงแก้ไขมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป ดังต่อไปนี้

ข้อ ๑ ให้ยกเลิกความใน (๔) ของข้อ ๒ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๐ (พ.ศ. ๒๕๓๕) ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป และให้ใช้ความต่อไปนี้แทน

"(๔) ค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์ ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๑๒ ส่วนในล้านส่วน หรือไม่เกิน ๐.๓๐ มิลลิกรัมต่อลูกบาศก์เมตร และค่ามัธยฐานเลขคณิต (Arithmetic Mean) ในเวลา ๑ ปี จะต้องไม่เกิน ๐.๐๔ ส่วนในล้านส่วน หรือไม่เกิน ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร"

ข้อ ๒ ให้ยกเลิกความใน (๒) และ (๓) ของข้อ ๔ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๐ (พ.ศ. ๒๕๓๕) ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป และให้ใช้ความต่อไปนี้แทน

"(๒) ค่าเฉลี่ยของฝุ่นละอองขนาดเล็กไม่เกิน ๑๐ ไมครอน ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๑๒ มิลลิกรัมต่อลูกบาศก์เมตร และค่ามัธยฐานเลขคณิต (Arithmetic Mean) ในเวลา ๑ ปี จะต้องไม่เกิน ๐.๐๕ มิลลิกรัมต่อลูกบาศก์เมตร

(๓) ค่าเฉลี่ยของฝุ่นละอองรวมหรือฝุ่นละอองขนาดเล็กไม่เกิน ๑๐๐ ไมครอน ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๓๐ มิลลิกรัมต่อลูกบาศก์เมตร และค่ามัธยฐานเลขคณิต (Arithmetic Mean) ในเวลา ๑ ปี จะต้องไม่เกิน ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร"

ประกาศ ณ วันที่ ๙ สิงหาคม พ.ศ. ๒๕๕๗

(ลงนาม) จาตุรนต์ ฉายแสง
(นายจาตุรนต์ ฉายแสง)

รองนายกรัฐมนตรี

ปฏิบัติหน้าที่ประธานคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ราชกิจจานุเบกษา ฉบับประกาศทั่วไป เล่ม ๑๒๑ ตอนพิเศษ ๑๐๔ ง วันที่ ๒๒ กันยายน ๒๕๕๗



ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๒๑ (พ.ศ. ๒๕๔๔)

ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ

พ.ศ. ๒๕๓๕

เรื่อง กำหนดมาตรฐานค่าก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไป

ในเวลา ๑ ชั่วโมง

อาศัยอำนาจตามความในมาตรา ๓๒ และมาตรา ๓๔ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ คณะกรรมการสิ่งแวดล้อมแห่งชาติ จึงมีมติว่า ให้ยกเลิกมาตรฐานค่าก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไปในเวลา ๑ ชั่วโมงไว้ดังต่อไปนี้

(๑) ให้ยกเลิกข้อ ๒ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๒ (พ.ศ. ๒๕๓๔) ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ เรื่อง กำหนดมาตรฐานค่าก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไปในเวลา ๑ ชั่วโมง

(๒) ให้ยกเลิกความในข้อ ๓ และข้อ ๕ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๒ (พ.ศ. ๒๕๓๔) ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ เรื่อง กำหนดมาตรฐานค่าก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไปในเวลา ๑ ชั่วโมง และให้ความต่อไปนี้แทน

“ข้อ ๓ ค่าเฉลี่ยความเข้มข้นของก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไปเป็นเวลา ๑ ชั่วโมง จะต้องไม่เกิน ๐.๓๐ ส่วนในล้านส่วน (ppm) หรือไม่เกิน ๗๘๐ ไมโครกรัมต่อลูกบาศก์เมตร”

“ข้อ ๕ การวัดค่าเฉลี่ยความเข้มข้นของก๊าซซัลเฟอร์ไดออกไซด์ในบรรยากาศโดยทั่วไปในเวลา ๑ ชั่วโมง ตามข้อ ๓ ให้ใช้เครื่องวัดระบบ ยูวี ฟลูออโรสเซน หรือระบบอื่นที่กรมควบคุมมลพิษประกาศในราชกิจจานุเบกษา”

ประกาศ ณ วันที่ ๕ เมษายน พ.ศ. ๒๕๔๔
(นายเดช บุญ-หลง)

รองนายกรัฐมนตรี ปฏิบัติหน้าที่
ประธานคณะกรรมการสิ่งแวดล้อมแห่งชาติ

(ประกาศในราชกิจจานุเบกษา เล่ม ๑๑๘ ตอนพิเศษ ๓๕ ง ลงวันที่ ๓๐ เมษายน ๒๕๔๔)



ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ณ วันที่ ๑๐ (พ.ศ. ๒๕๓๕)

ออกตามความในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ

พ.ศ. ๒๕๓๕

เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป

อาศัยอำนาจตามความในมาตรา ๓๒ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ คณะกรรมการสิ่งแวดล้อมแห่งชาติได้กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไปไว้ดังต่อไปนี้

ข้อ ๑ ในประกาศนี้

"เครื่องวัด ระบบนินทีสเปกโตรสโกปี อินฟราเรด ดิสเพอร์สिव (Non-dispersive Infrared Detection)" หมายความว่า เครื่องมือวัดค่าก๊าซคาร์บอนมอนอกไซด์โดยใช้รังสีอินฟราเรด

"เครื่องวัดระบบเคมีลูมิเนสเซน (Chemiluminescence)" หมายความว่า (๑) เครื่องมือวัดค่าก๊าซไนโตรเจนไดออกไซด์โดยใช้ก๊าซไอโซนทำปฏิกิริยากับก๊าซไนตริกออกไซด์ ซึ่งถูกเปลี่ยนมาจากก๊าซไนโตรเจนไดออกไซด์แล้ววัด

ความเข้มของแสงซึ่งเกิดจากปฏิกิริยานี้ ณ ที่ความยาวคลื่นที่สูงกว่า ๖๐๐ นาโนเมตร (Nanometer) หรือ (๒) เครื่องมือวัดค่าก๊าซไอโซนโดยใช้ก๊าซคาร์บอนไดออกไซด์ทำปฏิกิริยากับก๊าซไอโซน

แล้ววัดความเข้มของแสงซึ่งเกิดจากปฏิกิริยานี้ ณ ที่ความยาวคลื่นระหว่าง ๓๕๐ ถึง ๕๕๐ นาโนเมตร

"ระบบพาราโรซาลีน (Pararosaniline)" หมายความว่า การวัดค่าก๊าซซัลเฟอร์ไดออกไซด์ โดยการดูดกลืนแสงตามสเปกตรัมโฟโตสเต็มเมตรสโคปโรเบคการูด (Parasium Tetrachloromercure) เกิดกับสารไดคลอโรซัลไฟด์โมลิกิวรูด กลอมเพลกซ์

๒๔๓

(Dichlorosulfite Mercurate Complex) ทำปฏิกิริยากับสารพาราโรซาลีนและฟอร์มาลดีไฮด์ (Pararosaniline and Formaldehyde) เกิดเป็นสีของพาราโรซาลีนไดมิด ซัลฟอนิก แอซิด (Pararosaniline Methyl Sulfonic Acid) ซึ่งจะถูกวัดความยาวคลื่นในการดูดซับแสง ณ ที่ช่วงคลื่น ๕๔๔ นาโนเมตร

"เครื่องวัดระบบอะตอมมิค แอปซอร์ปชัน สเปกโตรมิเตอร์ (Atomic Absorption Spectrometer)" หมายความว่า เครื่องมือวัดปริมาณของตัว โดยใส่เปลวไฟอะเซทิลีน (Acetylene Flame) ที่ความยาวคลื่น ๒๘๓.๓ หรือ ๒๑๗ นาโนเมตร

"ระบบกราวิเมตริก (Gravimetric)" หมายความว่า การวัดค่าฝุ่นละออง โดยดูดอากาศผ่านแผ่นกรอง ซึ่งมีประสิทธิภาพในการกรองฝุ่นละอองขนาด ๐.๓ ไมครอน (Micron) ได้ร้อยละ ๙๙ แล้วหาน้ำหนักฝุ่นละอองจากแผ่นกรองนั้น

ข้อ ๒ ถ้าก๊าซในบรรยากาศโดยทั่วไปในช่วงเวลาหนึ่งเวลาใดให้เป็นไปดังต่อไปนี้

(๑) ค่าเฉลี่ยของก๊าซคาร์บอนมอนอกไซด์ในเวลา ๑ ชั่วโมง จะต้องไม่เกิน ๓๐ ส่วนในล้านส่วน (ppm) หรือไม่เกิน ๓๔.๒ มิลลิกรัมต่อลูกบาศก์เมตรและในเวลา ๘ ชั่วโมง จะต้องไม่เกิน ๕ ส่วนในล้านส่วน หรือไม่เกิน ๑๐.๖ มิลลิกรัมต่อลูกบาศก์เมตร

(๒) ค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์ในเวลา ๑ ชั่วโมง จะต้องไม่เกิน ๐.๑๗ ส่วนในล้านส่วน หรือไม่เกิน ๐.๓๒ มิลลิกรัมต่อลูกบาศก์เมตร

(๓) ค่าเฉลี่ยของก๊าซโอโซนในเวลา ๑ ชั่วโมง จะต้องไม่เกิน ๐.๑๐ ส่วนในล้านส่วน หรือไม่เกิน ๐.๒๐ มิลลิกรัมต่อลูกบาศก์เมตร

(๔) ค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๑๒ ส่วนในล้านส่วน หรือไม่เกิน ๐.๓๐ มิลลิกรัมต่อลูกบาศก์เมตร และค่าเฉลี่ยมีเมธิลเมตริก (Geometric Mean) ในเวลา ๑ ปี จะต้องไม่เกิน ๐.๐๔ ส่วนในล้านส่วน หรือไม่เกิน ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร

ข้อ ๓ การคำนวณค่าความเข้มข้นของก๊าซแต่ละชนิดในบรรยากาศโดยทั่วไปให้คำนวณเทียบกับที่ความดัน ๑ บรรยากาศ และอุณหภูมิ ๒๕ องศาเซลเซียส

ข้อ ๔ ค่าสารในบรรยากาศโดยทั่วไป ในช่วงเวลาหนึ่งเวลาใดให้เป็นไปดังต่อไปนี้ (๑) ค่าเฉลี่ยของตัวในเวลา ๑ เดือน จะต้องไม่เกิน ๑.๕ ไมโครกรัมต่อ

ลูกบาศก์เมตร

(๒) ค่าเฉลี่ยของฝุ่นละอองขนาดไม่เกิน ๑๐ ไมครอน ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๑๒ มิลลิกรัมต่อลูกบาศก์เมตร และค่าเฉลี่ยมีเมธิลเมตริกค่าในเวลา ๑ ปี จะต้องไม่เกิน ๐.๑๕ มิลลิกรัมต่อลูกบาศก์เมตร

๒๔๔

(๓) ค่าเฉลี่ยของฝุ่นละอองรวมหรือฝุ่นละอองขนาดเล็กไม่เกิน ๑๐๐ ไมครอน ในเวลา ๒๔ ชั่วโมง จะต้องไม่เกิน ๐.๓๓ มิลลิกรัมต่อลูกบาศก์เมตร และถ้ามีขมิ้ม เราคาดคะเนของสารดังกล่าวในเวลา ๑ ปี จะต้องไม่เกิน ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร

ข้อ ๕ การวัดค่าเฉลี่ยของก๊าซคาร์บอนมอนอกไซด์เป็นเวลา ๑ ชั่วโมงหรือในเวลา ๘ ชั่วโมง ให้ใช้เครื่องมือวัดระดับบนนั้นดีสเพลอร์ซีฟ อินฟราเรด ดีเทกชั่น หรือระบบอื่นที่กรม ความปลอดภัยให้ความเห็นชอบ

ข้อ ๖ การวัดค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์หรือก๊าซโอโซนในเวลา ๑ ชั่วโมง ให้ใช้เครื่องมือวัดระดับบนที่มีคุณสมบัติ หรือระบบอื่นที่กรมความปลอดภัยให้ความเห็นชอบ

ข้อ ๗ การวัดค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์เป็นเวลา ๒๔ ชั่วโมง หรือใน เวลา ๑ ปี ให้ใช้วิธีการวัดแบบแพร่โรซาบีลีน หรือระบบอื่นที่กรมความปลอดภัยให้ความเห็นชอบ

ข้อ ๘ การวัดค่าเฉลี่ยของตะกั่วเป็นเวลา ๑ เดือน ให้เก็บอากาศผ่านแผ่นกรองใน เครื่องเก็บตัวอย่างอากาศชนิดไฮโดรเจน (High Volume-Air Sampler) สักดะกักออกจาก แผ่นกรองโดยให้กรดดินประสีวและกรดเกลือ แล้วนำไปวัดค่าของตะกั่วโดยใช้เครื่องมือวัด ระบบเคตตอมมิก แกรฟิเคชัน สเปกโตรมิเตอร์ หรือระบบอื่นที่กรมความปลอดภัยให้ตาม เห็นชอบ

ข้อ ๙ การวัดค่าเฉลี่ยของฝุ่นละอองรวมหรือฝุ่นละอองขนาดเล็กไม่เกิน ๑๐ ไมครอน ในเวลา ๒๔ ชั่วโมง หรือในเวลา ๑ ปี ให้ใช้วิธีการวัดตามระบบกราวินดริก หรือระบบ อื่นที่กรมความปลอดภัยให้ความเห็นชอบ

ข้อ ๑๐ การวัดค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์อย่างใดตามข้อ ๕ ถึงข้อ ๗ ให้ ทำในบรรยากาศทั่วๆ ไป และต้องสูงจากพื้นดินอย่างน้อย ๓ เมตร แต่ไม่เกิน ๖ เมตร การวัดค่าเฉลี่ยของตะกั่วและฝุ่นละอองตามข้อ ๘ และข้อ ๙ ให้ทำในบรรยากาศ ทั่วๆ ไป และต้องสูงจากพื้นดินอย่างน้อย ๑.๕๐ เมตร แต่ไม่เกิน ๖ เมตร

ประกาศ ณ วันที่ ๑๗ เมษายน พ.ศ. ๒๕๓๘

ชวน หลีกภัย

นายกรัฐมนตรี

ประธานคณะกรรมการสิ่งแวดล้อมแห่งชาติ

(ประกาศในราชกิจจานุเบกษา เล่ม ๑๑๒ ตอนที่ ๒๕ พงศก ๒๕๓๘)

แก้คำผิด

ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๑๐ (พ.ศ. ๒๕๓๘) ออกตามความในพระราชบัญญัติส่งเสริมและรักษา
คุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕

เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป
ซึ่งประกาศในราชกิจจานุเบกษา
ฉบับประกาศทั่วไป เล่ม ๑๑๒ ตอนที่ ๒๕ พงศก ๒๕๓๘

หน้า ๕๑ บรรทัดที่ ๑๕ คำว่า
“ไม่เกิน ๐.๑๕ มิลลิกรัม” ให้แก้เป็น
“ไม่เกิน ๐.๐๕ มิลลิกรัม”

(ประกาศในราชกิจจานุเบกษา เล่ม ๑๑๒ ตอนที่ ๑๖ ง วันที่ ๕ กันยายน ๒๕๓๘)

ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๓๓ (พ.ศ. ๒๕๕๒)

เรื่อง กำหนดมาตรฐานค่าก๊าซไนโตรเจนไดออกไซด์ในบรรยากาศโดยทั่วไป

โดยที่เป็นการสมควรกำหนดมาตรฐานค่าก๊าซไนโตรเจนไดออกไซด์ในบรรยากาศโดยทั่วไป เพื่อเป็นเกณฑ์ทั่วไปสำหรับการส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมตามพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕

อาศัยอำนาจตามความในมาตรา ๓๒ (๔) และมาตรา ๓๔ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ อันเป็นพระราชบัญญัติที่มีบทบัญญัติบางประการเกี่ยวกับการจัดตั้งและอำนาจของวุฒิสภาไทย ประกอบกับมาตรา ๓๓ มาตรา ๓๔ มาตรา ๔๑ และมาตรา ๔๓ ของรัฐธรรมนูญแห่งราชอาณาจักรไทย บัญญัติให้กระทำได้ โดยอาศัยอำนาจตามบทบัญญัติแห่งกฎหมาย คณะกรรมการสิ่งแวดล้อมแห่งชาติจึงออกประกาศกำหนดมาตรฐานค่าก๊าซไนโตรเจนไดออกไซด์ในบรรยากาศโดยทั่วไป ดังต่อไปนี้

ข้อ ๑ ในประกาศนี้

“เครื่องวัดระนาบเคมีอินทรีย์ (Chemiluminescence) หมายถึงค่าก๊าซไนโตรเจนไดออกไซด์โดยวิธีก๊าซไอโซนทำปฏิกิริยากับก๊าซไนตริกออกไซด์ซึ่งถูกเปลี่ยนมาจากก๊าซไนโตรเจนไดออกไซด์แล้ววัดความเข้มของแสงซึ่งเกิดจากปฏิกิริยานี้ ณ ที่ความยาวคลื่นที่ต่ำกว่า ๖๐๐ นาโนเมตร (Nanometer)”

ข้อ ๒ ให้ยกเลิก

(๑) กวามใน (๒) ของข้อ ๒ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๐ (พ.ศ. ๒๕๓๔) ออกความหมายในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ (เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป)

(๒) กวามใน (๑) ของข้อ ๖ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๐ (พ.ศ. ๒๕๓๔) ออกความหมายในพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ (เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป) แต่ให้เพิ่มเติมโดยประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๒๔ (พ.ศ. ๒๕๕๐) เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไป

ข้อ ๓ ให้กำหนดมาตรฐานค่าก๊าซไนโตรเจนไดออกไซด์ในบรรยากาศโดยทั่วไปไว้ดังต่อไปนี้

(๑) ค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์ในเวลา ๑ ชั่วโมง จะต้องไม่เกิน ๐.๑๖ ส่วนในล้านส่วนหรือไม่เกิน ๐.๓๒ มิลลิกรัมต่อลูกบาศก์เมตร

(๒) ค่าพหุคูณเลขคณิต (Arithmetic Mean) ของก๊าซไนโตรเจนไดออกไซด์ในเวลา ๑ ปี จะต้องไม่เกิน ๐.๐๓ ส่วนในล้านส่วน หรือไม่เกิน ๐.๐๕๖ มิลลิกรัมต่อลูกบาศก์เมตร

ข้อ ๔ การคำนวณค่าความเข้มข้นของก๊าซไนโตรเจนไดออกไซด์ในบรรยากาศโดยทั่วไป ให้คำนวณเทียบที่ความดัน ๑ บรรยากาศ และอุณหภูมิ ๒๕ องศาเซลเซียส

ข้อ ๕ การวัดค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์ในเวลา ๑ ชั่วโมง หรือค่าพหุคูณเลขคณิต (Arithmetic Mean) ในเวลา ๑ ปี ให้ใช้เครื่องวัดระบบเคมีอินทรีย์ หรือระบบอื่นที่กรมควบคุมมลพิษให้ความเห็นชอบ

ประกาศ ณ วันที่ ๑๖ มิถุนายน พ.ศ. ๒๕๕๒

อภิสิทธิ์ เวชชาชีวะ

นายกรัฐมนตรี

ประธานกรรมการสิ่งแวดล้อมแห่งชาติ

ประกาศกรมควบคุมมลพิษ

เรื่อง กำหนดค่าเฝ้าระวังสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมง

โดยที่ในการสมการกำหนดค่าเฝ้าระวังสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในภาค ๒๔ ชั่วโมง พังสารอินทรีย์ระเหยง่าย (Volatile Organic Compounds) ในบรรยากาศโดยทั่วไป ที่เกินสารก่อมะเร็ง (carcinogen) และสารที่ไม่ได้เป็นสารก่อมะเร็ง (non-carcinogen) ซึ่งอาจมีความเข้มข้นสูงในช่วงเวลา ๒๔ ชั่วโมง จนส่งผลกระทบต่อสุขภาพอากาศ และอาจเป็นอันตรายต่อสุขภาพของประชาชนที่สัมผัสโดยการหายใจเข้าสู่ร่างกาย แม้ว่าปริมาณของสารอินทรีย์ระเหยง่ายในบรรยากาศดังกล่าว จะไม่เกินมาตรฐานตามที่กำหนดไว้ในประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๓๐ (พ.ศ. ๒๕๕๐) เรื่อง กำหนดมาตรฐานค่าสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๑ ปี

ดังนั้น กรมควบคุมมลพิษในฐานะหน่วยงานที่มีภารกิจเกี่ยวกับการกำกับ ดูแล อำนวยการ ประสานงาน ติดตาม และประเมินผลเกี่ยวกับการฟื้นฟู คุ้มครอง และรักษาคุณภาพสิ่งแวดล้อมจึงออกประกาศไว้ ดังต่อไปนี้

ข้อ ๑ กำหนดค่าเฝ้าระวังสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมงไว้ ดังต่อไปนี้

- (๑) อะซีตัลดีไฮด์ (Acetaldehyde) ต้องไม่เกิน ๘๖๐ ไมโครกรัมต่อลูกบาศก์เมตร
- (๒) อะครอลีน (Acrolein) ต้องไม่เกิน ๐.๕๕ ไมโครกรัมต่อลูกบาศก์เมตร
- (๓) อะคริไนด์ไนไตรด์ (Acrylonitrile) ต้องไม่เกิน ๑๐ ไมโครกรัมต่อลูกบาศก์เมตร
- (๔) เบนซีน (Benzene) ต้องไม่เกิน ๗.๖ ไมโครกรัมต่อลูกบาศก์เมตร
- (๕) แกมมาคลอโลไนด์ (Benzyl Chloride) ต้องไม่เกิน ๑๒ ไมโครกรัมต่อลูกบาศก์เมตร
- (๖) ๑, ๓ - บิวทาไดอีน (1, 3 - Butadiene) ต้องไม่เกิน ๕.๓ ไมโครกรัมต่อลูกบาศก์เมตร
- (๗) ไบรโมโทเทน (Bromomethane) ต้องไม่เกิน ๑๕๐ ไมโครกรัมต่อลูกบาศก์เมตร
- (๘) คาร์บอนเตตระคลอไรด์ (Carbon Tetrachloride) ต้องไม่เกิน ๑๕๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๙) คลอโรฟอร์ม (Chloroform) ต้องไม่เกิน ๕๗ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๐) ๑, ๒ - ไดโบรมีอีเทน (1, 2 - Dibromoethane) ต้องไม่เกิน ๓๑๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๑) ๑, ๔ - ไดคลอโรเบนซีน (1, 4 - Dichlorobenzene) ต้องไม่เกิน ๑,๑๐๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๒) ๑, ๒ - ไดคลอโรอีเทน (1, 2 - Dichloroethane) ต้องไม่เกิน ๔๘ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๓) ไดคลอโรมีเทน (Dichloromethane) ต้องไม่เกิน ๒๑๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๔) ๑, ๒ - ไดคลอโรโพรเพน (1, 2 - Dichloropropane) ต้องไม่เกิน ๘๒ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๕) ๑, ๔ - ไดออกเซน (1, 4 - Dioxane) ต้องไม่เกิน ๘๖๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๖) เตตระคลอโรเอทิลีน (Tetrachloroethylene) ต้องไม่เกิน ๔๐๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๗) ๑, ๑, ๒, ๒ - เตตระคลอโรอีเทน (1, 1, 2, 2 - Tetrachloroethane) ต้องไม่เกิน ๘๓ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๘) ไตรคลอโรเอทิลีน (Trichloroethylene) ต้องไม่เกิน ๓๐๐ ไมโครกรัมต่อลูกบาศก์เมตร

(๑๙) ไวนิลคลอไรด์ (Vinyl Chloride) ต้องไม่เกิน ๒๐ ไมโครกรัมต่อลูกบาศก์เมตร

ข้อ ๒ หลักการ ขอบเขต และการคำนวณ วิธีการเก็บตัวอย่าง การตรวจวัด และเครื่องมือตรวจสอบวิเคราะห์สำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมง ปรากฏตามภาคผนวกท้ายประกาศนี้

ประกาศ ณ วันที่ ๑๘ ธันวาคม พ.ศ. ๒๕๕๑

สุพัฒน์ หวังวงศ์วัฒนา
อธิบดีกรมควบคุมมลพิษ

ในการคำนวณค่าเผื่อรังสี และให้กำหนดค่าเผื่อรังสีสำหรับ vinyl chloride เท่ากับ ๒ เท่าของ
ค่ามาตรฐานในบรรยากาศโดยทั่วไปในเวลา ๑ ปี

๒. ขอบเขต

สำหรับให้หน่วยงานของรัฐ และเอกชนที่เกี่ยวข้องกับการรังสีและสุขภาพสิ่งแวดล้อม
นำไปใช้เป็นการกำหนดค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไป
ในเวลา ๒๔ ชั่วโมง ที่จะไม่ทำให้เกิดผลกระทบต่อคุณภาพสิ่งแวดล้อมหรือภาวะที่เป็นอันตรายต่อสุขภาพ
อนามัยของประชาชนได้

อย่างไรก็ตาม ค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไป
ในเวลา ๒๔ ชั่วโมง ไม่ใช่เป็นเส้นแบ่งระหว่างความเข้มข้นที่ปลอดภัย และความเข้มข้นที่เกิดอันตราย
ไม่ชัดเจนถึงความเข้มข้น และให้ใช้เฉพาะผู้ที่มีความเข้าใจเกี่ยวกับข้อจำกัด และผลกระทบ
มลพิษอากาศต่อสุขภาพ โดยควรมีการศึกษาถึงผลกระทบต่อสุขภาพจากการสัมผัสสารอินทรีย์ระเหยง่าย
ชนิดนั้น ๆ ในรายละเอียดต่อไป

๓. การคำนวณ วิธีการเก็บตัวอย่าง การตรวจวัด และเครื่องมือตรวจวิเคราะห์

๓.๑ การหาค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมง
แต่ละชนิด ให้นำผลการตรวจวิเคราะห์ตัวอย่างอากาศแบบต่อเนื่องตลอด ๒๔ ชั่วโมง มาคำนวณค่าสารอินทรีย์
ระเหยง่ายในบรรยากาศโดยทั่วไปแต่ละชนิด ตามข้อ ๑ โดยให้คำนวณผลที่ความดัน ๑ บรรยากาศ หรือ
ที่ ๗๖๐ มิลลิเมตรปรอท และที่อุณหภูมิ ๒๕ องศาเซลเซียส

๓.๒ วิธีการเก็บตัวอย่าง การตรวจวัด และเครื่องมือตรวจวิเคราะห์ค่าเผื่อรังสีสำหรับ
สารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมงแต่ละชนิด ตามข้อ ๑ ให้หลักการ และ
เครื่องมืออย่างใดอย่างหนึ่งดังต่อไปนี้มาใช้ เว้นแต่ประกาศนี้จะกำหนดให้เป็นอย่างอื่น

(๑) US EPA Compendium Method TO-14A "Determination of Volatile
Organic Compounds (VOCs) in ambient air using specially prepared canisters with subsequent
analysis by Gas Chromatography (GC)" ตามที่องค์การพิทักษ์สิ่งแวดล้อมแห่งประเทศสหรัฐอเมริกา
กำหนด หรือ

(๒) US EPA Compendium Method TO-15 "Determination of Volatile
Organic Compounds (VOCs) in air collected in specially prepared canisters and analyzed by
Gas Chromatography/Mass Spectrometry (GC/MS)" ตามที่องค์การพิทักษ์สิ่งแวดล้อมแห่งประเทศ
สหรัฐอเมริกากำหนด หรือ

(๓) US EPA Compendium Method TO-11A "Determination of Formaldehyde
in ambient air using adsorbent cartridge followed by High Performance Liquid Chromatography
(HPLC) (Active sampling method)" ตามที่องค์การพิทักษ์สิ่งแวดล้อมแห่งประเทศสหรัฐอเมริกากำหนด
หรือ

(๔) วิธีการเก็บตัวอย่าง การตรวจวัด และเครื่องมือตรวจวิเคราะห์อื่นที่กรมควบคุมมลพิษ
ประกาศในราชกิจจานุเบกษา

ภาคผนวก

ท้าย

ประกาศกรมควบคุมมลพิษ

เรื่อง กำหนดค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมง

๑. หลักการ

การกำหนดค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา
๒๔ ชั่วโมง โดยประยุกต์ใช้ค่า Permissible Exposure Limit (PEL) ของ Occupational Safety and
Health Administration (OSHA) มีขั้นตอนดังนี้

(๑) ปรับค่า PEL ซึ่งกำหนดภายใต้เงื่อนไขของค่าเฉลี่ยตลอดเวลาการทำงานในสภาวะปกติ
๔ ชั่วโมงต่อวัน เป็นเวลาทั้งสิ้น ๕ วันต่อสัปดาห์ (รวมทั้งสิ้น ๔๐ ชั่วโมงต่อสัปดาห์) ให้เป็นค่าเฉลี่ยที่
ประชาชนทั่วไปจะได้รับสัมผัสตลอดระยะเวลาทั้งวัน (๒๔ ชั่วโมง) เป็นเวลาทั้งสัปดาห์ (๗ วัน)
หรือคิดเป็นเวลาทั้งสิ้น ๑๖๘ ชั่วโมง โดยการหารค่า PEL ด้วย ๔.๒ (ตัวเลขดังกล่าวได้จาก ๑๖๘/๔๐)
ทั้งนี้ภายใต้สมมติฐานว่าประชาชนทั่วไป และคนงานมีอัตราการหายใจเท่ากัน

(๒) ปรับค่า PEL ซึ่งกำหนดภายใต้เงื่อนไขที่คนงานซึ่งเป็นกลุ่มของประชากรที่มีสุขภาพ
แข็งแรงได้รับสัมผัสในช่วงวัยที่เป็นผู้ใหญ่ หากแต่การกำหนดค่าเฉลี่ยในสิ่งแวดล้อมต้องคำนึงถึง
ประชากรทั่วไป และมีโอกาสได้รับสัมผัสตลอดชีวิต ไปที่เพียงระยะเวลาในช่วงวัยที่เป็นผู้ใหญ่
ที่ทำงานในโรงงานเท่านั้น ดังนั้นจึงหารค่า PEL ด้วย ๑๐ เพื่อเป็น safety factor ในประเด็นดังกล่าว
ทั้งนี้ค่า safety factor ดังกล่าวใช้ภายใต้สมมติฐานว่ากลุ่มประชากรทั่วไปมีความเสี่ยงต่อสารมลพิษ
ทางอากาศมากกว่ากลุ่มคนงาน ๑๐ เท่า

(๓) ปรับค่า PEL จากข้อเท็จจริงที่ว่ากลุ่มประชากรทั่วไปอาจมีระดับความเสี่ยงต่อการ
ได้รับสัมผัสสารอินทรีย์ระเหยง่ายแตกต่างกัน ดังนั้นจึงหารค่า PEL ด้วย ๑๐ เพื่อเป็น safety factor
ในประเด็นดังกล่าว ทั้งนี้ค่า safety factor ดังกล่าวใช้ภายใต้สมมติฐานว่าประชากรกลุ่มอ่อนไหว
(sensitive population) เช่น เด็ก คนชรา และคนป่วย จะมีความอ่อนไหว (sensitive) ต่อสารมลพิษ
ทางอากาศมากกว่ากลุ่มประชากรทั่วไป ๑๐ เท่า

โดยสรุปการกำหนดค่าเผื่อรังสีของสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไป
ในเวลา ๒๔ ชั่วโมง ดำเนินการโดยใช้สมการดังนี้

ค่าเผื่อรังสีสำหรับสารอินทรีย์ระเหยง่ายในบรรยากาศโดยทั่วไปในเวลา ๒๔ ชั่วโมง

= PEL ของแต่ละสาร / (๔.๒x๑๐x๑๐)

สำหรับสารอินทรีย์ระเหยง่าย ๔ ชนิด ตามที่กำหนดไว้ในประกาศคณะกรรมการ
สิ่งแวดล้อมแห่งชาติ ฉบับที่ ๓๐ (พ.ศ. ๒๕๔๐) เรื่อง กำหนดมาตรฐานค่าสารอินทรีย์ระเหยง่าย
ในบรรยากาศโดยทั่วไปในเวลา ๑ ปี ให้ใช้หลักการประยุกต์ค่า PEL กำหนดค่าเผื่อรังสี ด้วยตัวหารที่ chloroform,
1,2 - dichloroethane, 1,2 - dichloropropane และ trichloroethylene ให้เพิ่มค่า safety factor อีก ๑๐



ประกาศ ณ วันที่ ๑๒ มีนาคม พ.ศ. ๒๕๕๐

(พลเอกทวีป มงใจพร)
นายกรัฐมนตรี
ประธานคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ
ฉบับที่ ๑๕ (พ.ศ. ๒๕๕๐)
เรื่อง กำหนดมาตรฐานระดับเสียงโดยทั่วไป

(ประกาศในราชกิจจานุเบกษา เล่ม ๑๑๕ ตอนที่ ๒๗ ลงวันที่ ๓ เมษายน ๒๕๕๐)

อาศัยอำนาจตามความในมาตรา ๓๒ (๕) แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อม
แห่งชาติ พ.ศ. ๒๕๑๕ คณะกรรมการสิ่งแวดล้อมแห่งชาติกำหนดมาตรฐานระดับเสียงโดยทั่วไป ไว้ดังต่อไปนี้

- ข้อ ๑ ในประกาศนี้
- "ระดับเสียงโดยทั่วไป" หมายความว่า ระดับเสียงที่เกิดขึ้นในสิ่งแวดล้อม
- "ค่าระดับเสียงสูงสุด" หมายความว่า ค่าระดับเสียงสูงสุดที่เกิดขึ้นในขณะโดยหนึ่งระหว่างการ
ตรวจวัดระดับเสียง โดยมีหน่วยเป็นเดซิเบลเอ หรือ dB(A)
- "ค่าระดับเสียงเฉลี่ย ๒๔ ชั่วโมง" หมายความว่า ค่าระดับเสียงเฉลี่ยที่มีพลังงานเทียบเท่าระดับเสียง
ที่เกิดขึ้นจริง ซึ่งมีระดับเสียงเปลี่ยนแปลงตามเวลาในช่วง ๒๔ ชั่วโมง (๒๔ hours A-weighted Equivalent
Continuous sound Level) ซึ่งเรียกโดยย่อว่า Leq ๒๔ hr โดยมีหน่วยเป็นเดซิเบลเอ หรือ dB(A)
- "มาตรฐานระดับเสียง" หมายความว่า เครื่องวัดระดับเสียงตามมาตรฐาน IEC ๖๕๑ หรือ IEC ๘๐๔
ของคณะกรรมการระหว่างประเทศว่าด้วยเทคนิคไฟฟ้า (International Electrotechnical Commission, IEC)

ข้อ ๒ ให้กำหนดมาตรฐานระดับเสียงโดยทั่วไป ไว้ดังต่อไปนี้

(๑) ค่าระดับเสียงสูงสุด ไม่เกิน ๑๑๕ เดซิเบลเอ

(๒) ค่าระดับเสียงเฉลี่ย ๒๔ ชั่วโมง ไม่เกิน ๗๐ เดซิเบลเอ

ข้อ ๓ การตรวจวัดระดับเสียงโดยทั่วไป ให้ดำเนินการดังต่อไปนี้

(๑) การตรวจวัดค่าระดับเสียงสูงสุด ให้ใช้มาตรฐานระดับเสียงตรวจวัดระดับเสียงในบริเวณที่มีคน
อยู่หรืออาศัยอยู่

(๒) การตรวจวัดค่าระดับเสียงเฉลี่ย ๒๔ ชั่วโมง ให้ใช้มาตรฐานระดับเสียงตรวจวัดระดับเสียง
อย่างต่อเนื่องตลอดเวลา ๒๔ ชั่วโมงใด ๆ

(๓) การตั้งไมโครโฟนของมาตรฐานระดับเสียงที่บริเวณภายนอกอาคารให้ตั้งสูงจากพื้นไม่น้อย
กว่า ๑.๒๐ เมตร โดยในรัศมี ๓.๕๐ เมตร ตามแนวราบรอบไมโครโฟน ต้องไม่มีกำแพงหรือสิ่งอื่นใดที่มี
คุณสมบัติในการสะท้อนเสียงที่ขวางอยู่

(๔) การตั้งไมโครโฟนของมาตรฐานระดับเสียงที่บริเวณภายในอาคารให้ตั้งสูงจากพื้นไม่น้อยกว่า
๑.๒๐ เมตร โดยในรัศมี ๑.๐๐ เมตร ตามแนวราบรอบไมโครโฟน ต้องไม่มีกำแพงสิ่งอื่นใดที่มีคุณสมบัติในการ
สะท้อนเสียงที่ขวางอยู่และต้องห่างจากช่องหน้าต่างหรือช่องทางที่เปื้อนออกนอกอาคารอย่างน้อย ๑.๕๐ เมตร

ข้อ ๔ การคำนวณค่าระดับเสียงจะต้องเป็นไปตามวิธีการที่องค์การระหว่างประเทศว่าด้วย
มาตรฐาน (International Organization for Standardization, ISO) กำหนด ซึ่งกรมควบคุมมลพิษจะประกาศใน
ราชกิจจานุเบกษา

ประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๒๕ (พ.ศ. ๒๕๕๐)

เรื่อง กำหนดเสียงรบกวน

โดยที่เป็นการสมควร ปรับปรุงมาตรฐานระดับเสียงรบกวน ให้เหมาะสมกับกฎหมายและหลักฐานทางวิทยาศาสตร์ โดยคำนึงถึงความเป็นไปได้ในเชิงเศรษฐกิจสังคมและเทคโนโลยีที่เกี่ยวข้อง อีกทั้งจำนวนความในมาตรา ๓๔ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ. ๒๕๓๕ และคำสั่งสำนักนายกรัฐมนตรี ที่ ๑๑/๒๕๕๐ คณะกรรมการสิ่งแวดล้อมแห่งชาติ จึงออกประกาศกำหนดค่าระดับเสียงรบกวน ไว้ดังต่อไปนี้

ข้อ ๑ ให้ยกเลิกประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๑๗ (พ.ศ. ๒๕๔๓)

ลงวันที่ ๖ มิถุนายน ๒๕๔๓ เรื่อง ค่าระดับเสียงรบกวน

ข้อ ๒ ให้กำหนดระดับเสียงรบกวนเท่ากับ ๑๐ เดซิเบลเอ

และการดำเนินการตามที่กำหนดไว้ได้มากกว่าระดับเสียงรบกวนเดซิเบลแรก ให้ถือว่าเป็น

เสียงรบกวน

ข้อ ๓ วิธีการตรวจวัดระดับเสียงพื้นฐาน ระดับเสียงขณะไม่มีการรบกวน การตรวจวัด และกับแหล่งระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับเสียงรบกวน และแบบบันทึกการตรวจวัด เสียงรบกวนให้เป็นไปตามที่ คณะกรรมการควบคุมมลพิษประกาศในราชกิจจานุเบกษา

ประกาศ ณ วันที่ ๒๕ มิถุนายน พ.ศ. ๒๕๕๐

โฆสิต ปั้นเปี่ยมรัษฎ์

รองนายกรัฐมนตรี

ประธานกรรมการสิ่งแวดล้อมแห่งชาติ

ประกาศคณะกรรมการควบคุมมลพิษ

เรื่อง วิธีการตรวจวัดระดับเสียงพื้นฐาน ระดับเสียงขณะไม่มีการรบกวน การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับการรบกวน และแบบบันทึกการตรวจวัดเสียงรบกวน

พ.ศ. ๒๕๖๕

โดยที่เป็นการสมควรปรับปรุงวิธีการตรวจวัดระดับเสียงพื้นฐาน ระดับเสียงขณะไม่มีการรบกวน การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับการรบกวน และแบบบันทึกการตรวจวัดเสียงรบกวน ให้สอดคล้องกับความรู้ทางวิทยาศาสตร์และเทคโนโลยีสมัยใหม่ในการตรวจสอบระดับเสียงให้เป็นไปอย่างมีประสิทธิภาพ

อาศัยอำนาจตามความในข้อ ๓ แห่งประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๒๙ (พ.ศ. ๒๕๕๐) เรื่อง ค่าระดับเสียงรบกวน ลงวันที่ ๒๙ มิถุนายน พ.ศ. ๒๕๕๐ คณะกรรมการควบคุมมลพิษ จึงออกประกาศไว้ ดังต่อไปนี้

ข้อ ๑ ให้ยกเลิกประกาศคณะกรรมการควบคุมมลพิษ เรื่อง วิธีการตรวจวัดระดับเสียงพื้นฐานระดับเสียงขณะไม่มีการรบกวน การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับการรบกวน และแบบบันทึกการตรวจวัดเสียงรบกวน ลงวันที่ ๓๑ สิงหาคม พ.ศ. ๒๕๕๐

ข้อ ๒ วิธีการตรวจวัดระดับเสียงพื้นฐาน ระดับเสียงขณะไม่มีการรบกวน การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับการรบกวน และแบบบันทึกการตรวจวัดเสียงรบกวนให้เป็นไปตามภาคผนวกท้ายประกาศนี้

ข้อ ๓ ประกาศนี้ให้ใช้บังคับตั้งแต่วันถัดจากวันประกาศในราชกิจจานุเบกษาเป็นต้นไป

ประกาศ ณ วันที่ ๒๑ กันยายน พ.ศ. ๒๕๖๕

จิตพร บุรัชชีพัฒน์

ปลัดกระทรวงทรัพยากรธรรมชาติและสิ่งแวดล้อม

ประธานกรรมการควบคุมมลพิษ

ภาคผนวก

ท้ายประกาศคณะกรรมการควบคุมมลพิษ

เรื่อง วิธีการตรวจวัดระดับเสียงพื้นฐาน ระดับเสียงขณะไม่มีการรบกวน การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน การคำนวณค่าระดับการรบกวน และแบบบันทึกการตรวจวัดเสียงรบกวน

พ.ศ. ๒๕๖๕

๑. ในประกาศนี้

“เสียงรบกวน” หมายความว่า ระดับเสียงจากแหล่งกำเนิดในขณะมีการรบกวนที่มีระดับเสียงสูงกว่าระดับเสียงพื้นฐาน โดยมีระดับการรบกวนเกินกว่าระดับเสียงรบกวนที่กำหนดไว้ในประกาศคณะกรรมการสิ่งแวดล้อมแห่งชาติ ฉบับที่ ๒๙ (พ.ศ. ๒๕๕๐) เรื่อง ค่าระดับเสียงรบกวน

“ระดับเสียงพื้นฐาน” (Background sound level) หมายความว่า ระดับเสียงที่ตรวจวัดในสิ่งแวดล้อมในขณะยังไม่เกิดเสียงหรือไม่ได้รับเสียงจากแหล่งกำเนิดที่ประชาชนร้องเรียนหรือแหล่งกำเนิดที่คาดว่าจะประชาชนจะได้รับผลกระทบเป็นระดับเสียงเปอร์เซ็นต์ที่ ๙๐ (Percentile Level 90, L_{90})

“ระดับเสียงขณะไม่มีการรบกวน” (Residual sound level) หมายความว่า ระดับเสียงที่ตรวจวัดในสิ่งแวดล้อมในขณะยังไม่เกิดเสียงจากแหล่งกำเนิดที่ประชาชนร้องเรียนหรือแหล่งกำเนิดที่คาดว่าจะประชาชนจะได้รับผลกระทบเป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level, L_{Aeq})

“ระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด” (Specific sound level) หมายความว่า ระดับเสียงที่ตรวจวัดในสิ่งแวดล้อมในขณะเกิดเสียงจากแหล่งกำเนิดที่ประชาชนร้องเรียนหรือแหล่งกำเนิดที่คาดว่าจะประชาชนจะได้รับผลกระทบเป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level, L_{Aeq})

“ระดับเสียงขณะมีการรบกวน” (Rating level) หมายความว่า ระดับเสียงที่ได้จากการคำนวณจากระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด และระดับเสียงขณะไม่มีการรบกวน รวมทั้งบวกเพิ่มระดับเสียงในกรณีบริเวณที่ทำการตรวจวัดเสียงของแหล่งกำเนิดเป็นพื้นที่ที่ต้องการความเงียบสงบ หรือเป็นแหล่งกำเนิดที่ก่อให้เกิดเสียงดัง เสียงที่ก่อให้เกิดความสั่นสะเทือนอย่างหนึ่ง

“เสียงกระแทก” หมายความว่า เสียงที่เกิดจากการตก ตี เตะ หรือกระทบของวัตถุ หรือลักษณะอื่นใด ซึ่งมีระดับเสียงสูงกว่าระดับเสียงทั่วไปในขณะนั้น และเกิดขึ้นในทันทีทันใดและสิ้นสุดลงภายในเวลาไม่น้อยกว่า ๑ วินาที (Impulsive Noise) เช่น การตอกเสาเข็ม การนับขั้วปูนไล่ตุ้ง

“เสียงแหลมดัง” หมายความว่า เสียงที่เกิดจากการเบียด เสียง สี เสียง หรือวัตถุอย่างใด ๆ ที่เกิดขึ้น ในทันทีทันใด เช่น การใช้สว่านไฟฟ้าเจาะเหล็กหรือปูน การเจียรโลหะ การบีบหรืออัดโลหะโดยเครื่องอัดการขึ้นรูปวัสดุด้วยเครื่องมือกล เป็นต้น

“เสียงที่มีความสั่นสะเทือนเกิดร่วมด้วย” หมายความว่า เสียงเครื่องจักร เครื่องดนตรี เครื่องเสียง หรือเครื่องมืออื่นใดที่มีความสั่นสะเทือนเกิดร่วมด้วย เช่น เสียงเบสกีตาร์เครื่องขยายเสียง เป็นต้น

“ระดับการรบกวน” หมายความว่า ค่าความแตกต่างระหว่างระดับเสียงขณะมีการรบกวนกับระดับเสียงพื้นฐาน

“มาตรฐานระดับเสียง” หมายความว่า เครื่องวัดระดับเสียงตามมาตรฐาน IEC 61672 class 1 ของคณะกรรมการระหว่างประเทศด้วยเทคโนโลยีไฟฟ้า (International Electrotechnical Commission, IEC) “เครื่องกำเนิดสัญญาณเสียงอ้างอิง” หมายความว่า เครื่องกำเนิดสัญญาณเสียงตามมาตรฐาน IEC 60942 class 1 ของคณะกรรมการระหว่างประเทศด้วยเทคโนโลยีไฟฟ้า (International Electrotechnical Commission, IEC)

๒. การเตรียมเครื่องมือก่อนทำการตรวจวัด

๒.๑ ให้ใช้มาตรฐานระดับเสียงที่ได้รับการสอนเทียบในช่วงไม่เกิน ๒ ปี เครื่องกำเนิดสัญญาณเสียงอ้างอิงที่ได้รับการสอนเทียบในช่วงไม่เกิน ๑ ปี โดยห้องปฏิบัติการที่ได้รับการรับรองมาตรฐาน มอก. ๓๐๖๒๕ (ISO 17025) หรือมีความสามารถในการสอบกลับได้ในหัวข้อที่ทำการสอนเทียบ

๒.๒ ให้ปรับเทียบมาตรฐานระดับเสียงกับเครื่องกำเนิดสัญญาณเสียงอ้างอิงตามคู่มือการใช้งานของผู้ผลิตมาตรฐานระดับเสียงกำหนดไว้ทุกแห่งก่อนที่จะทำการตรวจวัดระดับเสียง และให้ปรับมาตรฐานระดับเสียงให้มีการถ่วงน้ำหนักความถี่แบบ “A” (A Frequency weighting) และการถ่วงน้ำหนักเวลาแบบ “Fast” (Fast Time weighting)

๓. การตั้งไมโครโฟนและมาตรฐานระดับเสียง

การตั้งไมโครโฟนของมาตรฐานระดับเสียงให้เป็นไปตามหลักเกณฑ์ดังต่อไปนี้

๓.๑ เป็นบริเวณที่ประชาชนร้องเรียนหรือที่คาดว่าจะได้รับการรบกวน แต่หากแหล่งกำเนิดเสียงไม่สามารถหยุดกิจกรรมที่เกิดเสียงได้ ให้ตั้งไมโครโฟนของมาตรฐานระดับเสียงในการตรวจวัดระดับเสียงพื้นฐาน และระดับเสียงขณะไม่มีการรบกวนบริเวณอื่นที่มีสภาพแวดล้อมใกล้เคียง

๓.๒ การตั้งไมโครโฟนของมาตรฐานระดับเสียงที่บริเวณภายนอกอาคาร ให้ตั้งสูงจากพื้นไม่น้อยกว่า ๑.๒ – ๑.๕ เมตร โดยในรัศมี ๓.๕ เมตร ตามแนวราบรอบไมโครโฟน ต้องไม่มีกำแพงหรือสิ่งอื่นใดที่มีคุณสมบัติในการสะท้อนเสียงที่ตรวจอยู่

๓.๓ การตั้งไมโครโฟนของมาตรฐานระดับเสียงที่บริเวณภายในอาคาร ให้ตั้งสูงจากพื้นไม่น้อยกว่า ๑.๒ – ๑.๕ เมตร โดยในรัศมี ๑ เมตร ตามแนวราบรอบไมโครโฟน ต้องไม่มีกำแพงหรือสิ่งอื่นใดที่มีคุณสมบัติในการสะท้อนเสียงที่ตรวจอยู่ และต้องห่างจากช่องหน้าต่างหรือช่องทางออกนอกอาคารอย่างน้อย ๑.๕ เมตร

๔. การตรวจวัดระดับเสียงพื้นฐานและระดับเสียงขณะไม่มีการรบกวน

ให้ตรวจวัดเป็นเวลาไม่น้อยกว่า ๕ นาที ขณะไม่มีเสียงจากแหล่งกำเนิดในช่วงเวลาใดเวลาหนึ่ง ซึ่งสามารถให้เป็นตัวแทนของระดับเสียงพื้นฐาน และระดับเสียงขณะไม่มีการรบกวน โดยระดับเสียงพื้นฐานให้วัดเป็นระดับเสียงต่อเฮิรตซ์ที่ ๙๐ (Percentile Level 90, L_{Aeq}) ระดับเสียงขณะไม่มีการรบกวนให้วัดเป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level, L_{Aeq}) แบ่งออกเป็น ๓ กรณี ดังนี้

๔.๑ แหล่งกำเนิดเสียงยังไม่เกิดหรือยังไม่เกิดหรือยังไม่มีการดำเนินกิจกรรม ให้ตรวจวัดระดับเสียงพื้นฐานและระดับเสียงขณะไม่มีการรบกวน ในวัน เวลา และตำแหน่งที่คาดว่าจะได้รับการรบกวน

๔.๒ แหล่งกำเนิดเสียงมีการดำเนินกิจกรรมอย่างต่อเนื่อง ให้ตรวจวัดระดับเสียงพื้นฐานและระดับเสียงขณะไม่มีการรบกวน ในวัน เวลา และตำแหน่งที่คาดว่าจะได้รับการรบกวน และเป็นตำแหน่งเดียวกันกับตำแหน่งที่มีการวัดระดับเสียงขณะ เกิดเสียงของแหล่งกำเนิด โดยให้หยุดกิจกรรมของแหล่งกำเนิดเสียงหรือวัดทันทีก่อนหรือหลังการดำเนินกิจกรรม

๔.๓ แหล่งกำเนิดเสียงมีการดำเนินกิจกรรมอย่างต่อเนื่องไม่สามารถหยุดการดำเนินกิจกรรมได้ให้ตรวจวัดระดับเสียงพื้นฐานและระดับเสียงขณะไม่มีการรบกวน ในบริเวณอื่นที่มีสภาพแวดล้อมคล้ายคลึงกับบริเวณที่คาดว่าจะได้รับการรบกวนและไม่ได้รับผลกระทบจากแหล่งกำเนิดเสียง

ทั้งนี้ ระดับเสียงขณะ ไม่มีการรบกวนที่จะนำไปใช้คำนวณระดับเสียงขณะมีการรบกวนตามข้อ ๕ และระดับเสียงพื้นฐานที่จะนำไปใช้คำนวณค่าระดับการรบกวนตามข้อ ๖ ให้เป็นค่าที่ตรวจวัดเวลาเดียวกัน

๕. การตรวจวัดและคำนวณระดับเสียงขณะมีการรบกวน แบ่งออกเป็น ๔ กรณี ดังนี้

๕.๑ กรณีที่เสียงจากแหล่งกำเนิดเกิดขึ้นอย่างต่อเนื่องตั้งแต่ ๑ ชั่วโมงขึ้นไป ให้วัดระดับเสียงขณะเกิดเสียงของแหล่งกำเนิดเป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level) ๑ ชั่วโมง และนำผลการตรวจวัดมาคำนวณระดับเสียงขณะมีการรบกวน ตามสมการที่ ๑

$$L_{Aeq,Tr} = [10 \log_{10}(10^{0.1L_{Aeq,Tr}} - 10^{0.1L_{Aeq,R}})] + 10 \log_{10}(\frac{T_r}{T_s}) \quad \text{สมการที่ ๑}$$

โดย $L_{Aeq,Tr}$ = ระดับเสียงขณะมีการรบกวน (มีหน่วยเป็น เดซิเบลเอ)

$L_{Aeq,Tr}$ = ระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด (มีหน่วยเป็น เดซิเบลเอ)

$L_{Aeq,R}$ = ระดับเสียงขณะไม่มีการรบกวน (มีหน่วยเป็น เดซิเบลเอ)

T_s = ระยะเวลาของช่วงเวลาที่แหล่งกำเนิดเกิดเสียง (มีหน่วยเป็น นาที)

T_r = ระยะเวลาอ้างอิงที่กำหนดขึ้นเพื่อใช้ในการคำนวณระดับเสียงขณะมีการรบกวน โดย

- ถ้าเป็นแหล่งกำเนิดที่ก่อให้เกิดเสียงในช่วงเวลา ๐๖.๐๐ – ๒๒.๐๐ นาฬิกา กำหนดให้มีค่าเท่ากับ ๖๐ นาที

- ถ้าบริเวณที่ทำการตรวจวัดระดับเสียงเป็นพื้นที่ที่ต้องการความเงียบสงบ หรือเป็นแหล่งกำเนิดที่ก่อให้เกิดเสียงในช่วงเวลา ๒๒.๐๐ – ๐๖.๐๐ นาฬิกา กำหนดให้มีค่าเท่ากับ ๕ นาที

๕.๒ กรณีที่เสียงจากแหล่งกำเนิดเกิดขึ้นอย่างต่อเนื่องแต่ไม่ถึง ๑ ชั่วโมง ให้วัดระดับเสียงขณะเกิดเสียงของแหล่งกำเนิดตั้งแต่เริ่มต้นจนสิ้นสุดการดำเนินกิจกรรมนั้น ๆ เป็นระดับเสียงเฉลี่ย (Equivalent Sound Pressure Level) และนำมาผลการตรวจวัดมาคำนวณระดับเสียงขณะมีการรบกวนตามสมการที่ ๑

๕.๓ กรณีเสียงจากแหล่งกำเนิดขึ้นอย่างไม่ต่อเนื่องและเกิดขึ้นมากกว่า ๑ ช่วงเวลา โดยแต่ละช่วงเวลาเกิดขึ้นไม่ถึง ๑ ชั่วโมง ให้วัดระดับเสียงขณะเกิดเสียงของแหล่งกำเนิดเป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level) ทุกช่วงเวลาที่เกิดขึ้นในเวลา ๑ ชั่วโมง และให้คำนวณ ระดับเสียงขณะมีการรบกวนตามลำดับ ดังนี้

(ก) คำนวณระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด ตามสมการที่ ๒

$$L_{Aeq,Ts} = 10 \log_{10} \left\{ \left(\frac{1}{T_s} \right) \sum T_i 10^{0.1 L_{Aeq,Ti}} \right\} \quad \text{สมการที่ ๒}$$

โดย $L_{Aeq,Ts}$ = ระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด (มีหน่วยเป็น เดซิเบลเอ)

$$T_s = \sum T_i \quad (\text{มีหน่วยเป็น นาฬิกา})$$

$$L_{Aeq,Ti} = \text{ระดับเสียงที่ตรวจวัดได้ในช่วงที่แหล่งกำเนิดเกิดเสียงที่ช่วงเวลา } T_i, \quad (\text{มีหน่วยเป็น เดซิเบลเอ})$$

$$T_i = \text{ระยะเวลาของช่วงเวลาที่แหล่งกำเนิดเกิดเสียงที่ } i, \quad (\text{มีหน่วยเป็น นาฬิกา})$$

(ข) นำผลที่ได้จากการคำนวณตามข้อ ๕ (ก) มาคำนวณเพื่อหาระดับเสียงขณะมีการรบกวน

ตามสมการที่ ๑

๕.๔ กรณีบริเวณที่จะทำการตรวจวัดเสียงของแหล่งกำเนิดเป็นพื้นที่ที่ต้องการความเงียบสงบ เช่น โรงพยาบาล โรงเรียน หาสงสน ห้างสรรพสินค้า หรือสถานที่อื่นที่มีลักษณะทางนองเดียวกัน หรือเป็นแหล่งกำเนิด ที่ก่อให้เกิดเสียงในช่วงเวลาว่าง ๒๒.๐๐ - ๐๖.๐๐ นาฬิกา ให้วัดระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด เป็นระดับเสียงเฉลี่ย (Equivalent A-Weighted Sound Pressure Level) ๕ นาฬิกา และคำนวณระดับเสียงขณะมีการรบกวน ตามสมการที่ ๑ และบวกเพิ่มด้วย ๓ เดซิเบลเอ

๕.๕ กรณีแหล่งกำเนิดเสียงที่ทำให้เกิดเสียงกระทบ เสียงแหลมดัง เสียงท้อให้เกิดความสั่นสะเทือน อย่างใดอย่างหนึ่งแก่ผู้ได้รับผลกระทบจากเสียงนั้น ไม่ว่าเสียงที่เกิดขึ้นจะต่อเนื่องหรือไม่ก็ตาม ให้นำระดับเสียง ขณะมีการรบกวนตามข้อ ๕.๑, ๕.๒, ๕.๓ หรือ ๕.๔ แล้วแต่กรณี บวกเพิ่มด้วย ๕ เดซิเบลเอ

๖. วิธีการคำนวณค่าระดับการรบกวน

ให้นำระดับเสียงขณะมีการรบกวนตามข้อ ๕ หักออกด้วยระดับเสียงพื้นฐาน ตามข้อ ๔ ผลลัพธ์ เป็นค่าระดับการรบกวน

ผลลัพธ์เป็นตัวเลขทศนิยม ๑ ตำแหน่ง และการปัดเศษทศนิยมให้เป็นไปตามมาตรฐานผลิตภัณฑ์อุตสาหกรรม มอก. ๙๒๙ - ๒๕๓๓ ดังนี้

๖.๑ ถ้าเศษตัวแรกมีค่าน้อยกว่า ๕ ให้ปัดเศษทิ้ง และคงตัวเลขตัวสุดท้ายในตำแหน่งที่ต้องการ คงไว้

๖.๒ ถ้าเศษตัวแรกมีค่านมากกว่า ๕ หรือเท่ากับ ๕ แล้วตามด้วยเลขอื่นที่ไม่ใช่ ๐ ทั้งหมด ให้ปัดเศษทิ้ง และคงตัวเลขตัวสุดท้ายในตำแหน่งที่ต้องการไว้ดังนี้

๖.๓ ถ้าเศษตัวแรกมีค่าเท่ากับ ๕ โดยไม่มีเลขอื่นต่อท้าย หรือเท่ากับ ๕ แล้วตามด้วย ๐ ทั้งหมด ให้ปัดเศษทิ้ง

- (ก) เมื่อตัวเลขตัวสุดท้ายในตำแหน่งที่ต้องการคงไว้เป็นเลขดี ให้เพิ่มค่าของตัวเลขนี้ขึ้นอีก ๑
(ข) เมื่อตัวเลขตัวสุดท้ายในตำแหน่งที่ต้องการคงไว้เป็นเลขคู่หรือ ๐ ให้ปัดเศษทิ้ง

๗. แบบบันทึกการตรวจวัดเสียงรบกวน

ให้ผู้ตรวจวัดบันทึก

๗.๑ ชื่อ สกุล ตำแหน่งของผู้ตรวจวัด

๗.๒ ลักษณะเสียงและช่วงเวลาการเกิดเสียงของแหล่งกำเนิด

๗.๓ สถานที่ วัน และเวลาการตรวจวัดเสียง

๗.๔ ผลการตรวจวัดและคำนวณระดับเสียง

๗.๕ สรุปผล

ทั้งนี้ ผู้ตรวจวัดอาจจัดทำแบบบันทึกการตรวจวัดเสียงรบกวนรูปแบบอื่นที่มีเนื้อหาไม่น้อยกว่า ที่กำหนดไว้

แบบบันทึกการตรวจวัดเสียงรบกวน

ชื่อสถานประกอบการ/โรงงาน/เจ้าของ	
ลักษณะเสียงของแหล่งกำเนิด <input type="radio"/> เสียงเกิดขึ้นต่อเนื่องตั้งแต่ ๑ ชั่วโมงขึ้นไป <input type="radio"/> เสียงเกิดขึ้นต่อเนื่องไม่ถึง ๑ ชั่วโมง <input type="radio"/> เสียงเกิดขึ้นไม่ต่อเนื่อง และเกิดขึ้นมากกว่า ๑ ช่วงเวลา แต่ละช่วงเวลาก่อให้เกิดขึ้นไม่ถึง ๑ ชั่วโมง <input type="radio"/> ไม่มีเสียงรบกวน เสียงหมดไป เสียงที่มีความถี่สูงเกิน อย่างใดอย่างหนึ่ง (ระบุ) : ช่วงเวลาที่พื้นที่ที่เกิดเสียง <input type="radio"/> กลางวัน (๐๖.๐๐-๑๖.๐๐ น.) <input type="radio"/> กลางคืน (๒๒.๐๐-๐๖.๐๐ น.) <input type="radio"/> พื้นที่ที่ต้องการความเงียบสงบ (ระบุ) : เครื่องมือตรวจวัดและปรับเทียบ มาตรระดับเสียง ยี่ห้อ : รุ่น : มาตรฐาน IEC Class หมายเลขเครื่อง : เครื่องกำเนิดเสียงเสียงอ้างอิง ยี่ห้อ : รุ่น : มาตรฐาน IEC Class หมายเลขเครื่อง : สถานที่ วัน และเวลาการตรวจวัดเสียง การตรวจวัดระดับเสียงพื้นฐาน และระดับเสียงขณะไม่มีการรบกวน สถานที่ : วันที่ : เวลา : น. การตรวจวัดระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด สถานที่ : วันที่ : เวลา : น. สภาพแวดล้อมของสถานที่ตรวจวัด สถานที่ : วันที่ : เวลา : น.	
ผลการตรวจวัดระดับเสียง	ผลการคำนวณระดับเสียง
ระดับเสียงขณะเกิดเสียงของแหล่งกำเนิด ระดับเสียงขณะไม่มีการรบกวน : เดซิเบลเอ ระดับเสียงรบกวน : เดซิเบลเอ	ระดับเสียงขณะมีการรบกวน : เดซิเบลเอ ค่าระดับการรบกวน : เดซิเบลเอ
สรุปผล <input type="radio"/> เป็นเสียงรบกวน (มากกว่า ๑๐ เดซิเบลเอ) <input type="radio"/> ไม่เป็นเสียงรบกวน	
ความเห็น/ ข้อเสนอแนะ	
(.....) ตำแหน่ง : ผู้ตรวจวัดและบันทึกผล	(.....) ตำแหน่ง : ผู้ตรวจสอบข้อมูล

(๒) การตรวจสอบคุณภาพน้ำได้ดำเนินการโดยใช้วิธี Standard Methods for the Examination of Water and Wastewater ซึ่งสมาคมสุขภาพของประชาชนอเมริกัน (American Public Health Association - APHA) สมาคมการประปาแห่งสหรัฐอเมริกา (American Water Works Association) และ Water Environment Federation ของสหรัฐอเมริการ่วมกันกำหนด หรือวิธีอื่นที่กรมโรงงานอุตสาหกรรมเห็นชอบ

หลักเกณฑ์การตรวจสอบคุณภาพดินและน้ำได้ดำเนินการในบริเวณโรงงานให้เป็นไปตามหมวดที่ ๒ หายีประกาศนี้

ข้อ ๘ การตรวจสอบคุณภาพดินและน้ำได้ดำเนินการเก็บตัวอย่างดินและน้ำได้ตามคู่มือหรือวิธีการโรงงานอุตสาหกรรมกำหนดโดยประกาศในราชกิจจานุเบกษา

ข้อ ๙ กรณีที่ผู้ประกอบการโรงงานตามบัญชีท้ายกฎกระทรวงควบคุมการปนเปื้อนในดินและน้ำได้ดำเนินการในบริเวณโรงงาน พ.ศ. ๒๕๕๙ เห็นว่าโรงงานของตนไม่มีกิจกรรมหรือไม่มีการใช้หรือเก็บรักษาสารเคมี ของเสีย หรือสิ่งอื่นใดภายในบริเวณโรงงาน ซึ่งอาจก่อให้เกิดอันตรายต่อสุขภาพ อนามัย และสิ่งแวดล้อมและอาจก่อให้เกิดการปนเปื้อนในดินและน้ำได้ดิน ผู้ประกอบการโรงงานอาจแสดงเหตุผล โดยแจ้งเป็นหนังสือต่อกรมโรงงานอุตสาหกรรมหรือสำนักงานอุตสาหกรรมจังหวัดที่โรงงานตั้งอยู่ เพื่อขอไม่ดำเนินการเก็บตัวอย่างดินและน้ำได้ดิน และให้ถือว่าการแจ้งดังกล่าวเป็นการตรวจสอบคุณภาพดินและน้ำได้ดิน และจัดทำรายงานผลการตรวจสอบคุณภาพดินและน้ำได้ดินตามกฎกระทรวงควบคุมการปนเปื้อนในดินและน้ำได้ดินภายในบริเวณโรงงาน พ.ศ. ๒๕๕๙ ทั้งนี้ กรมโรงงานอุตสาหกรรมหรือสำนักงานอุตสาหกรรมจังหวัดแล้วแต่กรณี อาจตรวจสอบความถูกต้องของการแจ้งดังกล่าวภายหลังได้

ในการนี้ทั้งการแจ้งในวรรคหนึ่งไม่ถูกต้องตามความเป็นจริง ให้ถือว่าผู้ประกอบการโรงงานนั้นไม่ได้จัดให้มีการตรวจสอบคุณภาพดินและน้ำได้ดิน และไม่จัดทำการรายงานผลการตรวจสอบคุณภาพดินและน้ำได้ดินตามบัญชีท้ายกฎกระทรวงควบคุมการปนเปื้อนในดินและน้ำได้ดินและน้ำได้ดิน

ข้อ ๑๐ เพื่อประโยชน์ในการดำเนินการควบคุมกฎกระทรวงควบคุมการปนเปื้อนในดินและน้ำได้ดินภายในบริเวณโรงงาน พ.ศ. ๒๕๕๙ ผู้ประกอบการโรงงานตามบัญชีท้ายกฎกระทรวงดังกล่าวต้องแสดงหลักฐานว่าได้ดำเนินการติดตั้งอุปกรณ์การส่งสัญญาณการตรวจวัดและน้ำได้ดินภายในบริเวณโรงงาน ขยายครอบคลุมด้วยบ่อสองประเภท คือ บ่อที่อยู่ในตำแหน่งเหนือน้ำเพื่อใช้เป็นบ่อเก็บน้ำ (เก็บน้ำ) และบ่ออื่น ๆ เป็นกรณีพิเศษ กรณีที่ผู้ประกอบการประสงค์จะขอการปนเปื้อนจากกระบวนการ (process) ให้มีหลักฐาน (evidence) โดยให้หลักฐานเหล่านี้ที่โรงงานที่ได้ยกมาเพื่อให้เกิดการปนเปื้อนแล้ว

ข้อ ๑๑ ถ้าดำเนินการตามข้อ ๑๐ หากระดับน้ำได้ดินเฉลี่ยในพื้นที่สถานประกอบการโรงงาน อยู่ต่ำกว่าระดับน้ำใต้ดินทั่วพื้นที่แล้ว และพิสูจน์ด้วยวิธีการที่ยอมรับได้ว่าพื้นที่ดินซึ่งอยู่ใต้พื้นที่โรงงานนั้นไม่มีการปนเปื้อนและทำการติดตั้งอุปกรณ์การเก็บตัวอย่างน้ำได้ดินได้ด้วยวิธีการปกติ ให้ผู้ประกอบการโรงงานนั้นถือว่าได้ดำเนินการตามข้อกำหนดนี้แล้ว

การปนเปื้อนในดิน ผู้ประกอบการโรงงานต้องดำเนินการตรวจสอบคุณภาพดินและน้ำได้ดินภายในบริเวณโรงงาน โดยละเอียดต่อไปทันที

ข้อ ๑๒ การติดตั้งบ่อสังเกตการณ์ด้านข้อ ๑๐ จะต้องให้มีระดับความลึกของบ่อจากระดับน้ำได้ดินลงไปไม่กี่ปอนด์เพื่อให้มีปริมาณน้ำได้ดินอยู่ในบ่อดังกล่าวเพียงพอเพื่อดำเนินการเก็บตัวอย่างน้ำได้ดินได้

ข้อ ๑๓ เพื่อเป็นประโยชน์ในการดำเนินการตามข้อ ๑๐

(๑) ในกรณีที่ผู้ประกอบการโรงงาน มีการติดตั้งบ่อสังเกตการณ์ก่อนประกาศนี้ใช้บังคับ ถ้าตำแหน่งและความลึกของบ่อสังเกตการณ์ดังกล่าวสอดคล้องกับวัตถุประสงค์ของประกาศนี้ ผู้ประกอบการโรงงานอาจใช้บ่อสังเกตการณ์นั้นเก็บตัวอย่างน้ำได้ดินก็ได้

(๒) ผู้ประกอบการโรงงานอาจใช้บ่อสังเกตการณ์ที่อยู่นอกพื้นที่โรงงานของตนเป็นบ่อสังเกตการณ์ที่ใช้เป็นบ่ออ้างอิง (Up-gradient) โดยไม่ต้องติดตั้งบ่อสังเกตการณ์เพิ่มเติมก็ได้ หากบ่อดังกล่าวมีตำแหน่ง ความลึกและมีแนวของทิศทางการไหลของน้ำได้ดินที่เหมาะสมและผู้ประกอบการโรงงานสามารถเข้าไปเก็บตัวอย่างหรือแสดงหลักฐานการไหลของน้ำได้ดินที่สอดคล้องกับวัตถุประสงค์ของประกาศนี้ได้

ประกาศนี้ให้ใช้บังคับตั้งแต่วันถัดจากวันประกาศในราชกิจจานุเบกษาเป็นต้นไป

ประกาศ ณ วันที่ ๓๑ ตุลาคม พ.ศ. ๒๕๕๙

อรรถภา สิญูเรือง

รัฐมนตรีว่าการกระทรวงอุตสาหกรรม

ภาคผนวกที่ ๑

รายการของสารเคมีที่เป็นอันตรายในดินและน้ำใต้ดินภายในบริเวณโรงงาน

ลำดับที่	ชื่อสาร	เลขทะเบียน ซีไอเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๑	อะซีแนฟทีน (Acenaphthene)	๘๓-๓๒-๙	๑,๐๐๐	๑๔๐
๒	อะซีโตน (Acetone) หรือ ๒-โพรพาโนน (2-Propanone)	๖๗-๖๔-๑	๑,๐๐๐	๒๓๐
๓	อัลดริน (Aldrin)	๓๐๙-๐๐-๒	๐.๑	๐.๐๐๓
๔	แอนทราซีน (Anthracene)	๑๒๐-๑๒-๗	๑,๐๐๐	๗๒
๕	แอนติโมนี (Antimony)	๗๔๔๐-๓๖-๐	๑,๐๐๐	๑.๐
๖	อาร์เซนิก หรือสารหนู (Arsenic)	๗๔๔๐-๓๘-๖	๒๗	๐.๑
๗	แอสเบสตอส (Asbestos*)	๑๓๓๒-๒๑-๔	๑.๐	-
๘	อะทราซีน (Atrazine)	๑๘๑๒-๖๔-๙	๑๑๐	๐.๐๒
๙	แบเรียม (Barium)	๗๔๔๐-๓๙-๓	๑,๐๐๐	๑๖๐
๑๐	เบนซี(เอ)แอนทราซีน (Benz(a)anthracene)	๕๖-๕๕-๓	๕.๕	๐.๐๑
๑๑	เบนซีน (Benzene)	๗๑-๔๓-๒	๑๕	๐.๒
๑๒	เบนโซ(ก)ฟลูออแรนซีน Benzol(b)fluoranthene	๒๐๕-๙๙-๒	๒.๒	๐.๑
๑๓	เบนโซ(เค)ฟลูออแรนซีน Benzol(k)fluoranthene	๒๐๗-๐๘-๙	๒.๒	๐.๗
๑๔	กรดเบนซอิก (Benzoic acid)	๖๕-๘๕-๐	๑,๐๐๐	๑๐๐
๑๕	เบนโซ(เอ)ไพรีน (Benzo(a)pyrene)	๕๐-๓๒-๘	๒.๙	๐.๐๑
๑๖	เบนโซ(จี)เฮกโซไพริลีน (Benzol(g,h,i)pyrene)	๑๘๑๖-๒๔-๒	๑,๐๐๐	๗๒
๑๗	เบอริลเลียม (Beryllium)	๗๔๔๐-๔๑-๗	๑๓	๐.๐๑
๑๘	บิส(๒-คลอโรเอทิล)อีเทอร์ (Bis(2-chloroethyl)ether)	๑๑๑-๔๔-๔	๕๒	๐.๐๔
๑๙	บิส(๒-เอทิลเฮกซิล)ฟทาเลต (Bis(2-ethylhexyl)phthalate)	๑๑๗-๘๑-๗	๑๑๗	๓.๕
๒๐	โบรมีนไดคลอโรมีเทน (Bromodichloromethane)	๗๕-๒๗-๔	๔๒๖	๐.๘
๒๑	โบรมีโนฟอร์ม (Bromoform) หรือ ไตรโบรมี มีเทน(Tribromomethane)	๗๕-๒๕-๒	๑,๐๐๐	๖.๐

ลำดับที่	ชื่อสาร	เลขทะเบียน ซีไอเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๒๒	บิวทานอล (Butanol)	๗๑-๓๖-๓	๑,๐๐๐	๒๔๐
๒๓	บิวทิลเบนซิลฟทาเลต (Butyl benzyl phthalate)	๘๕-๖๘-๗	๐.๓	๔๘
๒๔	แคดเมียม (Cadmium)	๗๔๔๐-๓๓-๙	๘๑๐	๒.๐
๒๕	คาร์บาโซล (Carbazole)	๘๖-๗๔-๘	๘๒	๒.๐
๒๖	คาร์บอนไดซัลไฟด์ (Carbon disulfide)	๗๕-๑๕-๐	๓๐	๔.๐
๒๗	คาร์บอนเตตระคลอไรด์ (Carbon tetrachloride)	๕๖-๒๓-๕	๕.๓	๐.๔
๒๘	คลอร์เดน (Chlordane)	๕๗-๗๕-๙	๑๑๐	๐.๐๔
๒๙	พาราคลอโรอะนิลีน (p - Chloroaniline)	๑๐๖-๔๗-๘	๓๒๕	๙.๕
๓๐	คลอโรเบนซีน (Chlorobenzene)	๑๐๘-๙๐-๗	๔๖๐	๔๘
๓๑	คลอโรไดโบรมีเทน (Chlorodibromomethane)	๑๒๔-๔๘-๑	๒๐	๐.๖
๓๒	คลอโรฟอร์ม (Chloroform)	๖๗-๖๖-๓	๑,๐๐๐	๘.๐
๓๓	๒-คลอโรฟีโนล (2-Chlorophenol)	๙๕-๕๗-๘	๔๒๐	๑๒
๓๔	โครเมียม (Chromium)	๗๔๔๐-๔๗-๓	๖๔๐	๖.๐
๓๕	โครเมียม (III) (Chromium (III))	๑๖๐๖๕-๘๓-๑	๑,๐๐๐	๔๐
๓๖	โครเมียม (VI) (Chromium (VI))	๑๘๕๕๐-๖๙-๙	๖๔๐	๖.๐
๓๗	ไครซีน (Chrysene)	๒๑๘-๐๑-๙	๒๒๐	๗.๐
๓๘	ไซยาไนด์ (Cyanide)	๕๗-๑๒-๕	๓๕	๕.๐
๓๙	๒,๔-ดี (2,4-D)	๙๔-๗๕-๗	๑๒,๐๐๐	๑๒
๔๐	ดีดีที (DDD)	๗๒-๕๕-๘	๗.๐	๐.๒
๔๑	ดีดีอี (DDE)	๗๒-๕๕-๙	๐.๐๐๑	๐.๑
๔๒	ดีดีที (DDT)	๕๐-๒๙-๓	๑๒๐	๐.๑
๔๓	ไดเบนซี(เอ,เอ)แอนทราซีน Dibenz(a,h)anthracene	๕๓-๗๐-๓	๐.๒๒	๐.๐๑
๔๔	ไดนอร์มอลบิวทิลฟทาเลต (Di-n-butyl phthalate)	๘๕-๗๕-๒	๑,๐๐๐	๒๔
๔๕	๑,๒-ไดคลอโรเบนซีน (1,2-Dichlorobenzene)	๙๕-๕๐-๑	๑,๐๐๐	๒๑
๔๖	๑,๓-ไดคลอโรเบนซีน (1,3-Dichlorobenzene)	๕๕๑-๗๓-๑	๑,๐๐๐	๒๑
๔๗	๑,๔-ไดคลอโรเบนซีน (1,4-Dichlorobenzene)	๑๐๖-๔๖-๗	๑,๐๐๐	๐.๒

ลำดับที่	ชื่อสาร	เลขทะเบียน ซีไอเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๔๖๖	๒,๓-ไดคลอโรโพรเพน (2,3-Dichloropropane)	๗๕๕-๗๕-๑	๔.๐	๐.๑
๔๖๗	๒,๓,๓-ไตรคลอโรโพรเพน (1,1,1-Trichloropropane)	๗๗๕-๗๕-๓	๑,๐๐๐	๒๔
๔๖๘	๒,๓,๓-ไตรคลอโรโพรเพน (1,1,2-Trichloropropane)	๗๗๖-๗๕-๓	๗.๖	๐.๕
๔๖๙	๒,๓,๓-ไตรคลอโรโพรเพน (1,1,3-Trichloropropane)	๗๗๕-๗๕-๔	๑.๒	๐.๑
๔๗๐	๒,๓,๓-ไตรคลอโรโพรเพน (1,1,๓-Trichloropropane)	๑๕๖๖-๔๐๐-๐	๑๕.๐	๒.๐
๔๗๑	๒,๓,๓-ไตรคลอโรโพรเพน (1,1,๓-Trichloropropane)	๑๕๖๖-๔๐๐-๕	๒๑.๐	๕.๐
๔๗๒	๒,๓,๓-ไตรคลอโรโพรเพน (1,2-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒๔.๔	๗.๒
๔๗๓	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๗๕๕-๗๕-๕	๗.๒	๐.๗
๔๗๔	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๕๖๖-๔๐๐-๕	๔๖.๒	๑.๒
๔๗๕	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๕๕๕๖-๗๕-๖	๑๓	๐.๓
๔๗๖	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๖๐๐๕-๗๕-๑	๑.๕	๐.๐๐๓
๔๗๗	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๕๕๕๖-๗๕-๖	๑,๐๐๐	๓.๐
๔๗๘	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๐๐๕-๖๗๕-๕	๑,๐๐๐	๕.๐
๔๗๙	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๕๕๕๖-๗๕-๕	๑๖.๒	๕.๐
๔๘๐	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๑	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๒	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๓	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๔	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๕	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๖	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๗	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๘	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๘๙	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๐	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๑	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๒	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๓	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๔	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๕	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๖	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๗	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๘	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๔๙๙	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑
๕๐๐	๒,๓,๓-ไตรคลอโรโพรเพน (1,3-Dichloropropane)	๑๖๐๐-๔๓๖-๒	๒.๕	๐.๑

ลำดับที่	ชื่อสาร	เลขทะเบียน ซีไอเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๓๕๕	อัลฟา เฮกซีกโซน (α-HCH) หรืออัลฟา-ป็อทซี (α-BHC)	๓๑๕-๕๕-๖	๐.๓	๐.๐๑
๓๖๖	เบตา-เฮกซีกโซน (β-HCH) หรือเบตา-ป็อทซี (β-BHC)	๓๑๕-๕๕-๗	๐.๕	๐.๐๓
๓๗๗	แกมมา-เฮกซีกโซน (γ-HCH) หรือลินเดน (Lindane)	๕๕๕-๕๕-๕	๒.๕	๐.๐๔
๓๘๘	เฮกซาคลอร์ไซโคลเพนทาไดเอน (Hexachlorocyclopentadiene)	๗๗๕-๕๕-๕	๑.๖	๕.๐
๓๙๙	เฮกซาคลอร์อีเทน (Hexachloroethane)	๖๗๕-๕๕-๑	๑๑.๗	๒.๐
๔๐๐	อินดีโน (๑,๒,๓-ซีดีไพรีน (Indeno(1,2,3-cd)pyrene	๑๕๓๓-๓๕๕-๕	๒.๒	๐.๑
๔๑๑	ไอโซฟอรอน (Isophorone)	๗๕๕-๕๕-๑	๑,๐๐๐	๕.๑
๔๒๒	เลด หรือ ตะกั่ว (Lead)	๗๕๕-๕๕-๑	๗.๕๐	๔.๐
๔๓๓	แมงกานีส (Manganese)	๗๕๕๕-๕๖-๕	๓๒,๐๐๐	๓๓
๔๔๔	เมอร์คิวรี หรือปรอท (Mercury)	๗๕๕๕-๕๗-๖	๖.๑๐	๐.๗
๔๕๕	เมทานอล (Methanol)	๖๗๕-๕๖-๑	๑,๐๐๐	๖.๐
๔๖๖	เมทอกซีคลอร์ (Methoxychlor)	๗๕๕-๕๓-๕	๔๑.๖	๑.๒
๔๗๗	เมทิลโบรมไนด์ (Methyl bromide)	๗๕๕-๕๓-๕	๑๑.๖	๓.๐
๔๘๘	เมทิลคลอไรด์ (Methylene chloride) หรือไดคลอโรมีเทน (Dichloromethane)	๗๕๕-๐๕๖-๒	๒.๑๐	๖.๐
๔๙๙	๒-เมทิลฟีนอล (2-methylphenol) หรือ ออร์โท-ครีซอล (o-cresol)	๕๕๕-๕๕-๗	๑,๐๐๐	๕.๕
๕๐๐	๒-เมทิลแนฟทาเลิน (2-Methylnaphthalene)	๕๕๕-๕๗-๖	๑,๐๐๐	๖.๐
๕๑๑	เมทิล เทร์ต-บิวทิล อีเทอร์ (Methyl tert-butyl ether)	๑๖๓๕-๐๕๔-๕	๑,๐๐๐	๒.๕
๕๒๒	แนฟทาเลิน (Naphthalene)	๕๕๕-๖๐-๓	๑,๐๐๐	๕.๕
๕๓๓	นิกเกิล (Nickel)	๗๕๕๐-๐๖๐-๐	๕๑,๐๐๐	๕.๐
๕๔๔	ไนโตรเบนซีน (Nitrobenzene)	๗๕๕-๕๕-๓	๔.๖	๑.๒
๕๕๕	เอน-ไนโตรไซด์ฟีนิลามีน (N-Nitrosodiphenylamine)	๕๖๖-๓๐-๖	๓๓.๕	๑.๐
๕๖๖	เอ็น-ไนโตรไพรไพลามีน (N-Nitrosodi-n-propylamine)	๖๖๖-๖๕-๗	๐.๒	๐.๐๑

ลำดับที่	ชื่อสาร	เลขทะเบียน ซีเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๔๔๖	โพลีคลอริเนตเตดไบบีฟีนิลส์ (Polychlorinated Biphenyls) หรือ พีซีบี (PCB)	๑๓๓๖-๓๖-๓	๑๐	๐.๑
๔๔๘	เพนตะคลอโรฟีนอล (Pentachlorophenol)	๘๗-๘๖-๕	๑๑๐	๐.๒
๔๔๙	ฟีนานทรีน (Phenanthrene)	๘๕-๐๑-๘	๑,๐๐๐	๗๒
๑๐๐	ฟีนอล (Phenol)	๑๐๘-๕๕-๖	๑,๐๐๐	๗๒
๑๐๑	ไพรีน (Pyrene)	๑๒๙-๐๐-๐	๑,๐๐๐	๗๒
๑๐๖	ซีลีเนียม (Selenium)	๗๘๘๒-๔๙-๖	๑๐,๐๐๐	๑๒
๑๐๓	ซิลเวอร์ (Silver)	๗๔๔๐-๖๒-๔	๑,๐๐๐	๑๒
๑๐๔	สไตรีน (Styrene)	๑๐๐-๔๒-๕	๑,๗๐๐	๒๔
๑๐๔	๑,๑,๑,๒-เตตระคลอโรอีเทน (1,1,2,2-Tetrachloroethane)	๗๙-๓๔-๕	๕๐	๐.๒
๑๐๖	เตตระคลอโรอีทิลีน (Tetrachloroethylene) หรือ เพอร์คลอโร เอทิลีน (Perchloroethylene)	๑๒๗-๑๘-๔	๑๙๐	๐.๙
๑๐๗	โทลูอีน (Toluene)	๑๐๘-๘๘-๓	๕๒๐	๕.๐
๑๐๘	ท็อกซาฟีน (Toxaphene)	๘๐๑๑-๓๕-๖	๑.๕	๐.๐๔
๑๐๙	ทีพีเอช (คาร์บอน _n -คาร์บอน _n) (TPH (C _n - C _n)) หรือโททอลปิโตรเลียมไฮโดรคาร์บอน (คาร์บอน _n -คาร์บอน _n) (Total Petroleum Hydrocarbon (C _n - C _n))	-	๒๕	๑.๔
๑๑๐	ทีพีเอช (คาร์บอน _n -คาร์บอน _n) (TPH (C _n - C _n)) หรือโททอลปิโตรเลียมไฮโดรคาร์บอน (คาร์บอน _n -คาร์บอน _n) (Total Petroleum Hydrocarbon (C _n - C _n))	-	๒๕	๑.๗
๑๑๑	ทีพีเอช (คาร์บอน _n -คาร์บอน _n) (TPH (C _n - C _n)) หรือโททอลปิโตรเลียมไฮโดรคาร์บอน (คาร์บอน _n -คาร์บอน _n) (Total Petroleum Hydrocarbon (C _n - C _n))	-	๕๐	๐.๑
๑๑๒	๑,๒,๓-ไตรคลอโรเบนซีน (1,2,3-Trichlorobenzene)	๑๒๐-๘๒-๑	๑,๐๐๐	๒๔
๑๑๓	๑,๑,๑-ไตรคลอโรอีเทน (1,1,1-Trichloroethane)	๗๑-๔๕-๖	๑,๔๐๐	๐.๒

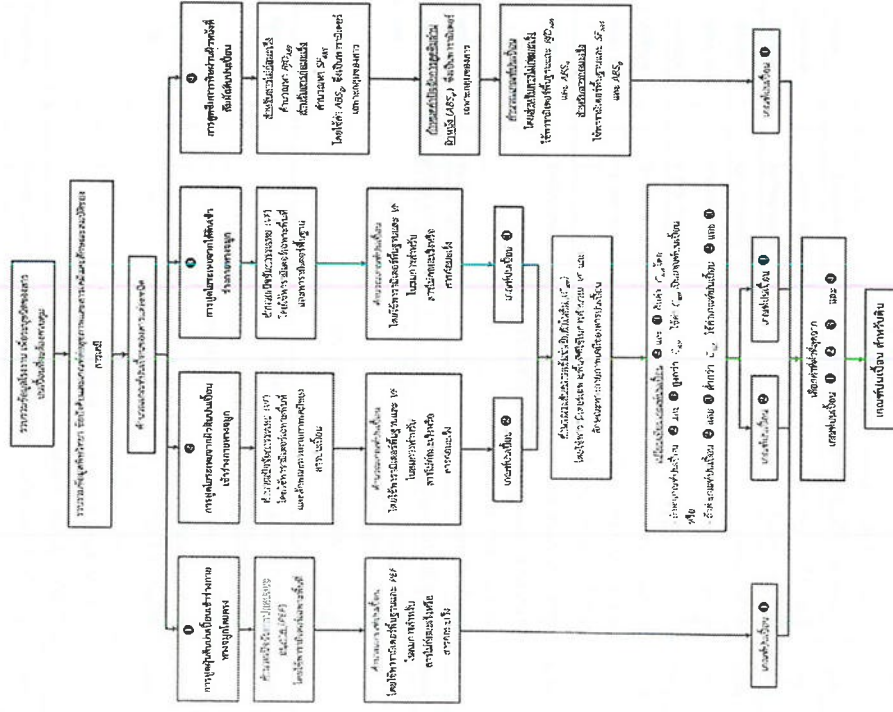
ลำดับที่	ชื่อสาร	เลขทะเบียน ซีเอส (CAS No.)	เกณฑ์การปนเปื้อน	
			ดิน (มก./กก.)	น้ำใต้ดิน (มก./ล.)
๑๑๔	๑,๑,๒-ไตรคลอโรอีเทน (1,1,2-Trichloroethane)	๗๙-๐๐-๕	๑๙	๐.๘
๑๑๕	ไตรคลอโรอีทิลีน (Trichloroethylene)	๗๙-๐๑-๖	๖๑	๔.๔
๑๑๖	๒,๔,๕-ไตรคลอโรฟีนอล (2,4,5-trichlorophenol)	๙๕-๕๕-๔	๑,๐๐๐	๒๔
๑๑๗	๒,๔,๖-ไตรคลอโรฟีนอล (2,4,6-Trichlorophenol)	๘๘-๐๖-๖	๑๕๑	๔.๔
๑๑๘	๑,๓,๕-ไตรเมทิลเบนซีน (1,3,5-Trimethylbenzene)	๑๐๘-๖๗-๘	๑๓๙	๑๒
๑๑๙	วานาเดียม (Vanadium)	๗๔๔๐-๖๒-๖	๑,๐๐๐	๑๗
๑๒๐	ไวนิลอะซิเตต (Vinyl acetate)	๑๐๘-๐๕-๔	๑,๐๐๐	๑๑๙
๑๒๑	ไวนิลคลอไรด์ (Vinyl chloride) หรือ คลอไรอีthin (chloroethene)	๗๕-๐๑-๔	๘.๓	๐.๐๓
๑๒๒	เมตา-ไซลีน (m-Xylene)	๑๐๘-๓๘-๓	๒๑๐	๒๔
๑๒๓	ออโร-ไซลีน (o-Xylene)	๙๕-๔๗-๖	๒๑๐	๒๔
๑๒๔	พารา-ไซลีน (p-Xylene)	๑๐๖-๔๒-๓	๒๑๐	๒๔
๑๒๕	ไซลีน (ทั้งหมด) (Xylene (Total))	๑๓๓๐-๒๐-๗	๒๑๐	๒๔
๑๒๖	ซิงค์ หรือสังกะสี (Zinc)	๗๔๔๐-๖๖-๖	๑,๐๐๐	๑๐

* หน่วยเกณฑ์การปนเปื้อน คือ จำนวนส่นในต่อลิตรกรัม

หมายเหตุ

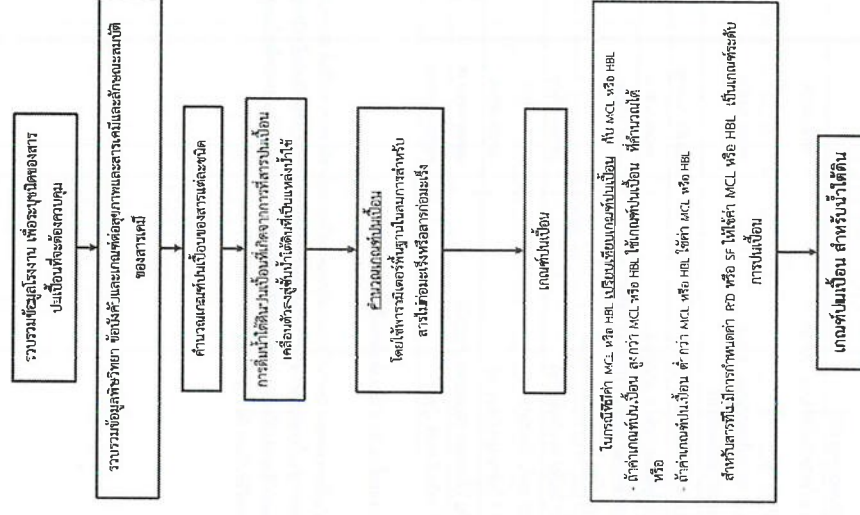
ในการที่มีผลการปนเปื้อนของสารหรือต่างให้เปรียบเทียบผลการวิเคราะห์ค่าที่ออกจากรายการนี้กับค่าที่ยกมาใช้ในการ
ติดตามตรวจสอบการปนเปื้อนกับผลการวิเคราะห์ค่าที่ออกจากรายการนี้ให้เป็นอย่างเดียวกันที่ใช้เป็นอ้างอิงกับทิศทางการไหลของน้ำ
ใต้ดินในพื้นที่ โดยค่าที่เปรียบเทียบจะต้องไม่เกินระดับ และไม่อยู่ช่วงค่าเกณฑ์ของข้อมูลของมาตรฐาน
คุณภาพน้ำบาดาลที่บังคับคือ ๖.๕ - ๙.๒

๒.๑ วิธีคำนวณเกณฑ์การประเมินที่ดินภายในบริเวณโรงงาน



พจนานุกรม: RfD_{AD} หรือ Dermal-Adjusted Reference Dose
 SF_{AD} หรือ Dermal-Adjusted Cancer Slope Factor
 ABS_{GI} หรือ Gastro-Intestinal Absorption Factor

๒.๒ วิธีคำนวณเกณฑ์การปันปัน^{๒๕}นำ^{๒๖}ใต้^{๒๗}เงิน^{๒๘}ใน^{๒๙}บริ^{๓๐}เว^{๓๑}ณ^{๓๒}โ^{๓๓}ร^{๓๔}ง^{๓๕}งาน^{๓๖}



๓.๒ ตารางแสดงรายละเอียดเกี่ยวกับข้อมูลการใช้ การเก็บรักษา สารเคมีภายในบริเวณโรงงาน

ของโรงงาน.....

[illegible]

นางสาวดวงใจ

(๕) ตามระบบ IARC คือสารในกลุ่ม Group 1, Group 2A และ Group 2B

๓) หากมีสารจำนวนมากกว่าที่จะแสดงได้ในตารางให้จัดทำเป็นใบแนบเพิ่มเติม

ลงข้อแจ้งข้อเสีย ()

ตำแหน่ง.....

PLC57500

ข้อมูล ณ วันที่.....

[illegible]

ลงชื่อผู้แจ้งข้อมูล.....
(.....)
ตำแหน่ง.....

ขอโรงงาน.....



หมายเหตุ: โปรดดูอัตราส่วน ทิศทางการไหลของน้ำใต้ดิน และพิกัดตำแหน่งบ่อสังเกตการณ์

ลงชื่อผู้แจ้งข้อมูล.....
(.....)
ตำแหน่ง.....

.....ព្រះរាជាណាចក្រកម្ពុជា
(.....)
.....មិត្តភាពកម្ពុជា-សូវៀត

(ឃ/ស្រ) កម្មវិធីស្រាវជ្រាវ	(ឃ/ស្រ) កម្មវិធីស្រាវជ្រាវ	(ឃ/ស្រ) កម្មវិធីស្រាវជ្រាវ	(ឃ/ស្រ) កម្មវិធីស្រាវជ្រាវ	ស្ថាប័នស្រាវជ្រាវ	នាមក្រុមស្រាវជ្រាវ	ស្ថានភាព	កម្មវិធីស្រាវជ្រាវ ស្រាវជ្រាវស្រាវជ្រាវ	(CAS No.) លេខកូដកម្មវិធីស្រាវជ្រាវ	
កម្មវិធីស្រាវជ្រាវស្រាវជ្រាវ		កម្មវិធីស្រាវជ្រាវស្រាវជ្រាវ							

[illegible][illegible][illegible][illegible]

หลักการเกณฑ์การตรวจสอบคุณภาพดินและน้ำใต้ดินภายในบริเวณโรงงาน

ข้อ ๑ รวบรวมข้อมูลพื้นฐานของโรงงานได้แก่ ที่ตั้งและประวัติของโรงงาน สภาพแวดล้อมทางกายภาพ
ของพื้นที่ ผังโรงงาน วัตถุดิบ กระบวนการผลิต ปริมาณการใส่สารเคมี ระบบบำบัดน้ำเสีย ระบบรวบรวม
สารเคมีและนำเสีย การจัดการและสุขภาพ การจัดการกากอุตสาหกรรม ข้อมูลความปลอดภัย และอื่นๆ

ข้อ ๒ ระบอบนี้ของสารป่งเปื้อนต้องกำหนดหน้าที่การคำนวณเกณฑ์การป่งเปื้อนในดินและ
น้ำใต้ดิน จัดทำบัญชีรายชื่อสารป่งเปื้อนของโรงงานที่ได้ผ่านกระบวนการคัดกรองในเบื้องต้นแล้วว่าเป็น
สารอันตรายที่มีศักยภาพก่อให้เกิดการป่งเปื้อนในดินและน้ำใต้ดิน

ข้อ ๓ กำหนดเกณฑ์การประเมินและน้ำได้คืน จากภาคผนวกที่ ๑ หรือในกรณีที่ไม่มีปรากฏวิธี
สารต้องกำหนดเกณฑ์ในภาคผนวกที่ ๑ ให้ทำการคำนวณเกณฑ์การประเมินในดินและน้ำได้คืน
ตามภาคผนวกที่ ๒

ข้อ ๔ จัดทำบัญชีเยื่อสารปูนเอนและกรงการจำแนกความเป็นอันตรายของสารปูนเอน แสดงปริมาณการใช้ ปริมาณแหล่งซื้อและการจัดการสารปูนเอน เกณฑ์การปนเปื้อนในดินและน้ำใต้ดิน และแผนผังแสดงจุดเก็บตัวอย่างและจัดตั้งห้องปฏิบัติการเฝ้าระวังในภาคผนวกที่ ๓ เยื่อสารปูนเอนเริ่มทดสอบหากรณหรือสำนักงานอุตสาหกรรมจังหวัดที่โรงงานต้องอยู่ภายในหนึ่งร้อยแปดสิบวัน นับแต่วันเริ่มประกอบกิจการโรงงาน กรณีได้ประกอบกิจการโรงงานมาก่อนวันที่ประกาศนี้มีผลใช้บังคับ ให้ยื่นเอกสารยืนยันตัวภายในหนึ่งร้อยแปดสิบวัน นับแต่วันที่ประกาศนี้มีผลใช้บังคับ และให้แจ้งตั้งต่อไปพร้อมกับการขอต่ออายุใบอนุญาตประกอบกิจการโรงงาน

ข้อ ๕ ดัดแปลงสังคมและเก็บด้วยเทคโนโลยี เพื่อวิเคราะห์หาความเห็นของผู้
 การการเป็นไปในดินและน้ำได้ ใน การเก็บด้วยวิธีดังสามารถดำเนินการพร้อมกับการติดตั้ง
 ย่อสังคมการ โดยให้เก็บด้วยวิธีดังจากควาลีก ๒ ระดับ ได้แก่

(๑) ตัวอย่างดินระดับบน เก็บตัวอย่างดินที่ระดับตึกผิวดิน (ไม่มีความหนาของวัสดุลาด)

(๒) ตัวอย่างดังนี้เพื่อรายงานครั้งถัดไปในกรณีที่ไม่พบการปนเปื้อนให้เก็บตัวอย่างดิน
จุดเดิมไว้ด้วยอย่าง และเพิ่มการเกิดดินจากะดักผิวอีกชั้น ตามความเหมาะสมแล้วแต่กรณี

การเก็บตัวอย่างน้ำใต้ดินให้เก็บจากบ่อสังเกตการณ์ ในกรณีที่พบการปนเปื้อนสูงกว่าเกณฑ์
การปนเปื้อน อาจจำเป็นต้องเพิ่ม ความถี่ จุดเก็บตัวอย่าง และเพิ่มการเก็บตัวอย่างน้ำใต้ดินจากระดับความลึก
อื่น ตามความเหมาะสมแล้วแต่กรณี

ข้อ ๖ เปรียบเทียบค่าความเข้มข้นของสารปนเปื้อนในดินและน้ำใต้ดินกับเกณฑ์การปนเปื้อนที่ได้จาก
การคำนวณ

ข้อ ๗ ในกรณีที่มีความจำเป็นของสารปรมาณูในดินและน้ำใต้ดินสูงกว่าเกณฑ์การปรมาณูในดิน และน้ำใต้ดินภายในบริเวณโรงงาน ให้ดำเนินการตามมาตรการควบคุมการปรมาณูในดินและน้ำใต้ดิน และการจัดการลดการปรมาณูในดินและน้ำใต้ดินที่โรงงานเสนอทันที เพื่อให้ความเข้มข้นของสารปรมาณูในดินและน้ำใต้ดินต่ำกว่าเกณฑ์การปรมาณูดังกล่าว

ประกาศกรมสวัสดิการและคุ้มครองแรงงาน

เรื่อง ขีดจำกัดความเข้มข้นของสารเคมีอันตราย

อาศัยอำนาจตามความในข้อ ๒๘ แห่งกฎกระทรวงกำหนดมาตรฐานในการบริหาร จัดการ และดำเนินการด้านความปลอดภัย อาชีวอนามัย และสภาพแวดล้อมในการทำงานเกี่ยวกับสารเคมีอันตราย พ.ศ. ๒๕๕๖ อธิบดีกรมสวัสดิการและคุ้มครองแรงงาน จึงออกประกาศไว้ ดังต่อไปนี้

ข้อ ๑ ประกาศนี้เรียกว่า “ประกาศกรมสวัสดิการและคุ้มครองแรงงาน เรื่อง ขีดจำกัด ความเข้มข้นของสารเคมีอันตราย”

ข้อ ๒ ประกาศนี้ให้ใช้บังคับตั้งแต่วันถัดจากวันประกาศในราชกิจจานุเบกษาเป็นต้นไป

ข้อ ๓ ขีดจำกัดความเข้มข้นของสารเคมีอันตรายในบรรยากาศของสถานที่ทำงานและ สถานที่เก็บรักษาสารเคมีอันตราย ให้เป็นไปตามท้ายประกาศนี้

ประกาศ ณ วันที่ ๒๘ มิถุนายน พ.ศ. ๒๕๖๐

สุเมธ มโหสถ

อธิบดีกรมสวัสดิการและคุ้มครองแรงงาน

ขีดจำกัดความเข้มข้นของสารเคมีอันตราย

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No.	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายทั้งที่ การสัมผัสในระยะเวลาดำเนิน ชีวิตการทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายทั้งที่ การสัมผัสในระยะเวลาดำเนิน ชีวิตการทำงานปกติ		ขีดจำกัด ความเข้มข้น ของสารเคมี อันตรายเมื่อ ไม่ทำงาน
					ขีดจำกัด ความเข้มข้น	ระยะเวลา ที่สัมผัส ได้	
1	อะซีตัลดีไฮด์	acetaldehyde	75-07-0	200 ppm	-	-	-
2	กรดอะซิติก (กรดน้ำส้ม)	acetic acid	64-19-7	10 ppm	-	-	-
3	กรดอะซิติก แอนไฮไดรด์	acetic anhydride	108-24-7	5 ppm	-	-	-
4	อะซีโตน	acetone	67-64-1	1000 ppm	-	-	-
5	อะซีโตนไฮดรอกซีไดรีนโมโนไฮดรอกซีไดรีนไฮไดรด์	acetone cyanohydrin, as CN	75-86-5	-	-	-	5 mg/m ³
6	อะซีโตนไนไตรล์	acetonitrile	75-05-8	40 ppm	-	-	-
7	อะโครลีน	acrolein	107-02-8	0.1 ppm	-	-	-
8	อะคริลาไมด์	acrylamide	79-06-1	0.3 mg/m ³	-	-	-
9	กรดอะครีลิก	acrylic acid	79-10-7	2 ppm	-	-	-
10	อะครีโลไนไตรล์	acrylonitrile	107-13-1	2 ppm	10 ppm	15 min	-
11	กรดอะดิปิก	adipic acid	124-04-9	5 mg/m ³	-	-	-
12	อัลดีน	aldrin	309-00-2	0.25 mg/m ³	-	-	-
13	อัลลิลแอลกอฮอล์	allyl alcohol	107-18-6	2 ppm	-	-	-
14	อัลลิลคลอไรด์	allyl chloride	107-05-1	1 ppm	-	-	-
15	อัลลิลไกลิไซด์อีเธอร์	allyl glycidyl ether	106-92-3	-	-	-	10 ppm
16	อัลลิลโพรพิลไดซัลไฟด์	allyl propyl disulfide	2179-59-1	2 ppm	-	-	-
17	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
18	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
19	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
20	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
21	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
22	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
23	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
24	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
25	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
26	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
27	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
28	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
29	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
30	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
31	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
32	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
33	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
34	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
35	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
36	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
37	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
38	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
39	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
40	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
41	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
42	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
43	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
44	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
45	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
46	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
47	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
48	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
49	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
50	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
51	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
52	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
53	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
54	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
55	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
56	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
57	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
58	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
59	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
60	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
61	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
62	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
63	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
64	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
65	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
66	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
67	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
68	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
69	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
70	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
71	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
72	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
73	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
74	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
75	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
76	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
77	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
78	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
79	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
80	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
81	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
82	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
83	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
84	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
85	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
86	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
87	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
88	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
89	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
90	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
91	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
92	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
93	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
94	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
95	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
96	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
97	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
98	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
99	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-
100	อะลูมิเนียมไฮดรอกไซด์	aluminum metal, as Al	7429-90-5	-	-	-	-

[illegible]

ลำดับที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No.	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายเฉลี่ยต่อระยะ เวลาการทำงาน	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายสำหรับการสัมผัสชั่วขณะเดียว	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายสำหรับการสัมผัสในระยะเวลานาน	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายสำหรับการสัมผัสในระยะเวลานาน
39	เบนซีน	benzene	71-43-2	1 ppm	5 ppm	15 min	-
40	เบนโซิลไฮดรอกไซด์	benzoyl peroxide	94-36-0	5 mg/m ³	-	-	-
41	เบนซิล คลอไรด์	benzyl chloride	100-44-7	1 ppm	-	-	-
42	เบริลเลียมและสารประกอบของเบริลเลียม ในรูปของเบริลเลียม	beryllium and beryllium compounds, as Be	7440-41-7	0.002 mg/m ³	0.025 mg/m ³	30 min	0.005 mg/m ³
43	ไบฟีนิล (ไดฟีนิล)	biphenyl (diphenyl)	92-52-4	0.2 ppm	-	-	-
44	บิสฟีนอล เอ	bisphenol A	1304-82-1	-	-	-	-
45	โบรอน ไตรไฮไดรด์	borane, tetra, sodium salts	-	-	-	-	-
46	โบรอน ไตรโบไรด์	boron trihydride	1330-43-4	1 mg/m ³	-	-	1 ppm
47	โบรอน ไตรฟลูออไรด์	boron trifluoride	7637-07-2	-	-	-	1 ppm
48	โบรมีน	bromine	354-00-9	10 mg/m ³	-	-	-
49	โบรมีน เพนตะฟลูออไรด์	bromine pentafluoride	7789-30-2	0.1 ppm	-	-	-
50	โบรมีนไพลีน	bromine	75-25-2	0.5 ppm	-	-	-
51	1,3-บิวทาไดเอน	1,3-butadiene	106-99-0	1 ppm	5 ppm	15 min	-
52	บิวทีน	butene, all isomers	-	250 ppm	-	-	-
53	บิวทิลแอลกอฮอล์	n-butanol	71-36-3	100 ppm	-	-	-
54	เพนทาไมน	sec-butanol	78-92-2	150 ppm	-	-	-
55	เพนทาไมน	tert-butanol	75-65-0	100 ppm	-	-	-
56	2-บิวทอกซีเอทานอล	2-butoxyethanol	111-76-2	50 ppm	-	-	-
57	เพนทาไมน	tert-butyl acetate	540-88-5	200 ppm	-	-	-
58	บิวทิลแอลกอฮอล์	n-butyl alcohol	141-32-2	2 ppm	-	-	-
59	บิวทิลเอมีน	butylamine	109-73-9	-	-	-	5 ppm
60	บิวทิลไฮดรอกไซด์	n-butyl alcohol	2426-08-6	50 ppm	-	-	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)	ขีดจำกัด ความเข้มข้น ให้ทำงานได้	ขีดจำกัด ความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)
65	คาร์บอนมอนอกไซด์	Carbon monoxide	50-28-2	5 ppm	-	-	-
66	คาร์บอนไดออกไซด์	Carbon dioxide	74-20-4	10 ppm	-	-	-
67	แคลเซียมโครเมอไรต์	Calcium chromate, as Cr	13765-19-0	0.001 mg/m ³	-	-	-
68	แคลเซียมไซยาไนด์	Calcium cyanamide	156-62-7	0.5 mg/m ³	-	-	-
69	แคลเซียมไฮดรอกไซด์	Calcium hydroxide	1305-62-0	15 mg/m ³	-	-	-
70	คาร์บอนมอนอกไซด์	Carbon monoxide	50-28-2	5 ppm	-	-	-
71	คาร์บอนไดออกไซด์	Carbon dioxide	74-20-4	10 ppm	-	-	-
72	คาร์บอนมอนอกไซด์	Carbon monoxide	50-28-2	5 ppm	-	-	-
73	คาร์บอนไดออกไซด์	Carbon dioxide	74-20-4	10 ppm	-	-	-
74	คาร์บอนมอนอกไซด์	Carbon monoxide	50-28-2	5 ppm	-	-	-
75	คาร์บอนไดออกไซด์	Carbon dioxide	74-20-4	10 ppm	-	-	-
76	ซีเซียมไฮดรอกไซด์	Cesium hydroxide	21351-79-1	2 mg/m ³	-	-	-
77	คลอโรฟลูโอโรเมเทน	Chlorofluoromethane	75-45-6	1000 ppm	-	-	-
78	คลอโรฟลูโอโรเมเทน	Chlorofluoromethane	75-45-6	1000 ppm	-	-	-
79	คลอรีน	Chlorine	7782-50-5	-	-	-	-
80	คลอรีน	Chlorine	7782-50-5	-	-	-	-
81	คลอรีน	Chlorine	7782-50-5	-	-	-	-
82	คลอรีน	Chlorine	7782-50-5	-	-	-	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)	ขีดจำกัด ความเข้มข้น ให้ทำงานได้	ขีดจำกัด ความเข้มข้น ของสารเคมีอันตราย การสัมผัสในระยะเวลาดำเนิน การ (mg/m ³)
83	คลอโรฟอร์ม	Chloroform	67-66-3	-	-	-	-
84	คลอโรฟลูโอโรเมเทน	Chlorofluoromethane	600-25-9	20 ppm	-	-	-
85	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	76-15-3	1000 ppm	-	-	-
86	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	76-06-2	0.1 ppm	-	-	-
87	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	126-99-8	25 ppm	-	-	-
88	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	598-78-7	0.1 ppm	-	-	-
89	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	2039-87-4	50 ppm	-	-	-
90	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	95-49-8	50 ppm	-	-	-
91	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	2921-88-2	0.1 mg/m ³	-	-	-
92	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
93	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
94	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
95	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
96	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
97	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
98	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
99	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
100	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
101	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
102	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
103	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-
104	คลอโรฟลูโอโรเอเทน	Chlorofluoroethane	-	-	-	-	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เมื่อคิดต่อระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับ การสัมผัสในระยะเวลาลำบาก	ขีดจำกัด ความเข้มข้น	ขีดจำกัด ความเข้มข้น
109	ไฮดรอกซีเบนซีน (กรดไฮโดรซัลฟิสิก) ไฮดรอกซีเบนซีน	Hydroxiation (tricyclohexyltin hydride)	13121-70-5	5 mg/m ³	-	-	ขีดจำกัด ความเข้มข้น ของสารเคมี อันตรายที่มี อันตรายสูง ไม่รุนแรงใดๆ ในระหว่าง ทำงาน
106	ดีดีที (ไดคลอโรไดฟีนิลไดเอทิลฟอสฟอไรต์) ดีดีที	DDT (dichlorodiphenyltrichloro ethylene)	50-29-3	1 mg/m ³	-	-	-
107	ไดคลอโรเบนซีน (ออร์โท)	dichlorobenzene (ortho)	8061-48-3	0.1 mg/m ³	-	-	-
108	ไดคลอโรเบนซีน	dichlorobenzene	333-41-5	0.01 mg/m ³	-	-	-
109	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	95-50-1	-	-	-	50 ppm
110	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	106-46-7	15 ppm	-	-	-
111	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	75-52-3	150 ppm	-	-	-
112	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	561-59-6	200 ppm	-	-	-
113	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	64-76-7	10 mg/m ³	-	-	-
114	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	595-27-9	10 mg/m ³	-	-	10 ppm
115	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	64-76-7	10 mg/m ³	-	-	-
116	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	64-76-7	10 mg/m ³	-	-	-
117	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	64-76-7	10 mg/m ³	-	-	-
118	ไดคลอโรไดฟีนิลไฮดรอกซีเบนซีน	o dichlorobenzene	64-76-7	10 mg/m ³	-	-	-
119	2 ไดคลอโรเบนซีนไฮดรอกซีเบนซีน	2 dichlorobenzene	100-37-8	10 ppm	-	-	-
120	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	diethylene triamine	111-40-0	1 ppm	-	-	-
121	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	diethyl ketone	96-22-0	200 ppm	-	-	-
122	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	diisobutyl ketone	108-83-8	50 ppm	-	-	-
123	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	diisopropylamine	108-18-9	5 ppm	-	-	-
124	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	dimethylaniline	121-69-7	5 ppm	-	-	-
125	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	(N,N-dimethylaniline)	68-12-2	10 ppm	-	-	-
126	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	dimethylformamide	57-14-7	0.5 ppm	-	-	-
127	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	1,1 dimethylhydrazine	77-78-1	1 ppm	-	-	-
128	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	dimethyl sulfate	528-29-0	1 mg/m ³	-	-	-
129	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	diminobenzene, all isomers	99-05-0	1 mg/m ³	-	-	-
130	ไดคลอโรเบนซีน ไฮดรอกซีเบนซีน	ortho	100-25-4	1 mg/m ³	-	-	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เมื่อคิดต่อระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับ การสัมผัสในระยะเวลาลำบาก	ขีดจำกัด ความเข้มข้น	ขีดจำกัด ความเข้มข้น
129	ไดไนโตร-ออร์โท-ครีโซล	dnitro-o-cresol	534-52-1	0.2 mg/m ³	-	-	ขีดจำกัด ความเข้มข้น ของสารเคมี อันตรายที่มี อันตรายสูง ไม่รุนแรงใดๆ ในระหว่าง ทำงาน
130	ไดไนโตร-พาร์โท-ครีโซล	dnitro-p-cresol	25321-14-6	1.5 mg/m ³	-	-	-
131	ไดออกเซน (ไดเอทิลีน ไดออกไซด์)	dioxane (diethylene dioxide)	123-91-1	100 ppm	-	-	-
132	ไดออกเซน ไดออกไซด์	dioxathion	78-34-2	0.1 mg/m ³	-	-	-
133	ไดฟีนิลอะมีน	diphenylamine	122-39-4	10 mg/m ³	-	-	-
134	ไดโพรพิล คีโตน	dipropyl ketone	123-19-3	50 ppm	-	-	-
135	ไดออกซ์	dioxat	85-00-7 2764-72-9 6385-62-2	-	-	-	-
136	ไดออกซ์	dioxat	-	-	-	-	-
137	ไดออกซ์	dioxat	-	-	-	-	-
138	ไดออกซ์	dioxat	-	-	-	-	-
139	ไดออกซ์	dioxat	-	-	-	-	-
140	ไดออกซ์	dioxat	-	-	-	-	-
141	ไดออกซ์	dioxat	-	-	-	-	-
142	ไดออกซ์	dioxat	-	-	-	-	-
143	ไดออกซ์	dioxat	-	-	-	-	-
144	ไดออกซ์	dioxat	-	-	-	-	-
145	ไดออกซ์	dioxat	-	-	-	-	-
146	ไดออกซ์	dioxat	-	-	-	-	-
147	ไดออกซ์	dioxat	-	-	-	-	-
148	ไดออกซ์	dioxat	-	-	-	-	-
149	ไดออกซ์	dioxat	-	-	-	-	-
150	ไดออกซ์	dioxat	-	-	-	-	-
151	ไดออกซ์	dioxat	-	-	-	-	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No.	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เฉลี่ยตลอดระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับ การสัมผัสในระยะเวลาดำเนิน ชีวิตที่ ความเข้มข้น	ระยะเวลา ที่กำหนด ให้ทำงานได้	ขีดจำกัด ความเข้มข้น
142	เอทิลีน ไคลไฮไดรด์	ethylene chlorohydrin	107-07-3	5 ppm	-	-	-
143	เอทิลีนไดคลอไรด์	ethylene dichloride	107-15-3	10 ppm	-	-	-
144	เอทิลีน ไดออกไซด์	ethylene dibromide	106-93-4	20 ppm	50 ppm	5 min	30 ppm
145	เอทิลีน ไดออกไซด์ (1,2 dichloroethane)	ethylene dichloride (1,2 dichloroethane)	107-06-2	50 ppm	200 ppm	5 min in any 3 hr	100 ppm
146	เอทิลีน ไกลคอล	ethylene glycol	107-21-1	-	-	-	100 mg/m ³
147	เอทิลีน ไกลคอล ไดเมทาไธล	ethylene glycol dimethate	628-96-6	-	-	-	0.2 ppm
148	เอทิลีน ออกไซด์	ethylene oxide	75-21-8	1 ppm	5 ppm	15 min	-
149	เอทิลีน ออกไซด์	ethylene oxide	60-29-7	400 ppm	-	-	-
150	เอทิลีน ซัลไฟด์	ethyl formate	109-94-4	100 ppm	-	-	-
151	เอทิลีน ไกลคอล ไดเมทาไธล	ethyl mercaptan	75-08-1	-	-	-	10 ppm
152	เอทิลีน ไกลคอล	ethyl sulfide	78-13-4	100 ppm	-	-	-
153	เฟอร์ริลฟอสเฟต	ferusulfation	115-90-2	0.01 mg/m ³	-	-	-
154	เฟอร์ริลฟอสเฟต	ferusulfation	55-38-9	0.05 mg/m ³	-	-	-
155	ฟลูออรีน	fluorine	7782-41-4	0.1 ppm	-	-	-
156	ฟลูออรีน ไนโตรเจนไดออกไซด์	fluorides, as F	-	2.5 mg/m ³	-	-	-
157	ฟอสฟอรัส	phosphorus	7804-22-9	0.1 mg/m ³	-	-	-
158	ฟอสฟอรัสไดออกไซด์	formaldehyde	50-00-0	0.75 ppm	2 ppm	15 min	-
159	ฟอสฟอรัสไดออกไซด์	formic acid	64-18-6	5 ppm	-	-	-
160	ฟอสฟอรัสไดออกไซด์	butanol	98-01-1	5 ppm	-	-	-
161	ฟอสฟอรัสไดออกไซด์	butyl alcohol	98-00-0	50 ppm	-	-	-
162	ฟอสฟอรัสไดออกไซด์	glycidol	556-52-5	50 ppm	-	-	-
163	ฟอสฟอรัสไดออกไซด์	heptachlor	76-44-8	0.5 mg/m ³	-	-	-
164	ฟอสฟอรัสไดออกไซด์	heptane (n-heptane)	142-82-5	500 ppm	-	-	-
165	ฟอสฟอรัสไดออกไซด์	hexamethylene dicyanate	822-06-0	0.005 ppm	-	-	-
166	ฟอสฟอรัสไดออกไซด์	n-hexane	110-54-3	500 ppm	-	-	-
167	ฟอสฟอรัสไดออกไซด์	hydrozine	302-01-2	1 ppm	-	-	-
168	ฟอสฟอรัสไดออกไซด์	hydrogen bromide	10035-10-6	3 ppm	-	-	-
169	ฟอสฟอรัส ไดออกไซด์	hydrogen chloride	7647-01-0	-	-	-	5 ppm

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No.	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เฉลี่ยตลอดระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับ การสัมผัสในระยะเวลาดำเนิน ชีวิตที่ ความเข้มข้น	ระยะเวลา ที่กำหนด ให้ทำงานได้	ขีดจำกัด ความเข้มข้น
180	ไฮโดรเจน ไฮไดรด์	hydrogen cyanide	74-90-8	10 ppm	-	-	-
181	ไฮโดรเจน ฟลูออไรด์ ในรูปของ ฟลูออรีน	hydrogen fluoride, as F	7664-39-3	3 ppm	-	-	-
182	ไฮโดรเจน เพอร์ออกไซด์	hydrogen peroxide	7722-84-1	1 ppm	-	-	-
183	ไฮโดรเจน ซัลไฟด์	hydrogen sulfide	7783-06-4	-	50 ppm	10 min	20 ppm
184	ไฮดรอกซีเบน	hydroquinone	123-31-9	2 mg/m ³	-	-	-
185	2-ไฮดรอกซีโพรพิล อะคริเลต	2-hydroxypropyl acrylate	999-61-1	0.5 ppm	-	-	-
186	ไอโอดีน	iodine	7553-56-2	-	-	-	0.1 ppm
187	ไอโซบิวทิล อะซิเตต	isobutyl acetate	110-19-0	150 ppm	-	-	-
188	ไอโซฟอสฟอรัส	isophorone	78-59-1	25 ppm	-	-	-
189	ไอโซพรีน ไดไอโซไซยาเนต	isophorone diisocyanate	4098-71-9	0.005 ppm	-	-	-
190	2-ไอโซโพรพอกซีเอทานอล	2-isopropoxyethanol	109-59-1	25 ppm	-	-	-
191	ไอโซโพรพิล อะซิเตต	isopropyl acetate	108-21-4	250 ppm	-	-	-
192	ไอโซโพรพิล แอลกอฮอล์ (ไอโซ)	isopropyl alcohol (IPA)	67-63-0	400 ppm	-	-	-
193	ไอโซโพรพิลอะมีน	isopropylamine	75-31-0	5 ppm	-	-	-
194	ตะกั่วอินทรีย์ ในรูปของตะกั่ว	lead inorganic, as Pb	7439-92-1	0.05 mg/m ³	-	-	-
195	ตะกั่ว อินทรีย์	lead chromate	7758-97-6	-	-	-	-
-	ในรูปของตะกั่ว	- as Pb	-	0.05 mg/m ³	-	-	-
-	ในรูปของโครเมียม	- as Cr	-	0.012 mg/m ³	-	-	-
196	แอล.พี.จี. (แก๊สโพรเพนและเมทานอล)	L.P.G. liquefied petroleum gas	68476-85-7	1000 ppm	-	-	-
197	เมอร์คิวรี (ปรอท)	mercury	7439-97-6	-	-	-	0.1 mg/m ³
198	ออลกีน (อัลคิล) เมอร์คิวรี	organo (alkyl) mercury	7439-97-6	0.01 mg/m ³	-	-	0.04 mg/m ³
199	เมทิล ไซคลอเฮกซัน	methyl n-butyl ketone	591-78-6	100 ppm	-	-	-
200	เมทิล คลอไรด์	methyl chloride	74-87-3	100 ppm	300 ppm	5 min in any 3 hr	200 ppm
201	เมทิลไซโคลเฮกเซน	methylcyclohexane	108-87-2	500 ppm	-	-	-
202	เมทิลไซโคลเฮกซันอล	methylcyclohexanol	25639-42-3	100 ppm	-	-	-
203	ออลฟา- เมทิลไซโคลเฮกซันอน	o-methylcyclohexanone	583-00-8	100 ppm	-	-	-
204	เมทิลลีน คลอไรด์	methylene chloride	75-09-2	25 ppm	125 ppm	15 min	-

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เฉลี่ยตลอดระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับการ การสัมผัสในระยะเวลาดำเนิน งาน	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย สำหรับการสัมผัสในระยะเวลาดำเนิน งาน	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย สำหรับการสัมผัสในระยะเวลาดำเนิน งาน
205	4,4 เมทิลไดอะมิน	4,4 methylene diamine	101-77-9	0.1 ppm	-	-	-
206	เมทิล เมทิล คีโตน (เมทิลเอ)	methyl ethyl ketone (MEK)	78-93-3	200 ppm	-	-	-
207	เมทิล เอทิล คีโตน เปอร์ออกไซด์	methyl ethyl ketone peroxide	1338-23-4	-	-	-	0.2 ppm
208	เมทิล ฟอสไฟต์	methyl formate	107-31-3	100 ppm	-	-	-
209	เมทิล ไดออกไซด์	methyl iodide	74-88-4	5 ppm	-	-	-
210	เมทิล ไดออกไซด์ คีโตน	methyl isomyl ketone	110-12-3	100 ppm	-	-	-
211	เมทิล ไดออกไซด์ คีโตน	methyl isobutyl cabinal	108-11-2	25 ppm	-	-	-
212	เมทิล ไดออกไซด์ คีโตน	methyl isobutyl ketone	108-10-1	100 ppm	-	-	-
213	เมทิล ไดออกไซด์ คีโตน	methyl isopropyl ketone	503-80-4	20 ppm	-	-	-
214	เมทิล เมอร์แคปแทน	methyl mercaptan	74-93-1	-	-	-	10 ppm
215	เมทิล เมทาคริเลต	methyl methacrylate	80-62-6	100 ppm	-	-	-
216	เมทิล พาราไธออน	methyl parathion	298-00-0	0.02 mg/m ³	-	-	-
217	เมทิล เมทิล สไตรีน	alpha methyl styrene	98-83-9	-	-	-	100 ppm
218	เมทิล ฟอสไฟต์ (เมทิลเอ)	methylnphos (phosidin)	7786-34-7	0.01 mg/m ³	-	-	-
219	เมทิล เมทาคริเลต	methyl methacrylate	12001-26-2	3 mg/m ³	-	-	-
220	เมทิล เมทาคริเลต	monomethacrylphos	6923-22-4	0.05 mg/m ³	-	-	-
221	เมทิล เมทาคริเลต	methacrylphos	110-91-8	20 ppm	-	-	-
222	เมทิล เมทาคริเลต	metal	1400-02-0	-	-	-	-
223	เมทิล เมทาคริเลต	metal and insoluble compounds, as Ni	-	1 mg/m ³	-	-	-
224	เมทิล เมทาคริเลต	soluble compounds, as Ni	-	1 mg/m ³	-	-	-
225	เมทิล เมทาคริเลต	nicotine	54-11-5	0.5 mg/m ³	-	-	-
226	เมทิล เมทาคริเลต	nitric acid	7697-37-2	2 ppm	-	-	-
227	เมทิล เมทาคริเลต	nitrous oxide	10034-91-2	50 ppm	-	-	-
228	เมทิล เมทาคริเลต	nitric oxide	10102-43-9	25 ppm	-	-	-
229	เมทิล เมทาคริเลต	nitrobenzene	98-95-3	1 ppm	-	-	-
230	เมทิล เมทาคริเลต	nitroethane	79-24-3	100 ppm	-	-	-
231	เมทิล เมทาคริเลต	nitrogen dioxide	10102-44-0	-	-	-	5 ppm

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เฉลี่ยตลอดระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย สำหรับการสัมผัสในระยะเวลาดำเนิน งาน	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย สำหรับการสัมผัสในระยะเวลาดำเนิน งาน	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย สำหรับการสัมผัสในระยะเวลาดำเนิน งาน
230	ไนโตรกลีเซอริน	nitroglycerin	55-63-0	-	-	-	0.2 ppm
231	ไนโตรเบนซีน	nitrobenzene	75-52-5	100 ppm	-	-	-
232	1-ไนโตรโพรเพน	1-nitropropane	108-03-2	25 ppm	-	-	-
233	2-ไนโตรโพรเพน	2-nitropropane	79-06-9	25 ppm	-	-	-
234	ไนโตรโทลูอีน ทุกไอโซเมอร์	nitrotoluene, all isomers	88-72-2, 99-08-1, 99-09-0	5 ppm	-	-	-
235	ออกเทน	octane	111-65-9	500 ppm	-	-	-
236	ออกไซด์ของไนโตรเจน	osmium tetroxide, as Os	20816-12-0	0.002 mg/m ³	-	-	-
237	กรดออกซาลิก	oxalic acid	149-42-7	1 mg/m ³	-	-	-
238	ออกซิเจน ไดออกไซด์	oxygen difluoride	7783-41-7	0.05 ppm	-	-	-
239	พาราควาต ออกไซด์ของไนโตรเจน	paraquat, respliable dust	4685-14-7	0.5 mg/m ³	-	-	-
240	พาราไรออน	parathion	56-38-2	0.1 mg/m ³	-	-	-
241	เพนตาโบรน	pentaborane	19624-22-7	0.005 ppm	-	-	-
242	เพนตาคลอโรไนเฟทาเลน	pentachloronaphthalene	1321-64-8	0.5 mg/m ³	-	-	-
243	เพนตาคลอโรฟีนอล	pentachlorophenol	87-86-5	0.5 mg/m ³	-	-	-
244	เพนเทน	pentane	109-66-0	1000 ppm	-	-	-
245	เพอร์คลอโรเอทิลีน (เตตราคลอโรเอทิลีน)	perchloroethylene (tetrachloroethylene)	127-18-4	100 ppm	300 ppm	5 min in any 3 hr	200 ppm
246	ฟีนอล	phenol	108-95-2	5 ppm	-	-	-
247	ออร์โท-ฟีนิลไดอะมิน	o-phenylenediamine	95-54-5	0.1 mg/m ³	-	-	-
248	เมตา-ฟีนิลไดอะมิน	m-phenylene diamine	108-45-2	0.1 mg/m ³	-	-	-
249	พารา-ฟีนิลไดอะมิน	p-phenylene diamine	106-50-3	0.1 mg/m ³	-	-	-
250	ฟอสเฟต	phosphate	298-02-2	0.05 mg/m ³	-	-	-
251	ฟอสจีน (คาร์บอนิล คลอไรด์)	phosgene (carbonyl chloride)	75-44-5	0.1 ppm	-	-	-
252	กรดฟอสฟอริก	phosphoric acid	7664-38-2	1 mg/m ³	-	-	-
253	ฟอสฟอรัส (เหลือง)	phosphorus (yellow)	7723-14-0	0.1 mg/m ³	-	-	-
254	ฟอสฟอรัส ออกไซด์ไตรด์	phosphorus oxychloride	10025-87-3	0.1 ppm	-	-	-
255	ฟอสฟอรัส เพนตาคลอไรด์	phosphorus pentachloride	10026-13-8	1 mg/m ³	-	-	-

รหัสน้ำยา	ชื่อสามัญ (ไทย)	ชื่อสามัญภาษาอังกฤษ (อังกฤษ)	CAS No	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายในผลิตภัณฑ์บริโภค	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายในกระบวนการผลิต	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายในกระบวนการใช้	ขีดจำกัดความเข้มข้นของสารเคมีอันตรายในกระบวนการใช้
256	โพแทสเซียม เพอร์ซัลเฟต	phosphorus pentasulfide	1314-80-3	1 mg/m ³	-	-	-
257	โพแทสเซียม ไตรคลอไรด์	phosphorus trichloride	7719-12-2	0.5 ppm	-	-	-
258	พิกนิก แอมโมเนียม	phthalic anhydride	85-44-9	2 ppm	-	-	-
259	กรดซิตริก	picric acid	88-89-1	0.1 mg/m ³	-	-	-
260	พินโดน (2-พิวาลิ-1,3-ไดอินโดน)	pinone (2-pivalyl-1,3-indandione)	83-26-1	0.1 mg/m ³	-	-	-
261	โพแทสเซียม ไฮดรอกไซด์	potassium hydroxide	1310-58-3	-	-	-	2 mg/m ³
262	โพรพอกซิล แอลกอฮอล์	propargyl alcohol	107-19-7	1 ppm	-	-	-
263	1,3-ไดโพรพิลไดเอโนน	1,3 propiolactone	57-57-8	0.5 ppm	-	-	-
264	กรดโพรพิโอนิก	propionic acid	79-09-4	10 ppm	-	-	-
265	โพรพอกซิล	propoxur	114-26-1	0.5 mg/m ³	-	-	-
266	น-โพรพิล แอลกอฮอล์	n-propyl acetate	109-60-4	200 ppm	-	-	-
267	น-โพรพิล แอลกอฮอล์	n-propyl alcohol	71-23-8	200 ppm	-	-	-
268	พิกนิก	pyridine	73-55-8	2 ppm	-	-	-
269	พิกนิก	pyridine oxide	75-56-9	100 ppm	-	-	-
270	พิกนิก	pyridine	110-86-1	5 ppm	-	-	-
271	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
272	พิกนิก	pyridine	108-60-3	10 ppm	-	-	-
273	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
274	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
275	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
276	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
277	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
278	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
279	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
280	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
281	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
282	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
283	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
284	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
285	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
286	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
287	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
288	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
289	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
290	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
291	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
292	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
293	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
294	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
295	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
296	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
297	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
298	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
299	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
300	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
301	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
302	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
303	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
304	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
305	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
306	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
307	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
308	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
309	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
310	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
311	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
312	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
313	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
314	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
315	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
316	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
317	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
318	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
319	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
320	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
321	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
322	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
323	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
324	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
325	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
326	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
327	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
328	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
329	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
330	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
331	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
332	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
333	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
334	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
335	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
336	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
337	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
338	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
339	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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341	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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357	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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359	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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378	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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386	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
387	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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389	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
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395	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
396	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
397	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
398	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
399	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
400	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
401	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
402	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
403	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
404	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
405	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
406	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
407	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
408	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
409	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
410	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
411	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
412	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
413	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
414	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
415	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
416	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
417	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
418	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
419	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
420	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
421	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
422	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
423	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
424	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
425	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
426	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
427	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
428	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
429	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
430	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
431	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
432	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
433	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
434	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
435	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
436	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
437	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
438	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
439	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
440	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
441	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
442	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
443	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
444	พิกนิก	pyridine	73-55-8	10 ppm	-	-	-
445	พิกนิก	pyridine	73-55-8	10 ppm			

ลำดับ ที่	ชื่อสารเคมีอันตราย (ไทย)	ชื่อสารเคมีอันตราย (อังกฤษ)	CAS No.	ขีดจำกัดความเข้มข้น ของสารเคมีอันตราย เมื่อเทียบกับระยะเวลา การทำงานปกติ	ขีดจำกัดความเข้มข้น ของสารเคมีอันตรายสำหรับการ สัมผัสในระยะยาว		ขีดจำกัด ความเข้มข้น ในการทำงาน
					ขีดจำกัด ความเข้มข้น	ระยะเวลา ที่ทำงาน ได้ทุกวันได้	
278	โซเดียม ไบซัลไฟต์	sodium bisulfite	7631-90-5	5 mg/m ³	-	-	-
279	โซเดียม ไฮดรอกไซด์	sodium hydroxide	1310-73-2	2 mg/m ³	-	-	-
280	โครเมียม ไตรวาเลนต์	chromium trioxide, as Cr	7789-06-2	0.0005 mg/m ³	-	-	-
281	สตริควินีน	strychnine	57-24-9	0.15 mg/m ³	-	-	-
282	สไตรีน	styrene	100-42-5	100 ppm	600 ppm	5 min in any 3 hr	200 ppm
283	ซัลไฟท์	sulfite	3689-24-5	0.1 mg/m ³	-	-	-
284	ซัลเฟอร์ ไดออกไซด์	sulfur dioxide	7446-09-5	5 ppm	-	-	-
285	กรดซัลฟูริก	sulfuric acid	7664-93-9	1 mg/m ³	-	-	-
286	ทัลค์	talc	14807-96-6	-	-	-	-
287	ใยหินประเภทของเส้นใย และเศษซาก อนุภาคขนาดเล็กที่ อาจดูดเข้าสู่ระบบทางเดินหายใจได้ - ใยหินประเภทของเส้นใยและ เศษซาก อนุภาคขนาดเล็กที่อาจดูด เข้าสู่ระบบทางเดินหายใจได้	- containing no asbestos fibres, respirable dust	-	2 mg/m ³	-	-	-
		- containing asbestos fibres, respirable dust	-	0.1 f/cm ³	-	-	-
287	ซีทีพีซี (เอสเตอร์เทคทีล ไพร ฟอสเฟต)	TEPP (tetraethyl pyrophosphate)	107-49-3	0.05 mg/m ³	-	-	-
288	เฮกซะฟลูออโรเอทาน์	tellurium hexafluoride, as Te	7783-80-4	0.02 ppm	-	-	-
289	1,1,2,2-เตตระคลอโรเอเทน	1,1,2,2-tetrachloroethane	79-34-5	5 ppm	-	-	-
290	เอทาน์-เอทิล เอท, ไนวซ์เอทาน์	tetraethyl lead, as Pb	78-30-2	0.075 mg/m ³	-	-	-
291	เอทาน์-ไดเอทิล-เอทาน์	tetrahydrofuran	109-99-9	200 ppm	-	-	-
292	เอทาน์-เมทิล, เอท, ไนวซ์เอทาน์	tetraethyl lead, as Pb	75-74-1	0.075 mg/m ³	-	-	-
293	เอทาน์-สารประกอบฟอสเฟต ในรูปของเอทาน์	thallium, soluble compounds, as Tl	7440-28-0	0.1 mg/m ³	-	-	-
294	เอทาน์-ไดเอทิล	thioxylic acid	68-11-1	1 ppm	-	-	-
295	ไดเอทิล คลอไรด์	thionyl chloride	7719-09-7	-	-	-	0.2 ppm
296	ไทโรล	thiram	137-26-8	5 mg/m ³	-	-	-
297	โทลูอีน	toluene	108-88-3	200 ppm	500 ppm	10 min	300 ppm
298	โซเดียม 2,4-ไดไธโอไซยาเนต (ไซไดท์)	toluene - 2,4-diisocyanate (TDI)	584-84-9	-	-	-	0.02 ppm

Endnotes and Abbreviations

- * 2022 Addition.
- † See Notice of Intended Changes (NIC).
- (1) Adopted values or notations enclosed are those for which changes are proposed in the TLV.
- ‡ 2022 Revision or Addition to the Notice of Intended Changes.
- A Refers to Appendix A: Carcinogenicity.
- C Ceiling limit; see definition in the "Introduction to the Chemical Substances."
- (D) Simple asphyxiant; see discussion covering Minimal Oxygen Content found in the "Definitions and Notations" section following the NIC tables.
- (E) The value is for particulate matter containing no asbestos and < 1% crystalline silica.
- (EX) Explosion hazard; the substance is a flammable asphyxiant or excursions above the TLV® could approach 10% of the lower explosive limit.
- (F) Respirable fibers: length > 5 µm, aspect ratio ≥ 3:1, as determined by the membrane filter method at 400–450X magnification (4-mm objective), using phase-contrast illumination.
- (G) As measured by the vertical elutriator, cotton-dust sampler; see the TLV® Documentation.
- (H) Airborne only.
- (I) Insoluble in water; see Appendix C, paragraph A.
- (IV) Insoluble in water and vapor; see Notations/Endnotes section, p. 71.
- (J) Does not include isomers of toxic metals.
- (K) Should not exceed 2 mg/m³ respirable particulate matter.
- (L) Exposure by all routes should be carefully controlled to levels as low as possible.
- (M) Classification refers to sulfuric acid contained in strong inorganic acid mists.
- (O) Sample by method that does not collect vapor.
- (P) Application restricted to conditions in which there are negligible aerosol exposures.
- (R) Respirable particulate matter; see Appendix C, paragraph C.
- (T) Transient particulate matter; see Appendix C, paragraph B.
- (V) Vapor fraction.
- B = Background; see BEI Intro.
- BEI = Substances for which there is a Biological Exposure Index or Indices (see BEI section).
- BEI₁ = BEI for Cholinesterase Inhibiting Pesticides.
- BEI₂ = BEI for Methemoglobin Inducers.
- BEI₃ = BEI for Polycyclic Aromatic Hydrocarbons (PAHs).
- DSENI = Dermal Sensitization; see definition in the "Definitions and Notations" section.
- MW = Molecular weight.
- NOS = Not otherwise specified.
- Nq = Nonquantitative; see BEI Intro.
- Ns = Nonspecific; see BEI Intro.
- OTO = Occupational; see definition in the "Definitions and Notations" section.
- RSENI = Respiratory Sensitization; see definition in the "Definitions and Notations" section.
- SEN = Sensitization; see definition in the "Definitions and Notations" section.
- Skin = Danger of cutaneous absorption; see discussion under Skin in the "Definitions and Notations" section.
- SL = Surface limit; see definition in the "Introduction to the Chemical Substances."
- Sq = Semi-quantitative; see BEI Intro.
- STEL = Short-term exposure limit; see definition in the "Introduction to the Chemical Substances."
- TWA = 8-hour, time-weighted average; see definition in the "Introduction to the Chemical Substances."
- ppm = Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 750 torr.
- mg/m³ = Milligrams of substance per cubic meter of air.

TLV®

BEI®



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10101-41-4	Calcium sulfate, the dihydrate [see Calcium sulfate]
10102-43-9	Nitric oxide
10102-44-0	Nitrogen dioxide
10210-68-1	Cobalt carbonyl
10294-33-4	Boron tribromide
10294-34-5	Boron trichloride
11070-44-3	Methyltetrahydrophthalic anhydride [see Methyltetrahydrophthalic anhydride isomers]
1071-83-6	Glyphosate
11097-69-1	Chlorodiphenyl (54% chlorine)
11103-66-9	Zinc potassium chromate [see Appendix G]
12001-28-2	Mica
12001-28-4	Crocidolite [see Asbestos, all forms]
12001-29-5	Chrysotile [see Asbestos, all forms]
12035-72-2	Nickel subsulfide [see Nickel and inorganic compounds]
12070-12-1	Tungsten carbide [see Hard metals, containing Cobalt and Tungsten carbide]
12079-65-1	Manganese cyclopentadienyl tricarbonyl
12108-13-3	2-Methylcyclopentadienyl manganese tricarbonyl
12125-02-9	Ammonium chloride luma
12172-73-5	Amosite [see Asbestos, all forms]
12179-04-3	Sodium tetraborate, pentahydrate [see Borate compounds, inorganic]
12185-10-3	Phosphorus (yellow)
12604-58-9	Ferrovandium
13071-79-9	Terbutol
13121-70-5	Cyhexatin (Tricyclohexyltin hydroxide)
13149-00-3	Hexahydrophthalic anhydride, cis-isomer
13397-24-5	Calcium sulfate, gypsum [see Calcium sulfate]
13429-07-7	Dipropylene glycol methyl ether (DPGME)
13463-39-3	Nickel carbonyl
13463-40-6	Iron pentacarbonyl
13463-67-7	Titanium dioxide
13466-78-9	Δ -3-Carene [see Turpentine and selected monoterpenes]
13494-80-9	Tellurium
13530-65-9	Zinc chromate [see Appendix G]

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13588-26-2	Dipropylene glycol methyl ether (DPGME)
13765-19-1	Calcium chromate [see Appendix G]
13838-16-2	Enfuran
14166-21-3	Hexahydrophthalic anhydride, trans-isomer
14464-46-1	Silica, crystalline — cristobalite
14484-64-1	Ferrom
14807-66-6	Silica, nonasbestos form
14808-60-7	Silica, crystalline — quartz
14857-34-2	Dimethyltetrahydrophthalic anhydride
14977-61-8	Chloromethyl chloride [see Appendix G]
15972-60-3	Alamcor
16219-75-3	Fluoridone norbornene
16752-77-5	Methomyl
16842-03-8	Cosalt hydrocarbon
17702-41-9	Dacacorene
17804-35-2	Beromyl
19287-45-7	Clorane
19430-93-4	Perfluorobutyl ethylene
19438-63-2	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
19438-64-3	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
19624-22-7	Pentaborane
20324-32-7	Dipropylene glycol methyl ether (DPGME)
20816-12-0	Osmium tetroxide
21087-64-9	Metriquin
21351-79-1	Cesium hydride
21651-19-4	Tin oxide
21725-46-2	Cyanazine
22224-92-6	Fenamiphos
22248-79-9	Tetrachlorophosphos [(Z)-isomer]
22350-76-1	Tetrachlorophosphos [(E)-isomer]
22781-23-3	Bendiocarb
25013-15-4	Vinyltoluene (Methyl styrene, all isomers)
25154-54-5	Dinitrobenzene, all isomers
25167-67-3	Butene, mixture of isomers
25321-14-6	Dinitrotoluene
25551-13-7	Trimethyl benzene, mixed isomers [see Trimethyl benzene, isomers]
25639-42-2	Methylcyclohexanol

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26140-60-3	Terphenyls
26590-20-5	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
26628-22-8	Sodium azide
26675-46-7	Isosulfurane
26952-21-6	Isocetyl alcohol
31242-93-0	Chlorinated diphenyl oxide
34590-94-8	Dipropylene glycol methyl ether (DPGME)
35400-43-2	Sulprolos
37300-23-5	Zinc yellow [see Appendix G]
42498-58-8	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
50926-11-9	Indium tin oxide
51235-04-2	Hexazinone
53469-21-9	Chlorodiphenyl (42% chlorine)
55568-30-6	Tetrakis (hydroxymethyl) phosphonium sulfate
55568-21-3	Dipropylene glycol methyl ether (DPGME)
55355-75-8	Methyl acetylene-propadiene mixture
59689-28-0	Thiodicarb
61788-32-7	Hydrogenated terphenyls
64742-81-0	Hydrogenated kerosene [see Kerosene/Jet fuels as total hydrocarbon vapor]
65956-93-2	Coal tar pitch volatiles
65997-15-1	Portland cement
66215-27-8	Cyromazine
68334-30-5	Diesel oil
68476-30-2	Fuel oil No. 2 [see Diesel fuel as total hydrocarbons]
68476-31-3	Diesel No. 4 [see Diesel fuel as total hydrocarbons]
68476-34-6	Diesel No. 2 [see Diesel fuel as total hydrocarbons]
68476-85-7	L.P.G. (Liquefied petroleum gas)
68694-11-1	Trifluorizole
74222-97-2	Sulfomeluron methyl
86290-81-5	Gasoline
95465-99-9	Cadusafos
111986-49-9	Thiodoprid
122548-33-8	Imazosulfuron
128539-02-1	Carfentrazone-ethyl

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131341-66-1	Fludioxonil
135410-20-7	Acetamiprid
210880-92-5	Clothianidin
308062-82-0	Coal dust, Bituminous or Lignite
946578-00-3	Sulfoxalor

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1314-62-1	Vanadium pentoxide
1314-80-3	Phosphorus pentasulfide
1317-95-9	Silica, crystalline — lripoli
1319-77-3	Cresol, all isomers
1321-64-8	Pentachloronaphthalene
1321-65-9	Trichloronaphthalene
1321-74-0	Divinylbenzene
1330-20-7	Xylene, mixed isomers (Dimethylbenzene)
1330-43-4	Sodium tetraborate, anhydrous [see Borate compounds, inorganic]
1331-22-2	Methylcyclohexanone, mixed isomers [see Methylcyclohexanone, all isomers]
1332-21-4	Asbestos
1332-58-7	Kaolin
1333-74-0	Hydrogen
1335-86-4	Carbon black
1335-87-1	Hexachloronaphthalene
1335-88-2	Tetrachloronaphthalene
1336-25-3	Methyl ethyl ketone peroxide
1344-95-2	Calcium silicate [see Appendix G for Calcium silicate, synthetic nonfibrous]
1395-21-7	Subtilisins (proteolytic enzymes)
1477-55-0	m-Xylene α, α' -diamine
1563-66-2	Carbolaran
1569-02-4	Propylene glycol ethyl ether
1610-18-0	Prometon
1634-04-4	Methyl tert-butyl ether
1910-42-9	Paraquat dichloride [see Paraquat]
1912-24-9	Atrazine
1918-02-1	Picloram
1929-82-4	Nitirapryn (2-Chloro-6-(trichloromethyl)- pyridine)
2039-87-4	o-Chlorostyrene
2074-50-2	Paraquat dimethyl sulfate [see Paraquat]
2104-64-5	EPN
2179-59-1	Allyl propyl disulfide
2234-13-1	Octachloronaphthalene
2238-07-5	Diglycidyl ether
2425-05-1	Caplaol
2426-08-6	n-Butyl glycidyl ether
2451-62-9	1,3,5-Triglycidyl-s-triazinetriene
2528-38-1	Dibutyl phenyl phosphate
2551-62-4	Sulfur hexafluoride
2687-51-4	N-Ethyl-2-pyrrolidone

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2598-41-1	o-Chlorobenzylidene malononitrile
2598-79-3	Sulfuryl fluoride
2764-72-9	Dquat
2921-85-2	Chlorpyrifos
2971-90-6	Cropcol
3033-52-3	bis(2-Dimethylaminoethyl)ether
3333-52-6	Tetramethyl succinonitrile
3383-96-6	Temaphos
3425-89-5	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
3689-24-5	Sulotapp
3710-64-7	N,N-Diethylhydroxy amine
3825-26-1	Ammonium perfluorooctanoate
4016-14-2	isopropyl glycidyl ether
4266-71-9	sophorone diisocyanate
4170-30-3	Chloroacetaldehyde
4385-14-7	Paraquat
5124-33-1	Methylene bis(4-cyclohexylisocyanate)
5333-84-6	Methyltetrahydrophthalic anhydride isomer [see Methyltetrahydrophthalic anhydride isomers]
5392-40-5	Coral
5714-22-7	Sulfur pentachloride
5153-56-6	Oxalic acid, dihydrate
5385-52-2	Dquat dibromide monoxyrate [see Dquat]
5423-43-4	Propylene glycol dinitrate
6923-22-4	Monocrotophos
7095-85-0	Ethyl cyanoacrylate [see Appendix G]
7287-19-6	Prometryn
7429-90-5	Aluminum
7439-02-1	Lead
7439-96-5	Manganese
7439-97-5	Mercury
7439-98-7	Molybdenum
7440-01-9	Neon
7440-02-0	Nickel
7440-05-4	Platinum
7440-16-6	Rhodium
7440-22-4	Silver
7440-28-0	Tin
7440-31-5	Tin
7440-33-7	Tungsten
7440-36-0	Antimony
7440-37-1	Argon
7440-38-2	Arsenic

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7440-39-3	Barium
7440-41-7	Beryllium
7440-43-9	Cadmium
7440-47-3	Chromium
7440-48-4	Cobalt
7440-50-8	Copper
7440-58-6	Hafnium
7440-59-7	Helium
7440-61-1	Uranium (natural)
7440-65-5	Yttrium
7440-67-7	Zirconium
7440-74-6	Indium
7446-09-5	Sulfur dioxide
7550-45-0	Titanium tetrachloride
7553-58-2	Iodine
7572-28-4	Dichloroacetylene
7580-67-8	Lithium hydride
7616-94-6	Perchloryl fluoride
7631-90-5	Sodium bisulfite
7637-07-2	Boron trifluoride
7646-85-7	Zinc chloride
7647-01-0	Hydrogen chloride
7664-38-2	Phosphoric acid
7664-39-3	Hydrogen fluoride
7664-41-7	Ammonia
7664-83-9	Sulfuric acid
7681-57-4	Sodium metabisulfite
7697-37-2	Nitric acid
7719-09-7	Thionyl chloride
7719-12-2	Phosphorus trichloride
7722-84-1	Hydrogen peroxide
7726-95-8	Bromine
7727-21-1	Potassium persulfate [see Persulfates, as persulfate]
7727-37-9	Nitrogen
7727-43-7	Barium sulfate
7727-54-0	Ammonium persulfate [see Persulfates, as persulfate]
7758-97-6	Lead chromate
7773-08-0	Ammonium sulfamate
7775-27-1	Sodium persulfate [see Persulfates, as persulfate]
7778-18-9	Calcium sulfate, the anhydride
7782-41-4	Fluorine
7782-42-5	Graphite (natural)
7782-49-2	Selenium
7782-50-5	Chlorine

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7782-65-2	Germanium tetrahydride
7783-06-4	Hydrogen sulfide
7783-07-5	Hydrogen selenide
7783-41-7	Oxygen difluoride
7783-54-2	Nitrogen trifluoride
7783-60-0	Sulfur tetrafluoride
7783-79-1	Selenium hexafluoride
7783-80-4	Tellurium hexafluoride
7784-42-1	Arsine
7786-34-7	Mevinphos
7789-06-2	Strontium chromate [see Appendix G]
7789-30-2	Bromine pentafluoride
7790-91-2	Chlorine trifluoride
7803-51-2	Phosphine
7803-52-3	Antimony hydride (Stibine)
7803-62-5	Silicon tetrahydride (Silane)
8001-35-2	Chlorinated camphene (Toxaphene)
8002-74-2	Paraffin wax fume
8003-34-7	Pyrethrum
8006-14-2	Natural gas [see Aliphatic hydrocarbon gases]
8006-64-2	Turpentine
8008-20-6	Kerosene
8022-00-2	Methyl demeton (Demeton-methyl)
8029-10-5	Coal dust, Anthracite
8050-09-7	Resin acids
8052-41-3	Stoddard solvent
8052-42-4	Asphalt (Bitumen) fume
8065-48-3	Demeton
9002-86-2	Polyvinyl chloride
9004-34-6	Cellulose
9005-25-8	Starch
9008-04-6	Natural rubber latex
9014-01-1	Bacillus subtilis [see Subtilisins, as crystalline active enzyme]
10024-97-2	Nitrous oxide
10025-67-9	Sulfur monochloride
10025-87-3	Phosphorus oxychloride
10026-13-8	Phosphorus pentachloride
10028-15-6	Ozone
10034-76-1	Calcium sulfate, the hemihydrate [see Calcium sulfate]
10035-10-6	Hydrogen bromide
10043-35-3	Boric acid [see Borate compounds, inorganic]
10049-04-4	Chlorine dioxide

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124-38-9	Carbon dioxide
124-40-3	Dimethylamine
124-54-1	Tetras (hydroxymethyl) phosphonium chloride
126-73-8	Tributyl phosphite
126-55-7	Methylacrylonitrile
126-59-8	β -Chloroprene (2-Chloro-1,3-butadiene)
127-03-4	1-Chloro-2-propanol
127-19-4	Tetrachloroethylene (Perchloroethylene)
127-15-5	N,N-Dimethylacetamide
127-51-3	β -Pinene [see Turpentine]
126-37-0	Butylated hydroxytoluene (2,6-Di-tert-butyl-p-cresol)
131-11-3	Dimethylphthalate
133-05-2	Capten
133-17-3	Folpat
135-88-6	N-Phenyl- β -naphthylamine
136-78-7	Sesone (Sodium-2,4-dichlorophenoxyethyl sulfate)
137-05-3	Methyl 2-cyanoacrylate [see Appendix G]
137-26-8	Thram
138-22-7	n-Butyl lactate
140-11-4	Benzyl acetate
140-86-5	Ethyl acrylate (Acrylic acid ethyl ester)
141-32-2	n-Butyl acrylate (Acrylic acid, n-Butyl ester)
141-43-5	Ethanolamine (2-Aminoethanol)
141-66-2	Dicroplos
141-78-6	Ethyl acetate
141-79-7	Mesityl oxide
142-64-3	Piperazine dihydrochloride [see Appendix G]
142-82-5	Heptane, isomers (n-Heptane)
143-33-9	Sodium cyanide [see Hydrogen cyanide and cyanide salts, as CN]
144-62-7	Oxalic acid, anhydrous
148-01-6	3,5-Dinitro-o-toluidine (Dinitolide)
149-57-5	2-Ethylhexanoic acid
150-76-5	4-Methoxyphenol
151-50-8	Potassium cyanide [see Hydrogen cyanide and cyanide salts, as CN]
151-56-4	Ethyleneimine
151-67-7	Halothane
156-59-2	1,2-Dichloroethane, cis-isomer
156-59-3	1,2-Dichloroethane, trans-isomer
156-62-7	Calcium cyanamide
205-99-2	Benzophenanthrene
218-01-3	Chrysene

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287-92-3	Cyclopentane
298-00-0	Methyl parathion
298-02-2	Phorate
298-04-4	Daulfolon
299-84-3	Ronnel
299-85-5	Cufomate
300-76-5	Naled (Dibrom)
302-01-2	Hydrazine
309-00-2	Aldrin
314-40-9	Bromacil
330-54-1	Diuron
333-41-5	Diazinon
334-88-3	Diazomethane
353-42-4	Boron trifluoride dimethyl ether [see Boron trifluoride ethers]
353-50-4	Carbonyl fluoride
382-21-8	Perfluoroisobutylene
409-21-2	Silicon carbide
420-04-2	Cyanamide
431-03-8	Diacetyl
460-19-5	Cyanogen
463-51-4	Ketene
463-58-1	Carbonyl sulfide
463-82-1	Neopentane
479-45-8	Tetlyl (2,4,6-Trinitrophenyl)methyl-nitramine
504-29-0	2-Aminopyridine
506-60-3	Cyanogen bromide
508-77-4	Cyanogen chloride
509-14-8	Tetranitromethane
513-35-9	2-Methyl-2-butene
526-73-8	1,2,3-Trimethyl benzene [see Trimethyl benzene, isomers]
526-75-0	2,3-Dimethylphenol [see Dimethylphenol, all isomers]
-528-29-0	o-Dinitrobenzene [see Dinitrobenzene, all isomers]
532-27-4	2-Chloroacetophenone (Phenacyl chloride)
532-32-1	Sodium benzoate [see Benzoic acid and Alkali benzoates]
534-52-1	4,6-Dinitro-o-cresol
540-59-0	1,2-Dichloroethylene, sym-isomer (Acetylene dichloride)
540-84-1	Isocane (2,2,4-Trimethylpentane) [see Octane, all isomers]

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540-88-0	tert-Butyl acetate [see Appendix G]
541-85-5	Ethyl amyl ketone (5-Methyl-3-heptanone)
542-55-3	Isobutyl nitrile
542-75-9	1,3-Dichloropropene
542-83-1	bis(Chloromethyl) ether
542-92-7	Cyclopentadiene [see Appendix G]
552-30-7	Trimellitic anhydride
556-52-5	Glycidol (2,3-Epoxy-1-propanol)
557-04-0	Magnesium stearates [see Stearates]
557-05-1	Zinc stearates [see Stearates]
559-13-4	Carbon tetrabromide
563-34-2	Trimethylsilyl phosphite
563-12-2	Ethion
563-80-4	Methyl isopropyl ketone
563-59-3	2,3-Dimethylpentane [see Heptane, isomers]
576-26-1	2,6-Dimethylphenol [see Dimethylphenol, all isomers]
592-25-2	Potassium benzoate [see Benzoic acid and Alkali benzoates]
593-60-8	2-Methylcyclohexanone [see Methylcyclohexanone, all isomers]
594-84-9	Toluene-2,4-disocyanate (TDI)
595-34-4	3-Methylhexane [see Hexane, isomers]
599-52-4	4-Methylcyclohexanone [see Methylcyclohexanone, all isomers]
590-19-1	cis-2-Butene
593-35-2	2,2-Dimethylpentane [see Heptane, isomers]
591-24-2	3-Methylcyclohexanone [see Methylcyclohexanone, all isomers]
591-76-4	2-Methylhexane [see Heptane, isomers]
591-78-5	Methyl n-butyl ketone (2-Hexanone)
592-01-8	Calcium cyanide [see Hydrogen cyanide and cyanide salts, as CN]
592-41-6	1-Hexene
593-60-2	Vinyl bromide
594-42-3	Perchloromethyl mercaptan
594-72-9	1,1-Dichloro-1-nitroethane
598-78-7	2-Chloropropionic acid
600-25-9	1-Chloro-1-nitropropane
623-11-1	3-Pentyl acetate [see Pentyl acetate, all isomers]
624-11-9	2-Methylbutyl acetate [see Pentyl acetate, all isomers]
624-54-6	trans-2-Butene

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624-83-9	Methyl isocyanate
624-92-0	Dimethyl disulfide
625-16-1	1,1-Dimethylpropyl acetate (tert-Amyl acetate) [see Pentyl acetate, all isomers]
626-17-5	m-Phthalodinitrile
626-36-0	2-Pentyl acetate (sec-Amyl acetate)
627-13-4	n-Propyl nitrate
628-63-7	1-Pentyl acetate (n-Amyl acetate)
628-96-5	Ethylene glycol dimethyl ether
630-08-0	Carbon monoxide
637-92-3	Ethyl tert-butyl ether
639-21-1	Phenylphosphine
643-79-8	o-Phthalaldehyde
646-06-0	1,3-Dioxolane
680-31-9	Hexamethyl phosphoramide
681-84-5	Methyl silicate
684-16-2	Hexafluoroacetone
764-41-0	1,4-Dichloro-2-butene
768-52-5	N-Isopropylaniline
822-06-0	Hexamethylene diisocyanate
822-16-2	Sodium stearates [see Stearates]
919-86-8	Demeton-S-methyl
944-22-9	Fonofos
961-11-5	Tetrachlorvinphos [mixed isomers]
994-05-8	tert-Amyl methyl ether
999-81-1	2-Hydroxypropyl acrylate
1024-57-3	Heptachlor epoxide
1120-71-4	Propane sulfone
1189-85-1	tert-Butyl chromate
1300-71-5	Dimethylphenol (mixed isomers)
1300-73-8	Xylidine, mixed isomers (Dimethylaminobenzene)
1303-00-0	Gallium arsenide
1303-86-2	Boron oxide
1303-98-4	Sodium tetraborate, decahydrate [see Borate compounds, inorganic]
1304-82-1	Bismuth telluride
1305-62-0	Calcium hydroxide
1305-78-8	Calcium oxide
1309-37-1	Iron oxide (Fe ₂ O ₃)
1309-48-4	Magnesium oxide
1309-64-4	Antimony trioxide
1310-58-3	Potassium hydroxide
1310-73-2	Sodium hydroxide
1314-13-2	Zinc oxide

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100-21-0	Terephthalic acid
100-25-4	p-Dinitrobenzene [see Dinitrobenzene, all isomers]
100-37-8	2-Diethylaminethanol
100-40-3	Vinyl cyclohexene
100-41-4	Ethyl benzene
100-42-5	Styrene, monomer (Phenylethylene; Vinyl benzene)
100-44-7	Benzyl chloride
100-61-8	N-Methylaniline (Monomethyl aniline)
100-63-0	Phenylhydrazine
100-74-3	N-Ethylmorpholine
100-97-0	Hexamethylenetetramine
101-14-4	4,4'-Methylene bis(2-chloroaniline)
101-56-8	Methylene bisphenyl isocyanate
101-77-9	4,4'-Methylenedianiline (4,4'-Diaminodiphenylmethane)
101-84-8	Phenyl ether
102-34-5	Dicyclopentadienyl iron (Ferrocene)
102-71-6	Triethanolamine
102-81-6	2-N-Dibutylaminoethanol
103-71-9	Phenyl isocyanate
104-76-7	2-Ethyl-1-hexanol
104-94-9	p-Anisidine
105-46-4	sec-Butyl acetate [see Appendix G]
105-80-2	Caprolactam
105-87-9	2,4-Dimethylphenol [see Dimethylphenol, all isomers]
106-35-4	Ethyl butyl ketone (3-Heptanone)
106-42-3	p-Xylene (1,4-Dimethylbenzene) [see Xylene]
106-44-5	p-Cresol [see Cresol, all isomers]
106-46-7	p-Dichlorobenzene (1,4-Dichlorobenzene)
106-49-0	p-Toluidine
106-50-3	p-Phenylenediamine
106-51-4	Benzoquinone
106-87-6	Vinyl cyclohexene dioxide
106-89-8	Epichlorohydrin (1-Chloro-2,3-epoxypropane)
106-92-3	Allyl glycidyl ether
106-93-4	Ethylene dibromide (1,2-Dibromoethane)
106-94-5	1-Bromopropane
106-95-0	Allyl bromide
106-97-8	Butane
106-98-9	n-Butene [see Butenes, all isomers]

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106-99-0	1,3-Butadiene
107-01-7	2-Butene (mixture of trans- and cis- isomers) [see Butenes, all isomers]
107-02-8	Acrolein
107-05-1	Allyl chloride
107-06-2	Ethylene dichloride (1,2-Dichloroethane)
107-07-3	Ethylene chlorohydrin (2-Chloroethanol)
107-13-1	Acrylonitrile (Vinyl cyanide)
107-15-3	Ethylenediamine (1,2-Diaminoethane)
107-18-6	Allyl alcohol
107-19-7	Propargyl alcohol
107-20-0	Chloroacetaldehyde
107-21-1	Ethylene glycol
107-22-2	Glyoxal
107-30-2	Chloromethyl methyl ether (Methyl chloromethyl ether; Monochlorodimethyl ether)
107-31-3	Methyl formate (Formic acid methyl ester)
107-41-5	Hexylene glycol
107-49-3	Tetraethyl pyrophosphate
107-66-4	Dibutyl phosphale
107-83-5	2-Methyl pentane [see Hexane, isomers]
107-87-9	Methyl propyl ketone (2-Pentanone)
107-98-2	1-Methoxy-2-propanol (Propylene glycol monomethyl ether)
108-03-2	1-Nitropropane
108-05-4	Vinyl acetate
108-08-7	2,4-Dimethylpentane [see Heptane, isomers]
108-10-1	Methyl isobutyl ketone (Hexone)
108-11-2	Methyl isobutyl carbinol (Methyl amyl alcohol; 4-Methyl-2-pentanol)
108-18-9	Diisopropylamine
108-20-3	Isopropyl ether
108-21-4	Isopropyl acetate [see Appendix G]
108-24-7	Acetic anhydride
108-31-6	Maleic anhydride
108-38-3	m-Xylene (1,3-Dimethylbenzene) [see Xylene]
108-39-4	m-Cresol [see Cresol, all isomers]
108-44-1	m-Toluidine
108-45-2	m-Phenylenediamine

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108-46-3	Resorcinol
108-67-6	1,3,5-Trimethyl benzene [see Trimethyl benzene, isomers]
108-68-9	3,5-Dimethylphenol [see Dimethylphenol, all isomers]
108-83-8	Diisobutyl ketone (2,6-Dimethyl-4-heptanone)
108-84-9	sec-Hexyl acetate
108-87-2	Methylcyclohexane
108-88-3	Toluene (Toluol)
108-90-7	Chlorobenzene (Monochlorobenzene)
108-91-8	Cyclohexylamine
108-93-0	Cyclohexanol
108-94-1	Cyclohexanone
108-95-2	Phenol
108-98-5	Phenyl mercaptan
109-59-1	2-Isopropoxyethanol (Ethylene glycol isopropyl ether)
109-60-4	n-Propyl acetate [see Appendix G]
109-63-7	Boron trifluoride diethyl ether [see Boron trifluoride ethers]
109-66-0	Pentane
109-73-9	n-Butylamine
109-79-5	Butyl mercaptan (Butanethiol)
109-86-4	2-Methoxyethanol
109-87-5	Methylal (Dimethoxymethane)
109-89-7	Diethylamine
109-90-0	Ethyl isocyanate
109-94-4	Ethyl formate (Formic acid ethyl ester)
109-99-9	Tetrahydrofuran
110-12-3	Methyl isomyl ketone
110-19-0	Isobutyl acetate [see Appendix G]
110-43-0	Methyl n-amyl ketone (2-Heptanone)
110-49-6	2-Methoxyethyl acetate
110-54-3	n-Hexane
110-62-3	n-Valeraldehyde
110-80-5	2-Ethoxyethanol
110-82-7	Cyclohexane
110-83-8	Cyclohexene
110-85-0	Piperazine and salts
110-86-1	Pyridine
110-91-8	Morpholine
111-15-9	2-Ethoxyethyl acetate
111-30-8	Glutaraldehyde
111-40-0	Diethylenetriamine
111-42-2	Diethanolamine
111-44-4	Dichloroethyl ether

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111-65-9	n-Octane
111-69-3	Adiponitrile
111-76-2	2-Butoxyethanol
111-84-2	Nonane
112-07-2	2-Butoxyethyl acetate
112-34-5	Diethylene glycol monobutyl ether
112-55-0	Dodecyl mercaptan
114-26-1	Propoxur
115-07-1	Propylene
115-11-7	Isobutene
115-29-7	Endosulfan
115-77-5	Pentaerythritol
115-86-6	Triphenyl phosphale
115-90-2	Fenstufthion
118-06-3	Aldicarb
118-14-3	Tetrafluoroethylene
118-15-4	Hexafluoropropylene
117-81-7	Di(2-ethylhexyl)phthalate (Di-sec-octyl phthalate)
118-52-5	1,3-Dichloro-5,5-dimethylhydantoin
118-74-1	Hexachlorobenzene
118-96-7	2,4,6-Trinitrotoluene
119-93-7	o-Tolidine (3,3'-Dimethylbenzidine)
120-80-9	Catechol (Pyrocatechol)
120-82-1	1,2,4-Trichlorobenzene
121-44-8	Triethylamine
121-45-9	Trimethyl phosphite
121-69-7	Dimethylaniline (N,N-Dimethylaniline)
121-75-5	Malathion
121-82-4	Cyclonile
122-34-9	Simazine
122-39-4	Diphenylamine
122-60-1	Phenyl glycidyl ether
123-19-3	Dipropyl ketone
123-31-9	Hydroquinone (Dihydroxybenzene)
123-38-6	Propionaldehyde
123-39-7	Monomethylformamide
123-42-2	Diacetone alcohol (4-Hydroxy-4-methyl-2-pentanone)
123-51-3	Isoamyl alcohol
123-54-6	2,4-Pentanedione
123-85-4	n-Butyl acetate [see Appendix G]
123-91-1	1,4-Dioxane (Diethylene dioxide)
123-92-2	Isopentyl acetate (Isoamyl acetate) [see Pentyl acetate]
124-04-9	Adipic acid
124-09-4	1,6-Hexanediamine

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71-55-6	Methyl trichloromethane (1,1,1-Trichloroethane)
72-20-9	Endrin
72-43-5	Methoxychlor
74-82-6	Methane
74-83-3	Methyl cyanide
74-94-0	Ethane
74-85-1	Ethylene
74-86-2	Acetylene [see Appendix G]
74-87-3	Methyl chloride
74-88-4	Methyl iodide
74-89-5	Methylamine
74-90-8	Hydrogen cyanide
74-93-1	Methyl mercaptan (Methanethiol)
74-95-4	Ethyl bromide (Bromoethane)
74-97-5	Chlorobromomethane (Bromochloromethane)
74-99-6	Propane
74-99-7	Methylacetylene (Propyne)
75-00-3	Ethyl chloride (Chloroethane)
75-01-4	Vinyl chloride (Chloroethene)
75-02-5	Vinyl fluoride
75-04-7	Ethylamine
75-05-8	Acetonitrile
75-07-0	Acetaldehyde
75-08-1	Ethyl mercaptan (Ethanthiol)
75-09-2	Dichloromethane (Methylene chloride)
75-12-7	Formamide
75-15-0	Carbon disulfide
75-18-3	Dimethyl sulfide
75-21-8	Ethylene oxide
75-25-2	Bromoform (Tribromomethane)
75-28-5	Isobutane [see Butane, isomers]
75-31-0	Isopropylamine
75-34-3	1,1-Dichloroethane (Ethylidene chloride)
75-35-4	Vinylidene chloride (1,1-Dichloroethene)
75-38-7	Vinylidene fluoride (1,1-Difluoroethene)
75-43-4	Dichlorofluoromethane
75-44-5	Phosgene (Carbonyl chloride)
75-45-6	Chlorodifluoromethane
75-47-8	Iodoform
75-50-3	Trimethylamine
75-52-5	Nitromethane
75-55-8	Propyleneimine (2-Methylaziridine)
75-55-9	Propylene oxide (1,2-Epoxypropane)
75-61-6	Difluorodibromomethane

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75-63-9	Trifluorobromomethane (Bromotrifluoromethane)
75-55-0	tert-Butanol (tert-Butyl alcohol)
75-93-4	Trichlorofluoromethane (Fluorotrichloromethane)
75-71-9	Dichlorodifluoromethane
75-74-1	Tetramethyl lead
75-83-2	2,2-Dimethyl butane [see Hexane, isomers]
75-85-5	Acetone cyanohydrin
75-91-2	tert-Butyl hydroperoxide
75-99-0	2,2-Dichloropropionic acid
76-03-9	Trichloroacetic acid
76-06-2	Chloropicrin (Nitrochloromethane, Trichloronitromethane)
75-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane
75-12-0	1,1,2,2-Tetrachloro-1,2-difluoroethane
75-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane
76-14-2	Dichlorotetrafluoroethane
76-15-3	Chloropentafluoroethane
76-22-2	Camphor, synthetic
76-44-8	Heptachlor
77-47-4	Hexachlorocyclopentadiene
77-73-6	Dicyclopentadiene
77-78-1	Dimethyl sulfate
78-00-2	Tetraethyl lead
78-10-4	Ethyl silicate (Silicic acid, tetraethyl ester)
78-30-8	1-norbornesyl phosphate
78-32-0	Triparacresyl phosphate
78-34-2	Dioxathion
78-59-1	Isophorone
78-78-4	Isopentane [see Pentane, all isomers]
78-83-1	Isobutanol (Isobutyl alcohol)
78-87-5	Propylene dichloride (1,2-Dichloropropane)
78-89-7	2-Chloro-1-propanol
78-92-2	sec-Butanol (sec-Butyl alcohol)
78-93-3	Methyl ethyl ketone (2-Butanone)
78-94-4	Methyl vinyl ketone (3-Buten-2-one)
78-95-5	Chloroacetone
79-00-5	1,1,2-Trichloroethane
79-01-6	Trichloroethylene
79-04-9	Chloroacetyl chloride
79-06-1	Acrylamide
79-09-4	Propionic acid
79-10-7	Acrylic acid
79-11-8	Monochloroacetic acid

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79-20-9	Methyl acetate
79-21-0	Peracetic acid
79-24-3	Nitroethane
79-27-6	1,1,2,2-Tetrabromomethane (Acetylene tetrabromide)
79-29-8	2,3-Dimethyl butane [see Hexane, isomers]
79-34-5	1,1,2,2-Tetrachloroethane (Acetylene tetrachloride)
79-41-4	Methacrylic acid
79-43-6	Dichloroacetic acid
79-44-7	Dimethyl carbamoyl chloride
79-46-9	2-Nitropropane
80-51-3	p,p'-Oxybis(benzenesulfonyl hydrazide)
80-56-8	α-Pinene [see Turpentine and selected monoterpenes]
80-62-6	Methyl methacrylate (Methacrylic acid, methyl ester)
81-81-2	Warfarin
82-68-8	Pentachloronitrobenzene
83-26-1	Pindone (2-Pivalyl-1,3-indandione)
83-79-4	Rolenone, commercial
84-66-2	Diethyl phthalate
84-74-2	Dibutyl phthalate
85-00-7	Diquat dibromide [see Diquat]
85-42-7	Hexahydrophthalic anhydride
85-44-9	Phthalic anhydride
86-50-0	Azaphos-methyl
86-88-4	ANTU (α-Naphthylthiourea)
87-68-3	Hexachlorobutadiene
87-86-5	Pentachlorophenol
88-120	N-Vinyl-2-pyrrolidone
88-72-2	o-Nitrotoluene
88-89-1	Picric acid (2,4,6-Trinitrophenol)
89-72-5	o-sec-Butylphenol
90-04-0	o-Anisidine
90-12-0	1-Methyl naphthalene
91-08-7	Toluene-2,6-diisocyanate
91-15-6	o-Phthalonitrile
91-20-3	Naphthalene
91-57-6	2-Methyl naphthalene
91-59-8	β-Naphthylamine
91-94-1	3,3'-Dichlorobenzidine
92-52-4	Biphenyl (Diphenyl)
92-67-1	4-Aminodiphenyl
92-94-2	Phenothiazine
92-87-5	Benzdine

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92-93-3	4-Nitrodiphenyl (4-Nitrobiphenyl)
93-76-5	2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)
94-36-0	Benzoyl peroxide (Dibenzoyl peroxide)
94-75-7	2,4-D (2,4-Dichlorophenoxyacetic acid)
95-13-6	Indane
95-47-6	o-Xylene (1,2-Dimethylbenzene) [see Xylene]
95-48-7	o-Cresol [see Cresol, all isomers]
95-49-8	o-Chlorotoluene
95-50-1	o-Dichlorobenzene (1,2-Dichlorobenzene)
95-53-4	o-Toluidine
95-54-5	o-Phenylenediamine
95-63-6	1,2,4-Trimethyl benzene [see Trimethyl benzene, isomers]
95-65-8	3,4-Dimethylphenol [see Dimethylphenol, all isomers]
95-87-4	2,5-Dimethylphenol [see Dimethylphenol, all isomers]
96-05-9	Allyl methacrylate
96-09-3	Styrene oxide
96-14-0	3-Methyl pentane [see Hexane, isomers]
96-18-4	1,2,3-Trichloropropane
96-22-0	Dialkyl ketone
96-33-3	Methyl acrylate (Acrylic acid methyl ester)
96-69-5	4,4'-Thiobis(6-tert-butyl-m-cresol)
97-77-8	Disulfiram
98-00-0	Furfuryl alcohol
98-01-1	Furfural
98-07-7	Benzotrithione
98-51-7	p-tert-Butyltoluene
98-73-7	4-tert-Butylbenzoic acid
98-82-6	Cumene
98-83-9	α-Methylstyrene
98-88-2	Acetophenone
98-88-4	Benzoyl chloride
98-95-3	Nitrobenzene
99-08-1	m-Nitrotoluene
99-55-8	5-Nitro-o-toluidine
99-65-0	m-Dinitrobenzene [see Dinitrobenzene, all isomers]
99-99-0	p-Nitrotoluene
100-00-5	p-Nitrochlorobenzene
100-01-6	p-Nitroaniline

CAS

effects data are largely of case reports and qualitative exposure assessments. The data available are sufficient to derive exposure-response relationships. Reasons for the absence of quantitative epidemiologic data on such relationships include the following:

1. Most data on concentrations of specific bioaerosols are derived from indicator measurements rather than from measurements of actual effector agents. For example, some investigators use the airborne concentration of culturable fungi to represent exposure to airborne fungal antigens. In addition, most measurements are from either area or source samples. These monitoring approaches are, at best, crude estimates of human exposure. Personal sampling for actual effector agents would be needed to establish data necessary to derive a TLV.
 2. Bioaerosol components and concentrations vary widely within and among different occupational, residential and environmental settings. Unfortunately, replicate sampling is uncommon in bioaerosol assessments. Further, the most commonly used air-sampling devices for indoor monitoring are designed to collect "grab" samples over relatively short time intervals. Measurements from single, short-term grab samples may be one or more orders of magnitude higher (or lower) than long-term average concentrations and are unlikely to represent occupant exposures accurately. Some organisms and sources release aerosols as "concentration bursts," which may only rarely be detected by limited grab sampling. Nevertheless, such episodic and transient bioaerosol releases may produce significant health effects.
 3. In studies (e.g., single workplaces or homes), the number of persons affected by exposure to biological agents may be small if contamination is localized, thereby affecting only a fraction of the building occupants. However, data from different studies can seldom be combined to reach meaningful numbers of test subjects because the specific types of biological agents responsible for bioaerosol-related illnesses are diverse and often differ from study to study. These factors contribute to the low statistical power common in evaluations of cause-effect relationships between exposures to specific biological agents and building-related adverse health complaints.
- C. **Infectious agents.** Suitable human exposure-response relationships for infectious bioaerosols have not been developed for the majority of microorganisms and viruses. At present, air-sampling protocols for infectious agents are extremely limited. Air sampling is not practical to determine TWA or transient exposures in most environments. They can be useful for academic research endeavors or as a part of an overall informed assessment of potential exposure to infectious bioaerosols. In most routine exposure settings, public health measures, such as immunization, active case finding, source control, and medical treatment, remain the primary defenses against infectious bioaerosols. Facilities with an increased risk of transmitting airborne infectious diseases (e.g., microbiology laboratories, animal-handling facilities, and health-care settings) should employ engineering controls (such as ventilation and filtration) to minimize airborne concentrations of infectious agents and subsequent exposures. Further, such facilities should implement administrative controls and provide personal protective equipment (PPE), such as appropriate respiratory protection, to reduce worker exposures

to infectious bioaerosols

- D. **Other biologically-derived contaminants.** Endotoxins, mycotoxins, antigens, allergens, and mVOCs are detected using chemical, immunological, or biological assays. Evidence does not yet support TLVs[®] or BEIs[®] for any of these substances. However, assay methods for certain common airborne antigens and endotoxins are steadily improving, and field validation of these assays is also progressing. Dose-response relationships for some assayable biologically-derived contaminants have been observed in experimental studies and occasionally in epidemiologic surveys. Therefore, exposure limits for certain assayable, biologically-derived airborne contaminants may be possible in the future. In addition, innovative molecular techniques have increasingly become available for specific bioaerosols or biologically-derived contaminants that previously were detectable only by culture or counting.
- ACGIH[®] actively solicits information, comments, and data in the form of peer-reviewed literature on health effects associated with bioaerosol exposures in occupational and related environments that may help ACGIH[®] evaluate the potential for proposing exposure guidelines for selected biological agents. Such information should be sent in electronic format to the ACGIH[®] Science Group at science@acgih.org.

Reference

1. ACGIH[®]. *Bioaerosols: Assessment and Control*. J.J. Macher, Ed. H.A. Armstrong, H.A. Burge, D.K. Klee, and P.R. Morey, Ass. Eds. ACGIH[®], Cincinnati, OH (1999).

BIOLOGICAL AGENTS UNDER STUDY

The Bioaerosols Committee notes that there are no biological agents under study by ACGIH[®]. However, ACGIH[®] solicits information, especially data, which may assist it in the establishment of TLVs[®] for biological agents. Comments and suggestions, accompanied by substantiating evidence in the form of peer-reviewed literature, should be forwarded in electronic format to the ACGIH[®] Science Group at science@acgih.org.

Agents
None

CAS NUMBER INDEX

50-00-0	Formaldehyde
50-29-3	DDT (Dichlorodiphenyltrichloroethane)
50-32-8	Benzo(a)pyrene
50-78-2	Acetylsalicylic acid (Aspirin)
52-68-6	Trichlorfon
54-11-5	Nicotine
55-38-9	Fenthion
55-63-0	Nitroglycerin
56-23-5	Carbon tetrachloride (Tetrachloromethane)
58-38-2	Parathion
58-55-3	Benz(a)anthracene
58-72-4	Coumaphos
58-81-5	Glycerin mist [see Appendix G]
57-11-4	Stearic acid [see Stearates]
57-14-7	1,1-Dimethylhydrazine
57-24-9	Stychnine
57-50-1	Sucrose
57-57-8	β-Propiolactone
57-74-8	Chlordane
58-89-9	Lindane (γ-Hexachlorocyclohexane)
60-29-7	Ethyl ether (Diethyl ether)
60-34-4	Methylhydrazine
60-35-5	Acetamide
60-57-1	Dieldrin
61-82-5	Amitrole (3-Amino-1,2,4-triazole)
62-53-3	Aniline
62-73-7	Dichlorvos
62-74-8	Sodium fluoroacetate
62-75-9	N-Nitrosodimethylamine (N,N-Dimethylnitrosamine)
63-25-2	Carbaryl
64-17-5	Ethanol (Ethyl alcohol)
64-18-6	Formic acid
64-19-7	Acetic acid
65-85-0	Benzoic acid [see Benzoic acid and Alkali benzoates]
67-56-1	Methanol (Methyl alcohol)
67-63-0	2-Propanol (Isopropanol; Isopropyl alcohol)
67-64-1	Acetone
67-66-3	Chloroform (Trichloromethane)
67-72-1	Hexachloroethane
68-11-1	Thioglycolic acid
68-12-2	Dimethylformamide
71-23-8	n-Propanol (n-Propyl alcohol)
71-36-3	n-Butanol (n-Butyl alcohol)
71-43-2	Benzene

2022 Biological Agents

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260 — Introduction

BIOLOGICAL AGENTS

Biological agents include bacteria, fungi, viruses, arachnids, algae and parasites. The term "biological agent" refers to a substance of biological origin that is capable of producing an adverse health effect (e.g., an infection or a hypersensitivity, irritant, inflammatory, or other adverse response). Bioaerosols are aerosols composed of or derived from living organisms and can include both viable and nonviable organisms and viruses, fragments, toxins, and particulate waste. Biological agents are ubiquitous in nature but may be amplified in man-made environments and materials. Many of these biological agents also contain or release, due to metabolic activity or decomposition of nutrients and substrates, endotoxins, mycotoxins, antigens, allergens, and/or microbial volatile organic compounds (mVOCs). Humans are frequently exposed, day after day, to a wide variety of these contaminants at varying concentrations (usually very low levels that do not elicit a response or pose a health risk) that do not necessarily result in harm.

TLVs[®] exist for certain substances of biological origin, including cellulose; subtilins (proteolytic enzymes); and some gases and mVOCs produced by living organisms (e.g., carbon dioxide, methanol, and acetaldehyde). However, a majority of the remainder of the biological agents of concern are microbiological in nature. For the reasons identified below, there are no TLVs[®] against which to compare environmental air concentrations of microbial agents.

Indoor biological contamination can be defined as the presence of: a) bioaerosols likely to cause or predispose humans to health effects; b) inappropriate indoor airborne concentrations of bioaerosols, as determined through the consideration of space type or occupancy purposes; or c) indoor microbial growth, amplification, or remnants of biological growth, or sources of infectious agents or pathogens, either deposited, accumulated, or amplified that may become aerosolized and to which humans may be exposed.

ACGIH[®] has developed and separately published guidance on the assessment, control, remediation, and prevention of bioaerosols (1). The ACGIH Bioaerosols Committee concurs that, at this time, the measurement and analysis of airborne concentrations of bioaerosols cannot be relied upon to determine whether conditions and exposures pose an adverse health risk. The ACGIH-recommended approach to assessing a bioaerosol exposure relies on visually inspecting buildings; assessing occupant adverse health symptoms; evaluating building performance, including ventilation; identifying potential environmental sources of amplification or accumulation; and dissemination, and applying professional judgment to the information to form an informed opinion concerning the potential for exposure to bioaerosols. The published guidance provides background information on the major groups of bioaerosols, including their sources and health effects, and describes methods to collect, analyze, and interpret bioaerosol samples from potential environmental sources. Occasionally, environmental monitoring (i.e., microbial air sampling) detects a single, or predominant, biological contaminant. More commonly, microbial air sampling reveals a mixture of many biologically-derived materials, reflecting the diverse and interactive nature of indoor microenvironments. Therefore, environmental sampling for bioaerosols should be conducted only following careful formulation of testable hypotheses about potential

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bioaerosol sources and mechanisms by which occupants may be exposed to bioaerosols from these sources. Even when investigators work from testable hypotheses and well-formulated sampling plans, results from environmental bioaerosol monitoring may be inconclusive and misleading. Interpretation of sample results is highly subjective and often NOT based upon scientific or evidence-based information. Due to the challenges related to repeatable airborne contaminant measurement and analytical methods, ill-defined dose-response relationships, individual susceptibility, and inherent variability in background concentrations, there are no TLVs[®] for airborne concentrations of: a) total culturable or countable bioaerosols (e.g., total bacteria, fungi, or viruses); b) specific culturable or countable bioaerosols (e.g., *Aspergillus fumigatus*); c) infectious agents (e.g., *Legionella pneumophila*, SARS-CoV-2, or *Mycobacterium tuberculosis*); or d) assayable biological contaminants (e.g., endotoxins, mycotoxins, antigens, or many of the mVOCs).

A. Total culturable or countable bioaerosols. Culturable bioaerosols are those bacteria, viruses, and fungi that can be sampled by recognized and accepted methods, and subsequently grown in culture media in the laboratory. Such results are reported as the number of colony-forming units (CFU) per volume sampled (e.g., cubic meter of air). Countable bioaerosols are those fungal spores, bacterial cells, and other material that can be identified and counted by microscope. A general TLV[®] for culturable or countable bioaerosol concentrations is not scientifically supportable because of the following:

1. Culturable microorganisms and countable biological particles do not comprise a single entity (i.e., bioaerosols in environmental and non-environmental settings are generally complex mixtures of many different microbial, animal, and plant particles).
 2. Human responses to bioaerosols range from innocuous effects to serious, even fatal, diseases, depending on the specific agent involved and the individual's susceptibility to it. Therefore, an appropriate exposure limit for one bioaerosol may be entirely inappropriate for another, and neither may be generalizable to a broad population.
 3. Many reliable methods are available to collect and analyze bioaerosol materials. However, different methods of sample collection and analysis may result in different estimates of culturable and countable bioaerosol concentrations, even when the same basic sampling methods are used.
 4. The inherent temporal and spatial variability of fungal spores, bacteria, and other suspended bioaerosol concentrations in outdoor and indoor environments makes collecting a few to several "grab samples" to estimate a time-weighted average (TWA) exposure an unreliable approach. The number of samples required to overcome this limitation is often infeasible for assessments outside of research settings.
 5. At present, information relating culturable or countable bioaerosol concentrations to health effects is generally insufficient to describe exposure-response relationships.
- B. Specific culturable or countable bioaerosols other than infectious agents. Specific TLVs[®] for individual culturable or countable bioaerosols have not been established to prevent hypersensitivity, irritant, infectious toxic, or other adverse health responses. At present, information relating culturable or countable bioaerosol concentrations to adverse health

sleep loss is slow and often incomplete (Belletky et al., 2003).

Health effects. Chronic insufficient, disrupted, and/or disordered sleep has been associated with chronic diseases such as diabetes and hypertension and with psychological conditions, including depression and anxiety. Substance abuse, suicide, obesity, and overall mortality also have been associated with insufficient and/or disordered sleep (Caldwell et al., 2019; IOM, 2006). Furthermore, sleep disturbances increase the risk of infectious and inflammatory diseases including colds, influenza, and herpes zoster (shingles), and some epidemiological research suggests shift work (which often results in sleep restriction as well as circadian disruption) may increase the risk of certain types of cancers (Caldwell et al., 2019).

Fatigue Countermeasures

Adequate sleep is essential for proper fatigue management even though obtaining it and avoiding circadian disruptions are difficult in modern society. However, fatigue can be mitigated in part with proven countermeasures (Caldwell and Caldwell, 2017). Any countermeasures implemented should be customized to the specific workplace and type of work in question. Various factors not discussed in this document such as environmental stressors (e.g., heat, cold), physical demands, and other factors should be taken into account.

Education. Personnel must be educated about the dangers of fatigue, the importance of adequate sleep, and facts about the slow recovery from sleep loss. Workers cannot manage problems if they are not fully aware of them.

Good sleep habits. Various strategies can optimize the restorative potential of available off-duty sleep opportunities. Employees should receive training on good sleep habits and other behavioral interventions.

Naps. Naps are valuable when full consolidated sleep periods are not feasible. Proper timing, sufficient length, and optimal placement within the circadian pattern are beneficial for workplace performance and using the correct practices can avoid post-nap sleepiness (sleep inertia).

Rest breaks. Short on-the-job rest breaks also positively impact alertness for short periods of time. They are most beneficial when employees can stand and engage in physical activity and/or social interactions. However, depending on the circumstances, napping, as discussed below, can also be an effective strategy.

Proper lighting. Light management can positively influence alertness and circadian alignment, but intensity, wavelength, exposure time, and correct placement with regard to circadian phase are essential. Properly timed bright light, particularly when blue-enriched, can increase arousal and facilitate better adaptation to a new schedule or to time zone changes. Blocking unwanted light exposure with special glasses can improve adaptation to night work and avoid increased sleepiness immediately prior to sleep (ACGIH, 2018). Lighting customization for individual tasks and for workers with impaired vision can also be helpful (National Telecommunications Safety Panel, 2009).

Caffeine. Caffeine is a non-prescription stimulant that is safe in moderate doses (Wilcock et al., 2017). It enhances alertness in rested and sleep-deprived individuals. Caffeine in moderate doses can be obtained in single servings of coffee, tea, soft drinks, energy drinks, or caffeinated gum. Eighty percent of the US population regularly consumes caffeine, often for its alertness-enhancing properties (McLellan et al., 2016).

Sleep-scheduling devices. When scheduling, environmental, or work factors pre-

vent proper rest, medications may be an option. Hypnotics can promote shuttily sleep, if opportunities for sleep are available, and stimulants can increase wakefulness if sleep deprivation is unavoidable. The choice of hypnotics should take into account the speed and duration of its effects. Both prescription and over-the-counter options are available. Correct hypnotic use can improve sleep without creating post-sleep hangover effects. Prescription hypnotics or stimulants are not typically provided to workers except for the treatment of a diagnosed sleep disorder such as primary insomnia, sleep apnea, narcolepsy or idiopathic hypersomnia. However, the stimulant modafinil and armodafinil are not used for treatment of excessive sleepiness associated with shift work sleepiness disorder, narcolepsy, and obstructive sleep apnea, and both medications can alert once the alertness of shift workers.

Behavioral sleep-optimization techniques. When sleeping difficulties arise, sleep optimization strategies such as stimulus control, relaxation, and cognitive therapies should be considered. These approaches, as well as meditation/ mindfulness training, may be effective; however, positive results may take time to achieve.

Identification/treatment of sleep disorders. This important countermeasure is often overlooked, but any condition that negatively affects the restorative value of sleep can adversely impact workplace performance. Diagnosis and treatment of sleep disorders such as insomnia, sleep apnea, restless legs syndrome, and periodic limb movement disorder will optimize on-the-job alertness and worker safety.

Fatigue monitoring technologies. Real-time monitoring of operator fatigue is usually not feasible but monitoring off-duty sleep can be beneficial. Continuous sleep/wake measurement via wrist actigraphy contributes to fatigue management since it assesses whether workers are obtaining 7 to 8 hours of daily sleep. However, worker privacy issues need to be carefully considered before implementing any type of monitoring program.

Bi-mathematical models. Combining actigraphy-based sleep monitoring with mathematical fatigue-prediction models can track and reduce employee fatigue. Such models use validated algorithms that estimate individual fatigue as a function of sleep/wake patterns. Use of the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model or other validated models (e.g., the Unified Model) can identify overly-fatiguing work schedules (Caldwell et al., 2019).

Science-based shift-schedule planning. Designing work/rest schedules based on proven scientific principles is essential for avoiding fatigue-related adverse effects on performance, health, and morale in the workplace. Advice on factors such as the optimal number of consecutive night shifts, shift rotation periods, time between shifts, and shift lengths is available from a variety of sources (Caldwell et al., 2019).

Fatigue Risk Management Systems (FRMS). An FRMS can reduce fatigue-associated risks by formally implementing procedures to ensure employees are getting sufficient sleep and are monitored for fatigue-related problems and organizations have controls to minimize fatigue-related errors (Caldwell et al., 2013; Lerman et al., 2012). It is essential that any plan be customized for the specific workplace and occupational tasks in question. It also is necessary to consider cultural factors when formulating guidance for specific workplaces. The schedules of some societies and occupations may differ from those of most industrial societies. For example, practices that are common in U.S. manufac-

turing facilities may not be feasible for agrarian settings or among populations in which long afternoon rest periods that offer sleep opportunities are common.

Conclusions and Recommendations

Given the present state of knowledge, ACGIH® considers that fatigue from excessive sleepiness in the workplace is a serious health, performance, and safety hazard. However, evidence-based strategies can promote better sleep, optimize sleep/wake and work scheduling, and mitigate the impact of fatigue in real-world settings. Organizations are advised:

1. All personnel should be educated about the nature of workplace fatigue and that: a) fatigue is a serious problem; b) it is due to physiological changes in the brain and more than a state of mind; and c) it can be mitigated with proven strategies.
2. Mitigation strategies should include: a) workplace-based modifications (i.e., optimal lighting, workplace napping facilities, appropriate rest-break planning, and science-based scheduling practices); b) personnel-based practices (i.e., behavioral strategies for better sleep, proper use of alertness/sleep aids, and effective light-exposure management); and c) screening for disorders such as sleep apnea that degrade sleep.
3. Interventions should be implemented using a formal, carefully planned FRMS that is evidence-based, data driven, cooperatively designed, and integrated into the organization. It should be continuously improved, fully justified, and accepted by the workforce and management, including senior leaders as a safety and health priority.

References

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unexpected fatigue, dizziness, lightheadedness, nausea, and headache; and (2) coworkers and supervisors to be alert to other workers for signs of heat-related disorders such as confusion, agitation, instability, delirium, seizures, loss of consciousness, and physiological monitoring measures that mark excessive heat strain. The HSMP should remind workers with personal risk factors that may lower tolerance to heat stress that they may be at greater risk for heat-related disorders. Lower tolerance is associated with: (1) a prior history of heat stroke or episodes of heat exhaustion; (2) health conditions or medications that affect the cardiovascular system, water and electrolyte balance, metabolism, or thermoregulation; (3) acclimatization state; and (4) lower aerobic capacity, obesity, pregnancy, or age.

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TLV®-PA

2022 PHYSICAL AGENTS AND OTHER ISSUES UNDER STUDY

The TLV® Physical Agents Committee solicits information, especially data, which may assist it in its deliberations regarding the following agents and issues. Comments and suggestions, accompanied by substantiating evidence in the form of peer-reviewed literature, should be forwarded in electronic format to the ACGIH® Science Group at science@acgih.org. In addition, ACGIH® solicits recommendations for additional agents and issues of concern to the industrial hygiene and occupational health communities. Please refer to the ACGIH® TLV®/BE® Development Process found on the ACGIH® website for a detailed discussion covering this procedure and methods for input to ACGIH® (acgih.org/science/tlv-be-guidelines/policies-procedures-presentations/tlv-be-development).

The Under Study list is published each year by February 1 on the ACGIH® website (acgih.org/tlv-be-guidelines/documentation-publications-and-data/under-study-list), in the *Annual Reports of the Committees on TLVs® and BEIs®*, and later in the annual *TLVs® and BEIs®* book. In addition, the Under Study list is updated by July 31 into a two-tier list:

- Tier 1 entries indicate which chemical substances and physical agents may move forward as an NIC or NIE in the upcoming year, based on their status in the development process.
- Tier 2 consists of those chemical substances and physical agents that will not move forward, but will either remain on or be removed from, the Under Study list for the next year.

This updated list will remain in two-tiers for the balance of the year. ACGIH® will continue this practice of updating the Under Study list by February 1 and establishing the two-tier list by July 31 each year.

The substances and issues listed below are as of January 1, 2022. After this date, please refer to the ACGIH® website (acgih.org/science/tlv-be-guidelines/documentation-publications-and-data/under-study) for the up-to-date list.

Physical Agents

1. Acoustic
 - Audible sound
2. Optical Radiation
 - Light and Near-infrared radiation
3. Ergonomics
 - Over shoulder work
 - Push/Pull
4. Thermal Stress
 - Cold stress

Other Issues Under Study

1. Appendix B: Personal Physiologic Monitoring in the Workplace
2. Head supported mass and neck loading
3. Hypobaric pressure

APPENDIX A: STATEMENT ON THE OCCUPATIONAL HEALTH ASPECTS OF NEW LIGHTING TECHNOLOGIES – CIRCADIAN, NEUROENDOCRINE AND NEUROBEHAVIORAL EFFECTS OF LIGHT

Over the past decade a revolution in indoor lighting has been underway, fueled partly by new technologies of compact fluorescent lamps (CFLs) and solid-state, light-emitting diode (LED) lamps, and partly by efforts to reduce the consumption of electrical energy. Do these changes in the work environment pose any real health concerns? The ACGIH® TLVs® for Light and Near Infrared Radiation for evaluating optical radiation have existed for decades and lamp-safety standards refer to these TLVs®. These are designed chiefly to avoid retinal injuries from exposure to very intense light sources (e.g., welding arcs). In most workplace settings, there is little to no chance that workers will be exposed to general lighting sources (GLS) used for visual purposes that exceed current TLVs®.

However, the new lighting technologies, in particular LED and CFL lighting that are now widely used in workplaces for energy conservation, have significantly different spectral output than traditional incandescent light bulbs. There is considerable evidence that the body is highly sensitive to the blue light that forms a considerable fraction of the output of these sources. Some of the new lamps have sufficiently different spectra (color spectra) that concerns have been raised about potential health effects (AMA, 2016; CIE, 2005; ESNA, 2008). This Statement addresses possible health and safety issues that are associated with artificial lighting at levels that would be used for visual purposes.

Light is a potent stimulus for regulating circadian, hormonal, and behavioral systems in humans. Research over the past 12 years has shown that the biological and behavioral effects of light are particularly influenced by a distinct photoreceptor in the eye, the melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs), in addition to the conventional rods and cones (Lucas et al., 2014; CIE, 2008; IESNA, 2008). Published action spectra show that ipRGCs are most sensitive to blue-appearing light with a strong sensitivity in the 450–520 nm spectral band for circadian, neuroendocrine and neurobehavioral regulation in humans (480 nm is widely cited when a single peak is provided). However, the relatively recent discovery of a new photopigment (melanopsin) in the retina located in a previously unknown photoreceptor (Berson et al., 2002; Hefner et al., 2002), referred to as the “intrinsically photoreceptive retinal ganglion cell” (ipRGC), has raised new questions regarding light and health (CIE, 2006). The ipRGC responds strongly to short-wavelength (blue) light and plays a key role in neurobiological and neurobehavioral effects that fall under the general umbrella of “circadian” effects (Lucas et al., 2014; Brainard and Hanifin, 2004). The circadian (24-h) rhythm affects many physiological processes in the body other than just the sleep/wake cycle. Most organ systems undergo circadian cycles regulated by the neuroendocrine system. These include circadian rhythms, variations in body temperature, heart rate, etc. (Turner et al., 2010). Variations in hormone levels beside melatonin include cortisol and thyroid stimulating hormone (TSH). Thus, the physiological processes that determine mood, performance, alertness and tiredness are affected. The adverse physiological effects of shift work are driven by circadian disruption.

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Particular attention has been paid to the potential for “blue light” (450–480 nm) to increase alertness, since the blue-sensitive ipRGCs signal the pineal body (through the suprachiasmatic nucleus) to suppress secretion of melatonin (the “sleep hormone”). Indeed, there have been suggestions to increase alertness in the workplace by increasing the blue light spectrum in office lighting. This is most often described in the lighting literature as increasing the correlated color temperature (CCT) of the lamp spectrum, although this is not the most accurate way to describe the “melanopic” content of light, as different light spectra can have the same CCT (Lucas et al., 2014). In reality, all visible wavelengths provide an alerting stimulus during the day.

Some life scientists have noted that blue light is frequently cited as producing a phototoxic effect at very high retinal exposure levels, but far more than produced by standard commercially available general-service lamps. Although concerns have arisen as to the potential for adverse effects from chronic exposure to new lighting installations with blue-rich emissions in workplace lighting (Behar-Cohen et al., 2011), routine, normal exposure to the newer blue-rich lamps will remain well below the TLVs® for UV, visible and infrared radiation. General lighting service lamps for illumination also meet photobiological safety standards (based on the TLVs®). The IARC classification of shift work as a probable carcinogen has accentuated concerns that lighting in workplaces might play a role in carcinogenesis; however, this hypothesis remains quite controversial (IARC, 2011).

Conclusions and Recommendations

Given the present state of knowledge, ACGIH® considers that its present TLVs® are sufficiently protective against photochemically induced “blue light” hazard. ACGIH® does not consider it practical or advisable to develop TLVs® to protect against light-induced changes in circadian rhythms or possible related health effects from shift work.

However, employers and occupational safety experts are advised:

1. Shift work involves a range of issues apart from disruption of circadian rhythms, and these are best addressed by measures such as optimal planning of work schedules, rather than exposure limits such as TLVs®. Employers should be aware of recommendations by NIOSH and other occupational health organizations about shift work. For example: <http://www.cdc.gov/niosh/topics/workshift/>.
2. Adjusting the color palette of computer displays to reduce their short-wavelength content or dimming computer screens for evening work has been shown to affect circadian physiology and cognitive performance (Cajochen et al., 2011; Chang et al., 2015). Tools to adjust the color palette exist. The magnitude, if any, of any health benefit from their use remains unproven.
3. In occupational settings, employee alertness, safety and health are key. The lighting conditions should provide the safest and most alerting environment possible, while maintaining typical visual function. Work environments should therefore incorporate high intensity, blue-enriched (high melanopic) light during both the day, and especially at night given the high risk of sleepiness-related accidents and injuries. In occupational settings where there are potentially conflicting needs, such as a hospital during the night when patients sleep but staff are awake, the patient bedroom or ward

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NOTICE OF INTENDED CHANGE—HEAT STRESS AND STRAIN

This NOIC contains revisions which eliminate the TLV and ALV as options to select for evaluation of heat stress based on professional expertise. There is now emphasis on the implementation of a heat stress management plan. Studies on the response to using vapor barrier clothing, recovery cycle, the basis for the screening criteria and a comparison with the result of the Heat Stress Decision Aid (HSDA) method was added. The physiological monitoring section clarifies the basis for the sustained heart rate and core temperature limits. References were updated.

Warning: The TLV₀ is based on the ability of most healthy hydrated acclimatized workers to sustain thermal equilibrium. The Action Limit (AL) is similarly prescribed for healthy hydrated unacclimatized workers. This TLV has a small margin of safety, and some workers may experience heat-related disorders below the TLV or AL.

Introduction: The goal of the TLV is to limit heat stress exposure for those that may be sustained for hours that a worker with professional expertise can achieve and maintain thermal equilibrium. The Action Limit (AL) describes conditions where most healthy acclimatized workers may lose thermal equilibrium. If thermal equilibrium cannot be sustained, there is an increasing likelihood of heat exhaustion or heat stroke. While heat is a concern for the TLV, there is also an increased likelihood of thermal injury, heat injury, and adverse incidents with increasing heat stress. Furthermore, the TLV assumes complete recovery from a previous heat stress exposure.

The TLV is represented in Figure 1 by the solid line, and the Action Limit is represented by the broken line. The Wet Bulb Globe Temperature (WBGT) incorporates the environmental factors of air temperature, humidity, air movement, and radiant heat. WBGT_{eff} is the measured WBGT plus the clothing adjustment value (CAV). The task Metabolic Rate (M) measured in Watts [W] is the energy expenditure.

For computational purposes, the TLV and AL are calculated with the following:

$$TLV(^{\circ}C) = 56.7 - 11.5 \log_{10}(M[W]) \quad (1)$$

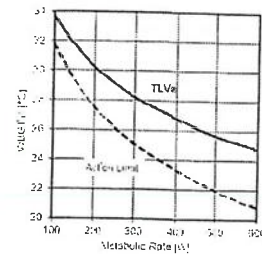
$$AL(^{\circ}C) = 60.0 - 14.1 \log_{10}(M[W]) \quad (2)$$

Heat Stress is the net heat load to which a worker may be exposed from the combined effects of metabolic heat, environmental factors, and thermal requirements. As heat stress increases and approaches the upper limit of heat tolerance, further increases may lead to unacceptable heat strain and the possibility of heat-related disorders.

Heat Strain is the overall physiological response resulting from heat stress. Normal physiological responses are dedicated to dissipating excess heat from the body. When these normal responses are no longer adequate, excessive heat strain may result.

Metabolic Rate is the energy expenditure associated with work activity and this expenditure generates internal heat that must be dissipated by the body. The metabolic rate due to work is as important as the WBGT assessment in evaluating heat stress. ISO 8996 (2021a) provides recognized methods to assess metabolic

FIGURE 1. TLV and Action Limit for Heat Stress



rate. While energy expenditure is best measured by oxygen consumption, various methods of estimation are available. Assignment of a category is among the least accurate methods but relatively easy to use. Table 1 provides useful categories of metabolic heat generation.

The TLV uses the WBGT (as defined above) index to estimate the environmental contributions to heat stress (International Organization for Standardization (ISO) 1998). WBGT uses air or dry-bulb temperature (T_{db}), natural wet-bulb temperature (T_{wb}), and globe temperature (T_g). The determination of WBGT depends on whether it is measured in direct sun ($WBGT_{direct}$) or in shaded or indoor conditions ($WBGT_{shaded}$) as follows:

$$WBGT_{direct} = 0.7 T_{wb} + 0.2 T_g + 0.1 T_{db} \quad (3)$$

$$WBGT_{shaded} = 0.7 T_{wb} + 0.3 T_g \quad (4)$$

WBGT_{eff} is the effective WBGT, which is the WBGT adjusted for clothing. Clothing affects the ability to dissipate internal heat to the ambient environment. To account for the effects of clothing, Clothing Adjustment Values (CAVs) are provided in Table 2 for some clothing configurations. The CAVs are expressed as equivalent values of WBGT that are added to the ambient WBGT to yield an effective WBGT ($WBGT_{eff}$).

Time-Weighted Averaging (TWA) of 1 hour can be used to assess changing heat stress exposures. TWAs of greater than an hour may result in unacceptable exposures.

Acclimatization is a physiological adaptation that improves an individual's ability to tolerate heat stress. Acclimatization requires physical activity under heat stress conditions like those anticipated for the work. With a recent history of heat stress exposures of at least 2 continuous hours for 5 of the last 7 days, a worker may be considered acclimatized for the purposes of the TLV. Acclimatization declines when activity under heat stress conditions is discontinued. A noticeable loss occurs after 4 days and may be completely lost in 3 weeks. A person may not be fully acclimatized to a sudden or episodic higher level of heat stress.

A Heat Stress Management Program (HSMP) sets workplace policy and

TABLE 1. Metabolic Rate Categories and the Representative Metabolic Rate with Example Activities

Category	Assigned Metabolic Rate [W]	Examples
Rest	115	Sitting
Light	180	Sitting with light manual work with hands or hands and arms and driving. Standing with some light arm work and occasional walking.
Moderate	300	Sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work, or light pushing and pulling. Normal walking.
Heavy	415	Intense hand and trunk work, carrying, shoveling, manual sawing, pushing and pulling heavy loads, and walking at a fast pace.
Very Heavy	520	Very intense activity at fast to maximum pace.

Note: The effect of body weight on the estimated metabolic rate can be accounted for by multiplying the estimated rate by the ratio of actual body weight divided by 70 kg (154 lb). Source: (International Organization for Standardization (ISO) 2017).

includes written plans for training, heat stress hygiene practices, surveillance, physiological monitoring, recordkeeping, and an emergency plan. Triggers for and components of an HSMP are presented below.

General Controls in an HSMP are those actions to protect workers that apply when heat stress is expected to be a hazard. They apply broadly to workplaces and exposure conditions. General Controls include training, heat stress hygiene practices, environmental surveillance, policies on acclimatization, policies on recognizing heat-related symptoms and first aid, and emergency planning.

Job Specific Controls in an HSMP are those actions that may be taken to control heat stress during particular heat stress exposure conditions. Job Specific Controls can be used to reduce the heat stress level to acceptable levels and include the traditional hierarchy of engineering controls, administrative controls, and personal cooling. After implementing Job Specific Controls, it is necessary to continue to assess their effectiveness and to make adjustments as needed.

Evaluation Process: The evaluation process should be started if heat stress is expected, for example, if: (1) there are reports of discomfort or other symptoms

TABLE 2. Clothing Adjustment Values (CAV) added to WBGT to estimate $WBGT_{eff}$

Clothing Type	CAV (°C)
Short Sleeves and Pants of Woven Material	-1.0
Work Clothes (Long Sleeve Shirt and Pants)	0
Cloth (woven material) Coveralls	0
SMS Polypropylene Coveralls	0.5
Polyolefin Coveralls	1
Double Layer Woven Clothing	3
Limited-Use Vapor-Barrier Coveralls with Hood	11
Adding a Hood (Full Head and Neck Covering; not Face)	+1.0

Notes:

- These values must not be used for completely encapsulating suits, often called Level A as defined by OSHA.
- CAVs cannot be added for multiple layers.
- Coveralls assume that only undergarments are worn underneath, not a second layer of clothing.
- There is no evidence to suggest that respirators or face coverings add to the heat stress burden.

associated with heat stress; (2) professional judgment indicates heat stress conditions; or (3) the Heat Index or air temperature is 27 °C (80 °F). When heat stress is suspected, establishing an HSMP that includes the General Controls (see Table 5) is recommended.

Four methods to evaluate the level of heat stress, with increasing levels of complexity and increasing levels of professional expertise, are presented below. The TLV and AL is represented by Method 2.

Method 1: Screening Criteria Based on WBGT. This screening criteria are an approximation of the TLV and AL as presented in Figure 1. Screening criteria for heat stress exposure considers the contributions of environment, metabolic work demands, work-rest pattern, clothing, and acclimatization status. Table 3 provides the screening criteria.

If the estimated $TWA-WBGT_{eff}$ is less than the criteria for unacclimatized workers found in Table 3, then there is little risk of excessive exposures to heat stress.

If the estimated $TWA-WBGT_{eff}$ is above the criteria for unacclimatized workers found in Table 3, but below the limits for acclimatized workers, then an HSMP that includes the General Controls in Table 5 is recommended.

If there are observed signs or reports of symptoms of heat-related disorders, such as fatigue, nausea, dizziness, and lightheadedness, then establishing an HSMP with General Controls is recommended.

Method 2: TLV Analysis. Method 1 (Table 3) is a screening step that requires less effort than a full evaluation. The actual TLV and AL are based on the TWAs of WBGT_{eff} and task metabolic rate (M). A task analysis is used to compute

TABLE 3. Metabolic Rate Categories and the Representative Metabolic Rate with Example Activities

Category	Metabolic Rate (W)	Examples
Rest	115	Sitting
Light	180	Sitting with light manual work with hands or hands and arms, and driving. Standing with some light arm work and occasional walking.
Moderate	300	Sustained moderate hand and/or work, moderate arm and leg work, moderate arm and trunk work, or light pushing and pulling. Normal walking.
Heavy	415	Intense arm and trunk work, carrying, shoveling, manual sawing, pushing and pulling heavy loads, and walking at a fast pace.
Very Heavy	520	Very intense activity at fast to maximum pace.

The effect of body weight on the estimated metabolic rate can be accounted for by multiplying the estimated rate by the ratio of actual body weight divided by 70 kg (154 lb).

As metabolic rate increases (i.e., work demands increase), the criteria values in the table decrease to ensure that most workers will not have a core body temperature above 38°C. Correct assessment of work rate is of equal importance to environmental assessment in evaluating heat stress. Table 3 provides broad guidance for selecting the work rate category to be used in Table 2. Often there are natural or prescribed rest breaks within an hour of work, and Table 2 provides the screening criteria for three allocations of work and rest.

Based on metabolic rate category for the work and the approximate proportion of work within an hour, a WBGT criterion can be found in Table 2 for the TLV and for the Action Limit. If the measured time-weighted average WBGT adjusted for clothing is less than the table value for the Action Limit, the "NO" branch in Figure 1 is taken, and there is little risk of excessive exposures to heat stress. If the conditions are above the Action Limit, but below the TLV, then consider general controls described in Table 5. If there are reports of the symptoms of heat-related disorders such as fatigue, nausea, dizziness, and lightheadedness, then the analysis should be reconsidered.

If the work conditions are above the TLV screening criteria in Table 2, then a further analysis is required following the "YES" branch.

Section 3: Detailed Analysis. Table 2 is intended to be used as a screening step. It is possible that a condition may be above the TLV or Action Limit values provided in Table 2 and still not represent an exposure above the TLV or the

TLV. In this determination, a detailed analysis is required. Methods for this are beyond the scope of this document in most of hygiene and safety books (14,15).

If the goal is to have accurate information on the heat stress effects of the exposure, then a detailed analysis is a task analysis that includes the determination of the Effective WBGT (environmental WBGT plus clothing and metabolic heat). Some clothing adjustment values are listed in Table 1. Values for other clothing ensembles should be used in similar fashion on following good professional judgment. The TLV and Action Limit are shown in Figure 2.

The second level of detailed analysis would follow a rational model of heat stress such as the International Standards Organization (ISO) Predicted Heat Strain (16,17) or the ASHRAE (18,19). While a rational method (even with conservatively adjusted WBGT thresholds) is computationally more difficult, it may be more revealing of the sources of the heat stress and is a means to evaluate the benefits of proposed modifications in the exposure. Guidance for the method and other rational methods is described in the literature (16,17).

If the goal is to ensure the minimal set of data to make a determination, a detailed analysis requires more data about the exposures. Following Figure 1, the next question asks about the availability of data for a detailed analysis. If the data are not available, the "NO" branch takes the evaluation to physiological monitoring to assess the degree of heat strain.

If the data for a detailed analysis are available, the next step in Figure 1 is the determination of the exposure does not exceed the criteria for the TLV and the Action Limit (workers) for the appropriate detailed analysis (e.g., WBGT, taking an empirical method, or a rational method). Then the TLV and Action Limit are taken. If the Action Limit criteria are exceeded but the exposure is below the TLV (for acclimatized workers) in the detailed analysis, the "NO" branch is taken. General controls include training for workers and supervisors, heat stress hygiene practices, and medical surveillance (Table 5). If the exposure is above the TLV for acclimatized workers in the detailed analysis, then a detailed analysis to physiological monitoring as the only alternative to control when adequate protection is provided.

Section 4: Heat Strain. The risk and severity of excessive heat strain will vary among people even under identical heat stress conditions. The normal physiological responses to heat stress provide an opportunity to monitor heat strain among workers and to use this information to assess the level of heat strain in the workforce, to control exposures, and to assess the effectiveness of implemented controls. Table 4 provides guidance for acceptable levels of heat strain.

For most good industrial hygiene sampling practice, which considers likely extremes and the less tolerant workers, the absence of any of these limiting observations indicates acceptable management of the heat stress exposures. With acceptable levels of heat strain, the "NO" branch in Figure 1 is taken. Nevertheless, if the heat strain among workers is considered acceptable at the time, consideration of the general controls is recommended. In addition, per-

TABLE 4. Guidelines for Limiting Heat Strain

Monitoring heat strain and signs and symptoms of heat-related disorders is sound industrial hygiene practice, especially when clothing may significantly reduce heat loss. For surveillance purposes, a pattern of workers exceeding the heat strain limits is indicative of a need to control the exposures. On an individual basis, the limits represent a time to cease an exposure and allow for recovery.

One or more of the following measures may mark excessive heat strain, and an individual's exposure to heat stress should be discontinued when any of the following occur:

- Sustained (several minutes) heart rate is in excess of 180 bpm (beats per minute) minus the individual's age in years (e.g., 180 – age) for individuals with assessed normal cardiac performance; or
- Body core temperature is greater than 38.5°C (101.3°F) for medically selected and acclimatized personnel; or greater than 38°C (100.4°F) in unselected, unacclimatized workers; or
- Recovery heart rate at one minute after a peak work effort is greater than 120 bpm; or
- There are symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness.

An individual may be at greater risk of heat-related disorders if:

- Profuse sweating is sustained over hours; or
- Weight loss over a shift is greater than 1.5% of body weight; or
- 24-hour urinary sodium excretion is less than 50 mmol/day.

EMERGENCY RESPONSE: If a worker appears to be disoriented or confused, suffers incontinence (urinary, anal, or chills), the worker should be removed for rest in a cool location with rapidly circulating air and kept under skilled observation. Absent medical advice to the contrary, treat this as an emergency with immediate transport to a hospital. An emergency response plan is necessary.

— NEVER ignore anyone's signs or symptoms of heat-related disorders —

odic physiological monitoring should be continued to ensure acceptable levels of heat strain.

If limiting heat strain is found during the physiological assessments, then the "YES" branch is taken. This means that suitable job-specific controls should be implemented to a sufficient extent to control heat strain. The job-specific controls include engineering controls, administrative controls, and personal protection.

After implementation of the job-specific controls, it is necessary to assess

their effectiveness and to adjust them as needed.

Section 5: Heat Stress Management and Controls. The elements of a heat stress management program including general and job-specific controls should be considered in the light of local conditions and the judgment of the industrial hygienist. The recommendation to initiate a heat stress management program is marked by 1) heat stress levels that exceed the Action Limit or 2) work in clothing ensembles that limit heat loss. In either case, general controls should be considered (Table 5).

Heat stress hygiene practices are particularly important because they reduce the risk that an individual may suffer a heat-related disorder. The key elements are fluid replacement, self-determination of exposures, health status monitoring, maintenance of a healthy lifestyle, and adjustment of expectations based on acclimatization state. The hygiene practices require the full cooperation of supervision and workers.

In addition to general controls, appropriate job-specific controls are often required to provide adequate protection. During the consideration of job-specific controls, Table 2 and Figure 2, along with Tables 1 and 3, provide a framework to appreciate the interactions among acclimatization state, metabolic rate, work-rest cycles, and clothing. Among administrative controls, Table 4 provides acceptable physiological and signs/symptoms limits. The mix of job-specific controls can be selected and implemented only after a review of the demands and constraints of any particular situation. Once implemented, their effectiveness must be confirmed and the controls maintained.

The prime objective of heat stress management is the prevention of heat stroke, which is life-threatening and the most serious of the heat-related disorders. The heat stroke victim is often manic, disoriented, confused, delirious, or unconscious. The victim's body core temperature is greater than 40°C (104°F). If signs of heat stroke appear, aggressive cooling should be started immediately, and emergency care and hospitalization are essential. The prompt treatment of other heat-related disorders generally results in full recovery, but medical advice should be sought for treatment and return-to-work protocols. It is worth noting that the possibility of accidents and injury increases with the level of heat stress.

Prolonged increases in deep body temperatures and chronic exposures to high levels of heat stress are associated with other disorders such as temporary infertility (male and female), elevated heart rate, sleep disturbance, fatigue, and irritability. During the first trimester of pregnancy, a sustained core temperature greater than 39°C may endanger the fetus.

References

- International Organization for Standardization (ISO 7933): Ergonomics of the thermal environment—Analytical determination and interpretation of heat stress using calculation of the predicted heat strain. ISO, Geneva (2004).
- McIntosh JB, Peltier A, Kampmann B, et al.: Development and validation of the predicted heat strain model. *Ann Occup Hyg* 45(2):123–35 (2001).

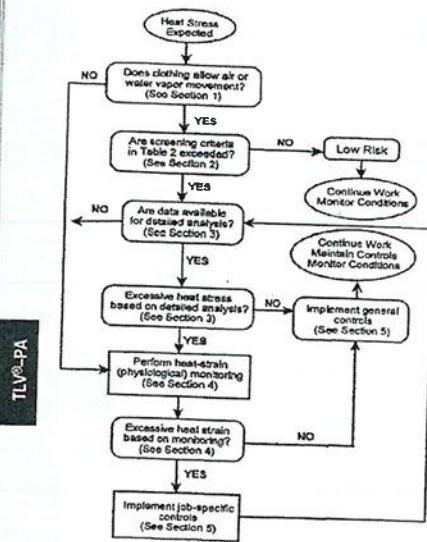
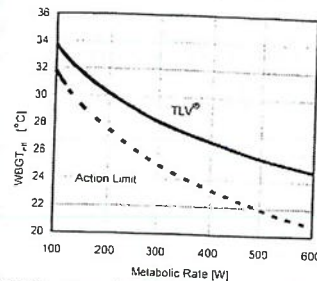


FIGURE 1. Evaluating heat stress and strain.

Acclimatization is a gradual physiological adaptation that improves an individual's ability to tolerate heat stress. Acclimatization requires physical activity under heat-stress conditions similar to those anticipated for the work. With a recent history of heat-stress exposures of at least two continuous hours (e.g., 5 of the last 7 days to 10 of 14 days), a worker can be considered acclimatized for the purposes of the TLV[®]. Its loss begins when the activity under those heat stress conditions is discontinued, and a noticeable loss occurs after four days and may be completely lost in three to four weeks. Because acclimatization is to the level of the heat stress exposure, a person will not be fully acclimatized to a sudden higher level, such as during a heat wave.

FIGURE 2. TLV[®] (solid line) and Action Limit (broken line) for heat stress. WBGT_{cl} is the measured WBGT plus the Clothing Adjustment Factor.

The decision process illustrated in Figure 1 should be started if (1) a qualitative exposure assessment indicates the possibility of heat stress, (2) there are reports of discomfort due to heat stress, or (3) professional judgment indicates heat stress conditions.

Section 1: Clothing. Ideally, free movement of cool, dry air over the skin's surface maximizes heat removal by both evaporation and convection. Evaporation of sweat from the skin is the predominant heat removal mechanism. Water-vapor-impermeable, air-impermeable, and thermally insulating clothing, as well as encapsulating suits and multiple layers of clothing, severely restrict heat removal. With heat removal hampered by clothing, metabolic heat may produce excessive heat strain even when ambient conditions are considered cool.

Figure 1 requires a decision about clothing and how it might affect heat loss. The WBGT-based heat exposure assessment was developed for a traditional work uniform of a long-sleeve shirt and pants. If the required clothing is adequately described by one of the ensembles in Table 1 or by other available data, then the "YES" branch is selected.

If workers are required to wear clothing not represented by an ensemble in Table 1, then the "NO" branch should be taken. This decision is especially applicable for clothing ensembles that are 1) totally encapsulating suits or 2) multiple layers where no data are available for adjustments. For these kinds of ensembles, Table 2 is not a useful screening method to determine a threshold for heat-stress management actions and some risk must be assumed. Unless a detailed analysis method appropriate to the clothing requirements is available, physiological and signs/symptoms monitoring described in Section 4 and Table 4 should be followed to assess the exposure.

TABLE 1. Clothing-Adjustment Factors for Some Clothing Ensembles^a

Clothing Type	Addition to WBGT (°C)
Work clothes (long sleeve shirt and pants)	0
Cloth (woven material) coveralls	0
Double-layer woven clothing	3
SMS polypropylene coveralls	0.5
Polyurethane coveralls	1
Limited-use vapor-barrier coveralls	11

^a These values must not be used for completely encapsulating suits, often called Level A. Clothing Adjustment Factors cannot be added for multiple layers. The coveralls assume that only modest clothing is worn underneath, not a second layer of clothing.

Section 2: Screening Threshold Based on Wet-Bulb Globe Temperature (WBGT). The WBGT offers a useful first order index of the environmental contribution to heat stress. It is influenced by air temperature, radiant heat, air movement, and humidity. As an approximation, it does not fully account for all the interactions between a person and the environment and cannot account for special conditions such as heating from a radiofrequency/microwave source. WBGT values are calculated using one of the following equations:

$$\text{With direct exposure to sunlight: } \text{WBGT}_{\text{out}} = 0.7 T_{\text{wet}} + 0.2 T_g + 0.1 T_{\text{db}}$$

$$\text{Without direct exposure to the sun: } \text{WBGT}_{\text{in}} = 0.7 T_{\text{wet}} + 0.3 T_g$$

where:

T_{wet} = natural wet-bulb temperature (sometimes called NWB)

T_g = globe temperature (sometimes called GT)

T_{db} = dry-bulb (air) temperature (sometimes called DB)

Because WBGT is only an index of the environment, the screening criteria are adjusted for the contributions of work demands and clothing. Table 2 provides WBGT criteria suitable for screening purposes. For clothing ensembles listed in Table 1, Table 2 can be used when the clothing adjustment values are added to the environmental WBGT.

To determine the degree of heat stress exposure, the work pattern and demands must be considered. If the work (and rest) is distributed over more than one location, then a time-weighted average WBGT should be used for comparison to Table 2 limits.

TABLE 2. Screening Criteria for TLV[®] and Action Limit for Heat Stress Exposure

Allocation of Work in a Cycle of Work and Rest ^a	TLV [®] (WBGT values in °C)					Action Limit (WBGT values in °C)				
	Light	Moderate	Heavy	Very Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy	
25% to 100% Recovery	31.0	28.0	—	—	—	28.0	25.0	—	—	
50 to 75%	31.0	29.0	27.5	—	—	28.5	26.0	24.0	—	
25 to 50%	29.0	30.0	29.0	29.0	24.5	29.5	27.0	22.5	24.5	
0 to 25%	23.5	31.5	30.5	30.0	27.0	30.0	29.0	28.0	27.0	

^a See Table 3 and the Determination for work demand categories.

^b WBGT values are expressed to the nearest 0.5°C.

^c WBGT values are compared to the TLV[®] limits when the metabolic rate for rest is taken as 1.5 W and work as the representative (mid-range) value of 10 W. The TLV[®] values are compared to the TLV[®] limits when the metabolic rate for rest is taken as 1.5 W and work as the representative (mid-range) value of 10 W. The TLV[®] values are compared to the TLV[®] limits when the metabolic rate for rest is taken as 1.5 W and work as the representative (mid-range) value of 10 W.

^d If work and rest environments are different, hourly time-weighted average (TW) WBGT should be calculated and used. TWAs for work rates should also be used when the work demands vary within the hour, but note that the metabolic rate for rest is already factored into the screening limit.

^e Values in the table are limited by reference to the "Work-Rest Regimen" section of the Determination and assume 4-hour workdays in a 5-day workweek with conventional breaks as discussed in the Determination. When conditions are extended, consult the "Application of the TLV[®] section of the Determination." Because of the physiological strain associated with Heavy and Very Heavy work among less fit workers regardless of WBGT, criteria values are not provided for continuous work and for up to 25% rest in an hour for Very Heavy work. The screening criteria are not recommended, and a detailed analysis and/or physiological monitoring should be used.

^f Table 2 is intended as an initial screening tool to evaluate whether a heat stress situation may exist (according to Figure 1) and thus, the table is more protective than the TLV[®] or Action Limit (Figure 2). Because the values are more protective, they are intended to prescribe work and recovery periods.

Imposing a single standard clothing ensemble for an entire group could result in overheating and sweating during work in some, while others would not be kept warm; therefore, people should adjust clothing according to their own needs. A common problem is that people begin working while still wearing clothing layers appropriate for resting conditions, and thus, are "overdressed" after the work is started. If the combination of environmental conditions, work intensity, and available clothing suggest that body heat cannot be maintained (e.g., low work intensity in rainy conditions), then ventilation of the work area or use of the buddy system should be encouraged. If workers need to be aware that the risk of hypothermia increases if the weather is wet and wet weather clothing is not available and work intensity is low (e.g., stop digging to rest). Remaining dry, especially for those working in remote regions, is extremely important and dictates that carrying extra clothing that is water-proof and dry clothing to change into is vital. If work is done in normal temperatures or in a hot environment before entering the cold area, the employee should make sure that clothing is not wet as a consequence of sweating. If clothing is wet, the employee should change into dry clothes before entering the cold area. The workers should change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots. The optimal frequency of change should be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.

If exposed areas of the body cannot be protected sufficiently to prevent sensation of excessive cold or frostbite, protective items should be supplied in auxiliary heated versions.

If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work should be modified or suspended until adequate clothing is made available or until weather conditions improve. Feet are susceptible to peripheral cold injuries. All workers should be provided with appropriately rated footwear for the conditions they are working in. For example, if the environment is wet, footwear should provide protection against water penetration; likewise, if the air temperatures have the potential to be extremely low (less than 0°F (-18°C)), specific boots for this environment need to be provided.

Work-Warming Regimen

If work is performed continuously in the cold at or below a WCT of -7°C (19.4°F), heated warming shelters (tents, cabins, rest rooms, etc.) should be made available nearby. The workers should be encouraged to use these shelters at regular intervals, the frequency depending on the severity of the environmental exposure. Indications for immediate return to the shelter are the onset of heavy shivering; frostnip; or the feeling of excessive fatigue, drowsiness, irritability, or euphoria. When entering the heated shelter, the outer layer of clothing should be removed and the remainder of the clothing loosened to permit sweat evaporation, or a change of dry work clothing should be provided as necessary to prevent workers from returning to their work with wet clothing. Dehydration, or the loss of body fluids, occurs insidiously in the cold environment and can impair work performance. However, dehydration likely does not increase susceptibility to cold injuries. Workers can drink a variety of fluids (milk, juice, sports drinks, tea, coffee). Hot beverages

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and soups should be provided at the work site as they provide calories and increase morale.

For work at or below -12°C (10.4°F) WCT, the following should apply:

1. The worker should be under constant protective observation (buddy system or supervision).
2. The work rate should not be so high as to cause heavy sweating that will result in wet clothing; if heavy work must be done, rest periods should be taken in heated shelters and opportunity for changing into dry clothing should be provided.
3. New employees should not be required to work full-time in the cold during the first days of employment until they become acclimated to the working conditions and required protective clothing.
4. The weight and bulkiness of clothing should be included in estimating the required work performance and weights to be lifted by the worker.
5. The work should be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected, metal chair seats should not be used. The worker should be protected from drafts to the greatest extent possible.
6. The worker should be instructed in safety and health procedures. The training program should include, as a minimum, instruction in:
 - a. Proper warming procedures and appropriate first aid treatment.
 - b. Proper clothing practices.
 - c. Proper eating and drinking habits.
 - d. Recognition of impending frostbite.
 - e. Recognition of signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
 - f. Safe work practices.

Special Workplace Recommendations

Special design requirements for refrigerated rooms include:

1. Air velocity should be minimized as much as possible and should not exceed 1 m/sec (200 fpm) at the job site. This can be achieved by properly designed air distribution systems.
2. Special wind protective clothing should be provided based on existing air velocities to which workers are exposed.

Special caution should be exercised when working with toxic substances and when workers are exposed to vibration. Cold exposure may require reduced exposure limits.

Eye protection for workers employed out-of-doors in a snow- and/or ice-covered terrain should be supplied. Special safety goggles to protect against ultraviolet light and glare (which can produce temporary conjunctivitis and/or temporary loss of vision) and blowing ice crystals should be required when there is an expanse of snow coverage causing a potential eye exposure hazard.

Workplace monitoring is required as follows:

1. Suitable thermometry should be arranged at any workplace where the environmental temperature is below 16°C (50.8°F) so that overall compliance with the requirements of the TLV® can be maintained.

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2. Whenever the air temperature at a workplace falls below -1°C (30.2°F), the air temperature should be measured and recorded at least every 4 hours.
3. In indoor workplaces, the wind speed should also be recorded at least every 4 hours whenever the rate of air movement exceeds 2 m/sec (5 mph).
4. In outdoor work situations, the wind speed should be measured and recorded together with the air temperature whenever the air temperature is below -1°C (30.2°F).
5. The WCT should be obtained from Table 4 in all cases where air movement measurements are required; it should be recorded with the other data whenever the WCT is below -7°C (19.4°F).

Employees should be excluded from work in cold at -1°C (30.2°F) or below if they are suffering from diseases or taking medication that interferes with normal body temperature regulation or reduces tolerance to work in cold environments. Workers who are routinely exposed to temperatures below -24°C (-11.2°F) with wind speeds < 2 m/sec (5 mph), or air temperatures below -18°C (0°F) with wind speeds above 2 m/sec (5 mph), should be medically certified as suitable for such exposures.

Trauma sustained in freezing or subzero conditions requires special attention because an injured worker is predisposed to cold injury. In addition to providing for first aid treatment, special provisions should be made to prevent hypothermia and freezing of damaged tissues.

References

- Casellani JW, Young AJ, Ducharme MB, et al.: Prevention of cold injuries during exercise. *Med Sci Sports Exerc* 38:2012-2029 (2006).
- National Weather Service: Windchill Temperature Index. NOAA, National Weather Service, Office of Climate, Water, and Weather Services (2001).
- US Department of the Army: Prevention and management of cold-weather injuries. Technical Bulletin Medical 508, (TB MED 508). Falls Church, VA (2005).
- Xu X, Tikulais P: Thermoregulatory modeling for cold stress. *Compr Physiol* 4:1057-1081 (2014).

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HEAT STRESS AND STRAIN

Warning: While the TLV® is based on the ability of most healthy, acclimatized workers to sustain a heat stress exposure, cases of heat stroke and other exertional heat illnesses may occur below the TLV®. A program of heat stress management should include acclimatization, early recognition of symptoms with appropriate first aid, and recognition of personal risk factors. Further, there is evidence of a carry-over effect from a previous day's exposure.

Personal risk factors include, among others, prior heat stroke, repeated heat exhaustion, cardiac or kidney disease, pregnancy, obesity, older age and certain medications. It is recommended that workers with personal risk factors consult a health care provider prior to working in a hot environment.

This TLV® has a small margin of safety. Therefore, those working near the TLV® should be warned to drink water regularly and be alert for dizziness, lightheadedness, nausea, and headache.

Goal: The goal of this TLV® is to maintain body core temperature within +1°C of normal (37°C) for the average person. For most individuals, body core temperature will be below 38.3°C. Body core temperature can exceed 38.3°C under certain circumstances with selected populations, environmental and physiologic monitoring, and other controls.

More than any other physical agent, the potential health hazards from work in hot environments depends strongly on physiological factors that lead to a range of susceptibilities depending on the level of acclimatization. Therefore, professional judgment is of particular importance in assessing the level of heat stress and physiological heat strain to adequately provide guidance for protecting nearly all healthy workers with due consideration of individual factors and the type of work. Assessment of both heat stress and heat strain can be used for evaluating the risk to worker safety and health. A decision-making process is suggested in Figure 1. The exposure guidance provided in Figures 1 and 2 and in the associated *Documentation* of the TLV® represents conditions under which it is believed that nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers may be repeatedly exposed without adverse health effects. The Action Limit (AL) is similarly protective of unacclimatized workers and represents conditions for which a heat stress management program should be considered. While not part of the TLV®, elements of a heat stress management program are offered. The exposure guidance is not a fine line between safe and dangerous levels.

Heat Stress is the net heat load to which a worker may be exposed from the combined contributions of metabolic heat, environmental factors (i.e., air temperature, humidity, air movement, and radiant heat), and clothing requirements. A mild or moderate heat stress may cause discomfort and may adversely affect performance and safety, but it is not harmful to health. As the heat stress approaches human tolerance limits, the risk of heat-related disorders increases.

Heat Strain is the overall physiological response resulting from heat stress. The physiological responses are dedicated to dissipating excess heat from the body.

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TABLE 2. Intensity of Exercise for Selected Outdoor Activities

Sedentary 100 Watts (1 MET)	Easy work 250 Watts (2-3 METS)	Moderate work 450 Watts (4-5 METS)	Hard work 600 Watts (6 METS)
<ul style="list-style-type: none"> Sleeping Seated, quiet 	<ul style="list-style-type: none"> Walking on level surface at 3-4 km/h Snowmobiling 	<ul style="list-style-type: none"> Walking in loose snow/sand at 2.5 mph, no load Walking on hard surface at 3.5 mph, < 40-lb load Handling 50-kg bags Pick and shovel work 	<ul style="list-style-type: none"> Walking on hard surface at 3.5 mph, 40-lb load Walking in loose sand at 2.5 mph with load Snowshoeing

Source: Department of the Army: Prevention and Management of Cold-Weather Injuries, Technical Bulletin Medical 308 (TB MED 308), Falls Church, VA (2005).

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TABLE 3. Cold-Water Immersion Time Limits (Hours) for Reaching a Core Temperature of 35.5°C at Different Water Temperatures and Immersion Depths. For Immersion Times Greater than 6 Hours, the Risk of Non-Freezing Cold Injury Substantially Increases

Water Temperature (°F)	Water Temperature (°C)	Knee-Deep	Waist-Deep	Chest-Deep
50-54	10-12	12.8	1.9	1.3
55-59	13-15	15.6	7.5	2.2
60-64	16-18	22.2	10.2	7.9
65-69	18-21	33	13.8	10.5

Source: Department of the Army: Prevention and Management of Cold-Weather Injuries, Technical Bulletin Medical 308 (TB MED 308), Falls Church, VA (2005).

TABLE 4. Wind Chill Temperature Index, Frostbite Times are for Exposed Facial Skin

Wind Speed (mi/h)	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
5	3	4	4	4	4	4	4	4	4	4	4	4
10	3	4	4	4	4	4	4	4	4	4	4	4
15	3	4	4	4	4	4	4	4	4	4	4	4
20	3	4	4	4	4	4	4	4	4	4	4	4
25	3	4	4	4	4	4	4	4	4	4	4	4
30	3	4	4	4	4	4	4	4	4	4	4	4
35	3	4	4	4	4	4	4	4	4	4	4	4
40	3	4	4	4	4	4	4	4	4	4	4	4
45	3	4	4	4	4	4	4	4	4	4	4	4
50	3	4	4	4	4	4	4	4	4	4	4	4
55	3	4	4	4	4	4	4	4	4	4	4	4
60	3	4	4	4	4	4	4	4	4	4	4	4
65	3	4	4	4	4	4	4	4	4	4	4	4
70	3	4	4	4	4	4	4	4	4	4	4	4
75	3	4	4	4	4	4	4	4	4	4	4	4
80	3	4	4	4	4	4	4	4	4	4	4	4

FROSTBITE GUIDE

Low risk of frostbite for most people

Increasing risk of frostbite for most people in 10 to 30 minutes of exposure

High risk for most people in 10 to 30 minutes of exposure

High risk for most people in 2 to 5 minutes of exposure

Frostbite may occur in minutes of exposure at this level

Source:

National Weather Service: Wind Chill Temperature Index. NOAA, National Weather Service, Office of Climate, Water and Weather Services (2001). Castellani JW, Young AJ, Dischauer MB, et al.: Prevention of cold injuries during exercise. Med Sci Sports Exerc 38:2012-2029 (2006).

1" rule. This states that the cold shock response with increased water aspiration occurs in the first minute; in 10 minutes the skeletal muscle temperatures decline to a point that muscle function is severely impaired, and in 1 hour, core temperature begins to fall to levels that are dangerous.

Cold-Weather Clothing

Cold-weather clothing protects against hypothermia and peripheral cold injuries by reducing heat loss through the insulation provided by the clothing and the trapped air within and between clothing layers. Typical cold-weather clothing consists of multiple layers: an inner layer (light-weight polyester or polypropylene) that is in direct contact with the skin and does not readily absorb moisture, but wicks moisture to the outer layers where it can evaporate; middle layers (polyester fleece or wool) provide the primary insulation; and an outer layer, which is designed to allow moisture transfer to the air, while repelling wind and rain. Sweating can easily exceed the vapor transfer rate of the outer shell layer, causing moisture to accumulate on the inside, even if the outer layer has substantial venting (e.g., zippers in anempts) to allow moisture to escape. The outer layer should typically not be worn during moderate/heavy work (unless it is rainy or very windy), but should be donned during subsequent rest periods.

TABLE 5. Time in Minutes Until the Occurrence of Chesh Frostbite in the Most Susceptible 5% of Military Personnel

Wind speed m/s	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
15	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
25	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
35	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
40	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
45	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
50	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
55	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
65	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
70	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
75	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
80	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
85	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
95	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Note: Wet skin could significantly increase the time to frostbite to occur.

LOW - Freezing could occur in 10-30 minutes (LIGHT GREY)

HIGH - Freezing could occur in 10-30 minutes (LIGHT GREY)

SEVERE - Freezing could occur in 5-10 minutes (DARK GREY)

EXTREME - Freezing could occur in < 5 minutes (MEDIUM GREY)

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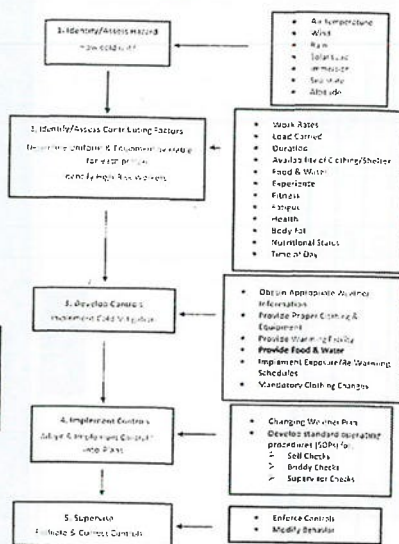


FIGURE 1. Risk Management Process for Evaluating Cold Stress and Strain

Source: Department of the Army: Prevention and Management of Cold-Weather Injuries. Technical Bulletin Medical 308 (TB MED 308). Falls Church, VA (2003).

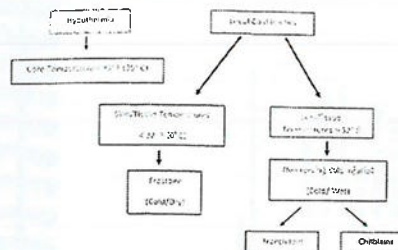


FIGURE 2. Types of cold injuries.

Source: Department of the Army: Prevention and Management of Cold-Weather Injuries. Technical Bulletin Medical 305 (TB MED 308). Falls Church, VA (2005).

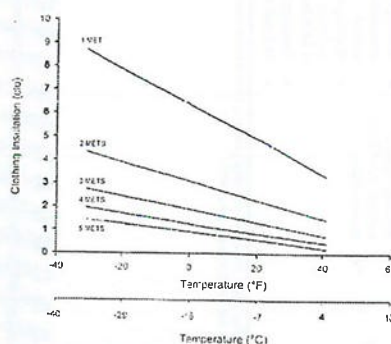


FIGURE 3. Approximate amount of clothing insulation needed at different air temperatures and physical activity levels. Wind speed is assumed to be less than 5 mph (2.2 m/s). 1 MET refers to energy expenditure at rest (58.2 W/m²). One clo of insulation is the clothing necessary to allow a resting person to be comfortable when the air temperature is 21°C (70°F).

Source: Castellani JP, Young AJ, Ducharme MB, et al.: Prevention of cold injuries during exercise. *Med Sci Sports Exerc* 38:2012-2029 (2006).

TABLE 1. Core Temperature and Associated Physiological Changes that Occur as Core Temperature Falls, Individuals Respond Differently at Each Level of Core Temperature

[illegible]

Spencer, C. and J. M. Young Jr.: Ductal injuries during transurethral prostatectomy. *Urology* 38:291-292 (1991).

Frostbite cannot occur if the air temperature is above 32°F (0°C). Wet skin exposed to the wind will cool even faster and if the skin is wet and exposed to wind, the ambient temperature used for the WCT table should be 10°C (50°F) lower than the actual ambient temperature. When cold surfaces below 7°F (19.4°F) are within reach, a warning should be given to each worker by the supervisor to prevent inadvertent contact by bare skin. If the air temperature is -17.5°C (0°F) or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

Manual dexterity is an important attribute in occupational settings. Manual dexterity is the ability to make coordinated hand and finger movements to grasp and manipulate objects. Manual dexterity includes muscular, skeletal, and neurological functions to produce small, precise movements in cold weather. manual dexterity can decrease 60-80% in gloved workers and, depending on the ambient conditions, can decrease just as much in nongloved personnel. When hand temperature declines, the manual performance deteriorates. This performance is reduced by 30% when the finger skin temperature decreases from 33°C (91°F) to 10°C (50°F). Special protection of the hands is required to maintain manual dexterity for the prevention of accidents:

1. If line work is to be performed with bare hands for more than 10–20 minutes in an environment below 16°C (60.8°F), special provisions should be established for keeping the workers warm. For example, use of warm air jets, radiant heaters (like furnace or electric radiator), or contact warm plates may be utilized. Metal handles of tools and control bars should be covered by thermal insulating material at temperatures below -1°C (30.2°F).
2. If the air temperature falls below 16°C (60.8°F) for sedentary work, 4°C (39.2°F) for light work, and -7°C (19.4°F) for moderate work and line manual dexterity is not required, then gloves should be used by the workers,

Dexterity is primarily impacted by peripheral skin and muscle temperatures, with little influence from core temperature.

Acute Cold-Water Exposure

Sudden immersion into cold water causes a cold shock response. Physiological responses to sudden immersion include gasping, hyperventilation, peripheral vasoconstriction, and increased heart rate and blood pressure. It is during the first few minutes of sudden immersion that drowning is likely to occur as gasping and hyperventilating increase the chances of aspirating water. After the initial responses subside, the core and muscle temperatures begin to fall over time. After ~10 minutes of immersion in water less than 10°C, muscle temperatures will have decreased so that there is reduced skeletal muscle function. Individuals at this point will no longer be able to swim/self-rescue and drowning will likely ensue if a flotation aid is not available. Finally, as an individual remains in the water, core temperature will continue to fall. Generally, the core temperature falls to 35°C in about 1 hour in 5°C water, in 2 hours in 10°C water, and in 3–6 hours in 15°C water. The progression from cold shock to hypothermia can be summed up in the "1-10-100" rule:

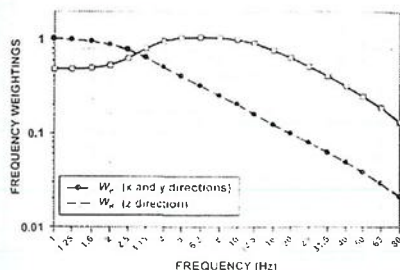


FIGURE 1 ISO 2631-1 Frequency Weightings (W_x and W_y for x and y directions and W_z for z direction) (ISO, 1997).

a_{wy} = The overall weighted rms acceleration for the w axis over the time period T , ($w = x, y$ or z) (in m/s^2) from Equations 1 or 2

T_0 = The reference duration of 3 hours or 18 000 seconds

The vector sum, standardised to an 8-hour reference period, a_{wv} , can then be calculated using Equation 1

7. With reference to ISO 2631-1, Section 6.3 (ISO, 1997, 2003), the weighted rms method described above may underestimate the effects of vibration containing occasional or substantial shocks or transient vibration. In addition to the rms method described above, the fourth power Vibration Dose Value (VDV) may be calculated in each direction as:

$$VDV = k_i \left(\int_0^T |a_w(t)|^4 dt \right)^{1/4} \quad (6)$$

It is noted that, unlike the overall weighted rms acceleration calculated in accordance with Equations 1 and 2, the VDV is dependent on the duration of the measurement. When using this method, the TLV⁹⁵ in any direction is defined by a VDV value of $17.0 \text{ ms}^{-1.75}$ and shall not be exceeded for the exposure duration. The AL in any direction is defined by a VDV value of $8.5 \text{ ms}^{-1.75}$. It is highly recommended that vibration mitigation activity be undertaken to reduce any VDV falling between 8.5 and $17.0 \text{ ms}^{-1.75}$. The VDV method should not be applied to exposures lasting more than 6 hours. For exposures lasting more than 6 hours, the TLV⁹⁵ and ALs associated with the rms method should be applied to assess health risk.

8. For vibration exposure with shocks or impacts that exceed 9.81 m/s^2 (1 g peak), the guidelines in ISO 2631-5 should be followed to calculate the stress variable R . The TLV is defined by an R value of 1.6 and should not be exceeded. This R value corresponds to a relatively low risk of injury. The ISO 2631-5 also provides an alternative method for exposures containing shocks or impacts at or below 9.81 m/s^2 (1 g peak).

9. When the daily exposure duration is unknown or expected to vary on different days, and the assumption can be made that the estimate of the seat pan vector sum, a_w , is expected to represent the exposure associated with the majority of daily exposures, the time duration, T , to reach the TLV⁹⁵ can be estimated as:

$$T = \frac{(6.0)}{a_w^2} \quad (7)$$

Likewise, the time duration, T , to reach the AL can be estimated as:

$$T = \frac{(1.5)}{a_w^2} \quad (8)$$

References

- International Standards Organization (ISO): ISO 10326-1:1992 *Mechanical Vibration—Laboratory Method for Evaluating Vehicle Seat Vibration—Part 1: Basic Requirements*. Geneva, Switzerland (1992).
- International Standards Organization (ISO): ISO 2631-1:1997 *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements*. Geneva, Switzerland (1997).
- International Standards Organization (ISO): ISO 2631-2:2003 *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 2: Vibration in Buildings (1 Hz to 80 Hz)*. Geneva, Switzerland (2003).
- International Standards Organization (ISO): ISO 2631-1:1997/Amend.1 2010 *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements, Amendment 1*. ISO, Geneva, Switzerland (2010).

THERMAL STRESS

COLD STRESS

(Documentation Date — 2018)

Introduction

The cold stress TLVs⁹⁵ are intended to protect workers from the most severe effects of cold stress (hypothermia and frostbite) and to describe exposures to cold working conditions under which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. The TLV⁹⁵ objective is to prevent the deep body core temperature from falling below 36°C (96.8°F); and to prevent frostbite to body extremities. Fatal exposures to cold among workers have almost always resulted from accidental exposures involving failure to escape from low environmental air temperatures or from immersion in low temperature water. Preventing cold injuries is best done through a risk management strategy that assesses cold hazards and then develops and implements controls to mitigate the effects of the cold environment. Figure 1 presents a risk management process to use in cold-weather environments. Figure 2 shows the types of cold injuries.

Hypothermia Prevention

Hypothermia is defined as a core body temperature below 35°C (95°F). The physiological changes that occur as the temperature goes below this value are presented in Table 1. In an occupational setting, workers should be protected from cold exposure so that the deep core temperature does not fall below 36°C (96.8°F); lower body temperatures can result in reduced mental alertness and rational decision making. As the core body temperature goes below 35.4°C (91.4°F), workers can become severely debilitated. Hypothermia is a life-threatening condition and must be treated promptly.

Early symptoms of hypothermia include feeling cold, shivering, and exhibiting signs of apathy and social withdrawal. Supervisors and workers should be aware of these early symptoms so that proper preventative measures can be taken at this time. More pronounced hypothermia manifests as confusion or sleepiness, slurred speech, and a change in behavior or appearance. Exposure to cold should be immediately terminated for any workers when severe shivering becomes evident.

Since prolonged exposure to extremely cold air, cold-wet conditions, and cold water immersion can lead to hypothermia, whole-body protection must be provided. Cold, wet, and windy weather poses the greatest risk for developing hypothermia. Figure 3 presents the clothing insulation required as a function of air temperature and work rate. As seen, the amount of insulation increases as the ambient temperature and work rate decrease. In wet weather, it is imperative that the outer layer of clothing be waterproof. In windy weather, a wind-proof outer layer is needed. Table 2 presents different activities and their associated work rate in Metabolic Equivalents (METS). This table can be used in conjunction with Figure 3 to determine the approximate clothing insulation required at different air temperatures.

Cold water immersion can cause life-threatening hypothermia in a matter of hours if proper protection is not worn. Table 3 presents the amount of time that an average person can be immersed based on the water temperature

and depth. This guidance is based on wearing normal personal protection that is not waterproof. It should also be noted that another type of cold injury—nonfreezing cold injury—can occur when skin is subjected to prolonged immersion or cold-wet exposures in temperatures between 32 – 60°F (0 – 15°C).

Risk factors for hypothermia include inactivity, energy depletion, endocrine disorders, age (old and young), burns and skin disorders, trauma, neuropathies, and drug/alcohol use.

Field expedient re-warming methods include removing wet clothes, increasing insulation (with dry clothes, blankets, sleeping bags), and moving to a sheltered area. If able to, patients can also exercise to increase heat production. Other techniques, using external re-warming, should be initiated by trained medical personnel.

Frostbite Prevention

Frostbite occurs when tissue temperature decreases below 32°F (0°C). Frostbite is most common in exposed skin (nose, ears, cheeks, exposed wrists), but also occurs in the hands and feet because peripheral vasoconstriction significantly lowers tissue temperatures. Wet skin cools faster. Instantaneous frostbite can occur when the skin comes in contact with super-cooled liquids, such as petroleum products, oil, fuel, antifreeze, and alcohol, all of which remain liquid at temperatures of -40°F (-40°C). Contact frostbite can occur by touching cold objects with bare skin (particularly highly conductive metal or stone), which causes rapid heat loss. To prevent contact frostbite, the workers should wear anti-contact gloves.

Usually, the first sign of frostbite is numbness. In the periphery, the initial sense of cooling begins at skin temperatures of 82°F (28°C) and pain appears at -68°F (20°C), but as skin temperature falls below 50°F (10°C), these sensations are replaced by numbness. Individuals often report feeling a “wooden” sensation in the injured area. After re-warming, pain is significant. The initial sensations are an uncomfortable sense of cold, which may include tingling, burning, aching, sharp pain, and decreased sensation. The skin color may initially appear red; it then becomes waxy white.

Risk factors for frostbite include temperature, wind, wind chill, constrictive clothing, race, sex, hypoxia, Raynaud’s syndrome, and vasoconstrictor drugs. African American men and women are 2–4 times more likely than Caucasians to suffer from frostbite. Raynaud’s disease is a peripheral vascular disorder more prevalent in women than men.

The Wind Chill Temperature (WCT) Index (Tables 4, 5) integrates wind speed and air temperature to provide an estimate of the cooling power of the environment. The WCT standardizes the cooling power of the environment to an equivalent air temperature for calm conditions. WCTs are specific in their correct application, only estimating the danger of cooling for the exposed skin of persons walking at 3 mph. Wind does not cause an exposed object to become cooler than the ambient temperature, but instead wind causes exposed objects to cool toward ambient temperature more rapidly than without wind. Wind speeds obtained from weather reports do not take into account man-made wind. The WCT presents the relative risk of frostbite and the predicted times in freezing (Tables 4, 5) of exposed facial skin. Facial skin was chosen because this area of the body is typically not protected.

TABLE 1. TLV* and AL Vector Sums of the Overall Weighted rms Accelerations (m/s^2 rms)

Duration (hours)	TLV* (ISO Upper Boundary)	AL (ISO Lower Boundary)
0.17	6.00	3.0000
0.5000	3.46	1.73
1.0000	2.45	1.22
2.0000	1.73	0.87
4.0000	1.22	0.61
8.0000	0.87	0.43
24.0000	0.5000	0.25

TLV* at Time T (hrs): $TLV^* = \frac{2.45}{\sqrt{T}}$ (m/s^2 rms)

AL at Time T (hrs): $AL = \frac{1.22}{\sqrt{T}}$ (m/s^2 rms)

Note: Equations do not apply for exposure durations shorter than 10 minutes

of the Health Guidance Caution Zones defined in ISO 2631-1 (ISO, 1997, 2003, 2010). With reference to ISO 2631-1, Annex B (ISO, 1997, 2003), operator and occupant exposures falling between the lower boundary (dashed line) and upper boundary (solid line) in Figure 1 within a 24-hour period have been associated with the potential for health risks.

- Vibration acceleration is a vector with magnitude expressed in units of meters per second squared (m/s^2). The gravitational acceleration, ' g ' = 9.81 m/s^2 . The biodynamic coordinate system used for measuring the accelerations is illustrated in Figure 2. The procedures described in this Documentation apply to translation-al accelerations of the seated upright operator or occupant. Other postures and directions are addressed in ISO 2631-1 (ISO, 1997, 2003).
- The TLVs* and ALs associated with the vector sum of the overall weighted rms accelerations may underestimate the health risk for vibration with occasional or substantial shocks, or transient vibration. ISO 2631-1 provides guidance on alternative methods. These methods include the Vibration Dose Value (VDV). The ISO 2631-5 provides guidance for assessing vibration with multiple shocks and should be considered for assessing exposures that include shocks or impacts that exceed 9.81 m/s^2 (1 g peak). The alternative methods should be used in addition to the rms method (see Notes 7 and 8). The TLV* and AL are not intended for use in fixed buildings (see ISO 2631-2) (ISO, 1992), in off-shore structures, or in large ships.
- A summary of WBV measurement procedures follows (ISO, 1997, 2003, 2010):
 - Three light-weight accelerometers (or triaxial accelerometer), each with a cross-axis sensitivity of less than 10%, are mounted orthogonally in the center of a hard rubber disc, per ISO 10326-1 (ISO, 1992).

The total weight of the instrumented rubber disc and cables should not exceed 400 g.

- At a minimum, and for health risk assessment, one instrumented rubber disc should be placed on the top of the operator's or occupant's seat and the interface between the buttocks and contacted seat or cushion surface. A second instrumented rubber disc may be placed at the interface between the back and the seat back, particularly if a comfort assessment is desirable (see ISO 2631-1 Section 8.2) (ISO, 1997, 2003).
 - At each measurement location (i.e. seat pan, seat back), continuous acceleration measurements should be simultaneously made and recorded along the three orthogonal axes (x, y, z) shown in Figure 2 (seat surface and seat back). The duration of the measurement should assure measurement accuracy and that the vibration is typical of the operator or occupant exposure being assessed (see ISO 2631-1, Section 5.5) (ISO, 1997, 2003).
- A summary of WBV data processing procedures, including the calculation of the overall weighted rms acceleration in each axis (x, y, z) and the vector sum of the overall weighted rms accelerations for assessing health risk follows:
 - It is highly recommended that signal processing techniques be applied to generate the unweighted spectral content in each axis to identify the frequencies corresponding to major acceleration peaks. The spectra can be generated in either narrow frequency bands of constant bandwidth, or proportional bands no greater than one-third octave.
 - At a minimum for health risk assessment, the acceleration measurements obtained for each axis at the buttocks-seat interface (seat pan) should be recorded and processed in accordance with ISO 2631-1 (ISO, 1997, 2010) for the seated operator or occupant using the basic evaluation method and the frequency weightings and multiplying factors for health risk. This can be done in the time domain or frequency domain using narrow band or one-third octave band data as mentioned above. The frequency weighting curves for health risk are illustrated in Figure 3. The multiplying factors (k_i) for health risk are given below for the respective direction. The frequency range is 0.5 to 80 Hz. This yields the overall weighted rms acceleration in each axis (x, y, z). The calculation in the time domain is illustrated in Equation 1 (ISO, 1997, 2010):

$$a_{wi} = k_i \left(\frac{1}{T} \int_0^T a_{wi}^2(t) dt \right)^{\frac{1}{2}} \quad (1)$$

where

a_{wi} = The overall weighted rms acceleration in the i -axis, ($i = x, y, \text{ or } z$) (m/s^2 rms)

k_i = The multiplying factor for direction i ($k = 1.4$ for $i = x, y$, $k = 1.0$ for $i = z$)

$a_{wi}(t)$ = The weighted acceleration as a function of time between 0.5 and 80 Hz (m/s^2)

T = Duration of the measurement(s)

The calculation in the frequency domain is illustrated in Equation 2

$$a_{wi} = k_i \left(\sum [W_i a_{wi}]^2 \right)^{\frac{1}{2}} \quad (2)$$

where:

a_{wi} = The overall weighted rms acceleration in the i -axis ($i = x, y, \text{ or } z$) (m/s^2 rms)

k_i = The multiplying factor for direction i ($k = 1.4$ for $i = x, y$, $k = 1.0$ for $i = z$)

W_i = The frequency weighting for the i -axis at the respective narrow band frequency or 1/3 octave band center frequency, i , from 0.5 to 80 Hz

a_i = rms acceleration value in the i -axis at the respective narrow band frequency or 1/3 octave band center frequency, i , from 0.5 to 80 Hz

If the vibration exposure includes periods with vibration of different magnitudes and durations occurring within contiguous 24 hours, the energy-equivalent overall weighted rms acceleration in each direction, x, y , and z , can be calculated as follows, in accordance with ISO 2631-1 (ISO, 1997, 2003, 2010):

$$a_{wte} = \left(\frac{\sum [a_{wi}^2 T_i]}{\sum T_i} \right)^{\frac{1}{2}} \quad (3)$$

where

a_{wte} = The equivalent overall weighted rms acceleration magnitude in either the $x, y, \text{ or } z$ direction (m/s^2 rms)

a_{wi} = The overall weighted rms acceleration magnitude in either the $x, y, \text{ or } z$ direction for exposure period j (m/s^2 rms) (from Equations 1 or 2)

T_j = The duration for exposure period j (s)

- The overall weighted rms accelerations may or may not be similar along the x, y , and z translational axes, as determined by Equations 1, 2, or 3. Therefore, the combined motion of all three axes is calculated as a vector sum of the overall weighted rms accelerations in the three orthogonal axes, a_x, a_y , and a_z defined in Equation 4:

$$a_v = \left([1.4 a_{wte}]^2 + [1.4 a_{wte}]^2 + [a_{wte}]^2 \right)^{\frac{1}{2}} \quad (4)$$

The vector sum also applies to the energy-equivalent weighted rms accelerations in the x, y , and z directions calculated in accordance with Equation 3.

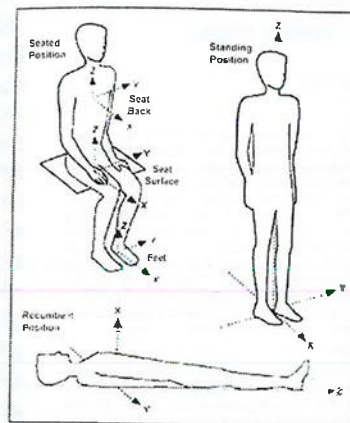


FIGURE 2. Biodynamic Coordinate System for the Seated, Standing, Recumbent Postures (Postures) (ISO, 1997, 2003, 2010). The coordinate system adheres to the right-hand rule for the seated and standing human.

- A summary of the analysis procedure is as follows.

If the vector sum of the overall weighted rms accelerations, a_v , equals or exceeds the values shown in Figure 1 (ISO upper boundary) or Table 1 (ISO upper boundary), for the relevant time period, then the TLV* is exceeded for that exposure duration. It is recommended that the overall weighted rms accelerations in all three axes be reported, in addition to the vector sum.

- It may be desirable to calculate the daily vibration exposure (within a 24-hour period) standardized to an 8-hour reference period as follows:

$$a_{w8}(8) = \left(\frac{\sum a_{wi}^2 T_i}{8} \right)^{\frac{1}{2}} \quad (5)$$

where

$a_{w8}(8)$ = The daily (8-hour) vibration exposure for the i -axis (m/s^2 rms)

NOTICE OF INTENDED CHANGE—UPPER LIMB LOCALIZED FATIGUE

The reason for this NIC is to add language, including an equation to be applied over the range of the TLV.

The TLV in Figure 1 is recommended for work-place tasks that require the use of the upper limbs, to which it is believed that most healthy workers may be exposed, day after day, to maintain their work capacity and normal performance for the duration of the workday without experiencing excessive or persistent upper limb musculoskeletal fatigue. Individual, environmental and other workplace factors may influence the likelihood that fatigue will be experienced as a pain or reduced upper limb motor control. This recommended TLV may not be protective for persons with pre-existing musculoskeletal disorders.

Localized fatigue is a complex phenomenon based on multiple factors, mechanisms, and outcomes that results from exertion of the body and affects our comfort and the ability of our musculoskeletal system to perform activities of work, daily living and leisure. Fatigue may be experienced as localized discomfort, pain, decreased strength, tremor or other symptoms or signs of reduced motor control. Physical exertions can cause fatigue that is brief, lasting for just a few hours, or fatigue that may persist for 24 hours or more, or, in extreme cases, tissue damage that can require several days or weeks for complete recovery. For purposes of this guideline, fatigue refers to discomfort or reduced upper limb function that occurs within 24 hours after sustained or repeated exertions of the hands and arms. Signs or symptoms that persist beyond 24 hours should be investigated as possible work-related musculoskeletal disorders. Fatigue may be a precursor to chronic soft tissue injuries.

A certain amount of localized fatigue, in and of itself, is not detrimental. Fatigue is a fact of life and a normal physiological response and may play an important role in adaptation of musculoskeletal tissues to physical stresses and unaccustomed work, but fatigue should not persist from one workday to the next or interfere with activities of work or daily living. As with any activity, workers may require several days or weeks to mentally and physically adapt to a new job. Abnormal symptoms may be experienced during this period of adaptation.

Localized fatigue that occurs during the workday should be reversibly resolved during the daily breaks from work, allowing for normal work function and typical life activities beyond work.

The recommended limits apply specifically to the upper limb: the hand/wrist, forearm, elbow and shoulder. There are underlying biomechanical and behavioral differences between the upper limb, trunk and lower limbs and care should be exercised in generalizing recommended limits for the upper limb to other body parts.

Workload Patterns

Work performance is measured as the ability to repeat and/or sustain biomechanical loads to reach, grasp, hold, and use or manipulate work objects. Loads, used in this context, refers to the exertion of forces and moments to support the weight of the body and work objects or to grasp, hold and manipulate work objects as necessary to meet the job requirements. Rapid body motions may briefly increase or decrease the loads during work due to acceleration and deceleration, but most fatigue computations are based on static or 'quasi static' conditions where these dynamic effects are negligible.

Loads can be normalized to strength by dividing the applied forces or moments by the strength of the corresponding joint and posture of an individual or population of interest. Strength refers to the maximum force or moment that can be voluntarily generated by the body segment of interest. Normalized loads are expressed as a fraction between 0 and 1, on a scale of 0 to 10, or as a percentage from 0 to 100%. These normalized loads are also frequently expressed as a Percent of Maximum Voluntary Contraction (%MVC).

Loads may be estimated from observations, perceived exertions estimated by workers, direct measurements, indirect measurements (e.g., electromyography) and biomechanical computations. Worker strength can be measured directly or estimated from population studies or biomechanical models. The best method will depend on the type of work being performed and the characteristics of the workers who perform the job. Procedures for analysis of load patterns are documented in the literature.

The equation for the TLV in Figure 1 is

$$\%MVC = (100\%) \cdot (0.143 \ln(DC/100)) + 0.666$$

where %MVC is the percent of maximum strength or effort of the hand, elbow or shoulder and DC is the duty cycle expressed as a percent of the total work cycle. The duty cycle is the percent of time over a work cycle or a certain time period that force is applied.

The TLV can also be expressed as

$$DC = (100\%) \cdot e^{(0.066 - \%MVC/0.143)}$$

The TLV fatigue curve can be used to compute acceptable percent duty cycle for a given force (%MVC) or an acceptable %MVC for a given percent duty cycle. The TLV applies to duty cycles within the range of 0.5% to 50%. The TLV is intended for cyclical work normally performed for 2 or more hours per day. If a worker does multiple tasks that are each 2 hours or more, none of the tasks should exceed the TLV. Static exertions of the hand, elbow or shoulder would not be expected to exceed 20 minutes.

The minimum recovery time (RT) from an exertion performed during repetitive tasks can be estimated using:

$$RT = (ET / e^{(0.066 - \%MVC/0.143)}) - ET$$

where ET is the exertion time. Duty cycle (DC) = $ET / (ET + RT)$. This equation can be applied over the applicable range of the TLV, which is 0.5% to 50% DC, which corresponds to exertion levels ranging from approximately 10% to 80% MVC.

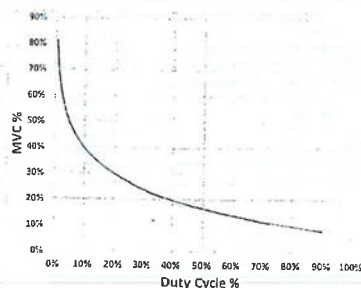


FIGURE 1. Fatigue TLV for MVC (%) versus duty cycle (%).

WHOLE-BODY VIBRATION (Documentation Date – 2020)

The Threshold Limit Values (TLVs), illustrated by the solid line in Figure 1 and tabulated at the center frequencies of one-third octave bands in Table 1, refer to the vector sum of the overall weighted root-mean-square (rms) acceleration magnitudes and durations of mechanically induced whole-body vibration (WBV). Operator or occupant exposures shall remain below the TLV curve for the respective exposure duration occurring within a 24-hour period. The Action Levels (ALs) represented by the dashed line in Figure 1, and tabulated at the center frequencies of one-third octave bands in Table 1, also refer to the vector sum of the overall weighted rms acceleration magnitudes and durations of mechanically induced WBV. It is highly recommended that vibration mitigation activity be undertaken to reduce any operator or occupant exposures that occur within a 24-hour period and fall within the region bounded by the TLV curve and AL curve. It is noted that unknown psychological or physiological influences may affect an individual's susceptibility to health risk. While the TLV and AL curves may be used as a guide in the control of WBV exposure, they should not be regarded as defining a distinct boundary between safe and dangerous levels.

Notes:

1. The TLV curve coincides with the upper boundary of the Health Guidance Caution Zones defined in ISO 2631-1 (ISO, 1997, 2003, 2010). The TLVs refer to the maximum vector sum of the overall weighted rms accelerations in the three orthogonal axes for a given exposure duration that it is believed a majority of operators and occupants of land, air, and water vehicles may be repeatedly exposed to within a 24-hour period with a low probability of health risks. The AL curve coincides with the lower boundary

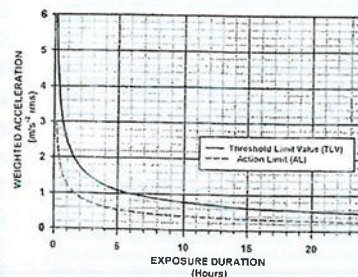


FIGURE 1. Threshold Limit Values (TLVs) and Action Limits (ALs) associated with the upper boundary and lower boundary of the ISO 2631-1 Health Guidance Caution Zones, respectively (ISO, 1997, 2010). Note: Values are constant for exposures at and below 10 minutes.

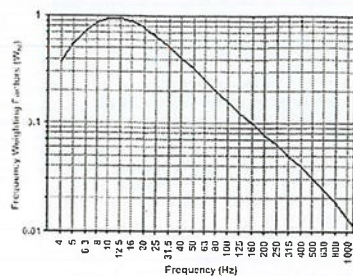


FIGURE 2. ISO Frequency Weighting Factors (ISO 5345-1, 2001a; ANSI S2.70, 2006).

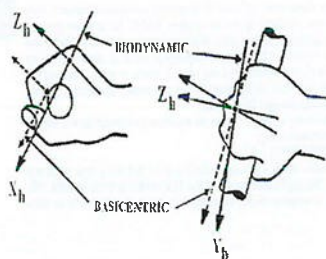


FIGURE 3. Biodynamic and basicentric coordinate systems for the hand, showing the directions of the acceleration components (ISO 5345, 2001a; ANSI S2.70, 2006).

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UPPER LIMB LOCALIZED FATIGUE

The TLV[®] in Figure 1 is recommended for workplace tasks that require the use of the upper limbs, to which it is believed that most healthy workers may be exposed, day after day, to maintain their work capacity and normal performance for the duration of the workday without experiencing excessive or persistent upper limb musculoskeletal fatigue. Individual, environmental and other workplace factors may influence the likelihood that fatigue will be experienced as a pain or reduced upper limb motor control. This recommended TLV[®] may not be protective for persons with pre-existing musculoskeletal disorders.

Localized fatigue is a complex phenomenon based on multiple factors, mechanisms, and outcomes that results from exertion of the body and affects our comfort and the ability of our musculoskeletal system to perform activities of work, daily living and leisure. Fatigue may be experienced as localized discomfort, pain, decreased strength, tremor or other symptoms or signs of reduced motor control. Physical exertions can cause fatigue that is brief, lasting for just a few hours, or fatigue that may persist for 24 hours or more or, in extreme cases, tissue damage that can require several days or weeks for complete recovery. For purposes of this guideline, fatigue refers to discomfort or reduced upper limb function that occurs within 24 hours after sustained or repeated exertions of the hands and arms. Signs or symptoms that persist beyond 24 hours should be investigated as possible work-related musculoskeletal disorders. Fatigue may be a precursor to chronic soft tissue injuries.

A certain amount of localized fatigue, in and of itself, is not detrimental. Fatigue is a fact of life and a normal physiological response and may play an important role in adaptation of musculoskeletal tissues to physical stresses and unaccustomed work, but fatigue should not persist from one workday to the next or interfere with activities of work or daily living. As with any activity, workers may require several days or weeks to mentally and physically adapt to a new job. Abnormal symptoms may be experienced during this period of adaptation.

Localized fatigue that occurs during the workday should be reversibly resolved during the daily breaks from work, allowing for normal work function and typical life activities beyond work.

The recommended limits apply specifically to the upper limb: the hand/wrist, forearm, elbow and shoulder. There are underlying biomechanical and behavioral differences between the upper limb, trunk and lower limbs and care should be exercised in generalizing recommended limits for the upper limb to other body parts.

Workload Patterns

Work performance is measured as the ability to repeat and/or sustain biomechanical loads to reach for, grasp, hold, and use or manipulate work objects. Loads, used in this context, refers to the exertion of forces and moments to support the weight of the body and work objects or to grasp, hold and manipulate work objects as necessary to meet the job requirements. Rapid body motions may briefly increase or decrease the loads during work due to acceleration and deceleration, but most fatigue computations are based on static or 'quasi static' conditions where these dynamic effects are negligible.

Loads can be normalized to strength by dividing the applied forces or moments by the strength of the corresponding joint and posture of an individual

or population of interest. Strength refers to the maximum force or moment that can be voluntarily generated by the body segment of interest. Normalized loads are expressed as a fraction between 0 and 1, on a scale of 0 to 10, or as a percentage from 0 to 100%. These normalized loads are also frequently expressed as a Percent of Maximum Voluntary Contraction (%MVC).

Loads may be estimated from observations, perceived exertions estimated by workers, direct measurements, indirect measurements (e.g., electromyography) and biomechanical computations. Worker strength can be measured directly or estimated from population studies or biomechanical models. The best method will depend on the type of work being performed and the characteristics of the workers who perform the job. Procedures for analysis of load patterns are documented in the literature.

The equation for the TLV[®] in Figure 1 is:

$$\%MVC = (100\%) \cdot (-0.143 \ln (DC/100\%)) + 0.066$$

Where %MVC is the percent of maximum strength or effort of the hand, elbow or shoulder and DC is the duty cycle expressed as a percent of the total work cycle. The duty cycle is the percent of time over a work cycle or a certain time period that force is applied.

The TLV[®] can also be expressed as:

$$\%DC = (100\%) \cdot e^{(0.0085 \cdot (\%MVC/100\%) - 0.143)}$$

The TLV[®] fatigue curve can be used to compute acceptable percent duty cycle for a given force (%MVC) or an acceptable %MVC for a given percent duty cycle. The TLV[®] applies to duty cycles within the range of 0.5% to 90%. The TLV[®] is intended for cyclical work normally performed for 2 or more hours per day. If a worker does multiple tasks that are each 2 hours or more, none of the tasks should exceed the TLV[®]. Static exertions of the hand, elbow or shoulder would not be expected to exceed 20 minutes.

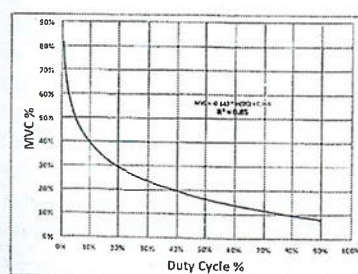
FIGURE 1. Fatigue TLV[®] for MVC (%) versus duty cycle (%).

TABLE 1. TLV[®] and AL Weighted Acceleration Levels

Vibration Exposure Time (hrs)	Weighted Acceleration (m/s ²)	
	TLV [®]	AL
0.25 (15 min)	28.28	14.14
1.0	14.14	7.07
2	10.0	5.0
4	7.07	3.54
6	5.77	2.89
8	5.0	2.5

$$a_{\text{root}(8\text{h})} = 5.0 \left(\frac{8}{T_v} \right)^{\frac{1}{2}}$$

$$a_{\text{root}(4\text{h})} = 2.5 \left(\frac{8}{T_v} \right)^{\frac{1}{2}}$$

$$T_v = \frac{200}{a_{\text{root}(8\text{h})}^2}$$

$$T_v = \frac{50}{a_{\text{root}(4\text{h})}^2}$$

TLV[®] at Time T_v (hrs):AL at Time T_v (hrs):Time Duration T_v (hrs) to reach TLV[®]:Time Duration T_v (hrs) to reach AL:

medical surveillance program. These guidelines should be based mainly from epidemiological data from forestry, mining, stone and metal-working occupations and should be used as guides with the knowledge of work and/or exposure. Due to individual susceptibility, the standard should be used in defining a boundary between safe and unsafe exposure levels.

Notes:

- The TLV[®] curve shown in Figure 1 conforms with the Daily Exposure Limit Values (DELVs) defined in ANSI S2.70 (2006) and the 24-hour equivalent value standardized to an 8-hour reference time (14.14 m/s²) (the 8-hour equivalent total value) defined in the European Directive 2002/44/EC. The AL curve shown in Figure 1 conforms with the Daily Exposure Action Values (DEAVs) defined in ANSI S2.70 (2006) and the 24-hour equivalent total value (or 8-hour energy equivalent vibration total value) defined in the European Union Directive 2002/44/EC.
- A(8) is the vector sum of the 8-hour energy equivalent total value, which is derived from the root-mean-square (rms) component accelerations measured in three orthogonal axes.
- The frequency weighting factors provided in ISO 5349-1 (1997) and ANSI S2.70 (2006) are considered the best available frequency weightings for the acceleration components for assessing hand-arm vibration exposure (see Figure 2). However, studies suggest that the frequency weighting at frequencies above 16 Hz may not adequately be a sufficient safety factor, and caution must be applied when this weighting factor components are used (Palmear et al. 1999; Wasserman 1967, 1974; Taylor and Palmear, 1975; Wasserman and Taylor 1977; Brammer 1982; Moxa 1987; Bovenzi et al. 2011; Dong et al. 2012).
- Acute exposures corresponding to measured frequency-weighted rms component accelerations either in compliance with or in excess of the TLV[®] for infrequent periods of time (i.e. intermittently 1 day per week or several days over a 2-week period) may be less harmful than continuous exposure (Taylor and Palmear, 1975; Wasserman and Taylor 1977; Brammer 1982; Moxa 1987).
- Good work practices should be used and should include instructing workers to employ a minimum hand grip force consistent with safe operation of the power tool or process, to keep the body and hands warm and dry, to avoid smoking and to use antivibration tools. As a general rule, gloves may dampen vibration at high frequencies (beyond 200 Hz) (Taylor and Palmear, 1975; Wasserman and Taylor 1977; Brammer 1982).
- A vibration measurement transducer, together with a device for attachment to the vibration source, should weigh less than 15 grams and should possess a cross-axis sensitivity of less than 10% (Taylor and Palmear 1975; Wasserman and Taylor 1977; Brammer 1982; Wasserman et al. 1982a; U.S. NIOSH, 1983, 1989).
- The measurement by many (mechanically under-damped) piezoelectric accelerometers of repetitive and large displacement impact vibrations, such as those produced by percussive pneumatic tools, is subject to error. The insertion of a suitable low-pass mechanical filter between the accelerometer and the source of vibration with a cutoff frequency of at least 1500 Hz (and cross-axis sensitivity of less than 10%) can help minimize incorrect readings.

TABLE 2. Stockholm Workshop HAVS Classification System for Cold-Induced Peripheral Vascular and Sensorineural Symptoms

Vascular Assessment		
Stage	Grade	Description
0		No attacks
1	Mild	Occasional attacks affecting only the tips of one or more fingers
2	Moderate	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers
3	Severe	Frequent attacks affecting ALL phalanges of most fingers
4	Very Severe	As in Stage 3, with trophic skin changes in the finger tips

Note: Separate staging is made for each hand, e.g., TLV(1R)/1L = Stage 2 on left hand in 2 fingers; Stage 1 on right hand in 1 finger.

Sensorineural Assessment	
Stage	Symptoms
0SN	Exposed to vibration but no symptoms
1SN	Intermittent numbness, with or without tingling
2SN	Intermittent or persistent numbness, reducing sensory perception
3SN	Intermittent or persistent numbness, reducing tactile discrimination and/or manipulative dexterity

Note: Separate staging is made for each hand.

- The manufacturer and type number of all apparatus used to measure vibration should be reported, as well as the value A(8) (Wasserman 1967; Wasserman and Taylor, 1977; Brammer, 1978, 1982; Wasserman et al. 1982b).
- The measurement of vibration should be performed in accordance with the procedures and instrumentation specified by ISO 5349-1 or ANSI S2.70. The procedures are summarized below.
 - It is highly recommended that signal processing techniques be applied to generate the spectral content in each axis to identify the frequencies corresponding to major acceleration peaks. The spectra can be generated in either narrow frequency bands of constant bandwidth, or proportional bands no greater than one-third octave.
 - A small and lightweight transducer should be mounted so as to accurately record one or more orthogonal components of the source vibration in the frequency range from 5 to 1500 Hz (one-third octave frequency bands 6.3 to 1250 Hz).
 - Evaluation of vibration should be made for each applicable direction (X_h, Y_h, Z_h) since vibration is a vector quantity (magnitude and direction).

- Each component should be frequency-weighted by a filter network with gain characteristics specified for human-response vibration measuring instrumentation, to account for the change in vibration hazard with frequency (ISO 5349-1, 2001a)

$$a_{hw} = \left(\frac{1}{T} \int_0^T a_{hw}^2(t) dt \right)^{\frac{1}{2}} \quad (1)$$

where: a_{hw} = The frequency-weighted rms acceleration associated with worker exposure time (T) in each respective direction (m/s² rms)

- The weighted acceleration can also be obtained in the one-third octave frequency domain per Equation 2.

$$a_{hw} = \left(\sum_i |W_{hi} a_{hi}|^2 \right)^{\frac{1}{2}} \quad (2)$$

where: a_{hw} = The frequency-weighted rms acceleration associated with the exposure time in each respective direction (m/s² rms)

W_{hi} = The ISO/ANSI frequency weighting factor for the i th one-third octave frequency band (see Figure 2)

a_{hi} = The rms acceleration in the i th one-third octave frequency band associated with the exposure time in each respective direction (m/s² rms)

- In each direction, the magnitude of the vibration total value, a_{hw} , during normal operation of the power tool, machine, or work piece should be expressed by the root-sum-of-squares of the rms frequency-weighted component accelerations, in units of meters per second squared (m/s²).

$$a_{hw} = \left([a_{hw}^2] + [a_{hw}^2] + [a_{hw}^2] \right)^{\frac{1}{2}} \quad (3)$$

- Assessment of vibration exposure should be made by determining the 8-hour energy equivalent vibration total value of the frequency-weighted rms acceleration components (alternatively termed the vector sum or frequency weighted acceleration sum). The 8-hour energy equivalent vibration total value is termed the A(8). These computations may be performed by commercially available human-response vibration measuring instruments.

$$A(8) = a_{hw} \left(\frac{T_v}{T_0} \right)^{\frac{1}{2}} \quad (4)$$

where: T_v = The total time in hours associated with the actual worker exposure (same as T in Equation 1)

T_0 = The reference time duration of 8 hours

- The guidelines in ANSI S2.70 (ANSI, 2006) should be used if the vibration exposure is made up of several operations with different vibration magnitudes.

TABLE 1. TLVs^a for Lifting Tasks:
 ≤ 2 Hours per Day with ≤ 60 Lifts per Hour
 OR
 ≥ 2 Hours per Day with ≤ 12 Lifts per Hour

Vertical Zone	Horizontal Zone ^A		
	Close: ≤ 30 cm	Inter- mediate: 30 to 60 cm	Extended: ^B ≥ 60 to 80 cm
Reach limit ^C or 30 cm above shoulder to 8 cm below shoulder height	16 kg	7 kg	No known safe limit for repetitive lifting ^D
Knuckle height ^E to below shoulder	32 kg	16 kg	9 kg
Middle shin to knuckle height ^E	18 kg	9 kg	7 kg
Floor to middle shin height	14 kg	No known safe limit for repetitive lifting ^D	No known safe limit for repetitive lifting ^D

Footnotes for Tables 1 through 3:

- Distance from midpoint between inner ankle bones and the load.
- Lifting tasks should not start or end at a horizontal reach distance more than 80 cm from the midpoint between the inner ankle bones (Figure 1).
- Routine lifting task - should not start or end at heights that are greater than 30 cm above the shoulder or more than 180 cm above floor level (Figure 1).
- Routine lifting tasks should not be performed for shaded table entries marked "No known safe limit for repetitive lifting." While the available evidence does not permit identification of safe weight limits in the shaded regions, professional judgment may be used to determine if infrequent lifts of light weights may be safe.
- Anatomical landmark for knuckle height assumes the worker is standing erect with arms hanging at the sides.

TABLE 2. TLVs^a for Lifting Tasks:
 ≥ 2 Hours per Day with > 12 and ≤ 30 Lifts per Hour
 OR
 ≥ 2 Hours per Day with > 60 and ≤ 360 Lifts per Hour

Vertical Zone	Horizontal Zone ^A		
	Close: ≤ 30 cm	Inter- mediate: 30 to 60 cm	Extended: ^B ≥ 60 to 80 cm
Reach limit ^C or 30 cm above shoulder to 8 cm below shoulder height	14 kg	5 kg	No known safe limit for repetitive lifting ^D
Knuckle height ^E to below shoulder	27 kg	14 kg	7 kg
Middle shin to knuckle height	16 kg	11 kg	5 kg
Floor to middle shin height	9 kg	No known safe limit for repetitive lifting ^D	No known safe limit for repetitive lifting ^D

See Notes in Table 1.

TABLE 3. TLVs^a for Lifting Tasks:
 ≥ 2 Hours per Day with > 30 and ≤ 360 Lifts per Hour

Vertical Zone	Horizontal Zone ^A		
	Close: ≤ 30 cm	Inter- mediate: 30 to 60 cm	Extended: ^B ≥ 60 to 80 cm
Reach limit ^C or 30 cm above to 8 cm below shoulder height	11 kg	No known safe limit for repetitive lifting ^D	No known safe limit for repetitive lifting ^D
Knuckle height ^E to below shoulder	14 kg	9 kg	5 kg
Middle shin to knuckle height ^E	9 kg	7 kg	2 kg
Floor to middle shin height	No known safe limit for repetitive lifting ^D	No known safe limit for repetitive lifting ^D	No known safe limit for repetitive lifting ^D

See Notes in Table 1.

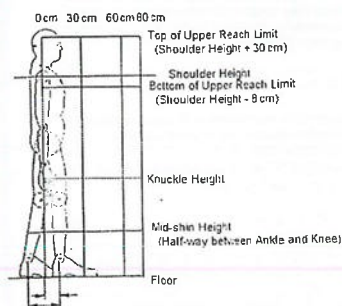


FIGURE 1. Graphic representation of hand location.

- Determine the lifting frequency as the number of lifts a worker performs per hour.
- Use the TLV^a table that corresponds to the duration and lifting frequency of the task.
- Determine the vertical zone (Figure 1) based on the location of the hands at the start of the lift.
- Determine the horizontal zone of the lift (Figure 1) by measuring the horizontal distance from the midpoint between the inner ankle bones to the midpoint between the hands at the start of the lift.
- Determine the TLV^a in kilograms for the lifting task, as displayed in the table cell that corresponds to the vertical and horizontal zones in the appropriate table, based upon frequency and duration.
- Consider load control at destination. If the load is placed at the destination in a controlled fashion (i.e., slowly or deliberately placed), repeat Steps 5 through 7 using the destination point instead of the start. The TLV^a is represented by the lower of the two limits.

These TLVs^a are designed to reduce the risk of low-back injuries associated with repeated lifting tasks. In addition to the low back, lifting and lowering tasks might expose other body regions to high stress. Depending on task parameters and specific posture requirements while lifting, joints such as shoulder, knee, elbow and wrist might be at equal or greater risk of injury than the low back. Additional research is needed to understand whole-body risk of injury from lifting. For example, expert opinion suggests that high frequency lifting while reaching at or above shoulder height might put a worker's shoulder at increased risk for injury even while the low back loads are below the lifting TLVs^a. Practitioners are encouraged to exercise professional judgement and supplement the lifting TLVs^a with appropriate task-specific assessments in order to minimize injury risk to other body regions.

HAND-ARM VIBRATION (Documentation Date = 2019)

Exposure to vibration may lead to Hand-Arm Vibration Syndrome (HAVS), a set of upper extremity disorders that include vascular, sensorineural, and musculoskeletal signs and symptoms. The Threshold Limit Value (TLV^a) for hand-arm vibration illustrated by the upper solid line in Figure 1 and tabulated in Table 1, refers to the daily vibration exposure [8-hour energy equivalent total value A(8)] of 5 m/s² that represents conditions under which it is believed that most workers may be exposed repeatedly without progressing beyond Stage 1 of the Stockholm Workshop Classification System for Vibration-Induced White Finger (VWF), also known as Raynaud's Phenomenon of Occupational Origin (see Vascular Assessment in Table 2). Vibration mitigation processes or controls should be employed that will maintain worker exposure below the TLV^a illustrated in Figure 1. It is not possible to specify a TLV^a that will be protective of all workers for all work situations, i.e., high force exertions, cold environments, and unusual postures. The Action Limit (AL) illustrated by the lower dashed line in Figure 1 and tabulated in Table 1 refers to an A(8) of 2.5 m/s². This limit represents conditions under which the risk of developing symptoms is very low for the large majority of workers. Therefore, the area between the AL and TLV^a corresponds to a caution zone that requires actions to control exposure, such as 1) the use of anti-vibration tools or gloves; 2) training of workers and supervisors on early symptoms of HAVS and the importance of keeping the worker's hands and body warm and reducing the vibration coupling between the hands and the vibrating tool to minimize vibration exposure, and 3) a conscientiously applied

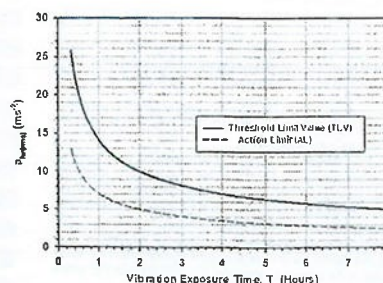


FIGURE 1. Threshold Limit Value (TLV^a) and Action Limit (AL) associated with ANSI Z39.23 Daily Exposure Limit Values (DELV) and Daily Exposure Action Values (DEAV), respectively.

to 0% to 100% of the predicted strength for the applicable population (males, females, young, old, etc.; various factory workers, etc.).

Normalized Peak Force (NPF) is a peak force posture specific relative strength.

PF and NPF can be estimated using ratings by a trained observer, rated by workers using a Borg or visual analog scale (see TLV® Documentation for definition), or measured using instrumentation, e.g., strain gauges or electromyography. In some cases, it can be calculated using biomechanical methods. These methods are intended to measure recurring peak forces. Random force peaks associated with noise that occur less than 10% of the time are disregarded.

Posture is included in the TLV® to the extent that it affects strength. For instance, strength is reduced by the use of a pinch posture, wrist deviation, or forearm rotation and consequently normalized peak force will be increased.

The solid line in Figure 1 represents those combinations of force and hand activity level associated with a significantly elevated prevalence of musculoskeletal disorders. Appropriate control measures should be employed so that the force for a given level of hand activity is below the upper solid line in Figure 1. It is not possible to specify a TLV® that protects all workers in all situations without profoundly affecting work rates. Therefore, an Action Limit is prescribed above for which general controls, including surveillance and training, are recommended.

Process

1. Identify the hand-activity tasks performed during the workday. There may be one or more and they should collectively represent four or more hours of work.
2. For each task, select a period of the task that represents an average activity. The selected period should include several complete work cycles. Videotapes may be used for documentation purposes and to facilitate rating of the job.
3. Rate the Hand Activity Level using the scale shown in Figure 2. Independent rating of jobs and discussion of results by three or more people can help produce a more precise rating than individual ratings.
4. Observe the job to identify forceful exertions and corresponding postures. Evaluate postures and forces using observer ratings, worker ratings, biomechanical analysis, or instrumentation. Normalized peak force is the required peak force divided by the representative maximum force for the posture multiplied by 10.
5. For jobs with multiple tasks, time-weighted averaging (TWA) may be used. One method is to determine the TWA of HAL across tasks and use the highest NPF observed among the tasks. A second method is to determine a TWA on the Peak Force Index (PFI) for each task (see Notes). A third method is to determine the TWA for NPF across all tasks and separately a TWA for HAL across all tasks.

Consideration of Other Factors

Professional judgment should be used to reduce exposures below the Action Limit if one or more of the following factors is present:

- sustained non-neutral postures such as wrist flexion, extension, wrist deviation, or forearm rotation;

- contact stresses
- low temperatures, or
- vibration

Employ appropriate control measures any time the TLV® is exceeded or an elevated incidence of work-related musculoskeletal disorders is observed.

Notes:

The actual TLV® and Action Limit (AL) are represented by Figure 1. There are alternative methods for expressing the limit values, and some are described here. In all cases, they are limited to the range of HAL between 1 and 3.

1. Equations for Lines

$$\text{TLV: NPF} = 5.6 - 0.56 \times \text{HAL}$$

$$\text{Action Limit: NPF} = 3.6 - 0.56 \times \text{HAL}$$

Or, equivalent description of lines:

$$\text{NPF}_{\text{TLV}} = 0.56 (10 - \text{HAL})$$

$$\text{NPF}_{\text{AL}} = \text{NPF}_{\text{TLV}} - 2$$

2. Peak Force Index (PFI)

A value greater than 1.0 means that the respective limit is exceeded.

$$\text{PFI}_{\text{TLV}} = \text{NPF} / \text{NPF}_{\text{TLV}}$$

$$\text{PFI}_{\text{AL}} = \text{NPF} / \text{NPF}_{\text{AL}}$$

TLV®-PA

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LIFTING

(Documentation Date — 2019)

These TLVs® recommend workplace lifting conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, without developing work-related low back disorders associated with repetitive lifting tasks. There are individual and organizational risk factors that may influence the likelihood that an individual will experience low back and shoulder disorders.

Lifting TLVs®

The TLVs® consist of three tables with weight limits, in kilograms (kg), for two-handed, mono-lifting tasks within 30 degrees of the sagittal (neutral) plane. A mono-lifting task is one in which the loads are similar and the starting and destination points are repeated, and this is the only lifting task performed during the day. Other manual material-handling tasks such as carrying, pushing, and pulling are not accounted for in the TLVs®, and care must be exercised in applying the TLVs® under these circumstances.

These TLVs® (Tables 1 through 3) are presented for lifting tasks defined by their durations, either less than or greater than 2 hours per day, and by their frequency, expressed in number of lifts per hour, as qualified in the Notes to each table.

In the presence of any factor(s) or working condition(s) listed below, professional judgment should be used to reduce weight limits below those recommended in the TLVs®:

- High-frequency lifting: > 360 lifts per hour.
- Extended workshifts: lifting performed for longer than 8 hours per day.
- High asymmetry: lifting more than 30 degrees away from the sagittal plane.
- Rapid lifting motions and motions with twisting (e.g., from side to side).
- One-handed lifting.
- Constrained lower body posture, such as lifting while seated or kneeling.
- High heat and humidity (see Heat Stress and Heat Strain TLVs®).
- Lifting unstable objects (e.g., liquids with shifting center of mass or lack of coordination or equal sharing in multi-person lifts).
- Poor hand coupling: lack of handles, cut-outs, or other grasping points.
- Unstable footing (e.g., inability to support the body with both feet while standing).
- During or immediately after exposure to whole-body vibration at or above the TLV® for Whole-Body Vibration (see the current TLV® Documentation for Whole-Body Vibration).

Instructions for Users

1. Read the Documentation for the Lifting TLVs® so you understand the basis for these TLVs® and their limitations.
2. Classify task duration as less than or equal to a cumulative 2 hours per day or greater than a cumulative 2 hours per day. Task duration is the total length of time that a worker performs the task in 1 day.

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2022 ACGIH Webinars Lineup

ACGIH has an exciting lineup of webinars for 2022! These webinars include a wide range of topics such as wearable devices, respirator fit testing, and pandemic facility risk assessment. ACGIH webinars are taught by OEHs experts and provide you with opportunities to expand your career depth. Here are some of the upcoming webinars in 2022!

January 12 - Risk Assessing Facility Pandemic Resilience

January 26 - Respirator Fit Testing: Common Errors and Solutions

February 9 - How the adoption of Revision 7 of the GHS of classification and labelling of chemicals in Canada and the US impact your SDSs and Labels

February 23 - Epidemiology-Based Analysis of Musculoskeletal Injuries: A Forensic Approach

March 9 - An Overview of U.S. Regulations Governing Hazards

April 6 - Wearable Sensing Devices for Worker Safety and Health



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- Level of physical condition
- Previous injuries
- Diabetes
- Recreational/leisure activities

The recommended TLV® may not provide protection for people with chronic conditions and/or exposures. Engineering and administrative actions can help eliminate ergonomic barriers for persons with predisposing conditions and thus help to minimize disability.

Chronology of the Statement

- 1995: Proposed 'Lifting Statement'
- 1996: Adopted with name change to 'Musculoskeletal Statement'
- 2000: Editorial changes
- 2004: Editorial changes

TLV®-PA

HAND ACTIVITY

(Documentation Date — 2010)

Although work-related musculoskeletal disorders can occur in a number of body regions (including the shoulders, neck, low back, and lower extremities), the focus of this TLV® is on the hand, wrist, and forearm.

The TLV® shown in Figure 1 is based on epidemiological, psychophysical, and biomechanical studies and is intended for jobs performed from 4 to 8 hours per day. The TLV® specifically considers average Hand Activity Level (HAL) and Normalized Peak Force (NPF) to represent conditions to which it is believed nearly all workers may be repeatedly exposed without adverse health effects.

HAL is based on the frequency of hand exertions and the duty cycle (distribution of work and recovery periods). HAL can be determined by trained observers based on exertion frequency, rest pauses and speed of motion using the rating scale shown in Figure 2. Only hand exertions greater than 10% of posture-specific strength should be considered. HAL can also be calculated based on empirical studies of expert ratings, hand exertion frequency and duty cycle (exertion time / exertion + rest time) × 100%. HAL can be calculated as

$$HAL = 6.54 \ln \left(\frac{F^{1.21}}{1 + 3.15 F^{1.21}} \right) \quad (1)$$

F = duty cycle [%] and F = hand exertion frequency [exertions/s] or estimated from Table 1. Calculated HAL values should be rounded to the nearest whole number.

Peak hand force (PF) is a typically high value of hand force, generally taken to be the 50th percentile force exerted by the hand over the task period. Peak hand force is normalized to a scale of 0 to 10, which corresponds

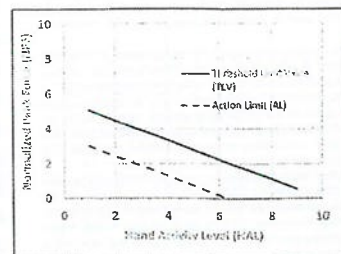
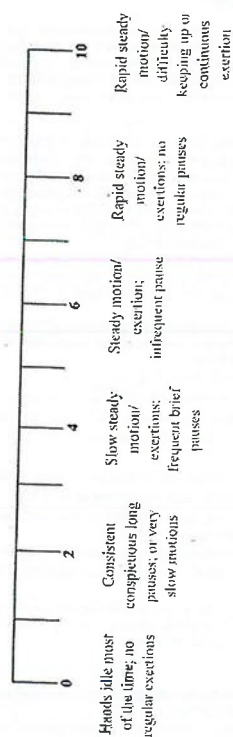


FIGURE 1. The Hand Activity TLV® for reduction of work-related musculoskeletal disorders based on hand activity level (HAL) and normalized peak hand force.

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TLV®-PA

TABLE 1. Hand Activity Level (HAL) (0–10) is Related to Hand Exertion Frequency and Duty Cycle (percent of work cycle where hand force is greater than 10% of posture-specific strength)

Frequency (exertions/s)	Duty Cycle (%)				
	0–20	20–40	40–60	60–80	80–100
0.125					
0.25	1	2	3	4	5
0.5	2	3	4	5	6
1.0	3	4	5	6	7
2.0	4	5	6	7	8

Notes:

1. Round HAL values to the nearest whole number.
2. Use Figure 2 to obtain HAL values outside those listed in the table.

TLV®-PA

tion of protection.

TLV® guidelines are the dose limits shown in Table 1. Application of the ALARA principle is achieved through optimization of protection, which is to be applied in all exposure situations and is the methodology by which doses are managed in practice to be well below the dose limit (NCRP, 2018).

^a This level of risk is based on the ICRP (2013) and ICRP (2007) estimate of a 5% lifetime risk of fatal cancer for a total exposure of one Sv distributed over occupational exposures of 20 mSv annual doses averaged over five years.

TABLE 1. Dose Limits for Management of Exposures to an Individual^a (abstracted from NCRP, 2018)

Exposure Situation	Dose Limit (mSv) ^b
Effective Dose: <i>Stochastic Effects</i> Annual (≥ 18 years of age)	Should not exceed 50 mSv (millisieverts)
Cumulative (≥ 18 years of age)	Should not exceed 10 mSv times current age in years ^c
Minors under 18 years of age	Should not exceed 1 mSv per year
Embryo-fetus of pregnant worker following declaration of pregnancy	Should not exceed 0.5 mSv per month (equivalent dose to the embryo-fetus) ^d
Radon and Radon Daughters	Includes annual dose if activity concentration in air > 200 Bq m ⁻³ after application of radon mitigation measures
Absorbed Dose ^e : <i>Tissue Reactions</i> a) lens of the eye	Should not exceed 50 mGy per year in the lens of the eye
b) skin, hands and feet	Should not exceed 500 mGy in skin or extremities per year, averaged over the most lightly exposed 10 cm ² of skin

^a Doses for stochastic effects are the effective doses from combined external and internal sources except from ubiquitous background radiation (with the exception of elevated levels of radon in the workplace, and solar and cosmic radiation in certain occupational circumstances). Doses for tissue reactions are the absorbed doses in the specified tissues. Definitions of absorbed dose and effective dose are given below.

^b In all cases, the phrase "should not exceed" conveys that the first objective for management of dose to an individual is to meet the applicable numeric protection criterion, and then to apply optimization of protection. The phrase "should not exceed" is not intended to mean that the value is suitable as a regulatory dose limit. NCRP recognizes (1) that there may be exposure situations in which initial doses to individuals are greater than the applicable numeric protection criterion, and (2) that the values are not a boundary between safe and unsafe exposures (NCRP, 2018).

^c 10 mSv = 1 rem.

^d NCRP acknowledges that, in practice, the doses and lengths of pregnancy may not be accurately known; therefore, the dose limit should be applied as a guideline.

^e Situations in which a worker who has declared her pregnancy may be exposed to ionizing radiation should be minimized or avoided if possible because of the risk of congenital hypothyroidism (NCRP, 2018).

^f If it is necessary to apply this recommendation to high-LET radiation, NCRP recommends that the absorbed dose in the skin or extremities or the lens of the eye should be multiplied by the biological effectiveness of the high-LET radiation that is appropriate for the tissue reaction (NCRP, 2018).

References

International Commission on Radiological Protection (ICRP). ICRP Publication 103. The 2007 Recommendations of the International Commission on Radiological Protection. Ann ICRP Vol. 37(2-4). Sage Publications, Thousand Oaks, California (2007).
National Council on Radiation Protection and Measurements (NCRP). NCRP Report No. 160. Management of Exposure to Ionizing Radiation: Radiation Protection Guidance for the United States. NCRP, Bethesda, MD (2018).

ERGONOMICS

Ergonomics is the term applied to the field that studies and designs the human-machine interface to prevent illness and injury and to improve work performance. It attempts to ensure that jobs and work tasks are designed to be compatible with the capabilities of the workers. ACGIH® recognizes that some physical agents play an important role in ergonomics. Force and acceleration are addressed, in part, in the Hand-Arm Vibration (HAV) and Whole-Body Vibration (WBV) TLVs®. Thermal factors are addressed, in part, in the TLVs® for Thermal Stress. Force is also an important causal agent in injuries from lifting. Other important ergonomic considerations include work duration, repetition, contact stresses, postures, and psychosocial issues.

STATEMENT ON WORK-RELATED MUSCULOSKELETAL DISORDERS

(Documentation Date — 2005)

ACGIH® recognizes work-related musculoskeletal disorders (MSDs) as an important occupational health problem that can be managed using an ergonomics health and safety program. The term musculoskeletal disorders refers to chronic muscle, tendon, and nerve disorders caused by repetitive exertions, rapid motions, high forces, contact stresses, extreme postures, vibration, and/or low temperatures. Other commonly used terms for work-related musculoskeletal disorders include cumulative trauma disorders (CTDs), repetitive motion illnesses (RMIs), and repetitive strain injuries (RSIs).

Some of these disorders fit established diagnostic criteria such as carpal tunnel syndrome or tendinitis. Other musculoskeletal disorders may be manifested by nonspecific pain. Some transient discomfort is a normal consequence of work and is unavoidable, but discomfort that persists from day to day or interferes with activities of work or daily living should not be considered an acceptable outcome of work.

Control Strategies

The incidence and severity of MSDs are best controlled by an integrated ergonomics program. Major program elements include:

- Recognition of the problem,
- Evaluation of suspected jobs for possible risk factors,
- Identification and evaluation of causative factors,
- Involvement of workers as fully informed active participants, and
- Appropriate health care for workers who have developed musculoskeletal disorders.

General programmatic controls should be implemented when risk of MSDs is recognized. These include:

- Education of workers, supervisors, engineers, and managers;
- Early reporting of symptoms by workers; and
- Ongoing surveillance and evaluation of injury, health and medical data.

Job-specific controls are directed to individual jobs associated with MSDs. These include engineering controls and administrative controls. Personal protection may be appropriate under some limited circumstances.

Among engineering controls to eliminate or reduce risk factors from the job, the following may be considered:

- Using work methods engineering, e.g., time study, motion analysis, to eliminate unnecessary motions and exertions.
- Using mechanical assists to eliminate or reduce exertions required to hold tools and work objects.
- Selecting or designing tools that reduce force requirements, reduce holding time, and improve postures.
- Providing user-adjustable workstations that reduce reaching and improve postures.
- Implementing quality control and maintenance programs that reduce unnecessary forces and exertions, especially associated with nonvalue-added work.

Administrative controls reduce risk through reduction of exposure time and sharing the exposure among a larger group of workers. Examples include:

- Implementing work standards that permit workers to pause or stretch as necessary but at least once per hour.
- Re-allocating work assignments (e.g., using worker rotation or work enlargement) so that a worker does not spend an entire workshift performing high-demand tasks.

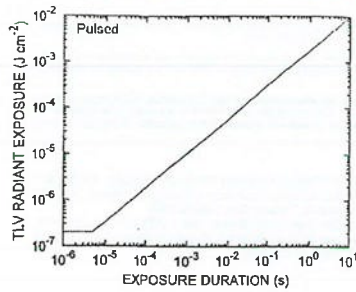
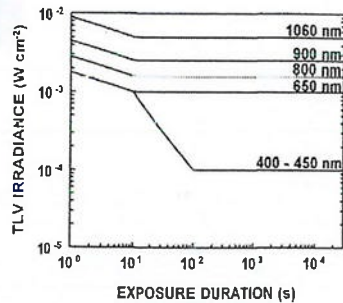
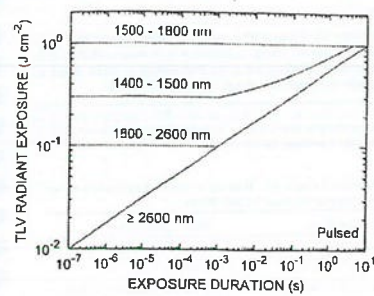
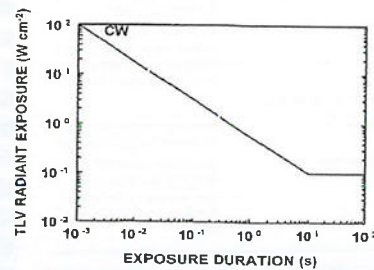
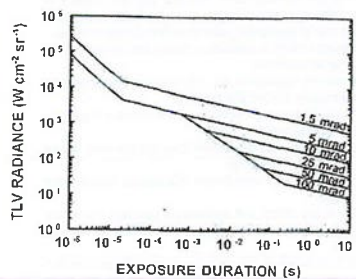
Due to the complex nature of musculoskeletal disorders, there is no "one size fits all" approach to reducing the incidence and severity of cases. The following principles apply to selecting actions:

- Appropriate engineering and administrative controls will vary from industry to industry and company to company.
- Informed professional judgment is required to select the appropriate control measures.
- Work-related MSDs typically require periods of weeks to months for recovery. Control measures should be evaluated accordingly to determine their effectiveness.

Nonoccupational Factors

It is not possible to eliminate all musculoskeletal disorders via engineering and administrative controls. There are individual and organizational factors that may influence the likelihood that an individual will experience musculoskeletal disorders. Some cases may be associated with nonoccupational factors such as:

- Rheumatoid arthritis
- Endocrinological disorders
- Acute trauma
- Obesity
- Pregnancy
- Age
- Gender

FIGURE 3a. TLV[®] for intrabeam viewing of laser beam (400-700 nm).FIGURE 3b. TLV[®] for intrabeam (direct) viewing of CW laser beam (400-1400 nm).FIGURE 4a. TLV[®] for user exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1400 nm).FIGURE 4b. TLV[®] for CW laser exposure of skin and eyes for far-infrared radiation (wavelengths greater than 1.4 μm).FIGURE 5. TLV[®] in terms of radiance for exposures to extended-source lasers in the wavelength range of 400 to 700 nm.

IONIZING RADIATION (Documentation Date – 2020)

TLVs[®]

ACGIH[®] has adopted as a TLV[®] for occupational exposure to ionizing radiation the guidelines of the National Council on Radiation Protection and Measurements (NCRP, 2018) and certain guidance from the International Council on Radiation Protection (ICRP, 2007). Ionizing radiation includes particulate radiation (α particles and β particles emitted from radioactive materials, and neutrons, protons and heavier charged particles produced in nuclear reactors and accelerators) and electromagnetic radiation (gamma rays emitted from radioactive materials and X-rays from electron accelerators and X-ray machines) with energy greater than 12.4 electron volts (eV) corresponding to wavelengths less than approximately 100 nanometers (nm).

The guiding principles of ionizing radiation protection are:

- **Justification:** Actions to add, increase, reduce or remove a source of exposure to humans require justification (i.e., the action does more good than harm). All factors, both radiological and nonradiological, and particularly the economic, societal, psychological and environmental implications (including to nonhuman biota), should be considered in that justification (NCRP, 2018).
- **Optimization of Protection:** The likelihood of incurring exposures, the number of individuals exposed, and the magnitude of the dose to an individual should be kept as low as reasonably achievable, taking into account societal, economic and environmental factors (i.e., ALARA principle). More generally, optimization of protection is satisfied when the expenditure of further resources would be unwarranted by improvement in health and safety (both radiological and nonradiological). The level of protection should be the best under the prevailing circumstances, maximizing the margin of benefit over harm (NCRP, 2018).
- **Dose Limit:** The dose limit is the numeric protection criterion recommended by NCRP for management of dose to an individual for a given exposure situation that establishes a starting point, below which the options for optimization of protection should be evaluated for that particular exposure situation. If the initial circumstances for a particular exposure situation are such that the dose limit is exceeded, the first objective is to meet that dose limit, then optimization of protection should be applied. Dose limits do not apply to medical exposure of patients or exposure to ubiquitous background radiation (with the exception of elevated levels of radon in dwellings and the workplace, and to solar and cosmic radiation in certain occupational circumstances) (NCRP, 2018).

There is no identified dose threshold for those radiation effects classified as stochastic. The dose limits are selected so that the risk of inducing a fatal cancer during the lifetime of the exposed individual is less than 10^{-3} per year.

There is also some question whether radiation-induced cataract formation has a low-dose threshold. Overall, the emphasis in radiation protection is on optimiza-

TLV®-PA

TABLE 3. TLV® for Extended-Source Laser Viewing Conditions (Continued)

Spectral Region	Wavelength	Exposure, (t) Seconds	TLV®
These correspond to values of W/cm^2 for $10^{-5} \leq t \leq 100$ s and W/cm^2 for $t > 100$ s as measured through a limiting cone angle γ .			
	$\gamma = 11$ mrad for $0.7 \leq t \leq 100$ s		
	$\gamma = 1.1 \times 10^{-2}$ mrad for $100 \leq t \leq 10^4$ s		
	$\gamma = 110$ mrad for $10^{-5} \leq t \leq 3 \times 10^{-4}$ s		
	$T_2 = 10 \times 10^{-4}$ s, α_{max} , for t expressed in mrad for $\lambda = 400$ to 1400 nm.		
For exposure duration t , the angle α_{max} is defined as:			
	$t_{max} = 5$ mrad for $t \leq 0.625$ ms		
	$\alpha_{max} = 200$ $t^{0.5}$ mrad for $0.625 \text{ ms} < t < 0.25$ s, and		
	$\alpha_{max} = 100$ mrad for $t \geq 0.25$ s		
	$L_2 = 100 C_A W/cm^2$ sr for $0.7 \leq t \leq 10^4$ s and $L_2 = C_A \times 10^{-4} W/cm^2$ sr for $t \geq 10^4$ s as measured through a limiting cone angle γ .		

TLV®-PA

Notes for Tables 2 and 3

^aTLV®: To protect the cornea and lens, the TLV® for wavelengths between 400 nm and 1400 nm, in Table 3 should not be exceeded.

Wavelength	Exposure (t) Seconds	NTE (Second of Dual Limits)
400 to 1400 nm	10^{-5} to 10^4	$6 C_A \times 10^{-4} W/cm^2$
400 to 1400 nm	10^{-5} to 10^4	$5.5 C_A \times 10^{-4} W/cm^2$
400 to 1400 nm	10^4 to 3×10^4	$0.5 C_A W/cm^2$

^cThese dual limits will likely apply except for exposures of very large angles, α , where $\alpha = \alpha_{max}$ at least for wavelength less than 1200 nm.

TLV®-PA

TABLE 4. TLV® for Skin Exposure from a Laser Beam

Spectral Region	Wavelength	Exposure (t) Seconds	TLV®
UV ^a	180 nm to 400 nm	10^{-5} to 3×10^4	Same as Table 2
Light & IR ^a	400 nm to 1400 nm	10^{-5} to 10^4	$2 C_A \times 10^{-4} W/cm^2$
	"	10^{-5} to 10^4	$6 C_A \times 10^{-4} W/cm^2$
	"	10^{-5} to 10^4	$2 C_A \times 10^{-4} W/cm^2$
	"	10^{-5} to 10^4	$1.1 C_A \times 10^{-4} W/cm^2$
IR ^b & IR ^c	1400 to 10 ⁶ nm	10^{-5} to 3×10^4	$0.2 C_A W/cm^2$
	"	"	Same as Table 2

^aOzone (O_3) is produced in air by sources emitting ultraviolet (UV) radiation at wavelengths below 250 nm. Refer to Chemical Substances TLV® for ozone.

^bAt wavelengths greater than 1400 nm, see Figure 2 for $\lambda = 700$ to 1400 nm.

^cAt wavelengths greater than 1400 nm, for beam cross-sectional areas exceeding 100 cm², the TLV® for exposure durations exceeding 10 s is:

$$TLV = (10,000 A) \text{ mW/cm}^2$$

where A is the irradiated skin area for 100 to 1000 cm², and the TLV® is 10 mW/cm² for irradiated skin areas exceeding 1000 cm² and is 100 mW/cm² for irradiated skin areas less than 100 cm².

TLV®-PA

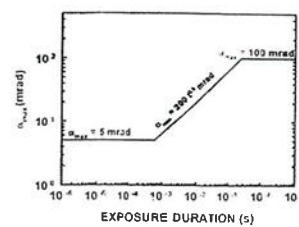
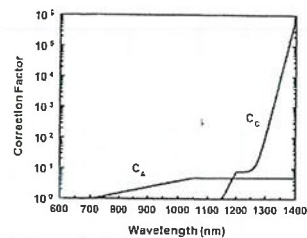
FIGURE 1. Variation of α_{max} with exposure duration.

FIGURE 2. TLV® correction factors for $\lambda = 700$ –1400 nm.
For $\lambda = 700$ –1049 nm, $C_C = 100,000 \times 10^{-4}$; for $\lambda = 1050$ –1400 nm, $C_C = 5$,
for $\lambda = 1150$ nm, $C_C = 1$; for $\lambda = 1150$ –1200 nm, $C_C = 10^{-1}$; for $\lambda = 1200$ –1229 nm, $C_C = 5 \times 100,000 \times 10^{-4}$, and for $\lambda = 1230$ –1400 nm, $C_C = 5 \times 100,000 \times 10^{-4}$.

TLV[®]-PATABLE 3. TLV[®]s for Extended-Source Laser Viewing Conditions

Spectral Region	Wavelength	Exposure, (t) Seconds	TLV [®]
Light	400 to 700 nm	10^{13} to 10^{14}	$C_e \times 10^{-13} \text{ J/cm}^2$
	400 to 700 nm	10^{11} to 5×10^6	$2 C_e \times 10^{-12} \text{ J/cm}^2$
	400 to 700 nm	5×10^6 to 10^7	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ J/cm}^2$
	400 to 700 nm	1.8×10^6 to 0.7	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ J/cm}^2$
Dust Limits for 400 to 600 nm visible laser exposure for $t < 0.7$ s			
Photoretinal			
For $\alpha \leq 11$ mrad, the MPE is expressed as irradiance and radiant exposure ^a			
400 to 600 nm	400 to 600 nm	0.7 to 100	$C_e \times 10^{-12} \text{ J/cm}^2$
		100 to 3×10^4	$C_e \times 10^{-12} \text{ W/cm}^2$
For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance ^b	400 to 600 nm	0.7 to 1×10^4	$100 C_e \text{ J/cm}^2 \text{ sr}$
		1×10^4 to 3×10^4	$C_e \times 10^{-12} \text{ W/cm}^2 \text{ sr}$
Thermal			
400 to 700 nm	400 to 700 nm	0.7 to T_2	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ J/cm}^2$
		T_2 to 3×10^4	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ W/cm}^2$

^aFor $\alpha \leq 11$ mrad, the MPE is expressed as irradiance and radiant exposure^a

For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^b

^bFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^b

^cFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^c

^dFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^d

^eFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^e

^fFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^f

^gFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^g

^hFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^h

ⁱFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radianceⁱ

^jFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^j

^kFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^k

^lFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^l

^mFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^m

ⁿFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radianceⁿ

^oFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^o

^pFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^p

^qFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^q

^rFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^r

^sFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^s

^tFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^t

^uFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^u

^vFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^v

^wFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^w

^xFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^x

^yFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^y

^zFor $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^z

^{aa}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{aa}

^{ab}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{ab}

^{ac}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{ac}

^{ad}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{ad}

^{ae}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{ae}

^{af}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{af}

^{ag}For $\alpha > 11$ mrad, the MPE is expressed as irradiance and integrated radiance^{ag}

TLV[®]-PATABLE 3. TLV[®]s for Extended-Source Laser Viewing Conditions (Continued)

Spectral Region	Wavelength	Exposure, (t)	TLV [®]
IR-A	700 to 1050 nm	10^{13} to 10^{14}	$C_e \times 10^{-12} \text{ J/cm}^2$
	700 to 1050 nm	10^{11} to 5×10^6	$5 C_e \times 10^{-12} \text{ J/cm}^2$
	700 to 1050 nm	5×10^6 to T_2	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ J/cm}^2$
	700 to 1050 nm	T_2 to 3×10^4	$1.8 C_e \times 10^{-12} \times 10^{-3} \text{ W/cm}^2$
	1050 to 1400 nm	10^{13} to 10^{14}	$C_e \times 10^{-12} \text{ J/cm}^2$
	1050 to 1400 nm	10^{11} to 1.3×10^6	$2 C_e \times 10^{-12} \text{ J/cm}^2$
	1050 to 1400 nm	1.3×10^6 to T_2	$9.0 C_e \times 10^{-12} \times 10^{-3} \text{ J/cm}^2$
	1050 to 1400 nm	T_2 to 3×10^4	$9.0 C_e \times 10^{-12} \times 10^{-3} \text{ W/cm}^2$
	1050 to 1400 nm	3×10^4 to T_2	TLV-C: 35 J/cm ²
	1050 to 1400 nm	T_2 to 3×10^4	TLV-C: 3.5 W/cm ²

^aFor sources subtending an angle greater than 1 mrad, the limit may also be expressed as an integrated radiance.

^b $L_e = 100 \text{ Cd J/cm}^2 \text{ sr}$ for $0.7 \text{ s} \leq t \leq 10^4 \text{ s}$ and $L_e = C_e \times 10^{-12} \text{ W/cm}^2 \text{ sr}$ for $t \geq 10^4 \text{ s}$ as measured through a limiting cone angle γ .

TLV[®]-PATable 2. TLV[®]s for Direct Ocular Exposures (In rainbow "Point-Source" Viewing) from a Laser Beam (Continued)

Spectral Region	Wavelength	Exposure, (t) Seconds	TLV [®]
IR-B & IR-C	1400 to 1.5 μm	10^{12} to 10^{13}	0.3 J/cm^2
	1400 to 1.5 μm	10^{11} to 10^{12}	0.56 J/cm^2
	1400 to 1.5 μm	10^{10} to 10^{11}	1.0 J/cm^2
	1400 to 1.5 μm	10^9 to 10^{10}	1.0 J/cm^2
	1400 to 1.5 μm	10^8 to 10^9	0.1 J/cm^2
	1400 to 1.5 μm	10^7 to 10^8	0.36 J/cm^2
	1400 to 1.5 μm	10^6 to 10^7	10 mJ/cm^2
	1400 to 1.5 μm	10^5 to 10^6	0.56 J/cm^2
	1400 to 1.5 μm	10^4 to 10^5	100 mJ/cm^2
	1400 to 1.5 μm	10^3 to 10^4	100 mJ/cm^2

*Ozone (O_3) is produced in air by sources emitting ultraviolet (UV) radiation at wavelengths below 250 nm. Refer to Chemical Substances TLV[®]s for O_3 .

Notes for Table 2

$C_e = 1$ for $\lambda = 400$ to 450 nm ; $C_e = 10^{-1}$ for $\lambda = 450$ to 600 nm ; $C_e = 1.0$ for wavelengths less than or equal to 1150 nm ; $C_e = 10^{-1}$ for wavelengths greater than 1150 nm and less than 1200 nm ; $C_e = 8.0 \times 10^{-1}$ for 1200 to 1400 nm .

$T_1 = 10 \text{ s}$ for $\lambda = 400$ to 450 nm ; $T_1 = 10 \times 10^{10} \text{ W/cm}^2$ for $\lambda = 450$ to 500 nm ; and $T_1 = 10 \text{ s}$ for $\lambda = 500$ to 700 nm .

For intermediate or large sources (e.g. laser diode arrays) at wavelengths between 400 nm and 1400 nm , the intrabeam viewing TLV[®]s can be increased by correction factor C_1 (see Table 3) provided that the angular subtense α of the source (measured at the viewer's eye) is greater than θ_{min} . C_1 depends on α as follows:

Angular Subtense	Source Size Designation	Correction Factor C_1
$\alpha \leq \theta_{min}$	Small	$C_1 = 1$
$\theta_{min} < \alpha \leq \theta_{max}$	Intermediate	$C_1 = \alpha/\theta_{min}$
$\alpha > \theta_{max}$	Large	$C_1 = \theta_{max}/\alpha$

The angle referred to as θ_{max} corresponds to the angular source size where the TLV[®]s may be expressed as a constant time-integrated radiance or radiance dose ($\text{J/cm}^2 \text{ sr}$) or radiance ($\text{W/cm}^2 \text{ sr}$) and the TLV[®]s for $\alpha > \theta_{max}$ can be written in terms of integrated radiance L_{int} or radiance L_e .

$L_{int} = (1.7 \times 10^{-12} \text{ J/cm}^2 \text{ sr}) / (1.1 \times 10^{-12} \text{ J/cm}^2 \text{ sr}) = 1.55$ for $400 < \lambda < 700 \text{ nm}$

$L_{int} = 7.6 \text{ J/cm}^2 \text{ sr}$ for $1150 < \lambda < 1200 \text{ nm}$

$L_{int} = 4.8 \text{ W/cm}^2 \text{ sr}$ for $1200 < \lambda < 1400 \text{ nm}$

Figure 3 illustrates these TLV[®]s for large sources expressed in terms of radiance. The measurement aperture should be placed at a distance of 100 mm or greater from the source. For large-area irradiation, the reduced TLV[®]s for skin exposure applies, as noted in the footnote to Table 3.

Source Size and Correction Factor C_p

The following considerations apply only at wavelengths in the retinal hazard region, 400–1400 nm (nanometers). Normally, a laser is a small source, which approximates a "point source" and subtends an angle less than α_{lim} , which is 15 mrad for all values of t . However, any source that subtends an angle, α , greater than α_{lim} , and is measured from the viewer's eye, is treated as an "intermediate source" ($\alpha_{lim} < \alpha \leq \alpha_{ext}$) or a "large, extended source" ($\alpha > \alpha_{ext}$). For exposure duration t , the angle α_{ext} is defined as:

$$\alpha_{ext} = 15 \text{ mrad for } t \leq 0.25 \text{ s}$$

$$\alpha_{ext} = 133 \text{ mrad for } 0.25 \text{ ms} < t < 0.25 \text{ s}$$

$$\alpha_{ext} = 100 \text{ mrad for } t \geq 0.25 \text{ s}$$

$$\alpha_{ext} = 1.5 \text{ mrad}$$

Figure 1 illustrates the time dependence of α_{ext} . If the source is oblong, α is determined from the arithmetic average of the longest and shortest viewable dimensions.

For intermediate and large sources, the TLVs in Table 2 are modified by correction factor C_p , as defined in the Notes for Table 2.

Correction Factors A, B, C (C_a , C_b , C_c)

The TLVs for ocular exposures in Table 2 are to be used as given for all wavelength ranges. The TLVs for wavelengths between 700 and 1049 nm are to be increased by the factor C_A (to account for reduced absorption of melanin) as given in Figure 2. For certain exposure times at wavelengths between 400 and 600 nm, a correction factor C_B (to account for reduced photochemical sensitivity for retinal injury) is applied. The correction factor C_C is applied from 1150 to 1400 nm to account for pre-retinal absorption of the ocular media. The TLVs for skin exposure are given in Table 4. The TLVs are to be increased by a factor C_A , as shown in Figure 2, for wavelengths between 700 nm and 1400 nm. To aid in the determination for exposure durations requiring calculations of fractional powers, Figures 3a, 3b, 4a, and 4b may be used.

Repetitively Pulsed Exposures

Scanned, continuous-wave (CW) lasers or repetitively pulsed lasers can both produce repetitively pulsed exposure conditions. The TLV for intrabeam viewing, which is applicable to wavelengths between 400 and 1400 nm and a single-pulse exposure (of exposure duration $t > t_{lim}$), is modified in this instance by a correction factor determined by the number of pulses in the exposure. First, calculate the number of pulses (n) in an expected exposure situation, this is the pulse repetition frequency (PRF in Hz) multiplied by the duration of the exposure. Normally, realistic exposures may range from 0.25 s for a bright visible source to 10 s for an infrared source. The corrected TLV on a per pulse basis is

$$TLV = C_p \cdot TLV \text{ for Single-pulse} \quad (1)$$

where $C_p = 1.0$ for $n < 5$, $n = 5$ for 400–1050 nm and 15 for 1050–1400

nm) and for $t > t_{lim}$, $C_p = 1.0$ for $\alpha < 5.9$ milliradians, which applies to all cases of intrabeam viewing. However, for larger, intermediate extended sources where $\alpha > 5.9$ mrad, $C_p = n \cdot 0.25$ for the following numbers of pulses, for $n < 40$ pulses, otherwise, $C_p = 0.4$ whenever $\alpha < \alpha_{ext}$, for $\alpha_{ext} \leq \alpha < 0.1$ radians and $n < 625$, $C_p = n \cdot 0.25$ and for greater n , $C_p = 0.2$. For $\alpha > 0.1$ radians, $C_p = 1.0$. This approach applies only to thermal-injury conditions, i.e., all exposures at wavelengths > 700 nm and for many exposures at shorter wavelengths. For wavelengths ≤ 700 nm, the corrected TLV from Equation 1 applies if the average irradiance does not exceed the TLV for continuous exposure. The average irradiance (i.e., the total accumulated exposure for n s) should not exceed the radiant exposure given in Table 2 for exposure durations of 10 s to T_1 . Some thermal additivity can occur for larger image sizes, and for pulse repetition frequencies (PRFs) between 150 Hz and 250 Hz where $\alpha > 3$ mrad and the pulse duration is between 1 ms and 100 ms, the single-pulse TLV applied should be reduced by a further correction factor, $C_p = 0.5$.

For ultraviolet wavelengths, the accumulated exposure of repetitive exposures is added up to the total duration of exposure (up to a maximal duration of 3×10^4 s). For repetitive pulse trains, the total accumulated radiant exposure for n s of a group of pulses should not exceed the exposure given in Table 2 for exposure durations of 10 s to 3×10^4 s with continuous exposures.

It is recommended that the user of the TLVs for laser radiation consult *A Guide for Control of Laser Hazards*, 4th Edition, 1993, published by ACGIH, for additional information on control measures.

TABLE 2. TLVs* for Direct Ocular Exposures (Intrabeam "Point-Source" Viewing) from a Laser Beam

Spectral Region	Wavelength	Exposure, (t) Seconds	TLV*
All UV	180 nm to 400 nm	10^{-9} to 10^{-8}	0.1 mJ/cm^2
	180 nm to 400 nm	10^{-9} to 10^{-8}	1 mJ/cm^2
UVC	180 nm to 260 nm	10^{-9} to 3×10^{-8}	$3 \times 10^{-3} \text{ J/cm}^2$
	260 nm to 280 nm	10^{-9} to 3×10^{-8}	3 mJ/cm^2
UVB	280 nm to 302 nm	"	4 mJ/cm^2
	303 nm	"	6 mJ/cm^2
	304 nm	"	10 mJ/cm^2
	305 nm	"	16 mJ/cm^2
	306 nm	"	25 mJ/cm^2
	307 nm	"	40 mJ/cm^2
	308 nm	"	65 mJ/cm^2
	309 nm	"	100 mJ/cm^2
	310 nm	"	160 mJ/cm^2
	311 nm	"	250 mJ/cm^2
UVA	312 nm	"	400 mJ/cm^2
	313 nm	"	620 mJ/cm^2
	314 nm	"	1.0 J/cm^2
	315 nm to 400 nm	10^{-6} to 10	0.56 J/cm^2
	315 nm to 400 nm	10 to 10^4	1.0 J/cm^2
	315 nm to 400 nm	10 to 3×10^4	1.0 mJ/cm^2

TLV-C: 0.56 J/cm^2 for $t \leq 10$ s

Table 2. TLVs* for Direct Ocular Exposures (Intrabeam "Point-Source" Viewing) from a Laser Beam

Spectral Region	Wavelength	Exposure, (t) Seconds	TLV*
Light	400 to 700 nm	10^{-9} to 10^{-8}	$1 \times 10^{-2} \text{ J/cm}^2$
	400 to 700 nm	10^{-9} to 5×10^{-6}	$2 \times 10^{-2} \text{ J/cm}^2$
	400 to 700 nm	5×10^{-6} to 10	$1.8 \times 10^{-1} \times 10^{-2} \text{ J/cm}^2$
	400 to 450 nm	10 to 100	10 mJ/cm^2
	450 to 500 nm	10 to T_1	1 mJ/cm^2
	450 to 500 nm	T_1 to 100	10 mJ/cm^2
	400 to 500 nm	100 to 3×10^4	0.1 J/cm^2
	500 to 700 nm	10 to 3×10^4	1.0 mJ/cm^2
	700 to 1050 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	700 to 1050 nm	10^{-11} to 5×10^{-10}	2.0 J/cm^2
IRA	700 to 1050 nm	5×10^{-10} to 10	1.8 J/cm^2
	700 to 1050 nm	10 to 3×10^4	$1.0 \times 10^{-2} \text{ J/cm}^2$
	700 to 1050 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$
	1050 to 1400 nm	10^{-11} to 10^{-10}	$1.0 \times 10^{-2} \text{ J/cm}^2$

TLV-C: 35 J/cm^2

TLV-C: 1.5 W/cm^2

and for broadband sources a modified spectral weighting function $S(\lambda)$ can be applied (Figure 2) in Equation 1 to determine E_{eff} .

Table 3 gives TLV[®] values for the effective irradiance for different daily exposure durations. In general, the maximum exposure time (t_{max}) [s] for a broadband UV source can be determined from Equation 3:

$$t_{max}[s] = \frac{0.003 [J/cm^2]}{E_{eff} [W/cm^2]} \quad (3)$$

Broadband UV-A Sources (315 to 400 nm) — Lens and Retinal Hazard

The irradiance, E_{UV-A} [mW/cm²], can be measured with an unfiltered meter that is sensitive to UV-A radiation. For daily exposure periods (t_{exp}) less than 1,000 seconds (17 minutes), the exposure is limited to 1,000 mJ/cm² as described in Equation 4:

$$1000 [mJ/cm^2] \geq E_{UV-A} [mW/cm^2] \times t_{exp}[s] \quad (4)$$

For daily exposure periods greater than 1,000 seconds (17 minutes), the exposure is rate limited to 1.0 mW/cm² as described in Equation 5:

$$1.0 [mW/cm^2] \geq E_{UV-A} [mW/cm^2] \quad (5)$$

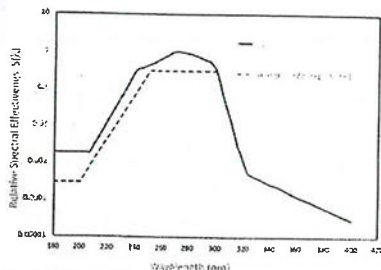


FIGURE 2. Hazard function (relative spectral effectiveness) $S(\lambda)$ for UV.

TABLE 3. Exposure Durations for Given Actinic UV Radiation Effective Irradiances

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (mW/cm ²)
8 hours	0.0001
4 hours	0.0002
2 hours	0.0004
1 hour	0.0008
30 minutes	0.0017
15 minutes	0.0033
10 minutes	0.005
5 minutes	0.01
1 minute	0.05
30 seconds	0.1
10 seconds	0.3
1 second	3
0.5 second	6
0.1 second	30

Narrowband Sources

Narrowband sources are comprised of one wavelength or a narrow band of wavelengths (e.g., 5 to 10 nm). Locate the center wavelength (λ_c) in Table 1, and find the TLV[®] as an 8-hour dose limit in J/m² or mJ/cm². The narrowband TLV[®] is protective for both corneal and retinal exposures.

The dose limit may be adjusted proportionately for work periods of longer or shorter duration. The TLV[®] dose limit of a daily exposure period (t_{exp}) for a narrowband source can be expressed as Equation 6 using the Spectral Sensitivity (S_{λ}) from Table 1 and unfiltered irradiance (E_{λ}) [W/m² or mW/cm²].

$$30 [J/m^2] \geq E_{\lambda} [W/m^2] \times S(\lambda) \times t_{exp}[s] \quad (6a)$$

$$30 [mJ/cm^2] \geq E_{\lambda} [mW/cm^2] \times S(\lambda) \times t_{exp}[s] \quad (6b)$$

The maximum exposure time (t_{max}) [s] for a narrowband source can be determined from Equation 7 using the TLV[®] and the unfiltered irradiance (E_{λ}) [W/m² or mW/cm²]. (Note: The energy and surface area units must match.)

$$t_{max}[s] = \frac{TLV_{\lambda}}{E_{\lambda}} \quad (7)$$

Notes

1. The probability of developing skin cancer depends on a variety of factors such as skin pigmentation, a history of blistering sunburns, and the accumulated UV dose. It also depends on genetic susceptibility and factors

such as skin and eye color. Individuals who have a familial history of melanoma, or numerous nevi over their body, for example, may be at higher risk of developing malignant melanoma. The risks for developing melanoma and non-melanoma cancers may differ from each other and depend on the UV exposure history. Because of their high spectral attenuation by the stratum corneum, UV-C wavelengths pose a much lower risk for delayed effects than UV-B (see Table 2).

2. Outdoor workers in latitudes within 40 degrees of the equator can be exposed outdoors to levels above the TLV[®]s in as little as 5 minutes around noon during the summer.
3. Exposure to UV radiation concurrently with topical or systemic exposure to a variety of chemicals, including some prescription drugs, can result in skin erythema at sub-TLV[®] exposures. Hypersensitivity should be suspected if workers present skin reactions when exposed to sub-TLV[®] doses or when exposed to levels (generally UV-A) that did not cause a noticeable erythema in the same individual in the past. Among the hundreds of agents that can cause hypersensitivity to UV radiation are certain plants and chemicals such as some antibiotics (e.g., tetracycline and sulphathiazole), some antidepressants (e.g., imipramine and sinequan), as well as some diuretics, cosmetics, antipsychotic drugs, coal tar distillates, some dyes, or lime oil.
4. Ozone is produced in air by sources emitting UV radiation at wavelengths below 220 nm. Refer to the latest version of the Chemical Substances TLV[®] for ozone. This is a particular problem at wavelengths less than 200 nm. Ozone-free UV-C lamps generally have a lamp envelope that heavily attenuates these shorter wavelengths.

LASERS

(Documentation Date — 2020)

TLVs[®]

These TLVs[®] are for exposure to laser radiation under conditions to which it is believed nearly all workers may be repeatedly exposed without adverse health effects. The TLVs[®] should be used as guides in the control of exposures and should not be regarded as fine lines between safe and dangerous levels. They are based on the best available information from experimental studies. In practice, hazards to the eye and skin can be controlled by application of control measures appropriate to the classification of the laser.

Classification of Lasers

Most lasers have a label affixed to them by the manufacturer that describes their hazard class. Normally, it is not necessary to determine laser irradiances or radiant exposures for comparison with the TLVs[®]. The potential for hazardous exposures can be minimized by the application of control measures that are appropriate to the hazard class of the laser. Control measures are applicable to all classes of lasers except for Class 1. Such measures, and other laser safety information, may be found in the ACGIH[®] publication, *A Guide for Control of Laser Hazards*, and the ANSI Z136 series published by the Laser Institute of America.

Limiting Apertures

For comparison with the TLVs[®] in this section, laser beam irradiance or radiant exposure is averaged over the limiting aperture appropriate to the spectral region and exposure duration. If the laser beam diameter is less than that of the limiting aperture, the effective laser beam irradiance or radiant exposure may be calculated by dividing the laser beam power or energy by the area of the limiting aperture. Limiting apertures are listed in Table 1.

TABLE 1. Limiting Apertures Applicable to Laser TLVs[®]

Spectral Region	Duration	Eye	Skin
180 nm to 400 nm	100 fs to 0.25 s	1 mm	3.5 mm
180 nm to 400 nm	0.25 s to 30 ks	3.5 mm	3.5 mm
400 nm to 1400 nm	10 ⁻⁴ ns to 0.25 s	7 mm	3.5 mm
400 nm to 1400 nm	0.25 s to 30 ks	7 mm	3.5 mm
1400 nm to 0.1 μm	10 ⁻⁵ ns to 0.25 s	1 mm	3.5 mm
1400 nm to 0.1 μm	0.25 s to 30 ks	3.5 mm	3.5 mm
0.1 μm to 1.0 μm	10 ⁻⁵ ns to 30 ks	11 mm	11 mm

ULTRAVIOLET RADIATION (2021)

TLVs®

These TLVs® refer to incoherent ultraviolet (UV) radiation with wavelengths between 180 and 400 nm and represent conditions under which it is believed that healthy workers may be repeatedly exposed without acute adverse health effects such as erythema and photochemicals. Some UV sources covered by this TLV® are welding and carbon arcs, gas and vapor discharges, fluorescent, incandescent, and germicidal lamps, and solar radiation. Coherent UV radiation from lasers is covered in the TLV® for Lasers.

The TLV® values apply to continuous sources for exposure durations equal to or greater than 0.1 second. The sources may subtend an angle less than 80 degrees at the detector. For those sources that subtend a greater angle, there is no need to measure an angle greater than 30 degrees.

The values do not apply to UV radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents (see Note 3). The values at wavelengths greater than 300 nm for the eye do not apply to athletes (persons who have had the lens of the eye removed in cataract surgery), for which case, see Light and Infrared Radiation TLVs®.

The TLVs® should be used as guides in the control of exposure to UV sources and should not be regarded as fine lines between safe and dangerous levels. The TLVs® in Table 1 apply directly to exposure of the cornea of the eye and provide conservative guidelines for skin exposures. If the eyes are protected, higher levels (Table 2) apply to exposures of the skin in the UV-C (180 to 280 nm) spectral region and below 300 nm.

Threshold Limit Values

The TLVs® for occupational exposure to UV radiation incident upon the skin or the eye follow. The flow chart in Figure 1 provides a map of the UV TLV®.

Broadband UV Sources (180 to 400 nm) — Corneal Hazard

The first step in evaluating broadband UV sources is to determine the effective irradiance (E_{eff}). To determine E_{eff} for a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), Equation 1 should be used.

$$E_{eff} = \sum_{\lambda=180}^{400} E_{\lambda} \times S(\lambda) \times \Delta\lambda \quad (1)$$

where: E_{eff} = effective irradiance relative to a monochromatic source at 270 nm [W/cm^2]
 E_{λ} = spectral irradiance at a center wavelength

$$[W/(cm^2 \times nm)],$$

$S(\lambda)$ = relative spectral effectiveness at the center wavelength (unitless);

$\Delta\lambda$ = bandwidth around the center wavelength (nm);

More practically, E_{eff} can be measured directly with a UV radiometer having a built-in spectral response that mimics the relative spectral effectiveness values in Table 1 and Figure 2.

The daily exposure (E_{exp}) based on E_{eff} is limited to 0.003 J/cm². That is,

$$0.003 J/cm^2 \geq E_{eff} [W/cm^2] \times t_{exp} [s] \quad (2)$$

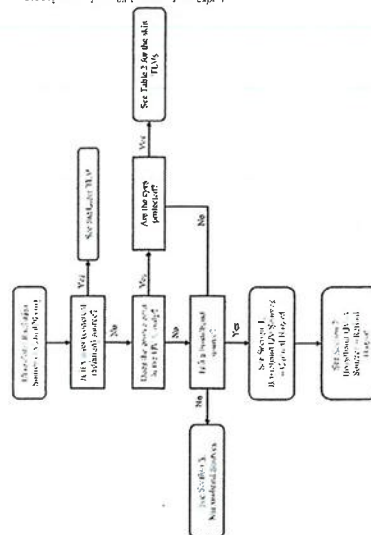


FIGURE 1. Flow chart for UV TLV®.

TABLE 1. Ultraviolet Radiation TLV® and Relative Spectral Effectiveness

Wavelength ^a (nm)	TLV® (J/m ²) ^b	TLV® (mJ/cm ²) ^b	Relative Spectral Effectiveness, S(λ)
180	16260	1626	0.00185
190	16260	1626	0.00185
200	16260	1626	0.00185
205	16260	1626	0.00185
210	10233	1023	0.00293
215	4732	473	0.00634
220	2188	218	0.0137
225	1012	101	0.0297
230	468	46.8	0.0641
235	216	21.6	0.139
240	100	10	0.300
245	83	8.3	0.360
250	70	7.0	0.430
254 ^c	60	6.0	0.500
255	58	5.8	0.520
260	46	4.6	0.650
265	37	3.7	0.810
270	30	3.0	1.00
275	31	3.1	0.960
280 ^c	34	3.4	0.880
285	39	3.9	0.770
290	47	4.7	0.640
295	56	5.6	0.540
297 ^c	65	6.5	0.460
300	100	10	0.300
303 ^c	250	25	0.120
305	500	50	0.060
308	1200	120	0.026
310	2000	200	0.015
313 ^c	5000	500	0.006
315	1.0 × 10 ⁴	1.0 × 10 ³	0.003
316	1.3 × 10 ⁴	1.3 × 10 ³	0.0024
317	1.5 × 10 ⁴	1.5 × 10 ³	0.0020
318	1.9 × 10 ⁴	1.9 × 10 ³	0.0016
319	2.5 × 10 ⁴	2.5 × 10 ³	0.0012
320	2.9 × 10 ⁴	2.9 × 10 ³	0.0010
322	4.5 × 10 ⁴	4.5 × 10 ³	0.00067
323	5.6 × 10 ⁴	5.6 × 10 ³	0.00054
325	6.0 × 10 ⁴	6.0 × 10 ³	0.00050
328	6.8 × 10 ⁴	6.8 × 10 ³	0.00044
330	7.5 × 10 ⁴	7.5 × 10 ³	0.00041
333	8.1 × 10 ⁴	8.1 × 10 ³	0.00037
335	8.8 × 10 ⁴	8.8 × 10 ³	0.00034
340	1.1 × 10 ⁵	1.1 × 10 ⁴	0.00028
345	1.3 × 10 ⁵	1.3 × 10 ⁴	0.00024
350	1.5 × 10 ⁵	1.5 × 10 ⁴	0.00020

TABLE 1 (cont.). Ultraviolet Radiation TLV® and Relative Spectral Effectiveness

Wavelength ^a (nm)	TLV® (J/m ²) ^b	TLV® (mJ/cm ²) ^b	Relative Spectral Effectiveness, S(λ)
355	1.9 × 10 ⁵	1.9 × 10 ⁴	0.00016
360	2.3 × 10 ⁵	2.3 × 10 ⁴	0.00013
365 ^c	2.7 × 10 ⁵	2.7 × 10 ⁴	0.00011
370	3.2 × 10 ⁵	3.2 × 10 ⁴	0.000093
375	3.9 × 10 ⁵	3.9 × 10 ⁴	0.000077
380	4.7 × 10 ⁵	4.7 × 10 ⁴	0.000064
385	5.7 × 10 ⁵	5.7 × 10 ⁴	0.000053
390	6.8 × 10 ⁵	6.8 × 10 ⁴	0.000044
395	8.3 × 10 ⁵	8.3 × 10 ⁴	0.000036
400	1.0 × 10 ⁶	1.0 × 10 ⁵	0.000030

^a Wavelengths chosen are representative; other values should be interpolated at intermediate wavelengths.

^b 1 mJ/cm² = 10 J/m².

^c Emission lines of a mercury discharge spectrum.

TABLE 2. Ultraviolet Radiation TLV® and Relative Spectral Effectiveness for the Skin (UV-C)

Wavelength ^a (nm)	TLV® (J/m ²) ^b	TLV® (mJ/cm ²) ^b	Relative Spectral Effectiveness, S(λ) (prime)
180	1.0 × 10 ⁵	10000	3.0 × 10 ⁻⁴
190	1.0 × 10 ⁵	10000	3.0 × 10 ⁻⁴
200	1.0 × 10 ⁵	10000	3.0 × 10 ⁻⁴
205	50120	5012	6.0 × 10 ⁻⁴
210	25120	2512	1.19 × 10 ⁻³
215	12540	1259	2.38 × 10 ⁻³
220	6310	631.0	4.75 × 10 ⁻³
225	3162	316.2	9.49 × 10 ⁻³
230	1585	158.5	0.0189
235	794	79.4	0.0380
240	400	39.8	0.075
245	200	20.0	0.150
250	100	10	0.30
260	100	10	0.30
270	100	10	0.30
280	100	10	0.30
290	100	10	0.30
300	100	10	0.30

Skin Hazard

The TLV® (Table 1) values are conservative for skin exposure (see Documentation).

For UV-C (germicidal) wavelengths, if the eyes are protected, higher exposure values (Table 2) can be applied for narrowband sources (e.g., at 254 nm).

TABLE 2. Retinal and UVR Hazard Spectral Weighting Functions

Wavelength (nm)	Aphakic Hazard Function A(λ)	Blue-Light Hazard Function B(λ)	Retinal Thermal Hazard Function R(λ)
305-335	6.000	0.01	—
340	5.880	0.01	—
345	5.710	0.01	—
350	5.460	0.01	—
355	5.220	0.01	—
360	4.620	0.01	—
365	4.290	0.01	—
370	3.750	0.01	—
375	3.560	0.01	—
380	3.190	0.01	0.01
385	2.310	0.0125	0.0125
390	1.880	0.025	0.025
395	1.380	0.050	0.050
400	1.430	0.100	0.100
405	1.300	0.200	0.200
410	1.250	0.400	0.400
415	1.200	0.800	0.800
420	1.150	0.900	0.900
425	1.110	0.950	0.950
430	1.070	0.980	0.980
435	1.030	1.000	1.000
440	1.000	1.000	1.000
445	0.970	0.970	1.000
450	0.940	0.940	1.000
455	0.900	0.900	1.000
460	0.800	0.800	1.000
465	0.700	0.700	1.000
470	0.620	0.620	1.000
475	0.550	0.550	1.000
480	0.450	0.450	1.000
485	0.400	0.400	1.000
490	0.220	0.220	1.000
495	0.160	0.160	1.000
500	0.100	0.100	1.000
505	0.079	0.079	1.000
510	0.063	0.063	1.000
515	0.050	0.050	1.000
520	0.040	0.040	1.000
525	0.032	0.031	1.000
530	0.025	0.025	1.000
535	0.020	0.020	1.000
540	0.016	0.016	1.000
545	0.013	0.013	1.000
550	0.010	0.010	1.000
555	0.008	0.008	1.000
560	0.006	0.006	1.000
565	0.005	0.005	1.000
570	0.004	0.004	1.000
575	0.003	0.003	1.000

TLV®-PA

TABLE 2 (cont.) Retinal and UVR Hazard Spectral Weighting Functions

Wavelength (nm)	Aphakic Hazard Function A(λ)	Blue-Light Hazard Function B(λ)	Retinal Thermal Hazard Function R(λ)
580	0.302	0.012	1.0
585	0.002	0.002	1.0
590	0.001	0.001	1.0
595	0.001	0.001	1.0
600-700	0.001	0.001	1.0
700-1650	—	—	10 ⁻⁵ to 3.25
1650-1150	—	—	0.2
1150-1200	—	—	0.3 to 1000 ^{1/2} 1150 ^{-1/6}
1200-400	—	—	0.02

Limits for IR only exposures are based on a 7-mm pupil diameter (since the aversion response may not exist due to absence of light) and a detector field of view of 0.011 rad. For exposures less than 310 s, an acceptable exposure is present when:

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 3.2 \cdot t^{0.25} \quad (9a)^*$$

For exposures greater than 310 s in a day, an acceptable exposure is present when:

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 0.6 \cdot t^{-1} \quad (9b)^*$$

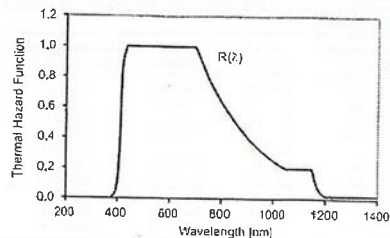
Section 4. To protect against retinal thermal injury from a visible light source: Determine the effective radiance of the lamp (L_{e}) in $W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$ [sr = steradian] by integrating the spectral radiance (L_{λ}) in $W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1} \cdot \text{nm}$ weighted by the thermal hazard function $R(\lambda)$ using Equation 10 or a light meter with an R(λ) filter. $R(\lambda)$ is shown in Figure 3.

$$L_{\text{e}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] = \int_{300}^{1400} L_{\lambda} \cdot R(\lambda) \cdot d\lambda \quad (10)$$

Some meters provide a total time-integrated radiance emitted in units of $J \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$ over the sampling period, which is the time integral of L_{e} over the sampling period. Therefore, an alternative expression of the retinal thermal injury TLV® is a dose limit (called DL_{R} in this TLV®).

Determine the angular subtense (α) of the source in radians (rad). For circular lamps, α is the lamp diameter divided by the viewing distance. If the lamp is oblong, α is estimated from the mean of the shortest and longest dimension that can be viewed divided by the viewing distance; that is according to Equation 11.

$$\alpha [\text{rad}] = \frac{(l + w)}{2r} \quad (11)$$

FIGURE 3. Retinal thermal hazard function $R(\lambda)$.

For instance, at a viewing distance $r = 100$ cm from a 0.8 cm diameter tubular flash lamp of length $l = 5$ cm, the viewing angle α is 0.029 rad.

Large sources are those with an angular subtense (α) greater than 0.1 rad. For large sources, Equations 12a through 12c define the TLV® for protection against retinal thermal injury depending on the exposure duration (t) in seconds [s]. These limits also serve as a useful screening step.

For viewing durations (t) from 1 μs (10^{-6} s) through 0.00063 s, an acceptable exposure is present when Equation 12a is true. For pulse durations less than 1 μs , the TLV® is the same as that for 1 μs . Since the retinal thermal hazard TLV® for pulsed sources assume a 7-mm, dark-adapted pupil, this exposure limit may be modified for daylight conditions.

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 640 \cdot t^{-0.25} \quad (12a)^*$$

OR

$$DL_{\text{R}} [J \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 640 \cdot t^{0.75}$$

For viewing durations between 0.63 ms (0.00063 s) and 0.25 s, an acceptable exposure is present when Equation 12b is true.

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 16 \cdot t^{-0.75} \quad (12b)^*$$

OR

$$DL_{\text{R}} [J \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 16 \cdot t^{0.75}$$

For viewing durations greater than 0.25 s, an acceptable exposure is present when Equation 12c is true. This is a rate-limited, rather than dose-limited, threshold.

TLV®-PA

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 45 \quad (12c)^*$$

Small sources have an angular subtense (α) less than 0.1 rad, but are limited to no less than 1.7 mrad. For small sources, the retinal thermal injury risk depends on both the exposure duration (t) and α . The interaction is a maximum value for α (α_{max}) as a function of viewing duration (t) [s].

For viewing durations from 1 μs (10^{-6} s) through 0.00063 s, an acceptable exposure is present when Equation 12a above is true. For pulse durations less than 1 μs , the TLV® is the same as that for 1 μs . Since the retinal thermal hazard TLV® for pulsed sources assume a 7-mm, dark-adapted pupil, this exposure limit may be modified for daylight conditions.

For viewing durations from 0.00063 to 0.25 s, an acceptable exposure is present when Equation 13a is true.

$$\text{With } \alpha < \alpha_{\text{max}} = 0.2 \cdot t^{0.25} \text{ rad,}$$

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 3.2 \cdot t^{-1} \cdot t^{-0.25} \quad (13a)^*$$

OR

$$DL_{\text{R}} [J \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 3.2 \cdot t^{-1} \cdot t^{0.75}$$

For viewing durations greater than 0.25 s, an acceptable exposure is present when Equation 13b is true. This is a rate-limited exposure and a dose limit does not apply.

$$\text{With } \alpha < \alpha_{\text{max}} = 0.1 \text{ rad,}$$

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 4.5 \cdot t^{-1} \quad (13b)^*$$

Note. There may be special individual circumstances where the pupil remains dilated (tonic) and exposures extend beyond 0.25 s. Under these conditions, Equation 13c is the limiting exposure.

$$\text{With } \alpha < \alpha_{\text{max}} = 0.1 \text{ rad,}$$

$$L_{\text{R}} [W \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}] \leq 3.2 \cdot t^{-1} \cdot t^{-0.25} \quad (13c)^*$$

* Equations 9, 12, and 13 are empirical and are not dimensionally correct. To obtain the correct value in the units given on the left side of the equation, α must be in radians and t in seconds. To make the equations dimensionally correct, one would have to insert unity dimensional correction factors in the right-hand numerator in each equation.

TLV®-PA

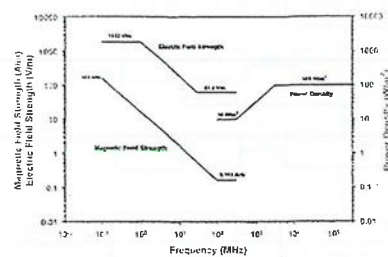


FIGURE 1. Threshold Limit Values (TLVs) for Radiofrequency/Microwave Radiation in the workplace for whole-body specific absorption rate (SAR) < 0.4 W/kg. (From IEEE Std. C95.1 - 2005a. Copyright © IEEE. All Rights Reserved.)

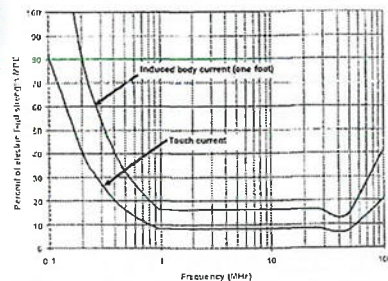


FIGURE 2. Percent of electric field strength TLVs below which induced and contact current limits are not required from 0.1 to 100 MHz. (From IEEE Std. C95.1 - 2005a. Copyright © IEEE. All Rights Reserved.)

TLV®-PA

TABLE 2. Major Frequency Ranges Covered by the TLV

	Part A — Frequency Range			
	30 kHz–100 kHz	100 kHz–100 MHz	100 MHz–300 MHz	300 MHz–300 GHz
Electric Field	X	X	X	
Magnetic Field	X	X	X	
Power Density			X	X
Contact Current	X	X ²		
Part B — Hazard Mechanism				
	Electrical stimulation	Thermal	Thermal	
Typical cause of injury	Contact current (current introduced into body from touching a charged conductor)	Contact current (possible RF heating of deep tissues)	RF heating of tissues	
Typical injury	Electric shock (sometimes burns)	Burns that can be deep	Excessive whole-body heating (heat stress)	
Example sources with potential overexposure	AM radio, transmission tower	RF heat sources and FM transmitting antennae	High-powered broadcasting antennae (e.g., TV, radio, microwave)	Industrial RF heating, RF welding, RF drying

¹Power density measurements should be used for the 300 MHz to 300 GHz range. The TLV measurements should be used for the 300 MHz to 300 GHz range.

²Maximum contact current if the electric field is greater than 100 V/m. The TLV is the frequency (see Figure 1).

- H_f or S_f incurred within each frequency interval should be determined and the sum of all such fractions should not exceed unity.
- The TLVs refer to values averaged over any 5 minute (2.1) period for frequencies less than 3 GHz, and over shorter periods for higher frequencies down to 10 seconds at 300 GHz as indicated in Table 1 Part A.
 - At frequencies between 0.1 and 3 GHz, the TLVs for electromagnetic field strengths may be exceeded if:
 - the exposure conditions can be shown by appropriate techniques to produce SARs below 0.4 W/kg, as averaged over the whole body;
 - the induced currents in the body conform with the TLVs in Table 1 Part B; and
 - spatial peak SAR values do not exceed 10 W/kg, as averaged over any cubic volume with 10 g of tissue, except for the hands, wrists, feet, ankles, and pinnae, where the spatial peak SAR exposure should not exceed 20 W/kg averaged over any cubic volume of tissue containing 10 g. The SARs are to be averaged over 6 minutes.

TLV®-PA

- Above 3 GHz, relaxation of the TLV conditions may be permissible under partial body exposure conditions.
- The measurement of RF field should follow the recommendations given in IEEE C95.3-2021 (IEEE, 2021).

References

- Institute of Electrical and Electronic Engineers (IEEE): IEEE Recommended Practice for Measurements and Computations of Radiofrequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz. IEEE C95.3-2021. IEEE, New York (2021).
- Institute of Electrical and Electronic Engineers (IEEE): IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. IEEE C95.1-2005. IEEE, New York (2005).

TLV®-PA

OPTICAL RADIATION

LIGHT AND NEAR-INFRARED RADIATION (Documentation Date – 2015)

These TLVs refer to values for incoherent (non-laser) visible and near-infrared radiation (LNIR) in the wavelength region of 305 to 3000 nm that nearly all workers may be exposed without adverse health effects. The values are based on the best available information from experimental studies. They should be used only as guides in the control of exposures to light and should not be regarded as fine lines between safe and dangerous levels. For purposes of specifying these TLVs, the optical radiation spectrum is divided into the regions shown in the figure "The Electromagnetic Radiation Spectrum and Related TLVs" found at the beginning of the section on Electromagnetic Fields 0–300 GHz.

Recommended Values

The TLVs for occupational exposure of the eyes to broadband light and near-infrared radiation apply to exposures in any 8 hour workday. Table 1 provides examples of sources and the applicable TLV. Figure 1 is a guide to the application of the TLVs for visible and near-infrared sources.

The LNIR TLVs are divided into four potential health effects and spectral regions as follows:

Section 1. To protect against retinal photo-chemical injury from chronic blue-light (305 < λ < 700 nm) exposure: Determine the effective radiance of the light source (L_B) in $W \cdot cm^{-2} \cdot sr^{-1}$ by integrating the spectral radiance (L_λ) in $W \cdot cm^{-2} \cdot sr^{-1} \cdot nm^{-1}$ weighted by the blue-light hazard function $B(\lambda)$ using Equation 1 or a light meter with a $B(\lambda)$ filter. $B(\lambda)$ is shown in Figure 2 and values are provided in Table 2.

$$L_B [W \cdot cm^{-2} \cdot sr^{-1}] = \sum_{305}^{700} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda \quad (1)$$

Some meters provide a total energy emitted in units of $J \cdot cm^{-2} \cdot sr^{-1}$ over the sampling period, which is the time integral of L_B over the sampling period. L_B is the total energy divided by the sample period.

For viewing durations (t) less than 10^4 s (157 mins or ~2.8 hrs) in a day, an acceptable exposure is present when:

$$L_B [W \cdot cm^{-2} \cdot sr^{-1}] \leq 100 \cdot t^{-1} \quad (2a)$$

Alternatively, when L_B exceeds $0.01 W \cdot cm^{-2} \cdot sr^{-1}$, the maximum acceptable exposure duration t_{max} in seconds is:

$$t_{max} [s] = 100 (L_B)^{-1} \quad (2b)$$

TLV®-PA

Modifications of the TLVs[®] will be made if warranted by new information. At this time, there is insufficient information on human responses and possible health effects to electric fields in the frequency range of 0 to 30 kHz to permit the establishment of a TLV[®] for time-weighted average exposures.

Reference

International Telecommunications Union (ITU). 1997. The Transmission Line Reference Book — Part 1: General Principles. Geneva, ITU, Paris, France, 1997.

TLV[®]-PA

RADIOFREQUENCY/MICROWAVE RADIATION (Documentation Date — 2016)

These TLVs[®] refer to radiofrequency (RF) radiation in the frequency range of 30 kilohertz (kHz) to 300 gigahertz (GHz). This includes microwave radiation (300 MHz–300 GHz), which is a region of the RF spectrum. These TLVs[®] represent conditions under which it is believed nearly all workers may be repeatedly exposed without adverse health effects.

The TLVs[®] were designed to limit electrostimulation of nerve and muscle tissue at frequencies from 0.03 to 0.1 MHz, and tissue heating above 0.1 MHz. The TLVs[®] are given in terms of root mean square (rms) electric (E), and magnetic (H) field strengths, the equivalent plane-wave free-space power densities (S), and induced currents (I) in the body.

The TLVs[®] are summarized in Table 1 as a function of frequency, *f*, in megahertz (MHz). Table 2 summarizes the major dosimetric quantities in different frequency ranges specified in the TLVs[®], and major hazard mechanisms and typical exposure scenarios that would be of concern.

A. For exposures to electric and magnetic free fields, TLVs[®] in Table 1, Part A refer to exposure values obtained by spatially averaging over an area equivalent to the vertical cross-section of the human body (projected area). In the case of partial body exposure, the TLVs[®] can be relaxed. In nonuniform fields, spatial peak values of field strength may exceed the TLVs[®] if the spatially averaged specific absorption rate (SAR) value remains within the specified limits.

B. Access should be restricted to limit the rms RF body current and potential for RF electrostimulation ("shock") below 0.1 MHz or perceptible heating (at or above 0.1 MHz) as follows (see Table 1, Part B):

1. For freestanding individuals (no contact with metallic objects), RF current induced in the human body, as measured through either foot, should not exceed the following values, where *f* is the frequency in MHz:

$$I = 1000 \text{ mA for } (0.03 < f < 0.1 \text{ MHz}) \text{ averaged over } 0.2 \text{ s;}$$

where mA = milliamperes

$$I = 100 \text{ mA for } (0.1 < f < 100 \text{ MHz}) \text{ averaged over } 6 \text{ min}$$

2. For conditions of possible contact with metallic bodies, the maximum RF current that can be passed into the body as measured with a contact current meter should not exceed the following values:

$$I = 1000 \text{ mA for } (0.03 < f < 0.1 \text{ MHz}) \text{ (where } f \text{ is the frequency in MHz) averaged over } 0.2 \text{ s}$$

$$I = 100 \text{ mA for } (0.1 < f < 100 \text{ MHz}) \text{ averaged over } 6 \text{ min}$$

TLV[®]-PA

TABLE 1. Radiofrequency and Microwave TLVs[®]

Part A—Electromagnetic Fields* (<i>f</i> = frequency in MHz)				
Frequency	Power Density, S (W/m ²)	Electric Field Strength, E (V/m)	Magnetic Field Strength, H (A/m)	Averaging Time E [†] , H [‡] , or S (min)
30 kHz–100 kHz		1842	163	6
100 kHz–1 MHz		1842	163/f	6
1 MHz–30 MHz		1842/f	163/f	6
30 MHz–100 MHz		61.4	163/f	6
100 MHz–300 MHz	10	61.4	0.163	6
300 MHz–3 GHz	170			6
3 GHz–30 GHz	100			34000/f ^{1/2} min
30 GHz–300 GHz	100			6800/f ^{1/2} min

*The exposure values in terms of electric and magnetic field strengths are obtained by spatially averaging over an area equivalent to the vertical cross-section of the human body (projected area). At frequencies between 100 MHz and 300 MHz, the TLV[®] is defined in the direction of the electric field. At frequencies above 30 GHz, the power density TLVs[®] are the limit of exposure averaged over an area equivalent to 0.01 m² of body surface. However, for 30 GHz the maximum power density is 1000 W/m² in any one square centimeter.

Part B—Maximum Induced and Contact Radiofrequency Currents (mA) [†]				
Frequency	Through Both Feet	Through Either Foot	Grasping [‡]	Averaging Time
30 kHz–100 kHz	2000	1000	1000	0.2 s [§]
100 kHz–100 MHz	200	100	100	6 min [§]

[†]It should be noted that the current limits given above may not adequately protect against electric shocks and burns caused by time-averaged currents when contacting an energized object.

[‡]The contact value for induced and contact currents is 200 mA for no more than 15 s per 6 min per day.

[§]Accession to touch current is limited to 50% of the maximum grasping current.

[¶]*f* = averaged over a 60-min period.

[‡]*f* = averaged over a 60-min period (e.g., for either foot or hand contact, i.e., $I \leq 60,000 \text{ mA}^2 \text{ min}$). In this table, *f* is the frequency in Hz.

3. For touch contact with conductive objects, the maximum RF current should not exceed more than one-half of the maximum RF current for grasping contact. The means of compliance with these current limits can be determined by the user of the TLVs[®] as appropriate. The use of protective gloves, the avoidance of touch contact with conductive objects, the prohibition of metallic objects, or training of personnel may be sufficient to ensure compliance with these TLVs[®]. Evaluation of the magnitude of the induced currents will normally require a direct measurement. However, induced and contact current measurements are not required if the spatially averaged electric field strength does not exceed the TLVs[®] given in Table 1, Part A at frequencies between 0.1 and 100 MHz, as shown graphically in Figure 2.

C. For source frequencies greater than 100 MHz, Table 1, Part A provides an equivalent plane-wave power density, *S* (in W/m²), which can be calculated from field strength measurement data as follows:

$$S = \frac{E^2}{377}$$

where: *E*[†] is in volts squared (V²) per meter squared (m²); and

$$S = 377 H^2$$

where: *H*[‡] is in amperes squared (A²) per meter squared (m²).

- D. For exposures to pulsed fields of pulse duration less than 100 milliseconds (ms) at frequencies in the range 0.1 MHz to 300 GHz, the total incident energy density during any 100 ms period within the averaging time (see Table 1, Part A) shall not exceed 20% of the total specific energy absorption (SEA) permitted during the entire averaging time for a continuous field, i.e., $0.2 \times 144 = 28.8 \text{ J/kg}$. For pulse durations greater than 100 ms, normal time-averaging calculations apply.

The TLV[®] values in Table 1 should be used as guides in the evaluation and control of exposure to radiofrequency and microwave radiation and should not be regarded as fine lines between safe and dangerous levels. The values of *E*, *H*, and *S* given in Table 1, Part A are shown graphically as a function of frequency in Figure 1. Figure 2 depicts the maximum permissible current values given in Table 1, Part B through one foot or touch current as a function of the maximum permissible electric field strength TLV[®] over the frequency range 0.1 to 100 MHz.

Notes:

1. It is believed that workers may be exposed repeatedly to fields up to these TLVs[®] without adverse health effects. Nevertheless, personnel should not needlessly be exposed to higher levels of RF radiation, approaching the TLVs[®], when simple measures can prevent it.
2. For mixed or broadband fields at a number of frequencies for which there are different values of the TLV[®], the fraction of the TLV[®] (in terms of *E*,

TLV[®]-PA

ELECTROMAGNETIC FIELDS 0–300 GHz

STATIC MAGNETIC FIELDS

(Documentation Date – 2015)

These TLVs® refer to static magnetic field flux densities to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. These values should be used as guides in the control of exposures to static magnetic fields and should not be regarded as fine lines between safe and dangerous levels.

Routine occupational exposures should not exceed 0.5 mT in the general workplace environment, but can have ceiling values of 8 mT or more with special training and operating in a controlled workplace environment. Special training involves making workers aware of transient sensory effects that can result from rapid motion in static magnetic fields which last less than 2 T. A controlled workplace environment is one in which forces created by static magnetic fields on metallic objects do not create potentially hazardous projectiles. Exposure of the limbs of workers in the general workplace environment should not exceed 1.0 T. Workers with implanted ferromagnetic or electronic medical devices should not be exposed to static magnetic fields exceeding 0.3 mT.

These TLVs® are summarized in Table 1.

TABLE 1. TLVs® for Static Magnetic Fields

Exposure	Ceiling Value
Whole body (general workplace)	2 T
Whole body (special worker training and controlled workplace environment)	8 T
Limbs	20 T
Medical device wearers	0.3 mT

SUB-RADIOFREQUENCY (30 kHz and below)
MAGNETIC FIELDS

(Documentation Date – 2017)

These TLVs® refer to the amplitude of the magnetic flux density (B) of sub-radiofrequency (sub-RF) magnetic fields in the frequency range of 30 kilohertz (kHz) and below to which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. The magnetic field strengths in these TLVs® are root-mean-square (rms) values. These values should be used as guides in the control of exposure to sub-radiofrequency magnetic fields and should not be regarded as fine lines between safe and dangerous levels.

Occupational exposures in the extremely-low-frequency (ELF) range from 1 to 300 hertz (Hz) should not exceed the ceiling value given by the equation

$$B_{TLV} = \frac{60}{f}$$

where: f = the frequency in Hz

B_{TLV} = the magnetic flux density in millitesla (mT)

For frequencies in the range of 300 Hz to 30 kHz (which includes the voice frequency [VF] band from 300 Hz to 3 kHz and the very-low-frequency [VLF] band from 3 to 30 kHz), occupational exposures should not exceed the ceiling value of 0.2 mT.

These ceiling values for frequencies of 300 Hz to 30 kHz are intended for both partial-body and whole-body exposures. For frequencies below 300 Hz, the TLV® for exposure of the extremities can be increased by a factor of 10 for the hands and feet and by a factor of 5 for the arms and legs.

The magnetic flux density of 60 mT at 60 Hz corresponds to a maximum permissible flux density of 1 mT. At 30 kHz, the TLV® is 0.2 mT, which corresponds to a magnetic field intensity of 160 amperes per meter (A/m).¹

Contact currents from touching ungrounded objects that have acquired an induced electrical charge in a strong sub-RF magnetic field should not exceed the following point contact levels to avoid startle responses or severe electrical shocks:

- 1.0 milliamperes (mA) at frequencies from 1 Hz to 2.5 kHz;
- 0.4 mA at frequencies from 2.5 to 30 kHz, where f is the frequency expressed in kHz.

¹ Magnetic fields are expressed in units of amperes per meter. In health and safety studies, a more common descriptive quantity is the magnetic flux density in units of Tesla (T) or Gauss (G). $1 \text{ T} = 10,000 \text{ G}$. The two quantities are related by the magnetic permeability of the medium. In air, 1 A/m corresponds to a flux density of 1.3 μT .

Notes:

- These TLVs® are based on an assessment of available data from laboratory research and human exposure studies. Modifications of the TLVs® will be made if warranted by new information. At this time, there is insufficient information on human responses and possible health effects of magnetic fields in the frequency range of 1 Hz to 30 kHz to permit the establishment of a TLV® for time-weighted average exposures.
- For workers wearing cardiac pacemakers, the TLVs® may not protect against electromagnetic interference with pacemaker function. Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50/60 Hz) magnetic flux densities as low as 0.1 mT. It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of persons wearing cardiac pacemakers or similar medical electronic devices be maintained at or below 0.1 mT at power frequencies.
- Fields in excess of the TLVs® are likely to be present only in close proximity to high powered electrical equipment; in most occupational environments sub-RF fields are likely to be far below the TLV®. There should consequently be little need for detailed field surveys in general occupational spaces, although such surveys may help to address workers' concerns. If field surveys are undertaken, however, they should use appropriate equipment that has been calibrated and suitable for the anticipated measurements. In particular, unless they are designed for such measurements, magnetic field meters can be significantly in error when used to measure non-sinusoidal waveforms or fields at frequencies other than 50/60 Hz.

TABLE 1. TLVs® for Sub-Radiofrequency (30 kHz and below) Magnetic Fields

Frequency Range	TLV®
1 to 300 Hz	Whole-body exposure: $\frac{60}{f}$ ceiling value in mT
1 to 300 Hz	Arms and legs: $\frac{300}{f}$ ceiling value in mT
1 to 300 Hz	Hands and feet: $\frac{600}{f}$ ceiling value in mT
300 Hz to 30 kHz	Whole-body and partial-body ceiling value: 0.2 mT
1 Hz to 2.5 kHz	Point contact current limit: 1.0 mA
2.5 to 30 kHz	Point contact current limit: $0.4/f$ mA
	where: f = frequency in kHz

SUB-RADIOFREQUENCY (30 kHz and below) AND
STATIC ELECTRIC FIELDS

(Documentation Date – 2016)

These TLVs® refer to the maximum workplace field strengths of sub-radiofrequency electric fields (30 kHz and below) and static electric fields that represent conditions under which it is believed that nearly all workers may be exposed repeatedly without special protection without adverse health effects. The electric field intensities in these TLVs® are root-mean-square (rms) values. The values should be used as guides in the control of exposure and should not be regarded as a fine line between safe and dangerous levels. The electric field strengths stated in these TLVs® refer to the field levels present in air, away from the surfaces of conductors (where spark discharges and contact currents may pose significant hazards).

Occupational exposures should not exceed a field strength of 25 kilovolts per meter (kV/m) at frequencies from 0 Hz to 220 Hz. For frequencies in the range of 220 Hz to 30 kilohertz (kHz), the ceiling value is given by

$$E_{TLV} = 5.625 \times 10^6 / f$$

where:

f = the frequency in Hz

E_{TLV} = the rms electric field strength in V/m

A rms value of 1842 V/m is the ceiling value for frequencies from 3 to 30 kHz. These ceiling values are intended for both partial-body and whole-body exposures.

Notes:

- These TLVs® are based on limiting field-induced effects at the body surface and induced currents within the body to levels below those that are believed to be hazardous. These are direct effects.
- Indirect effects associated with touching charged objects within the electric field can be the limiting phenomena that determine safe practice. A noticeable and potentially annoying spark discharge can be experienced beneath power lines when the ground level field strength is at or below 5 kV/m (EPRI, 2005). Mitigation of such effects requires compliance with safe work practices and electrical safety codes beyond the scope of this TLV®.
- Certain biological effects have been reported in laboratory studies at electric field strengths below those permitted in the TLV®, however, there is no convincing evidence at the present time that occupational exposure to such field levels leads to adverse health effects.

2. While auditory effects of noise are determined largely by signal intensity and frequency, non-auditory effects (e.g., cardiovascular effects and injury risk) may also be influenced by predictability of signal, perceived control, time of day, rise-time, and even information content.

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ULTRASOUND

(Documentation Date – 2001)

These TLVs® represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. Previous TLVs® for the frequencies 10 kHz to 20 kHz, et al. to prevent subjective effects, are referenced in a cautionary note to Table 1. The 8-hour TWA values are an extension of the TLV® for Noise, which is an 8-hour TWA of 85 dBA. The ceiling values may be verified by using a sound level meter with slow detection and 1/3 octave bands. The TWA values may be verified by using an integrating sound level meter with 1/3 octave bands. All instrumentation should have adequate frequency response and should meet the specifications of ANSI S1.4-1983 (R1997)¹ and IEC 60418.²

TABLE 1. TLVs® for Ultrasound

Mid-Frequency of Third-Octave Band (kHz)	One-third Octave-Band Level ²		
	Measured in Air in dB re: 20 µPa; Head in Air	Measured in Water in dB re: 1 µPa; Head in Water	
	Ceiling Values	8-Hour TWA	Ceiling Values
10	105 ^A	88 ^A	167
12.5	105 ^A	89 ^A	167
16	105 ^A	92 ^A	167
20	105 ^A	94 ^A	167
25	110 ^A	—	172
31.5	115 ^A	—	177
40	115 ^A	—	177
50	115 ^A	—	177
63	115 ^A	—	177
80	115 ^A	—	177
100	115 ^A	—	177

^A Subjective annoyance and discomfort may occur in some individuals at levels between 75 and 105 dB for the frequencies from 13.4 kHz to 20 kHz, especially if they are total in nature. Hearing protection or engineering controls may be needed to prevent subjective effects. Total sounds in frequencies below 10 kHz might also need to be reduced to 80 dB.

^B These values assume that human coupling with water or other substrate exists. These thresholds may be raised by 20 dB when there is no possibility that the ultrasound can couple with the body by touching water or some other medium. (When the ultrasound source directly contacts the body, the values in the table do not apply. The vibration level at the contact point must be used.) Acceleration values 15 g (1.49 above the reference of 1 g rms) should be avoided by reduction of exposure or isolation of the body from the coupling source (g = acceleration due to the force of gravity, 9.80665 meters/second²; rms = root-mean-square).

TLV®-PA

References

1. American National Standards Institute. Specification for Sound Level Meters. ANSI S1.4-1983 (R1997). ANSI, New York (1997).
2. International Electrotechnical Commission. Integrating-Averaging Sound Level Meters. IEC 604. IEC, New York (1995).
3. American National Standards Institute. Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters. ANSI S1.11-1996 (R1998). ANSI, New York (1998).

TLV®-PA

ELECTROMAGNETIC RADIATION SPECTRUM AND RELATED TLVs [®]										
Region ^a	Non-ionizing Radiation						Ionizing Radiation			
	Sub-Radiofrequency	Radiofrequency	Microwave	Infrared	Light	Ultraviolet				
Waveband	ELF	ELF	ELF	IR-A	IR-B	IR-C	UV-A	UV-B	UV-C	
Wavelength		10 km	1 m	1 mm	3 µm	1.4 µm	400 nm	315 nm	280 nm	100 nm
Frequency	300 Hz	30 kHz	300 GHz							
Applicable TLV [®]	Sub-Radiofrequency	Radiofrequency and Microwave		Light and Near Infrared		Ultraviolet				
										Ionizing Radiation

² The boundaries between regions are set by convention and should not be regarded as absolute dividing lines.

TLV®-PA

ACOUSTIC

INFRASOUND AND LOW-FREQUENCY SOUND
(Documentation Date – 2020)

These TLVs[®] address worker exposures to sound in the range of 1 to 100 Hz that can cause nonauditory effects on comfort, performance, and health. Exposures to sound in this frequency range can cause vibration of human body biological structures via the airborne transmission of low-frequency acoustical energy. Specifically, infrasound is defined as acoustical energy in the frequency range of 1 to < 20 Hz that is not detectable by the human ear. These TLVs[®] represent sound to which it is believed nearly all workers may be repeatedly exposed without adverse health effects that do not involve hearing.

The TLVs[®] do not apply to impulsive sound with durations of < 2 seconds. For all other exposures, the TLVs[®] are listed in Table 1. There are no time limits for these exposures. However, application of the TLVs[®] for Audible Sound, recommended to prevent noise-induced hearing loss, may provide a reduced acceptable exposure level with time. This reduction will depend upon the amount of attenuation allowed for hearing protection.

TABLE 1. TLVs[®] for Infrasound and Low-Frequency Sound

Sound Pressure Level (SPL)	TLV [®]
Unweighted one-third octave bands 1 between 1 and 100 Hz	145 dB
Unweighted overall between 1 and 100 Hz	150 dB

¹American National Standards Institute (ANSI), 2014

NOTE: Low-frequency sounds have been known to excite resonances in the upper torso of the human body primarily at frequencies between 50 and 100 Hz. Such an effect may cause worker annoyance and discomfort at levels below the TLVs described above and may warrant the reduction to a level where the problem disappears.

American National Standards Institute, ANSI/ASA S1.11-2014/Part 1/IEC 61260-1-2014 Electroacoustics-Octave-Band and Fractional-Octave-Band Filters – Part 1: Specifications, ANSI, New York (2014).

AUDIBLE SOUND
(Documentation Date – 2018)

These TLVs[®] refer to sound pressure levels of noise (i.e., unwanted audible sound between the frequencies of 20 and 20,000 Hz) and durations of exposure that represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. The values should be used as guides in the control of noise exposure and, due to individual susceptibility, should not be regarded as fine lines between safe and dangerous levels.

It should be recognized that the application of the TLVs[®] for noise will not protect all workers from the adverse auditory effects of noise exposure, and also may not protect against a range of non-auditory effects. The TLVs[®] should protect the median of the population against noise-induced hearing loss ≥ 2 decibels (dB) after 40 years of occupational exposure for the average hearing threshold level across the critical audiometric frequencies of 0.5, 1, 2, and 3 kHz. A hearing conservation program, including key program elements (exposure monitoring, implementation of noise controls, worker training, use of hearing protection devices, recordkeeping, otitis media evaluation, and audiometric testing) is necessary when workers are exposed to noise at or above the TLVs[®] levels.

Continuous or Intermittent Noise

The noise level should be determined by a sound level meter, integrating sound level meter, or dosimeter conforming, as a minimum, to the requirements of the American National Standards Institute (ANSI) Sound Level Meter – Part 1: Specifications, S1.4-1 Type 2 (ANSI, 2014), ANSI S1.25 – Specification for Personal Noise Dosimeters (ANSI, 2007), or IEC 61672-1 (IEC, 2013). The measurement device should be set to use the A-weighted network (i.e., dBA) with slow meter response. The duration of exposure should not exceed that shown in Table 1. These values apply to total duration of exposure per day regardless of whether this is one continuous exposure or a number of short-term exposures.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered rather than the individual effect of each. If the sum of the following fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n}$$

exceeds unity, then the combined exposure should be considered to exceed the TLV[®]. C_i indicates the total duration of exposure at a specific noise level, and T_i indicates the total duration of exposure permitted at that level. All on-the-job noise exposures of 80–140 dBA should be used in the above calculations.

This formula should be used for sounds with limited variability (± 2.5 dB or less) as measured with sound level meters (ANSI, 2014; b). For more variable sound pressure levels and when brief, impulsive or impact sounds are present, a dosimeter or an integrating sound level meter must be used. The limit is exceeded when the dose is more than 100% as indicated on a dosimeter set with a 5 dB time-exposure exchange rate and an 8-hour criteria level of 85 dBA. The TLV[®] is exceeded on an integrating sound level meter when the average noise level over a given duration exceeds the values given in Table 1.

TABLE 1. Threshold Limit Values for Audible Sound^A

	Duration per Day	Sound Pressure Level dBA ^B
Hours	34	80
	16	82
	8	85
	4	88
	2	91
	1	94
Minutes	30	97
	15	100
	7.50 ^C	103
	3.75 ^C	106
	1.88 ^C	109
	0.94 ^C	112
Seconds ^D	28.12	115
	14.06	118
	7.03	121
	3.52	124
	1.76	127
	0.88	130
	0.44	133
	0.22	136
	0.11	139
	0.08	140

^ANo exposure to continuous, intermittent, or impact noise (e.g., audible sound between the frequencies of 20 and 20,000 Hz) is permitted in excess of a peak C-weighted level of 140 decibels (dB).

^BNoise levels in dB are measured on a sound level meter, weighting, as a minimum, to the requirements of the American National Standards Institute Sound Level Meters – Part 1: Specifications, S1.4 (ANSI, 2014) Type 2, and set to use the A-weighted network with slow meter response.

^CLimited by engineering control of the noise source if feasible. Administrative control is permissible if engineering control is infeasible.

Impulsive or Impact Noise

Impact and impulse noise involves brief noise excursions that last < 1 sec. Impact noise results from colliding objects, causing them to “ring.” Impulsive noise results from explosions or formation of shock waves. Together, they comprise what is generically called impulse noise. Use of the instrumentation specified by ANSI S1.4-1 (2014), ANSI S1.25 (2007), or IEC 61672-1 (2013) ensures that impulse noise is integrated into the measured noise level. The only measurement requirements for impulse noise level are that the metering equipment should have a measurement range between 80 and 140 dBA and a pulse range response of at least 63 dB. No exposures of an unprotected ear in excess of a C-weighted peak sound pressure level of 140 dB are permitted. If instrumentation is not available to measure a C-weighted peak, a Z-weighted (IEC, 2013) or unweighted peak measurement below 140 dB may be used to imply that the C-weighted peak is below 140 dB.

Notes:

- For audible sound impulses above a C-weighted peak of 140 dB, hearing protection should be worn. The MIL-STD-1474E (U.S. DOD, 2015) provides guidance for those situations in which single protection (plugs or muffs) or double protection (both muffs and plugs) should be worn. Additional guidance on appropriate attenuated exposure levels is provided by the European Committee for Standardization (2004).
- Exposure to certain chemicals may also result in hearing loss and the exacerbation of the effects of noise (EU OSHA, 2009; Johnson and Morata, 2010; Choi and Kim, 2014). In settings where there may be exposures to noise and to Carbon monoxide, Hydrogen cyanide, Lead, and solvent mixtures, or exposures to Ethylbenzene, Styrene, Toluene, or Xylene in the absence of noise, periodic audiograms are advised and should be carefully reviewed, with the potential confounding effect of noise in mind (Nies, 2012). Other substances under investigation for ototoxic effects include Arsenic, Carbon disulfide, Chlorobenzene, Mercury, Nitrites, n-Hexane, pesticides, and Trichloroethylene.
- There is evidence to suggest that noise exposure in excess of a C-weighted, 8-hour TWA of 115 dBC or a peak exposure of 155 dBC to the abdomen of pregnant workers beyond the fifth month of pregnancy may cause hearing loss in the fetus.
- The sum of the fractions of any one day may exceed unity, provided that the sum of the fractions over a seven-day period is five or less and no daily fraction is more than three.
- Table 1 is based on daily exposures in which there will be time away from the workplace in effective quiet, i.e., < 70 dBA. This time away from the workplace will allow any temporary shifts in worker's hearing thresholds to recover. When the worker is restricted for periods of greater than 24 hours to employer-controlled spaces or areas that serve as both workplace and living quarters, the average noise exposure over any 24-hour period should not exceed 80 dBA.
- There is evidence to suggest that chronic exposures to occupational noise < 85 dBA – i.e., below that sufficient for a substantially elevated risk of noise-induced hearing loss – may be associated with an increased risk of elevated blood pressure, hypertension, and ischemic heart disease among manufacturing and production workers. The TLV[®] may not be protective against these effects.
- There is evidence to suggest that noise exposures > 85 dBA may be associated with an increased risk of occupational injury through distraction, stress, fatigue, performance degradation, or other mechanisms among manufacturing and production workers. The TLV[®] may be protective against these effects, though it is possible that acute injury risk is more highly associated with brief excursions rather than an 8-hour average level; if true, this suggests a different risk scenario than those presented for noise-induced hearing loss and cardiovascular disease.

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INTRODUCTION TO THE PHYSICAL AGENTS

This section presents Threshold Limit Values (TLVs®) for occupational exposure to physical agents of acoustic, electromagnetic, ergonomic, mechanical, and thermal nature. As with other TLVs®, those for physical agents provide guidance on the levels of exposure and conditions under which it is believed that nearly all healthy workers may be repeatedly exposed, day after day, without adverse health effects.

The target organs and health effects of these physical agents vary greatly with their nature, thus, TLVs® are not single numbers, but are integrations of the measured parameters of the agent, its effects on workers, or both. Due to the many types of physical agents, a variety of scientific disciplines, detection techniques, and instrumentation are applied. Therefore, it is especially important that the Physical Agents TLVs® be applied only by individuals adequately trained and experienced in the corresponding measurement and evaluation techniques. Given the unavoidable complexity of some of these TLVs®, the most current Documentation of the Physical Agents TLVs® must be consulted when they are applied.

Because of individual variations in individual susceptibility, exposure of an individual or even below the TLV® may result in annoyance, aggravation of a pre-existing condition, or physiological effects. Certain individuals may also be more susceptible or otherwise unusually responsive to some physical agents at the workplace because of a variety of factors such as age, sex, genetic factors (predisposition), personal behaviors (e.g., smoking, diet, exercise, abuse of alcohol or other drugs, extracurricular activities—hobbies), medications, and medical conditions (e.g., cardiovascular disease). Some workers may become more susceptible to adverse effects from a physical agent following previous exposures. Concurrent exposures to other physical agents may increase susceptibility. Changes in susceptibility may also occur at different work levels (e.g., light versus heavy work). Maternal and fetal susceptibility to the effects of some physical agents may be altered during different periods of fetal development. Such workers may not be adequately protected from adverse health effects from exposures to certain physical agents at or below the TLVs®. An occupational physician should evaluate the extent to which such workers require additional protection.

TLVs® are based on available information from industrial experience, from experimental human and animal studies, and when possible from a combination of the three, as noted in their Documentation.

Like all TLVs®, these limits are intended for use in the practice of occupational hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, 1) in the evaluation or control of the levels of physical agents in the community or 2) as proof or disproof of an existing physical disability.

These values are reviewed annually by ACGIH® for revision or additions as further information becomes available. ACGIH® regularly examines the data related to mutagenicity, cancer, adverse reproductive effects, and other health effects of physical agents. Comments, accompanied by substantive

documentation, are solicited and should be forwarded in electronic format to the ACGIH® Science Group at science@acgih.org.

ACGIH® disclaims liability with respect to the use of TLVs®.

Notice of Intended Changes

Each year, proposed actions for the forthcoming year are issued in the form of a "Notice of Intended Changes" (NIC). These physical agents, with their corresponding values, comprise those for which 1) a limit is proposed for the first time (i.e., NIE), 2) a change in the Adopted Values is proposed, 3) retention as an NIC is proposed, or 4) withdrawal of the Documentation and adopted TLV® is proposed. In each case, the proposals should be considered trial values during the period they are on the NIC/NIE. These proposals are ratified by the ACGIH® Board of Directors and will remain as NICs/NIEs for approximately one year following this ratification. If the Committee neither finds nor receives any substantive data that change its scientific opinion regarding physical agent TLVs® on the NIC/NIE, the Committee may approve its recommendation to the ACGIH® Board of Directors for adoption. If the Committee finds or receives substantive data that change its scientific opinion regarding a TLV® on the NIC/NIE, the Committee may change its recommendation to the ACGIH® Board of Directors for the matter to be either retained on or withdrawn from the NIC.

Documentation is available for each of these physical agents and their proposed values.

This notice provides an opportunity for comment on these proposals. Comments or suggestions should be accompanied by substantiating evidence in the form of peer-reviewed literature and forwarded in electronic format to the ACGIH® Science Group at science@acgih.org. Please refer to the ACGIH® TLV®/BEI® Development Process on the ACGIH® website (acgih.org/tlv-bei-guidelines/policies-procedures-presentations/tlv-bei-development-process) for a detailed discussion covering this procedure, methods for input to ACGIH®, and deadline date for receiving comments.

Definitions

TLV® categories used in this section include the following:

- Threshold Limit Value—Time-Weighted Average (TLV-TWA):** The time-weighted average exposure for an 8-hour workday and 40-hour workweek.
- Threshold Limit Value—Ceiling (TLV-C):** Exposure limit that should not be exceeded even instantaneously.

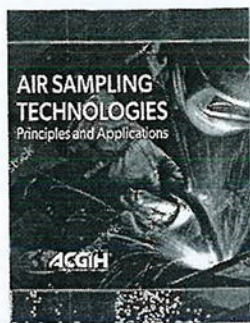
Physical and Chemical Factors

Combinations of such physical factors as heat, ultraviolet and ionizing radiation, humidity, abnormal pressure (altitude), and the like, as well as the interaction of physical factors with chemical substances in the workplace, may place added stress on the body so that the effects from exposure at a TLV®

may be altered. This stress may act adversely to increase the toxic response to a foreign substance. Although TLVs® have built-in uncertainty factors to guard against adverse health effects when there are moderate deviations from normal environments, the uncertainty factors for most exposures are not of such a magnitude as to compensate for gross deviations. In such instances, informed professional judgment must be exercised in the proper adjustment of the TLVs®.

Unusual Work Schedules

Work schedules markedly different from the traditional 8-hour day, 40-hour workweek require careful judgment in the application of the TLVs®. Non-traditional workshifts may result in overexposure and/or limited opportunity to recover prior to re-exposure. Some workers have more than one job, which may result in overexposure, even if neither job by itself entails overexposure. Extrapolation of the TLVs® to account for potential overexposure and/or insufficient recovery due to unusual work schedules should be approached with great caution.



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CHEMICAL SUBSTANCES AND OTHER ISSUES UNDER STUDY

The BEI® Committee solicits information, especially data, which may assist it in its deliberations regarding the following substances and issues. Comments and suggestions, accompanied by substantiating evidence in the form of peer-reviewed literature, should be forwarded in electronic form to the ACGIH Science Group at science@acgih.org. In addition, the Committee solicits recommendations for additional substances and issues of concern to the industrial hygiene and occupational health communities. Please refer to the ACGIH® TLV®/BEI® Development Process found on the ACGIH® website for a detailed discussion covering this procedure and methods for input to ACGIH® (acgih.org/tlv-bei-guidelines/development-process).

The Under Study list is published each year by February 1 on the ACGIH® website (acgih.org/science/tlv-bei-guidelines/documentation-publications-and-data/under-study), in the *Annual Reports of the Committees on TLVs® and BEIs®*, and later in the annual *TLVs® and BEIs®* book. In addition, the Under Study list is updated by July 31 into a two-tier list.

- Tier 1 entries indicate which chemical substances and physical agents may move forward as an NIC or NIE in the upcoming year, based on their status in the development process.
- Tier 2 consists of those chemical substances and physical agents that will not move forward, but will either remain on, or be removed from, the Under Study list for the next year.

This updated list will remain in two tiers for the balance of the year. ACGIH® will continue its practice of updating the Under Study list by February 1 and establishing the two-tier list by July 31 each year.

The substances and issues listed below are as of January 1, 2012. After this date, please refer to the ACGIH® website (acgih.org/science/tlv-bei-guidelines/documentation-publications-and-data/under-study) for the up-to-date list.

Chemical Substances

Acrylamide	Ethylene glycol
Acrylonitrile	Ethylene glycol carbonate
Adipates	Heptane
Arsenic	Iodine
Atrazine	Methylcyclohexane
Benzene	Nicotine
Bisphenol A	Nitrobenzene
Butadiene	Phthalates (see DEHP)
Copper	Platinum
3,3'-Dichlorobenzidine	
Diethylhexyl adipate	
Di(2-ethylhexyl)phthalate (DEHP)	
Dimethylacetamide	

Other Issues Under Study

1. Sq Notation
2. Introduction to the Documentation of the BEIs®

Feasibility Assessments

For the substances listed below, the BEI® Committee has determined that developing a BEI® is not currently feasible owing to inadequate scientific data. However, the Committee believes that these substances may pose important risks to the health of workers, and therefore, it encourages the submission of new data. Field or experimental studies on the relationship between biological indicators and either health risk or environmental exposure are needed for these agents. A brief summary of the current negative feasibility assessment, including data needs, for each of the listed substances is available from the ACGIH® Science Group at science@acgih.org.

Substance	Date of Feasibility Assessment
Acrylonitrile	March 1994
Alachlor	September 2009
Aluminum	September 2007
Antimony	November 1996
Beryllium	November 2010
1-Bromopropane	April 2017
Chlorpyrifos	October 1995
1,4-Dichlorobenzene	March 1994
2,4-Dichlorophenoxyacetic acid	March 1994
Diethanolamine	September 2013
Diethylhydroxylamine	September 2021
2-Ethyl hexanoic acid	September 2001
Hydrazines	March 1994
Inorganic borates	October 1995
Manganese	October 2017
Methyl tert-butyl ether	October 1993
Methyl n-butyl ketone	June 2020
Methylcyclohexane	June 2020
Methyl formate	September 2005
Methyl isobutyl carbinol	June 2020
α-Methylstyrene	November 2010
Nitrobenzene	September 2013
Perfluorooctanoic acid	April 2007
Selenium	October 1995
Styrene oxide	September 2021
Thallium	November 2010
Trimethylbenzene	August 1999
Vanadium pentoxide	September 2009
Vinyl chloride	August 2002

2022 Threshold Limit Values for Physical Agents in the Work Environment Adopted by ACGIH® with Intended Changes

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BEIS®

2022 NOTICE OF INTENDED CHANGES

These substances, with their corresponding indices, comprise those for which (1) a BEIS® is proposed for the first time, (2) a change in the Adopted Index is proposed, (3) retention as an NIC is proposed, or (4) withdrawal of the Documentation and adopted BEIS® is proposed. In each case, the proposals should be considered final indices during the period they are on the NIC. These proposals were ratified by the ACGIH® Board of Directors and will remain on the NIC for approximately one year following this notification. If the Committee receives either final or non-final comments, the Committee will review the comments and make changes by one year following this notification. If the Committee receives no comments, the Committee will retain the current index and will not make any changes. The Committee may then approve its final decision to the ACGIH® Board of Directors for adoption. If the Committee finds or receives substantive data that change its scientific opinion regarding an NIC BEIS®, the Committee may change its recommendation to the ACGIH® Board of Directors for the matter to be either retained on or withdrawn from the NIC.

Documentation is available for each of these substances and their proposed values. Comments or suggestions should be accompanied by substantiating evidence in the form of a letter to the ACGIH® Science Group at science@acgih.org. Please refer to the ACGIH® TLV®/BEIS® Development process-reviewed literature and forwarded in electronic format to the ACGIH® Science Group at science@acgih.org. For a detailed discussion covering this process on the ACGIH® website (acgih.org/science/tlv-beis-development) for a detailed discussion covering this procedure, methods for input to ACGIH® and deadline data for receiving comments.

2022 NOTICE OF INTENDED CHANGES

Chemical (CAS No.)	Determinant	BEIS®	Sampling Time	Notation
1 ACETYLCHOLINE (79-05-1)	N-2: Carbamoylcholine (CUEV) in blood S-2: Carbamoylcholine (CUEV) in urine	500 pmol/g creatinine 800 µg/g creatinine * after 120 days of representative work/vigilance to 270 µg/g creatinine	Not critical End of shift	B
1 2-ETHOXYETHANOL (109-89-9)	2-Ethoxyacetic acid in urine	40 mg/g creatinine	End of shift at end of workweek	C

2022 NOTICE OF INTENDED CHANGES

Chemical (CAS No.)	Determinant	BEIS®	Sampling Time	Notation
1 FURFURAL (98-01-1)	Furandiol in urine *	200 mg/L	End of shift	NS
1 STYRENE (100-42-9)	Nucleic acid plus phenylglyoxylic acid in urine Synone in urine	150 mg/g creatinine 20 µg/L	End of shift End of shift	NS

* With hydrolysis

* With hydrolysis; n-Hexane, Methyl n-butyl ketone and Trichloroethylene

* 2022 Revision or Addition to the Notice of Intended Changes

* 2022 San Notice of Intended Changes (NIC)

* 2022 San Notice of Intended Changes (NIC)

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BEIS®

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS

Chemical (CAS No.) (Documentation date)	Determinant	BEIS®	Sampling Time	Notation
PENTACHLOROPHENOL (107-85-3) (2011)	Phenol in urine *	—	Phenol in last shift of workweek	NS
PHENOL (108-95-2) (2005)	Phenol in urine *	250 mg/g creatinine	End of shift	C, NS
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) (2016)	1-Hydroxyphenanthrene in urine *	25 µg/L	End of shift at end of workweek	S
	3-Hydroxyphenanthrene in urine *	—	End of shift at end of workweek	NJ
* Adjusted for the Pyrene to Benz[a]pyrene ratio of the PAH mixture to which workers are exposed				
2 PROPANOL (67-63-0) (2005)	Acetone in urine	40 mg/L	End of shift at end of workweek	P, NS
1 STYRENE (100-42-9) (2014)	Nucleic acid plus phenylglyoxylic acid in urine	400 mg/g creatinine (20 µg/L)	End of shift End of shift	NS
TETRACHLOROETHYLENE (127-18-4) (2009)	Tetrachloroethylene in end-exhaled air	3 ppm	Prior to shift	—
	Tetrachloroethylene in blood	0.5 mg/L	Prior to shift	—
TETRAHYDROFURAN (109-99-9) (2005)	Tetrahydrofuran in urine	2 mg/L	End of shift	—

BEIS®

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS

Chemical (CAS No.) (Documentation date)	Determinant	BEIS®	Sampling Time	Notation
TOLUENE (108-88-3) (2009)	Toluene in blood	0.17 mg/L	Prior to last shift of workweek	—
	Toluene in urine	0.05 mg/L	End of shift	—
	o-Cresol in urine *	0.3 mg/g creatinine	End of shift	B
TOLUENE DIISOCYANATE 2,4-BIS (94-9) or 2,6-BIS (98-7)	or as a mixture of isomers (2015)	5 µg/g creatinine	End of shift	NS
* Sum of 2,4- and 2,6-isomers				
TRICHLOROETHYLENE (79-01-6) (2007)	Trichloroethylene in urine	15 mg/L	End of shift at end of workweek	NS
	Trichloroethylene in blood *	0.5 mg/L	End of shift at end of workweek	NS
	Trichloroethylene in blood	—	End of shift at end of workweek	S, NS
	Trichloroethylene in end-exhaled air	—	End of shift at end of workweek	S, NS
UPANUM (7440-61-1) (2008)	Uranium in urine	2 µg/g creatinine	End of shift	—
XYLENES (95-47-5, 100-42-3, 100-38-3, 1330-20-7) (Technical or commercial grades) (2011)	Methylphenylacetate in urine	15 µg/g creatinine	End of shift	—

* With hydrolysis

* Without hydrolysis: n-Hexane, Methyl n-butyl ketone and Trichloroethylene

Chemical [CAS No.] [Documentation date]	Determinant	Sampling Time	BE [®]	Notation
MERCURY, ELEMENTAL [7439-97-5] (2012)	Mercury in urine	Pre- to shift	20 µg/L creatinine	—
METHANOL [67-58-1] (2004)	Methanol in urine	End of shift	15 mg/L	D, NS
METHOXYGLUCURON INDUCERS (2020)	Methoxyglucuron in blood	During or end of shift	5% of hemoglobin	B, NS
2-METHOXYETHANOL [109-86-4] AND 2-METHOXYETHYL ACETATE [110-49-6] (2009)	2-Methoxyglucuron in urine	End of shift at end of workweek	1 ng/g creatinine	—
METHYL CHLOROFORM [71-55-8] (2020)	Methyl chloroform and ethanol or methyl chloroform in urine	Pre- to shift at end of workweek	20 µg/L	—
4,4'-METHYLENE BIS(2-CHLOROANILINE) (MBCA) (2012)	Total MBCA in urine *	End of shift	—	NS
METHYL ETHYL KETONE [78-93-3] (2012)	Methyl ethyl ketone in urine	End of shift	2 mg/L	NS

Chemical [CAS No.] [Documentation date]	Determinant	Sampling Time	BE [®]	Notation
NN-DIMETHYLACE AMIDE [127-19-5] (1953)	N,N-dimethylacetamide in urine	End of shift at end of workweek	20 mg/L creatinine	—
N,N-DIMETHYL-2-ETHANOLAMINE [68-12-7] (2013)	Local N,N-dimethylacetamide in urine **	End of shift	5 mg/L	—
2-ETHOXYETHANOL [109-86-4] AND 2-ETHOXYETHYL ACETATE [111-15-9] (1952)	2-Ethoxyglucuron in urine	End of shift at end of workweek	10 mg/L creatinine	—
ETHYL BENZENE [100-41-4] (2013)	Sum of local, parent and ethoxyglucuron in urine	End of shift	0.5 mg/L creatinine	NS
ETHYL ETHER [75-21-8] (2018)	Sum of local, parent and ethoxyglucuron in urine	End of shift	5 mg/L creatinine	NS
5-HYDROXY-N-ETHYL-2-PYRROLIDONE [539-91-4] (2018)	5-Hydroxy-N-ethyl-2-pyrrolidone (5-HEDP) in urine *	End of shift	—	NS

Chemical [CAS No.] [Documentation date]	Determinant	Sampling Time	BE [®]	Notation
FLUORIDES (2011)	Fluoride in urine	Pre- to shift	2 mg/L	H, NS
	Fluoride in urine	End of shift	3 mg/L	D, NS
1-FLUORURACIL [89-01-1] (2006)	Furic acid in urine *	End of shift	200 mg/L	NS
1,6-HEXAMETHYLENE DISOCYANATE [822-05-0] (2014)	1,6-Hexamethylenediamine in urine *	End of shift	15 µg/L creatinine	NS
n-HEXANE [110-54-3] (2010)	2,5-Hexametidine in urine **	End of shift	0.5 mg/L	—
INDIUM [7440-74-6] AND INDIUM INORGANIC COMPOUNDS, including indium in oxide and indium oxide (2020)	Indium (In) in serum or plasma	Not critical	1 µg/L	—
LEAD AND INORGANIC COMPOUNDS [7439-92-1] (2010)	Lead in blood	Not critical	200 µg/L	—

Note: Persons employed by BEIS are encouraged to consult inside workers of childbearing age about the risk of lowering a child with a pre-exposure over the current CDC reference value.

(CDC) Guidelines for the identification and management of lead exposure in pregnant and lactating women (2010).

Chemical [CAS No.] [Documentation date]	Determinant	Sampling Time	BE [®]	Notation
MFTHYL ISOBUTYL KETONE [105-10-1] (2016)	Methyl isobutyl ketone in urine	End of shift	1 mg/L	—
N-METHYL-2-PYRROLIDONE [127-50-4] (2003)	5-Hydroxy-N-methyl-2-pyrrolidone in urine	End of shift	100 mg/L	—
NAPHTHALENE [91-20-3] (2012)	1-Naphthol *	End of shift	—	NS, NS
NICKEL [7440-02-0] AND INORGANIC COMPOUNDS (2020)	Nickel in urine after exposure to elemental nickel and poorly soluble compounds	Post-shift at end of workweek	5 µg/L	B
NITROBENZENE [98-95-3] (2013)	Methoxyglucuron in blood	Post-shift at end of workweek	20 µg/L	—
PARATHION [56-38-3] (2013)	Parathion in urine	End of shift	0.5 mg/L creatinine	NS
TRIPHENYL METHYLENE DYE [118-90-4] (2013)	Triphenylmethylenediamine activity in red blood cells	End of shift	70% of individual baseline activity **	NS

** The average of two baseline triphenylmethylenediamine activity determinations 3 days apart, with no exposure to triphenylmethylenediamine for at least 30 days, is recommended for each worker prior to exposure to triphenylmethylenediamine. To be established at least once a year. Referral from workplace exposures is recommended until the triphenylmethylenediamine activity returns to within 70% of baseline.

BEI 50

However, it may be appropriate to remove the worker from exposure following a single high result if there is reason to believe that significant exposure may have occurred.

BEIS[®] apply to 8-hour exposures, 5 days per week. Although modified work schedules are sometimes used in various occupations, the BEIS[®] Committee does not recommend that any adjustment or correction factor be applied to the BEIS[®] (i.e., the BEIS[®] should be used as listed regardless of the work schedule).

Use of the BEC[®] should be accepted by a knowledgeable occupational health professional. Toxicologic and toxicodynamic information is often inadequate when establishing line BEC's. Thus, some knowledge of the metabolism, distribution, accumulation, excretion, and effects is helpful in using the BEC effectively. AGCHS[®] may be contacted for technical assistance on any BEC[®] issue. The BEC[®] is a guideline for the control of chemical health hazards to the worker and should not be used for other purposes. The values are inappropriate to use for the general population or for non-occupational exposures. The BEC[®] values are neither risk limits between safe and dangerous concentrations nor are they an index of toxicity.

Notes:

It is essential to consult the BEI[®] Documentation before designing biological monitoring protocols and interpreting BEI's[®]. In addition, each BEI[®] Documentation now provides a chronology that traces all BEI[®] actions for the chemical substance in question.

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS				
Chemical (CAS No.; Documentation date)	Determinant	Sampling Time	BE ^{RP}	Notation
	Acetone in urine	End of shift	25 mg/L	H ₂
	ANILINE (62-53-3) (2020) Aniline in urine <i>tr</i>	End of shift	0.5 mg/L	—
ARSENIC, ELEMENTAL (7440-38-2) AND SOLUBLE ORGANIC COMPOUNDS (excludes gallium arsenide and arsine) (1958)				
	Inorganic arsenic plus methylated metabolites in urine	End of workweek	35 µg As/L	B
BENZENE (71-43-2) (1939)				
	S-Phenylmercapturic acid in urine	End of shift	25 µg/L creatinine	D
	1-Mucosinic acid in urine	End of shift	500 µg/L creatinine	B
3-BUTADIENE (106-99-0) (2005)				
	1,2-Dihydroxy-4-(4-acetylcysteinyl) butane in urine	End of shift	25 mg/L	B, S ₁
	Mixture of N-1- and N-2-(p-mercaptophenyl)glutamine in urine	Natural	2.5 mmol/L-H ₂	S ₁
3-BUTOXYETHANOL (111-76-2) (2006)				
	Butyrosuccinic acid (BAA) in urine <i>★</i>	End of shift	200 mmol creatinine	—

BEIS

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ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS				
Chemical (CAS No.) (documentation date)	Determinant	Sampling Time	BE ^a	Action
ZINCUM (7440-66-3) AND INORGANIC COMPOUNDS (2015)	Cadmium in urine	Not critical	5 µg/g creatinine	B
	Cadmium in blood	Not critical	5 µg/L	B
CARBON DISULFIDE (75-10-1) (2000)	2-Thiothiazolidine-4-carboxylic acid (1:1) in urine	End of shift	0.5 mg/g creatinine	B, NS
CARBON MONOXIDE (CO) (49-13-0) (2015)	Carboxyhemoglobin in blood	End of shift	3.5% of hemoglobin	B, NS
	Carbon monoxide in end-saturated air	End of shift	20 ppm	B, NS
CHLOROBENZENE (108-90-7) (2000)	4-Chlorobenzil in urine *	End of shift at end of workweek	100 mg/g creatinine	NS
	p-Chlorophenol in urine *	End of shift at end of workweek	20 mg/g creatinine	NS
CHOLINESTERASE INHIBITING PESTICIDES (2017)	Acetylcholinesterase activity in red blood cells and	End of shift	70% of individual's baseline activity **	NS
	BuChE:acetylcholinesterase activity in serum or plasma	End of shift	63% of individual's baseline activity **	NS
	... The average of two baseline (pre-exposure) cholinesterase activity measurements 3 days apart, with an exposure to any pesticides for at least 10 days, is recommended for each worker prior to exposure to cholinesterase inhibitors because of higher inter-individual differences in published baseline values. To be established at least once a year. *Normal from worker's corporate exposure assessment and the cholinesterase activity remains in within 20% of baseline.			

ADOPTED BIOLOGICAL EXPOSURE DETERMINANTS

ADOPTED BIOLOGICAL EXPOSURE DE TERMINANTS				
Chemical (CAS No.) (Documentation date)	Determinant	Sampling Time	DEP ^a	Notation
CHROMIUM [7440-47-3] (2020)	Total chromium in urine	End of shift at end of workweek	0.7 µg/L	Pop
	COBAL [7440-48-4] AND INORGANIC COMPOUNDS, including Cobalt oxides but not contained with Tungsten carbide (2014)	End of shift at end of workweek	15 µg/L	Ns
	Cobalt in urine	End of shift at end of workweek	—	Ns, Nq
	Cobalt with Tungsten carbide	End of shift at end of workweek	—	Ns, Nq
1,2-CYCLOHEXANOL [110-82-7] (2021)	1,2-Cyclohexanol in urine *	End of shift, end of workweek	50 mg/L creatinine	Ns
1,2-CYCLOHEXANOL [109-93-4] (2003)	1,2-Cyclohexanol in urine *	End of shift at end of workweek	—	Nq, Ns
CYCLOHEXANOL [109-93-4] (2003)	Cyclohexanol in urine *	End of shift	—	Nq, Ns
1,2-CYCLOHEXANONE [109-94-1] (2003)	1,2-Cyclohexanone in urine *	End of shift at end of workweek	60 mg/L	Ns, Sq
CYCLOHEXANONE [109-94-1] (2003)	Cyclohexanone in urine *	End of shift	8 mg/L	Ns, Sq
DICHLOROMETHANE [75-29-2] (2004)	Dichloromethane in urine	End of shift	0.3 mg/L	Sq

BEIS

actions for the chemical substance in question.

BEIs® are developed by Committee consensus through an analysis and evaluation process. The detailed scientific criteria and justification for each BEI® can be found in the *Documentation of the Threshold Limit Values and Biological Exposure Indices*. The principal material evaluated by the BEI® Committee includes peer-reviewed published data taken from the workplace (i.e., field studies), data from controlled exposure studies, and from appropriate toxicokinetic modeling when available. The results of animal research are also considered when relevant. The *Documentation* provides essential background information and the scientific reasoning used in establishing each BEI®. Information given includes the analytical methods, possible potential for confounding exposures, specimen collection recommendations, limitations, as well as other essential information, specific for each compound and analyte.

In recommending a BEI®, ACGIH® considers whether published data are of reasonable quality and may also consider unpublished data if a complete copy of the data report is provided to ACGIH®. However, unpublished data are never used as the primary basis for a BEI®, although it may provide a secondary support. There are numerous instances when analytical techniques are available for the measurement of a biological determinant, but published information is unavailable or inadequate to determine a BEI®. The data needed to establish a BEI® include comprehensive assessment of total exposure and/or health effects. Therefore, occupational health professionals are encouraged to accumulate and report biological monitoring data together with exposure and health data.

Relationship of BEIs® to TLVs®

BEI® determinants are an index of an individual's uptake of a chemical by all routes. In some cases they correspond to the TLV® as a 'safe' level without reported health effects. In other cases they may reflect the highest 5% of levels seen in the general population. In addition, some BEIs® are without a numerical value and/or provide only qualitative estimates of exposure. These indices are useful to confirm that an exposure to a specific agent is occurring. The basis of each BEI® is provided in the *Documentation*. Air monitoring to determine the TLV® indicates the potential inhaled exposure of an individual or group. The internal dose for individuals within a workgroup may be different for a variety of reasons, some of which are indicated below:

- Exposure by routes other than inhalation, usually dermal, is often a major reason why there is less than perfect concordance between air sampling and biological monitoring. This is often the strongest argument for doing biological monitoring.
- Physiological makeup and health status of the worker, such as body build, diet (water and fat intake), metabolism, body fluid composition, age, gender, pregnancy, medication, and disease state.
- Occupational exposure factors, such as the work-rate intensity and duration, temperature and humidity, co-exposure to other chemicals, and other work factors.
- Nonoccupational exposure factors, such as community and home air pollution, water and food components, personal hygiene, smoking, alcohol and drug intake, exposure to household products or exposure

to chemicals from hobbies or from another workplace.

- Methodological factors, which include specimen contamination or deterioration during collection and storage and bias of the selected analytical method.
- Location of the air monitoring device in relation to the worker's breathing zone.
- Particle size distribution and penetrability.
- Variable effectiveness of personal protective devices.

It is important that the reader consult the *Documentation* of the TLVs® and BEIs® to understand the importance of each of these factors for each particular agent.

Specimen Collection

Because the concentration of some determinants can change rapidly the specimen collection time (sampling time) is very important and must be observed and recorded carefully. The sampling time is specified in the BEI® and is determined by the duration of retention of the determinant, modified in some cases by practicality (for example if the peak level is expected several hours after the end of a shift). Substances and determinants that accumulate may not require a specific sampling time. An explanation of the BEI® sampling time is as follows:

Sampling Time

1. Prior to shift
2. Prior to last shift
3. Increase during shift
4. During shift
5. End of shift
6. End of the workweek
7. Discretionary/Not Critical

Recommended Collection

- 16 hours after exposure ceases, but before any exposure on sampling day
- Prior to last shift of a workweek
- Requires pre- and post-shift sample collection
- Anytime after two hours of exposure
- As soon as possible after exposure ceases
- After four or five consecutive working days with exposure
- At any time*

*These determinants have long half-lives and their levels may take weeks, months or years after a worker first begins their job to approach steady state and be comparable to the BEI®. Health professionals should note that if sequential samples taken early in a worker's exposure career show a marked increase, an overexposure situation might be developing and must be addressed despite the values being below the BEI®.

Urine Specimen Acceptability

Urine specimens that are highly dilute or highly concentrated are generally not suitable for biomonitoring. The World Health Organization has adopted guidelines (without reference) for acceptable limits on urine specimens as follows:

Creatinine concentration: > 0.3 g/L and < 3.0 g/L
or
Specific gravity: > 1.010 and < 1.030

Specimens falling outside either of these ranges should be discarded and another specimen should be collected when possible.

Some BEIs® for determinants whose concentration is dependent on urine output are expressed relative to creatinine concentration. For other determinants such as those excreted by diffusion into the renal tubules, correction for urine output is not appropriate. In general, the best correction method is chemical-specific, but research data sufficient to identify the best method may not be available. When the field data are only available as adjusted for creatinine, the BEI® will continue to be expressed relative to creatinine. In other circumstances, no correction is recommended, and the BEI® will be expressed as concentration in urine (e.g., µg/L).

Notations

"B" = Background

The determinant may be present in biological specimens collected from subjects who have not been occupationally exposed, at a concentration that could affect interpretation of the result. A "B" notation is assigned to a determinant when the observed 95th percentile value of a random sample, from national population studies, such as the NHANES surveys, is more than 20% of the BEI®. When general population data are not available to make this assessment, the BEI® Committee may assign a "B" notation based on its interpretation of the available data in the scientific literature. In this case, the rationale for the notation is provided in the *Documentation* for the particular Index. Such background concentrations are incorporated in the BEI® value.

"Nq" = Nonquantitative

Biological monitoring should be considered for this compound based on the review, however, a specific BEI® could not be determined due to insufficient data.

"Ns" = Nonspecific

The determinant is nonspecific, since it is also observed after exposure to other chemicals.

"Sq" = Semi-quantitative

The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurement is ambiguous. These determinants should be used as a screening test if a quantitative test is not practical or as a confirmatory test if the quantitative test is not specific and the origin of the determinant is in question.

"Pop" = Population based

"Pop" indices are assigned when there are insufficient data to establish a numerical BEI® but where there are sufficient data on background levels in the general population. "Pop" values can be based on the 95th percentile of large studies of the general population, like the NHANES surveys by the CDC, or they can be based on nonoccupationally exposed populations from the scientific literature.

"Pop" values are not health-based and are intended to give the health professional guidance regarding exposures that are likely to be occupational and not from the general environment. A measurement at or above a "Pop" level will have a high probability of resulting from an occupational exposure.

Quality Assurance

Each aspect of biological monitoring should be conducted within an effective quality assurance (QA) program. The appropriate specimen must be collected at the proper time, without contamination or loss, utilizing a suitable container. Donor identification, time of exposure, source of exposure, and the sampling time must be recorded. The analytical method used by the laboratory must have the accuracy, sensitivity, and specificity needed to produce results consistent with the BEI®. Appropriate quality control specimens should be included in the analysis, and the laboratory must follow routine quality control rules. Whenever possible, the laboratory should participate in an external proficiency program.

The occupational health professional may also provide known challenge samples to the laboratory along with worker specimens (e.g., blanks, purchased specimens containing the determinant, or split specimens). These challenges will enable the occupational health professional to assess the ability to process, analyze, and report results properly, and to have confidence in their ability to estimate exposure.

The most effective means for controlling laboratory quality is through an external QA/QC program.

Application of BEIs®

BEIs® are intended as guidelines to be used in the evaluation of potential health hazards in the practice of occupational hygiene. BEIs® do not indicate a sharp distinction between hazardous and nonhazardous exposures. For example, it is possible for an individual's determinant concentration to exceed the BEI® without incurring an increased health risk. If measurements in specimens obtained from a worker on different occasions exceed the BEI®, the cause of the excessive value should be investigated and action taken to reduce the exposure. An investigation is also warranted if measurements in specimens obtained from a group of workers at the same workplace and workshift exceed the BEI®. It is desirable that relevant information on related operations in the workplace be recorded.

Due to the variable nature of concentrations in biological specimens, administrative action should not be normally based on a single result, but on measurements of multiple samplings, or an analysis of a repeat specimen.



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2022 Biological Exposure Indices

Adopted by ACGIH®
with Intended Changes

BEI®

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INTRODUCTION TO THE BIOLOGICAL EXPOSURE INDICES

Biological monitoring provides an important means to assess exposure and health risk to workers. It entails measurement of a chemical determinant in the biological media of those exposed and is an indicator of the uptake of a substance. Biological Exposure Indices (BEIs®) are guidance values for evaluating biological monitoring results. BEIs® generally represent the levels of determinants that are most likely to be observed in specimens collected from healthy workers who have been exposed to chemicals to the same extent as workers with inhalation exposure at the Threshold Limit Value-Time-Weighted Average (TLV-TWA). However, there are BEIs® for chemicals for which the TLVs® are based on protection against nonsystemic effects (e.g., irritation or respiratory impairment) where biological monitoring is desirable because of the potential for significant absorption via an additional route of entry (usually the skin). There are also BEIs® that better predict health effects than air levels and finally, BEIs® that are based on the levels in the environmentally exposed population. The BEI® generally indicates a concentration below which nearly all workers should not experience adverse health effects. The BEI® determinant can be the chemical itself; one or more metabolites; or a characteristic, reversible biochemical change induced by the chemical. The specimens used for BEIs® are urine, blood, or exhaled air. The BEIs® are not intended for use as a measure of adverse effects or for diagnosis of occupational illness.

Biological monitoring can assist the occupational health professional (occupational and industrial hygienists, occupational physicians and nurses, etc.) to determine absorption via the skin or gastrointestinal system, in addition to that by inhalation; assess body burden; reconstruct past exposure; detect nonoccupational exposures among workers; test the efficacy of personal protective equipment and engineering controls; and monitor work practices.

Biological monitoring serves as a complement to exposure assessment by air sampling and medical surveillance. The existence of a BEI® does not indicate a need to conduct biological monitoring. Conducting, designing, and interpreting biological monitoring protocols and the application of the BEI® require professional experience in occupational health and reference to the current edition of the *Documentation of the Threshold Limit Values and Biological Exposure Indices* (ACGIH®).

Editors' note: The approximate year that the current *Documentation* was last substantially reviewed and, where necessary, updated may be found following the CAS number for each of the adopted entries in the alphabetical listing, e.g., Acetone [67-64-1] (2014). The reader is advised to refer to the "BEI® Chronology" section in each *Documentation* for a brief history of the BEI® recommendations and notations.

Documentation

It is essential that the user consult the specific BEI® *Documentation* before designing biological monitoring protocols and interpreting BEIs® for a specific agent. The *Documentation* for each compound contains the explicit information that is only discussed in general in this Introduction. In addition, each BEI® *Documentation* now provides a chronology that traces all BEI® recommended

BEI®

TLV-CS

APPENDIX G: Substances Whose Adopted Documentation and TLVs[®] Were Withdrawn For a Variety of Reasons, Including Insufficient Data, Regrouping, Etc.
 [Individual entries will remain for a 10-year period, commencing with the year of withdrawal.]

Substance (CAS)	Year Withdrawn	Reason
Acetylene (74-86-2)	2015	See Appendix F: Minimal Oxygen Content
Aliphatic hydrocarbon gases, Alkanes (C ₁ -C ₄)	2013	Heptane, Ethane, Propane, Liquid petroleum gas (LPG) and flammable gas — see Appendix F: Minimal Oxygen Content; Butane and isobutane — see Butane, all isomers
Argon (7440-37-1)	2014	See Appendix F: Minimal Oxygen Content
n-Butyl acetate (123-86-4)	2016	See Butyl acetates, all isomers
sec-Butyl acetate (106-46-4)	2016	See Butyl acetates, all isomers
tert-Butyl acetate (84-58-5)	2016	See Butyl acetates, all isomers
Calcium chromate (13755-19-0), as Cr	2018	See Chromium and inorganic compounds
Calcium silicate, synthetic, nonfibrous (1344-95-2)	2016	Insufficient data
Chromium hexacarbonyl (Cr(CO) ₆), as Cr	2018	See Chromium and inorganic compounds
Chromium chloride (14677-61-5)	2018	See Chromium and inorganic compounds
Cyclopentadiene (542-92-7)	2019	See Cyclopentadiene, including Cyclopentadiene
Ethyl cyclopentadiene (7085-65-0)	2018	See Cyclopentadiene, Ethyl and Methyl
Glycerol (56-81-4)	2013	Insufficient data relevant to human occupational exposure

SO-VTL

APPENDIX G: Substances Whose Adopted Documentation and TLVs[®] Were Withdrawn For a Variety of Reasons, Including Insufficient Data, Regrouping, Etc.
 [Individual entries will remain for a 10-year period, commencing with the year of withdrawal] (cont.)

Substance (CAS)	Year Withdrawn	Reason
Helium (7440-59-7)	2014	See Appendix F: Minimal Oxygen Content
Hydrogen (1333-74-0)	2014	See Appendix F: Minimal Oxygen Content
Isobutyl acetate (110-19-0)	2016	See Butyl acetates, all isomers
Isopropyl acetate (108-21-4)	2016	See Butyl acetates, all isomers
Methyl 2-cyanoacrylate (131-06-3)	2018	See Cyanoacrylates, Ethyl and Methyl
Neon (7440-01-9)	2014	See Appendix F: Minimal Oxygen Content
Nitrogen (7727-37-9)	2014	See Appendix F: Minimal Oxygen Content
Mineral (111-80-2), all isomers	2012	See Minerals
Picric acid (142-04-3)	2012	See Picric acid and salts
n-Propyl acetate (103-60-4)	2018	See Butyl acetates, all isomers
Rubber latex (polyisoprene) products (9005-19-7)	2021	See Rubber latex
Selenium dioxide (7782-49-2), as Se	2016	See Chromium and inorganic compounds
Zinc chromite (11103-86-9, 1330-65-9, 37-200-25-1), as Cr	2018	See Chromium and inorganic compounds



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APPENDIX H: Reciprocal Calculation Method for Certain Refined Hydrocarbon Solvent Vapor Mixtures

The reciprocal calculation procedure (RCP) is a method for deriving occupational exposure limits (OELs) for certain refined hydrocarbon solvents based on their bulk composition. Refined hydrocarbon solvents often are found as mixtures created by distillation of petroleum oil over a particular boiling range. These mixtures may consist of up to 200 components consisting of aliphatic (alkanes), cycloaliphatic (cycloalkanes) and aromatic hydrocarbons ranging from 5 to 15 carbons.

The goal of the TLV-CS Committee is to recommend TLVs[®] for all substances where there is evidence of health effects at airborne concentrations encountered in the workplace. When a sufficient body of evidence exists for a particular substance or mixture, a TLV[®] is established. However, hydrocarbon solvents are often complex and variable in composition. The use of the mixture formula, found in Appendix E: Threshold Limit Values for Mixtures, is difficult to apply in such cases because these petroleum mixtures contain a large number of unique compounds, many of which do not have a TLV[®] recommendation. The RCP does not replace TLVs[®] but rather calculates a guidance OEL (e.g., GGV_{h-mix}) based on the composition of a specific complex mixture.

There are two aspects of the RCP — the methodology and the group guidance values (GGVs). The methodology is based on the special case formula found in pre-2004 versions of the Mixture Appendix in TLVs[®] and BEIs[®]. Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, the RCP formula calculates a unique OEL based on the mass composition of the mixture, the GGVs and where applicable, substance-specific TLVs[®].

Group guidance values are categorized based on similar chemical and toxicological concerns. Several entities (both trade groups and regulatory authorities) have adopted group guidance values to utilize with the reciprocal mixture formula (RMF) (Farnner, 1995; UKHSE, 2000; McKee et al., 2005). Two examples of published GGVs are found in Table 1. A mixture-specific time-weighted-average limit (GGV-TWA_{h-mix}) is calculated based on the mass percent makeup of the designated groups utilizing the reciprocal mixture formula and the GGVs from column B or C and TLV[®] values for the substances in column D found in Table 1.

ACGIH[®] considers this method to be applicable for mixtures if the toxic effects of individual constituents are additive (i.e., similar toxicological effect on the same target organ or system). The principal toxicological effects of hydrocarbon solvent constituents are acute central nervous system (CNS) depression (characterized by effects ranging from dizziness and drowsiness to anesthesia), eye, and respiratory irritation (McKee et al., 2005; ECETOC, 1997).

Application

The RCP is a specific use application. It applies only to hydrocarbon solvents containing saturated aliphatics (normal iso-alkanes and cycloalkanes) and aromatics with a carbon number of C₅ to C₁₅ derived from petroleum and

include metabolic, circulatory, and respiratory processes. Acute and chronic exposure to hypoxia can cause physiological adaptation and health. However, there may be some occupational exposure to hypoxia. The onset and severity of hypoxia depend on many factors such as the magnitude of the exposure, the individual's physical condition, work rate, breathing rate, and the health status of the individual. The onset of hypoxia is characterized by increased breathing and increased heart rate. The first symptoms of hypoxia are usually noticed when the oxygen saturation of the blood is less than 90%. An individual's oxygen saturation is between 90% and 100%. Respiratory adjustment occurs in healthy adults to resist hypoxia. For compromised individuals such as emphysema patients, oxygen in the blood should be measured for hemoglobin oxygen saturation. The partial pressure of oxygen in the blood (pO₂) in the pulmonary capillaries is about 100 mmHg. Hemoglobin will be more than 90% saturated and normal levels of oxygen in the blood will be maintained in healthy adults. The alveolar pO₂ is about 100 mmHg. The partial pressure of oxygen in the arterial blood is about 90 mmHg. The partial pressure of oxygen in the venous blood is about 40 mmHg. For additional information on gas exchange and pulmonary physiology, see Silverstein (1997) and Guyton (1991).

The U.S. National Institute for Occupational Safety and Health (NIOSH) used 60 torr as the pO₂ at the minimum level for the health of an individual. The minimum level of pO₂ is less than 132 torr (17.6 kPa). The minimum requirement of 132 torr (17.6 kPa) is based on the fact that the partial pressure of oxygen in the atmosphere at sea level is 159 torr (21.2 kPa). The minimum requirement of 132 torr (17.6 kPa) provides an adequate amount of oxygen for most workers and provides a margin of safety (NIOSH, 1976). However, the minimum level of pO₂ significantly diminishes as the O₂ partial pressure of the atmosphere decreases with increasing altitude, decreases with the passage of low pressure weather events, and decreases with increasing water vapor. Molander (1959) states that, at 5000 feet, the pO₂ of the atmosphere may approach 100 torr because of water vapor and the passage of fronts and air events. At 5000 feet, the pO₂ of the atmosphere may be expected to be less than 120 torr.

The physiological effects of oxygen deficiency and oxygen partial pressure variation with altitude for dry conditions at 20°C are given in Table F-1. No physiological effects due to oxygen deficiency are expected in healthy adults at oxygen partial pressures greater than 132 torr or at elevations less than 5000 feet. Some loss of dark adaptation is reported to occur at elevations greater than 5000 feet. At oxygen partial pressures less than 120 torr (equivalent to an elevation of about 6000 feet or about 5000 feet according to water vapor) and the passage of low pressure weather events, symptoms in unacclimated workers include increased pulmonary ventilation and cardiac output, increased dizziness and impaired judgment, and fatigue. These symptoms are recognized as being incompatible with safe performance of duties.

Accordingly, ACGIH recommends a minimum ambient oxygen partial pressure of 132 torr, which is protective against both oxygen displacing gases and oxygen consuming processes for all ages up to 5000 feet. Figure F-1 is a plot of pO₂ with increasing altitude, showing the recommended minimum value of 132 torr. If the partial pressure of oxygen is less than 132 torr or if it is less than the expected value for that altitude, given in Table F-1, then additional work practices are recommended such as thorough evaluation of the confined space to identify the cause of the low oxygen concentration; use of continuous monitoring equipment with warning devices; informing workers to the altitude of

the work; as adaptation to altitude can require an individual's work capacity by 70%; use of rest-work cycles with reduced work rates and increased rest periods; training, observation, and monitoring of workers; and easy, rapid access to oxygen-supplying respirators that are properly maintained.

Oxygen-displacing gases may have flammable properties or may produce physiological effects so that their identity and source should be thoroughly investigated. Some gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants without other significant physiological effects. A TLV® may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. Atmospheres deficient in O₂ do not provide adequate warning and most simple asphyxiants are odorless. Account should be taken of this factor in limiting the concentration of the asphyxiant, particularly at elevations greater than 5000 feet where the pO₂ of the atmosphere may be less than 120 torr.

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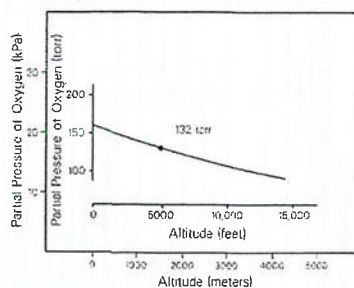


FIGURE F-1. Plot of oxygen partial pressure (pO₂) versus altitude (feet) and meters, showing the recommended oxygen partial pressure of 132 torr.

TABLE F-1. Barometric Pressure, Oxygen Partial Pressure, and Percent Oxygen Concentration Variation with Altitude and Physiological Effect (adapted from Molander, 1959)

Altitude Feet (meters)	Barometric Pressure torr; Dry Air ^a (kilopascals)	pO ₂ torr; Dry Air at 20.948% O ₂ ^b (kilopascals)	%O ₂ Equivalent, Dry Air at Sea Level ^c (percent)	Physiological Effect of pO ₂ Level ^d
0 (0)	760 (101.3)	159 (21.2)	20.9	
1000 (305)	721 (96.4)	153 (20.4)	20.1	
2000 (610)	704 (93.9)	147 (19.6)	19.3	
3000 (914)	677 (90.3)	142 (18.9)	18.7	
4000 (1219)	652 (86.9)	137 (18.3)	18.0	
5000 (1524)	627 (83.6)	131 (17.5)	17.2	Note in healthy adults
6000 (1829)	603 (80.4)	126 (16.8)	16.6	Loss of dark adaptation can occur at elevations above 5000 feet
7000 (2134)	580 (77.2)	121 (16.1)	16.0	Increased pulmonary ventilation and cardiac output, increased dizziness, and impaired judgment; fatigue
8000 (2438)	559 (74.5)	117 (15.6)	15.4	Rapid exposure to altitudes over 8000 feet may cause high altitude sickness (respiratory alkalosis, headache, nausea, and vomiting) in unacclimated individuals. Rapid ascent increases the risk of high altitude pulmonary edema and cerebral edema
9000 (2743)	537 (71.6)	112 (14.9)	14.7	
10000 (3048)	517 (68.9)	108 (14.4)	14.2	
11000 (3353)	498 (66.4)	104 (13.9)	13.7	Abnormal fatigue on exertion, faulty coordination, impaired judgment, emotional upset
12000 (3658)	479 (63.8)	100 (13.2)	13.2	
13000 (3962)	461 (61.5)	98 (12.9)	12.8	
14000 (4267)	443 (59.1)	93 (12.4)	12.2	Impaired respiration, very poor judgment and coordination, tunnel vision

^aCalculated from P_t , sea level = 760 mm Hg (101.3 kPa).

^bCalculated from $pO_2 = 0.20948 \times P_t$ (torr) or $pO_2 = 0.20948 \times P_t$ (kPa).

^cCalculated from: $\%O_2 = 20.948 \times \frac{pO_2}{P_t}$ (torr) or $\%O_2 = 20.948 \times \frac{pO_2}{P_t}$ (kPa).

^dThe approximate physiological effect in healthy adults is influenced by duration of the oxygen deficiency, work rate, breathing rate, temperature, health status, age and pulmonary acclimatization.

TLV®-CS

Common	Latin
TROPICAL WOODS	
African ash	<i>Pouteria</i>
African cedar	<i>Microbailina</i>
Antalis	<i>Antaris africana</i> <i>Antaris toxicaria</i>
Cabreva	<i>Myrcarpus fastigatus</i>
Cedar of Lebanon	<i>Cedra libani</i>
Central American walnut	<i>Juglans planchana</i>
Coccoloba	<i>Dalbergia retusa</i>
African ebony	<i>Diospyros crassiflora</i>
Fernam latic	<i>Caesalpinia</i>
Honduras rosewood	<i>Dalbergia stevensoni</i>
Iroko or kambala	<i>Khaya excelsa</i>
Kaapi	<i>Pterocarpus angianis</i>
Kutea	<i>Hesargordonia rapaytvera</i>
Limba	<i>Tarcinolia superba</i>
Manogany (African)	<i>Khaya spp.</i>
Makore	<i>Teghmetella ricketsi</i>
Mansonia/Bete	<i>Mansonia elstina</i>
Nara	<i>Pterocarpus excelsa</i>
Obeche/African maple/Samoa	<i>Trochodon sclerophyllon</i>
Okume	<i>Fucomma klansana</i>
Palisander (Brazilian rosewood)	<i>Dalbergia nigra</i>
Tulip wood/Jakaranda	
Pau marim	<i>Saurodendron niefianum</i>
Ramin	<i>Constylus bancanus</i>
Soapbark dust	<i>Quilaja saponaria</i>
Spindle tree wood	<i>Evonymus europaeus</i>
Tanganyika aninga	

APPENDIX E: Threshold Limit Values for Mixtures

Most threshold limit values are developed for a single chemical substance. However, the work environment is often composed of multiple chemical exposures both simultaneously and sequentially. It is recommended that multiple exposures that comprise such work environments be examined to assure that workers do not experience harmful effects.

There are several possible modes of chemical mixture interaction. Additivity occurs when the combined biological effect of the components is equal to the sum of each of the agents given alone. Synergy occurs where the combined effect is greater than the sum of each agent. Antagonism occurs when the combined effect is less.

The general ACGIH® mixture formula applies to the additive model. It is utilized when additional protection is needed to account for this combined effect:

The guidance contained in this Appendix does not apply to substances in mixed phases.

Application of the Additive Mixture Formula

The "TLV® Basis" column found in the table of Adopted Values lists the adverse effect(s) upon which the TLV® is based. This column is a resource that may help alert the reader to the additive possibilities in a chemical mixture and the need to reduce the combined TLV® of the individual components. Note that the column does not list the deleterious effects of the agent, but rather, lists only the adverse effect(s) upon which the threshold limit was based. The current Documentation of the TLVs® and BEIs® should be consulted for toxic effects information, which may be of use when assessing mixture exposures.

When two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or system is the same.

That is, if the sum of

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n}$$

exceeds unity, the threshold limit of the mixture should be considered as being exceeded (where C_1 indicates the observed atmospheric concentration and T_1 is the corresponding threshold limit; see example). It is essential that the atmosphere is analyzed both qualitatively and quantitatively for each component present in order to evaluate the threshold limit of the mixture.

The additive formula applies to simultaneous exposure for hazardous agents with TWA, STEL, and Ceiling values. The threshold limit value time interval base (TWA, STEL, and Ceiling) should be consistent where possible. When agents with the same toxicological effect do not have a corresponding TLV® type, use of mixed threshold limit value types may be warranted. Table E-1 lists possible combinations of threshold limits for the additive mixture formula. Multiple calculations may be necessary.

Where a substance with a STEL or Ceiling limit is mixed with a substance with a TLV-TWA but no STEL, comparison of the short-term limit with the applicable peak exposure may be appropriate. The maximum peak exposure is defined as a value five times the TLV-TWA limit. The amended formula would be:

TABLE E-1. Possible Combinations of Threshold Limits When Applying the Additive Mixture Formula

Full Shift or Short Term	Agent A	Agent B
Full Shift	TLV-TWA	TLV-TWA
Full Shift	TLV-TWA	TLV-Ceiling
Short Term	TLV-STEL	TLV-STEL
Short Term	TLV-Ceiling	TLV-Ceiling
Short Term	Peak exposure where there is no STEL (5 times TLV-TWA value)	TLV-Ceiling or TLV-STEL
Short Term	TLV-STEL	TLV-Ceiling

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$$\frac{C_1}{T_{1STEL}} + \frac{C_2}{(T_2/5)} \leq 1$$

where: T_{1STEL} = the TLV-STEL
 T_2 = the TLV-TWA of the agent with no STEL

The additive model also applies to consecutive exposures of agents that occur during a single workshift. Those substances that have TLV-TWAs (and STELs or peak exposure limits) should generally be handled the same as if they were the same substance, including attention to the recovery periods for STELs and peak exposure limits as indicated in the "Introduction to Chemical Substances." The formula does not apply to consecutive exposures of TLV-Ceilings.

Limitations and Special Cases

Exceptions to the above rule may be made when there is a good reason to believe that the chief effects of the different harmful agents are not additive. This can occur when neither the toxicological effect is similar nor the target organ is the same for the components. This can also occur when the mixture interaction causes inhibition of the toxic effect. In such cases, the threshold limit ordinarily is exceeded only when at least one member of the series (C_1/T_1 or C_2/T_2 , etc.) itself has a value exceeding unity.

Another exception occurs when mixtures are suspected to have a synergistic effect. The use of the general additive formula may not provide sufficient protection. Such cases at present must be determined individually. Potentiating effects of exposure to such agents by routes other than that of inhalation are also possible. Potentiation is characteristically exhibited at high concentrations, less probably at low. For situations involving synergistic effects, it may be possible to use a modified additive formula that provides additional protection by incorporating a synergy factor. Such treatment of the TLVs® should be used with caution, as the quantitative information concerning synergistic effects is sparse.

Care must be considered for mixtures containing carcinogens in categories A1, A2, or A3. Regardless of application of the mixture formula, exposure to mixtures containing carcinogens should be avoided or maintained as low as possible. See Appendix A.

The additive formula applies to mixtures with a reasonable number of agents. It is not applicable to complex mixtures with many components (e.g., gasoline, diesel exhaust, thermal decomposition products, fly ash, etc.).

Example

A worker's airborne exposure to solvents was monitored for a full shift as well as one short-term exposure. The results are presented in Table E-2.

TABLE E-2. Example Results

Agent	Full-Shift Results (TLV-TWA)	Short-Term Results (TLV-STEL)
1) Acetone	80 ppm (250 ppm)	325 ppm (500 ppm)
2) Cyclohexanone	2 ppm (20 ppm)	7.5 ppm (50 ppm)
3) Methyl ethyl ketone	90 ppm (200 ppm)	220 ppm (300 ppm)

According to the Documentation of the TLVs® and BEIs®, all three substances indicate irritation effects on the respiratory system and thus would be considered additive. Acetone and methyl ethyl ketone exhibit central nervous system effects.

Full-shift analysis would utilize the formula:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} \leq 1$$

thus,

$$\frac{80}{250} + \frac{2}{20} + \frac{90}{200} = 0.32 + 0.10 + 0.45 = 0.87$$

The full-shift mixture limit is not exceeded.

Short-term analysis would utilize the formula:

$$\frac{C_1}{T_{1STEL}} + \frac{C_2}{T_{2STEL}} + \frac{C_3}{T_{3STEL}} \leq 1$$

thus,

$$\frac{325}{500} + \frac{7.5}{50} + \frac{220}{300} = 0.65 + 0.15 + 0.73 = 1.53$$

The short-term mixture limit is exceeded.

APPENDIX F: Minimal Oxygen Content

Adequate oxygen delivery to the tissues is necessary for sustaining life and depends on 1) the level of oxygen in inspired air, 2) the presence or absence of lung disease, 3) the level of hemoglobin in the blood, 4) the kinetics of oxygen binding to hemoglobin (oxy-hemoglobin dissociation curve), 5) the cardiac output, and 6) local tissue blood flow. For the purpose of the present discussion, only the effects of decreasing the amount of oxygen in inspired air are considered.

The brain and myocardium are the most sensitive tissues to oxygen deficiency. The initial symptoms of oxygen deficiency are increased ventilation, increased cardiac output, and fatigue. Other symptoms that may develop

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possible. For A1 carcinogens with a TLV[®] and for A2 and A3 carcinogens, worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV[®] as indicated by the TLV endpoints in the TLV[®] table.

APPENDIX B: Particles (insoluble or poorly soluble) Not Otherwise Specified (PNOS)

The goal of the TLV[®]CS Committee is to recommend TLVs[®] for all substances for which there is evidence of health effects at airborne concentrations encountered in the workplace. When a sufficient body of evidence exists for a particular substance, a TLV[®] is established. Thus, by definition the substances covered by this recommendation are those for which little data exist. The recommendation at the end of this Appendix is supplied as a guideline rather than a TLV[®] because it is not possible to meet the standard level of evidence used to assign a TLV[®]. In addition, the PNOS TLV[®] and its predecessors have been misused in the past and applied to any unlisted particles rather than those meeting the criteria listed below. The recommendations in this Appendix apply to particles that:

- Do not have an applicable TLV[®];
- Are insoluble or poorly soluble in water (or, preferably, in aqueous lung fluid if data are available); and
- Have low toxicity (i.e., are not cytotoxic, genotoxic, or otherwise chemically reactive with lung tissue, and do not emit ionizing radiation, cause immune sensitization, or cause toxic effects other than by inflammation or the mechanism of "lung overload").

ACGIH[®] believes that even biologically inert, insoluble, or poorly soluble particles may have adverse effects and recommends that airborne concentrations should be kept below 3 mg/m³ respirable particles, and 10 mg/m³ inhalable particles, until such time as a TLV[®] is set for a particular substance.

APPENDIX C: Particle Size-Selective Sampling Criteria for Airborne Particulate Matter

For chemical substances present in inhaled air as suspensions of solid particles or droplets, the potential hazard depends on particle size as well as mass concentration because of 1) effects of particle size on the deposition site within the respiratory tract and 2) the tendency for many occupational diseases to be associated with material deposited in particular regions of the respiratory tract.

ACGIH[®] has recommended particle size-selective TLVs[®] for crystalline silica for many years in recognition of the well-established association between silicosis and respirable mass concentrations. The TLV[®]CS Committee is now re-examining other chemical substances encountered in particle form in

occupational environments with the objective of defining 1) the size-fraction most closely associated for each substance with the health effect of concern and 2) the mass concentration within that size fraction which should represent the TLV[®].

The Particle Size-Selective TLVs[®] (PSS-TLVs) are expressed in three forms:

1. *Inhalable Particulate Matter TLVs[®]* (IPM-TLVs) for those materials that are hazardous when deposited anywhere in the respiratory tract.
2. *Thoracic Particulate Matter TLVs[®]* (TPM-TLVs) for those materials that are hazardous when deposited anywhere within the lung airways and the gas-exchange region.
3. *Respirable Particulate Matter TLVs[®]* (RPM-TLVs) for those materials that are hazardous when deposited in the gas-exchange region.

The three particulate matter fractions described above are defined in quantitative terms in accordance with the following equations (ACGIH[®], 1985, 1999; Soderholm, 1989):

- A. IPM fraction consists of those particles that are captured according to the following collection efficiency regardless of sampler orientation with respect to wind direction:

$$IPM(d_{50}) = 0.5 [1 - \exp(-0.06 d_{50})]$$

for $0 < d_{50} \leq 100 \mu m$

where: IPM(d_{50}) = the collection efficiency
 d_{50} = aerodynamic diameter of particle in μm

- B. TPM fraction consists of those particles that are captured according to the following collection efficiency:

$$TPM(d_{50}) = IPM(d_{50}) [1 - F(x)]$$

where: F(x) = cumulative probability function of the standardized normal variable, x

$$x = \frac{\ln(d_{50}/\Gamma)}{\ln(\Sigma)}$$

ln = natural logarithm
 $\Gamma = 11.64 \mu m$
 $\Sigma = 1.5$

- C. RPM fraction consists of those particles that are captured according to the following collection efficiency:

$$RPM(d_{50}) = IPM(d_{50}) [1 - F(x)]$$

where F(x) = same as above, but with $\Gamma = 4.25 \mu m$ and $\Sigma = 1.5$

The most significant difference from previous definitions is the increase in the median cut point for a respirable particulate matter sampler from 3.5 μm to 4.0 μm ; this is in accord with the International Organization for Standardization/European Standardization Committee (ISO/CEN) protocol (ISO, 1995; CEN,

1993). At this time, no change is recommended for the measurement of respirable particles using a 10-mm nylon cyclone at a flow rate of 1.7 liters per minute. Two analyses of available data indicate that the flow rate of 1.7 liters per minute allows the 10-mm nylon cyclone to approximate the particulate matter concentration which would be measured by an ideal respirable particulate sampler as defined herein (Bartley, 1991; Lidén and Kenny, 1993).

Collection efficiencies representative of several sizes of particles in each of the respective mass fractions are shown in Tables 1, 2, and 3. Documentation for the respective algorithms representative of the three mass fractions is found in the literature (ACGIH[®], 1989; ISO, 1995).

TABLE 1. Inhalable Fraction

Particle Aerodynamic Diameter (μm)	Inhalable Particulate Matter (IPM) Fraction Collected (%)
0	100
1	97
2	94
5	87
10	77
20	65
30	58
40	54.5
50	52.5
100	50

TABLE 2. Thoracic Fraction

Particle Aerodynamic Diameter (μm)	Thoracic Particulate Matter (TPM) Fraction Collected (%)
0	100
2	94
4	89
6	80.5
8	67
10	50
12	35
14	23
16	15
18	9.5
20	6
25	2

TABLE 3. Respirable Fraction

Particle Aerodynamic Diameter (μm)	Respirable Particulate Matter (RPM) Fraction Collected (%)
0	100
1	97
2	91
3	74
4	50
5	30
6	17
7	9
8	5
10	1

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APPENDIX D: Commercially Important Tree Species Suspected of Inducing Sensitization

Common	Latin
SOFTWOODS	
California redwood	<i>Sequoia sempervirens</i>
Eastern white cedar	<i>Thuja occidentalis</i>
Pine	<i>Pinus</i>
Western red cedar	<i>Thuja plicata</i>
HARDWOODS	
Ash	<i>Fraxinus</i> spp.
Aspen/Poplar/Cottonwood	<i>Populus</i>
Beech	<i>Fagus</i>
Oak	<i>Quercus</i>

While relatively limited quantitative data currently exist with regard to skin absorption of gases, vapors, and liquids by workers, ACGIH® recommends that the information of data from acute dermal studies and repeated-dose dermal studies in animals and humans, along with the ability of the chemicals to be absorbed, be used in deciding on the appropriateness of this Skin notation. In general, available data which suggest that the potential for absorption via the hands and forearms during the workday could be significant, especially for chemicals with lower TLVs®, could justify a Skin notation. From acute animal toxicity data, materials having a relatively low dermal LD₅₀ (i.e., 1000 mg/kg of body weight or less) would be given a Skin notation. When chemicals penetrate the skin easily (i.e., higher octanol-water partition coefficients) and where extrapolations of systemic effects from other routes of exposure suggest dermal absorption may be important in the expressed toxicity, a Skin notation would be considered. A Skin notation is not applied to chemicals that cause irritation or corrosive effects in the absence of systemic toxicity.

Substances having a Skin notation and a low TLV® may present special problems for operations involving high airborne concentrations of the material, particularly under conditions where significant areas of the skin are exposed for a long period. Under these conditions, special precautions to significantly reduce or preclude skin contact may be required.

Biological monitoring should be considered to determine the relative contribution to the total dose from exposure via the dermal route. ACGIH® recommends a number of adopted Biological Exposure Indices (BEIs®) that provide an additional tool when assessing the total worker exposure to selected materials. For additional information, refer to *Dermal Absorption in the Introduction to the Biological Exposure Indices*, *Documentation of the Biological Exposure Indices* (2001), and to Leung and Paustenbach (1994). Other selected readings on skin absorption and the skin notation include Santorelli (2002), Schneider et al. (2000), Wester and Mabach (2000), Kennedy et al. (1992), Fiserova-Bergelova et al. (1990), and Scansetti et al. (1988).

The use of a Skin notation is intended to alert the reader that air sampling alone is insufficient to quantify exposure accurately and that measures to prevent significant cutaneous absorption may be required.

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All pertinent notes relating to the material in the Chemical Substances section of this book appear in the appendices for this section or on the inside back cover.


ADOPTED APPENDICES APPENDIX A: Carcinogenicity

ACGIH® has been aware of the increasing public concern over chemicals or industrial processes that cause or contribute to increased risk of cancer in workers. More sophisticated methods of bioassay, as well as the use of sophisticated mathematical models that extrapolate the levels of risk among workers, have led to differing interpretations as to which chemicals or processes should be categorized as human carcinogens and what the maximum exposure levels should be. The categories for carcinogenicity are:

- A1 — **Confirmed Human Carcinogen:** The agent is carcinogenic to humans based on the weight of evidence from epidemiologic studies.
- A2 — **Suspected Human Carcinogen:** Human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as a confirmed human carcinogen; or, the agent is carcinogenic in experimental animals at dose(s), by route(s) of exposure, at site(s), of histologic type(s), or by mechanism(s) considered relevant to worker exposure. The A2 is used primarily when there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals is supported by mechanistic evidence of key characteristics of carcinogens that are relevant to humans.
- A3 — **Confirmed Animal Carcinogen with Unknown Relevance to Humans:** The agent is carcinogenic in experimental animals at a relatively high dose, by route(s) of administration, at site(s), of histologic type(s), or by mechanism(s) that may not be relevant to worker exposure. Available epidemiologic studies do not confirm an increased risk of cancer in exposed humans. Available experimental animal evidence suggests mechanisms and/or dosimetry that the agent is unlikely to cause cancer in humans except under improbable routes or levels of exposure.
- A4 — **Not Classifiable as a Human Carcinogen:** Agents which cause concern that they could be carcinogenic for humans, but which cannot be assessed conclusively because of a lack of human data. *In vitro* or animal studies do not provide mechanistic evidence of key characteristics of carcinogenicity which are sufficient to classify the agent into one of the other categories.
- A5 — **Not Suspected as a Human Carcinogen:** The agent is not suspected to be a human carcinogen on the basis of properly conducted epidemiologic studies in humans. These studies have sufficiently long follow-up, reliable exposure histories, sufficiently high dose, and adequate statistical power to conclude that exposure to the agent does not convey a significant risk of cancer to humans, or the evidence suggesting a lack of carcinogenicity in experimental animals is supported by mechanistic data demonstrating a lack of the key characteristics of carcinogenicity.


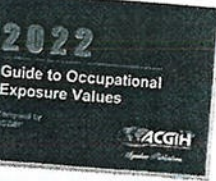
Note: Substances for which no human or experimental animal carcinogenicity data are available and no strong genotoxicity data have been reported are assigned no carcinogenicity designation.

Exposure to carcinogens must be kept to a minimum. Worker exposures to A1 carcinogens without a TLV® should be eliminated to the fullest extent



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by the ACGIH® Board of Directors. The proposals should be considered trial values during the period they are on the NIC. If the Committee neither finds nor receives any substantive data that change its scientific opinion regarding an NIC TLV®, the Committee may then approve its recommendation to the ACGIH® Board of Directors for adoption. If the Committee finds or receives substantive data that change its scientific opinion regarding an NIC TLV®, the Committee may change its recommendation to the ACGIH® Board of Directors for the matter to be either retained on or withdrawn from the NIC. Values appearing in parentheses in the Adopted TLV® section are to be used during the period in which a proposed change for that value or notation appears on the NIC.

Particulate Matter/Particle Size

For solid and liquid particulate matter, TLVs® are expressed in terms of "total" particulate matter, except where the terms inhalable, thoracic, or respirable particulate matter are used. The intent of ACGIH® is to replace all "total" particulate TLVs® with inhalable, thoracic, or respirable particulate mass TLVs®. Side-by-side sampling using "total" and inhalable, thoracic, or respirable sampling techniques is encouraged to aid in the replacement of current "total" particulate TLVs®. See Appendix C: Particle Size-Selective Sampling Criteria for Airborne Particulate Matter, for the definitions of inhalable, thoracic, and respirable particulate matter.

Particles (insoluble or poorly soluble) Not Otherwise Specified (PNOS)

There are many insoluble particles of low toxicity for which no TLV® has been established. ACGIH® believes that even biologically inert, insoluble or poorly soluble particles may have adverse effects and suggests that airborne concentrations should be kept below 3 mg/m³, respirable particles, and 10 mg/m³, inhalable particles, until such time as a TLV® is set for a particular substance. A description of the rationale for this recommendation and the criteria for substances to which it pertains are provided in Appendix B.

TLV® Basis

TLVs® are derived from publicly available information summarized in their respective Documentation. Although adherence to the TLV® may prevent several adverse health effects, it is not possible to list all of them in this book. The basis on which the values are established will differ from agent to agent (e.g., protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance, or other forms of stress may form the basis for others). Health impairments considered include those that shorten life expectancy, adversely affect reproductive function or developmental processes, compromise organ or tissue function, or impair the capability for resisting other toxic substances or disease processes.

The TLV® Basis represents the adverse effect(s) upon which the TLV® is based. The TLV® Basis column in this book is intended to provide a field reference for symptoms of overexposure and as a guide for determining whether components of a mixed exposure should be considered as acting independently or additively. Use of the TLV® Basis column is not a substitute

for reading the Documentation. Each Documentation is a critical component for proper use of the TLV(s)® and to understand the TLV® basis. A complete list of the TLV® bases used by the Threshold Limit Values for Chemical Substances Committee may be found in their Operations Manual online at: tcgh.org/TLV-guidelines/policies-and-procedures (these materials are also in the operations manual).

Abbreviations used

carb - carbonyl	inhal - inhalation
CNS - central nervous system	int - irritation
COH-em - carboxyhemoglobinemia	ir - irritation
conv - convulsion	LRT - lower respiratory tract
dam - damage	met - metabolism
eff - effects	met - metabolism
form - formation	MS - muscular system
func - function	MS - muscular system
GI - gastrointestinal	MS - muscular system
Hb - hemoglobin	MS - muscular system
	MS - muscular system

Notations/Endnotes

Biological Exposure Indices (BEIs®)

The notation "BE" is used in the Notations column when a BEI® (or BEIs®) is (are) also recommended for the substance. These subcategories to the "BE" notation have been added to help the user identify those substances that would use only the BEI® for Chromosomal and Related Effects or Methemoglobin Inducers. They are as follows:

BEI_C = See the BEI® for Chromosomal and Related Effects

BEI_M = See the BEI® for Methemoglobin Inducers

BEI_P = See the BEI® for Polycyclic aromatic hydrocarbons (PAHs)

Biological monitoring should be instituted for all substances to evaluate the total exposure from all sources, including occupational and nonoccupational. See the BEI® section in this book and the Documentation for the TLVs® and BEIs® for these substances.

Carcinogenicity

A carcinogen is an agent capable of inducing benign or malignant neoplasms. Evidence of carcinogenicity comes from epidemiology, toxicology, and mechanistic studies. Specific notations (i.e., A1, A2, A3, A4, and A5) are used by ACGIH® to define the categories for carcinogenicity and are listed in the Notations column. See Appendix A for these categories and definitions and their relevance to humans in occupational settings.

Inhalable Fraction and Vapor (IFV)

The Inhalable Fraction and Vapor (IFV) notation is used when a material exerts sufficient vapor pressure such that it may be present in both particle

and vapor phases, with each contributing a significant portion of the dose at the TLV-TWA concentration. The ratio of the Saturated Vapor Concentration (SVC) to the TLV-TWA is considered when assigning the IFV endnote. The IFV endnote is typically used for substances with an SVC/TLV® ratio between 0.1 and 10.

The industrial hygienist should also consider both particle and vapor phases to assess exposures from spraying operations, from processes involving temperature changes that may affect the physical state of matter, when a significant fraction of the vapor is dissolved into or adsorbed onto particles of another substance, such as water-soluble compounds in high humidity environments (Peraz and Soderholm, 1991).

Ototoxicant

The designation "OTO" for hearing disorders in the "Notations" column highlights the potential for a chemical to cause hearing impairment alone or in combination with noise, even below 85 dBA. The OTO notation is reserved for chemicals that have been shown, through evidence from animals or humans, to adversely affect anatomical structure or auditory function, manifested as a permanent audiometric threshold shift and/or difficulties in processing sounds. Some substances appear to act synergistically with noise, whereas others may potentiate noise effects. The OTO notation is intended to focus attention, not only on engineering controls, administrative controls and PPE needed to reduce airborne concentrations, but also on other means of preventing excessive combined exposures with noise to prevent hearing disorders. Specifically, affected employees may need to be enrolled in hearing conservation and medical surveillance programs to more closely monitor auditory capacity, even when noise exposures do not exceed the TLV® for Audible Sound. Please refer to the section on Ototoxicity in the TLV® Documentation for Audible Sound.

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Sensitization

The designations, "DSEN" and/or "RSEN", in the "Notations" column in the TLVs® and BEIs® book refer to the potential for an agent to produce dermal and/or respiratory sensitization. RSEN and DSEN are used in place of the SEN notation when specific evidence of sensitization by that route is confirmed by human or animal data. The DSEN and RSEN notations do not imply that sensitization is the critical effect on which the TLV® is based, nor do they imply that this effect is the sole basis for that agent's TLV®. If sensitization data exist, they are carefully considered when recommending the TLV® for the agent.

TLVs® that are based upon sensitization are meant to protect workers from induction of this effect. These TLVs® are not intended to protect those workers who have already become sensitized.

In the workplace, respiratory or dermal exposures to sensitizing agents may occur. Similarly, sensitizers may evoke respiratory or dermal reactions. The notation does not distinguish between sensitization involving any of these tissues. The absence of a DSEN or RSEN notation does not signify that the agent lacks the ability to produce sensitization but may reflect the paucity or inconclusiveness of scientific evidence.

Sensitization often occurs via an immunologic mechanism and should not be confused with hyperactivity, susceptibility, or sensitivity. Initially, there may be little or no response to a sensitizing agent. However, after a person is sensitized, subsequent exposure may cause intense responses, even at low exposure concentrations (well below the TLV®). These reactions may be life-threatening and may have an immediate or delayed onset. Workers who have become sensitized to a particular agent may also exhibit cross-reactivity to other agents that have similar chemical structures. A reduction in exposure to the sensitizer and its structural analogs generally reduces the frequency or severity of reactions among sensitized individuals. For some sensitized individuals, complete avoidance of exposure to the sensitizer and structural analogs provides the only means to prevent the specific immune response.

Agents that are potent sensitizers present special problems in the workplace. Respiratory and dermal exposures should be significantly reduced or eliminated through process control measures and personal protective equipment. Education and training (e.g., review of potential health effects, safe handling procedures, emergency information) are also necessary for those who work with known sensitizing agents.

For additional information regarding the sensitization potential of a particular agent, refer to the TLV® Documentation for the specific agent.

Skin

The designation "Skin" in the "Notations" column refers to the potential significant contribution to the overall exposure by the cutaneous route, including mucous membranes and the eyes, by contact with vapors, liquids and solids. Where dermal application studies have shown absorption that could cause systemic effects following exposure, a Skin notation would be considered. The Skin notation also alerts the industrial hygienist that overexposure may occur following dermal contact with liquid and aerosols, even when airborne exposures are at or below the TLV®.

A Skin notation is not applied to chemicals that may cause dermal irritation. However, it may accompany a sensitizer notation for substances that cause respiratory sensitization following dermal exposure. Although not considered when assigning a Skin notation, the industrial hygienist should be aware that there are several factors that may significantly enhance potential skin absorption of a substance that otherwise has low potential for the cutaneous route of entry. Certain vehicles can act as carriers, and when pre-treated on the skin or mixed with a substance can promote the transfer of the substance into the skin. In addition, the existence of some dermatologic conditions can also significantly affect the entry of substances through the skin or wound.



2022 ACGIH Webinars Lineup

ACGIH has an exciting lineup of webinars for 2022! These webinars include a wide range of topics such as wearable devices, respirator fit testing, and pandemic facility risk assessment. ACGIH webinars are taught by OEHHS experts and provide you with opportunities to expand your career depth. Here are some of the upcoming webinars in 2022!

January 12 – Risk Assessing Facility Pandemic Resilience

January 26 – Respirator Fit Testing: Common Errors and Solutions

February 9 – How the adoption of Revision 7 of the GHS of classification and labelling of chemicals in Canada and the US impact your SDSs and Labels

February 23 – Epidemiology-Based Analysis of Musculoskeletal Injuries: A Forensic Approach

March 9 – An Overview of U.S. Regulations Governing Hazards

April 6 – Wearable Sensing Devices for Worker Safety and Health



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CHEMICAL SUBSTANCES AND OTHER ISSUES UNDER STUDY

The TLV® Chemical Substances Committee solicits information, especially data, which may assist in its deliberations regarding the following substances and issues. Comments and suggestions, accompanied by substantiating evidence in the form of peer-reviewed literature, should be forwarded in electronic format to the ACGIH® Science Group at science@acgih.org. In addition, the Committee solicits recommendations for additional substances and issues of concern to the industrial hygiene and occupational health communities. Please refer to the ACGIH® TLV®/BE® Development Process found on the ACGIH® website for a detailed discussion covering this procedure and methods for input to ACGIH® (acgih.org/science/tlv-be-guidelines-development-process-presentations/tlv-be-development).

The Under Study list is published each year by February 1 on the ACGIH® website (acgih.org/science/tlv-be-guidelines/documentation/publications-and-data/under-study). In the *Annual Reports of the Committees on TLVs® and BEs®*, and later in the *annual TLVs® and BEs®* book. In addition, the Under Study list is updated by July 31 into a two-tier list.

Tier 1 entries indicate which chemical substances and physical agents may move forward as an NIC or BE in the upcoming year, based on their status in the development process.

Tier 2 consists of those chemical substances and physical agents that will not move forward, but will either remain on, or be removed from the Under Study list for the next year.

This updated list will remain in two tiers for the balance of the year. ACGIH® will continue this practice of updating the Under Study list by February 1 and establishing the two-tier list by July 31 each year.

The substances and issues listed below are as of January 1, 2022. After this date, please refer to the ACGIH® website (acgih.org/science/tlv-be-guidelines/documentation/publications-and-data/under-study) for the up-to-date list.

Chemical Substances

Acetyl salicylic acid	Carbon monoxide
Acrolein	Carbon nanotubes
Alkyl arylates	Chlorodiphenyl 42%
Anisidine	Chlorodiphenyl 54%
Antimony and compounds, as Sb	Chloromethyl methyl ether
Benzosulfide	Cobalt carbonyl, as Co
Benzidine	Cobalt hydrocarbyl
Bifenazate	Copper
Bupropion	Desflurane
1,3-Butadiene	Diacetyl
Cadmium	Diazinon
Cadmium carbonate	Dicamba
Cadmium hydroxide	3,3'-Dichlorobenzidine
Cadmium nitrate	Diesel exhaust
Caoloid	Difluorodibromomethane
Carbon dioxide	Diiodomethyl or poly sulfone

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Dimethenamid-P
1,2-Dimethoxyethane
Dimethyl carbamoyl chloride
1,4-Dioxane
Enflurane
Epichlorohydrin
Ethyl acrylate
Ethyl ether
Ethylene
Fenoxycarb
Fentanyl
Fluorides
Formic Acid
Furan
Furfural
Furfuryl alcohol
Germanium tetrahydride
Gram-negative bacterial endotoxins
Hainium and compounds
Halothane
Hydrogen peroxide
2-Hydroxy-4-methoxybenzo-phenone (oxybenzone)
Indole
Indomethacin
Indium and compounds
Isoprene
4-Isopropylidene diphenol (BPA)
Lead and inorganic compounds, as Pb
Malathion
Manganese cyclopentadienyl tricarbonyl
Methyl acrylate
Methyl ethyl ketone (2-butanone)
Methyl n-butyl ketone (2-Hexanone)
2-Methylcyclopentadienyl manganese tricarbonyl
4,4'-Methylene bis(2-chloroaniline)
Methylene bisphenyl isocyanate
Methyltetrahydrophthalic anhydride isomers
Metribuzin
Molybdenum
1-Naphthylamine
2-Naphthylamine (Beta)
Nickel and inorganic compounds, including Nickel subsulfide, as Ni

Nitroglycerin
Octachloronaphthalene
Parathion
Pentaborane
m-Phenylenediamine
o-Phenylenediamine
p-Phenylenediamine
Phosphoric acid
Phosphorus (white)
Phosphorus (yellow)
Phthalic anhydride
Propylene sulfone
Propylene dichloride
(1,2-Dichloropropane)
Sevoflurane
Sodium hypochlorite
Sodium silicates
Stoddard solvent
Styrene Oxide
Sublimis
Talc
Tetraethyl lead
1,2,3,6-Tetrahydrophthalic anhydride
Tetramethyl lead
Tin, organic compounds
Tolclofos-methyl
Trichloronaphthalene
Triclorpyr
Triethanolamine
Trioxystrobin
Trimellitic anhydride
Uranium and compounds
Vinylidene chloride
Vinylidene fluoride
Welding fumes

DEFINITIONS AND NOTATIONS

Definitions

Documentation

The source publication that provides the critical evaluation of the pertinent scientific information and data with reference to literature sources upon which each TLV® or BE® is based. See the discussion under "TLV®/BE® Development Process: An Overview" found at the beginning of this book. The general outline used when preparing the Documentation may be found in the Operations Manual of the Threshold Limit Values for Chemical Substances (TLV®-CS) Committee, accessible online at: acgih.org/about/volunteer-leadership/committees/committee-operations-manuals.

Minimal Oxygen Content

An oxygen (O₂)-deficient atmosphere is defined as one with an ambient pO₂ less than 132 torr (NIOSH, 1980). The minimum requirement of 19.5% oxygen at sea level (148 torr O₂ dry air) provides an adequate amount of oxygen for most work assignments and includes a margin of safety (NIOSH, 1987; McManus, 1999). Studies of pulmonary physiology suggest that the above requirements provide an adequate level of oxygen pressure in the lungs (alveolar pO₂ of 60 torr) (Silverthorn, 2001; Guyton, 1991; NIOSH, 1976).

Some gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants, without other significant physiologic effects. A simple asphyxiant may not be assigned a TLV® because the limiting factor is the available oxygen. Atmospheres deficient in O₂ do not provide adequate warning and most simple asphyxiants are odorless. Account should be taken of this factor in limiting the concentration of the asphyxiant particularly at elevations greater than 5000 feet where the pO₂ of the atmosphere is less than 120 torr. Several simple asphyxiants present an explosion hazard. See page 65 for adopted Appendix F: Minimal Oxygen Content.

Nanomaterials

Nanomaterials are objects that are 100 nm or smaller in one or more dimension. Substances composed of nanomaterials, even when agglomerated, may have greater or different toxicity than the same substance in fine or sometimes called "bulk" form. When supported by the literature, ACGIH® may differentiate TLVs® for nanomaterials.

Notation

A notation is a designation that appears as a component of the TLV® in which specific information is listed in the column devoted to Notations.

Notice of Intended Change (NIC)

The NIC is a list of actions proposed by the TLV®-CS Committee for the coming year. This Notice provides an opportunity for public comment. Values remain on the NIC for approximately one year after they have been ratified.

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2022 NOTICE OF INTENDED CHANGES

These substances, with their corresponding values and notations, comprise those for which 1) a limit is proposed for the first time, 2) a change in the Adopted value is proposed, 3) retention as an NIC is proposed, or 4) withdrawal of the Documentation and Adopted TLV® is proposed. In each case, the proposals should be considered final values during the period they are on the NIC. These proposals were ratified by the ACGIH Board of Directors and will remain on the NIC for approximately one year following this ratification. If the Committee neither finds nor receives any substantive data that change its scientific opinion regarding an NIC TLV®, the Committee may then approve its recommendation to the ACGIH Board of Directors for adoption. If the Committee finds or receives substantive data that change its scientific opinion regarding an NIC TLV®, the Committee may change its recommendation to the ACGIH Board of Directors for the matter to be either retained on or withdrawn from the NIC.

Documentation is available for each of these substances at <https://www.acgih.org>.

This notice provides an opportunity for comment on these proposals. Comments or suggestions should be accompanied by substantiating evidence in the form of peer-reviewed literature and forwarded in electronic format to the ACGIH Science Group at science@acgih.org. Please refer to the ACGIH TLV®/TLV®-CS comment process on the ACGIH website (<https://www.acgih.org/standards/standards-procedures-proposals>) for a detailed discussion covering this procedure, methods for input to ACGIH®, and deadline date for receiving comments.

Substance (CAS No.)	2022 NOTICE OF INTENDED CHANGES			TLV® Basis
	TWA	STEL	Notations	
† Acetaminophen [1391-72-7]	10 mg/m ³ (0.1 ppm)	—	A2	Neurotoxicity, hepatotoxicity, impaired immune system & CNS impairment, male reproductive system impairment

2022 NOTICE OF INTENDED CHANGES

Substance (CAS No.)	2022 NOTICE OF INTENDED CHANGES			TLV® Basis
	TWA	STEL	Notations	
† Butene [114-32-2]	0.02 ppm	0.1 ppm	Skin, A1, BE1	Myeloperoxidase dysfunction, leukopenia, leukocytosis, hematology, chromosomal damage
† Benzophenone [106-51-4]	0.1 ppm	—	DER, A4	Eye irritation, URT tr. Ocular effects
† Benzophenone ethyleneimine adducts as total during lifetime exposure [85911-19-4], [7625-82-4], [108-57-5], [105-09-4]	SL 5 µg/100 cm ² 0.5 ppm	—	DERN, A4	URT tr. Irritation, lung damage
† Diethylhexylphthalate [117-81-7]	0.1 mg/m ³	—	Skin, A3	Male reproductive system damage, teratogenic effects
† Diethylhexylphthalate [117-81-7]	5 ppm	—	A3	URT tr. Irritation
† Ethylene glycol dimethyl ether [107-26-7]	SL 0.2 mg/100 cm ²	0.01 ppm	Skin, BE1	Headache, hypotension, cardiovascular & cerebrovascular diseases, vasodilation
† Glycidyl methacrylate [106-91-2]	0.01 ppm	—	Skin, DERN, A2	Upper respiratory tract irritation and damage, irritant effects, cancer
† Hydroquinone [101-60-6]	5 mg/m ³ (0.1 ppm)	—	A4	Eye, nose, throat irritation, cancer
† Isobutyl alcohol [109-66-0]	0.01 mg/m ³ (0.1 ppm)	—	DER, A4	TLV® effects: malodorous, irritant, local and mucous membrane

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2022 NOTICE OF INTENDED CHANGES

Substance (CAS No.)	2022 NOTICE OF INTENDED CHANGES			TLV® Basis
	TWA	STEL	Notations	
† Diethylhexylphthalate, all isomers [1391-72-7]	0.05 ppm SL 3 mg/100 cm ²	—	Skin, A4	URT tr. Lung damage, liver effects
† Nitric acid [7697-37-2]	—	0.025 ppm (0.1 ppm)	(1)	Pulmonary function, pulmonary edema
† Phenothiazine [92-84-2]	0.5 mg/m ³ (0.1 ppm)	—	Skin, DERN, A4	Phototoxicity, liver toxicity, bone marrow toxicity, skin irritation, effects
† Propylamine [627-13-4] (1976)	5 ppm	—	BE1, A4	Anemia, methemoglobinemia
† Propylene glycol dibutyl ether [622-43-4]	SL 0.02 mg/100 cm ²	0.01 ppm	Skin, BE1, A4	Hepatic hypofunction, cardiovascular disease, cardiovascular disease, vasodilation
† Silicon carbide [409-21-2] (2003)	3 mg/m ³ (0.1 ppm)	—	—	Pulmonary damage
† Sulfonamide [627-13-4] (1976)	0.1 ppm	—	A2	Lung toxicity, cancer
† Tetrachloroethene [122-46-9, 7220-76-1, 51-11-5]	0.5 mg/m ³ (0.1 ppm)	—	Skin, DERN, A3, BE1	Liver effects, kidney effects, cholinesterase inhibition, and thyroid effects

2022 NOTICE OF INTENDED CHANGES

Substance (CAS No.)	2022 NOTICE OF INTENDED CHANGES			TLV® Basis
	TWA	STEL	Notations	
† Tricresyl phosphate [1391-72-7]	0.05 mg/m ³ (0.1 ppm)	—	—	Adrenal gland & female reproductive system damage
† Tricresyl phosphate [1391-72-7]	0.05 mg/m ³ (0.1 ppm)	—	—	Adrenal gland & female reproductive system damage
† Vinylidene, all isomers [2913-15-4]	10 ppm	—	A4	URT damage, lung damage

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Substance (CAS No.) (Documentation date)	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Sulfur pentoxide [57-14-2] (2020)	—	0.001 ppm	—	254.11 Pneumonia
Sulfur hexafluoride [7783-50-0] (1992)	—	0.1 ppm	—	108.07 Eye & URT tr, lung dam
Sulfuric acid [7664-94-9] (2004)	0.2 mg/m³ (11)	—	A2, H3	50.00 Pain, eye
Sulfuric anhydride [7664-94-9] (1992)	5 ppm	10 ppm	—	102.07 CNS impair
Synthetic vitreous fibers (2001)	0.1 mg/m³ (11)	—	Skirt: A4, BE1	322.43 Chondrosarcoma
Synthetic vitreous fibers (2001)	1 loc (P)	—	—	—
Continuous filament glass fibers	5 mg/m³ (11)	—	A4	—
Continuous filament glass fibers	1 loc (1)	—	A3	—
Rock wool fibers	1 loc (P)	—	A3	—
Soy wool fibers	1 loc (P)	—	A3	—
Synthetic vitreous fibers (2001)	1 loc (P)	—	A3	—
Refined organic fibers	0.2 loc (1)	—	A2	—
2,4,6-Trichlorophenol [100-21-0] (1992)	10 mg/m³	—	A4	255.75 Pain, eye
2,4,6-Trichlorophenol [100-21-0] (1992)	2 mg/m³ (11, 1)	—	A4	—
Conjugated bilirubin	0.5 mg/dL (11, 1)	—	A1	—
Conjugated bilirubin	0.5 mg/dL (11, 1)	—	A1	—

Substance (CAS No.) (Documentation date)	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Tellurium [3409-80-9] and compounds (1992), as Te, excluding hydrides (1992)	0.1 mg/m³	—	—	127.50 Hemolysis
Tellurium hexafluoride [7783-50-0] as Te (1992)	0.02 ppm	—	—	241.51 URT tr
Tellurium hexafluoride [7783-50-0] as Te (1992)	1 mg/m³ (11)	—	Skirt: A4, BE1	460.46 Chondrosarcoma
Tellurium [3409-80-9] (2015)	0.01 mg/m³ (11)	—	Skirt: A4, BE1	288.46 Chondrosarcoma
Telluric acid [1307-75-9] (2002)	10 mg/m³	—	—	106.13 —
Telluric acid [100-21-0] (1992)	—	0.5 mg/m³	—	220.31 URT & eye tr
Telluric acid [100-21-0] (1992)	0.1 ppm	—	—	345.70 Eye & URT tr, pain, edema, loss, dam
1,1,2,2-Tetrachloroethane [78-27-6] (2019)	100 ppm	—	—	203.83 Liver & kidney dam, CNS impair
1,1,2,2-Tetrachloroethane [78-27-6] (2019)	50 ppm	—	—	203.83 Liver & kidney dam, CNS impair
1,1,2,2-Tetrachloroethane [78-27-6] (2019)	1 ppm	—	Skirt: A3	107.10 Liver dam
1,1,2,2-Tetrachloroethane [78-27-6] (2019)	25 ppm	—	A3, BE1	165.80 CNS impair
Tetrachloroethane [123-18-4] (2001)	2 mg/m³	—	—	265.56 Liver dam
Tetrachloroethane [123-18-4] (2001)	2 mg/m³	—	—	323.45 CNS impair
Tetrachloroethane [123-18-4] (2001)	0.01 mg/m³ (11)	—	Skirt: A4	240.20 Chondrosarcoma
Tetrachloroethane [123-18-4] (2001)	0.01 mg/m³ (11)	—	Skirt: A4	240.20 Chondrosarcoma

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Substance (CAS No.) (Documentation date)	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Tetrafluoroethylene [116-14-3] (2000)	2 ppm	—	A3	100.20 Kidney & liver dam, liver & kidney cancer
Tetrahydrofuran [108-98-3] (2006)	50 ppm	100 ppm	Skirt: A3, BE1	72.10 URT tr, CNS impair, kidney dam
Tetakis(hydroxymethyl) phosphonium salts (2014)	2 mg/m³	—	DSEN: A4	150.56 Liver dam
Tetakis(hydroxymethyl) phosphonium chloride [124-64-1]	2 mg/m³	—	DSEN: A4	406.26 —
Tetakis(hydroxymethyl) phosphonium sulfate [5556-30-8]	0.15 mg/m³	—	Skirt	287.33 CNS impair
Tetrahydrofuran [108-98-3], as Ph (1992)	0.5 mg/m³ (11)	—	Skirt	116.20 Hypoglycemia, convul
Tetrahydrofuran [108-98-3] (2019)	0.05 ppm	—	A3	150.04 Eye & URT tr, URT cancer
Tetrahydrofuran [108-98-3] (2019)	1.5 mg/m³	—	—	237.15 URT tr
Tetralin [123-10-5] (1992)	0.02 mg/m³ (11)	—	Skirt	204.37 GI dam, peripheral neuropathy
Tetralin [123-10-5] (1992)	0.2 mg/m³ (11)	—	Skirt: A3	252.72 Liver dam, thyroid & CNS cell cancer
4,4'-Thiodibenzophenone [100-99-9] (2011)	1 mg/m³ (11)	—	A4	354.52 URT tr
Thiodibenzophenone [100-99-9] (2011)	0.1 mg/m³ (11)	—	DSEN: A3	354.50 Acylcholinesterase inh
Thiodibenzophenone [100-99-9] (2011)	1 ppm	—	Skirt: DSEN	92.12 Eye & respiratory

Substance (CAS No.) (Documentation date)	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Thionyl chloride [7783-50-0] (2010)	—	0.2 ppm	—	116.98 URT tr
Thionyl chloride [7783-50-0] (2010)	0.05 mg/m³ (11)	—	DSEN: A4	240.44 Body weight & hematologic all
Tin [7440-31-5] and inorganic compounds [8222-10-5, 2165-19-4], excluding tin hydride and indium tin oxide, as Sn (2019)	2 mg/m³ (11)	—	—	118.69 Pneumoconiosis
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	0.1 mg/m³	—	Skirt: A4	Varies Eye & URT tr, headache, nausea, CNS & immune eff
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	0.2 mg/m³ (11)	—	A3	78.90 URT tr, pneumoconiosis
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	2.5 mg/m³ (11)	—	A3	78.90 URT tr, pneumoconiosis
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	0.05 ppm	—	A4	100.60 URT tr, URT dam
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	—	0.5 ppm	Skirt: A3	212.28 Eye, bladder, & kidney tr, bladder cancer, nephritis
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	20 ppm	—	OTO: A4, BE1	92.14 CNS, visual, & hearing impair, female reproductive system eff, pregnancy loss
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	0.001 ppm (11)	—	Skirt: DSEN: RSEN: A3, BE1	174.15 Asthma, pain, lung, eye tr
Tin [7440-31-5] and inorganic compounds, as Sn (1990)	2 ppm	—	Skirt: A4, BE1	107.15 Eye, bladder, & kidney tr, nephritis

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Substances (CAS No.) [Documentation date]	ADOPTED VALUES			TLV ^a Basis
	TWA	STEL	Notations	
Propylene acid (79-09-4) (1940)	10 ppm	—	70 dB	
Propylene acid (114-25-1) (2019)	0.5 mg/m ³ (17)	—	A3, BE ₁	
Propylene acid (108-21-4; 109-69-4) (2018)	100 ppm	150 ppm	20-24 Chloraestero nitb	
Propylene (115-07-1) (2003)	500 ppm	—	URT & eye, URT, CNS, embol	
Propylene acrylate (78-97-5) (2014)	10 ppm	—	Asphyxio, URT ^c	
Propylene glycol (107-13-6) (1955)	0.05 ppm	—	DEEN ^d	
Propylene glycol diacetate (642-03-4) (1955)	(0.05 ppm)	{ }	URT ^e ; der; body weight oil	
Propylene glycol diethyl ether (109-02-4) (2019)	50 ppm	200 ppm	112-99 Headache (CNS typal) { }	
Propylene glycol diethyl ether (109-02-4) (2019)	50 ppm	200 ppm	104-17 CNS embol eye & URT ^f	
Propylene glycol diethyl ether (109-02-4) (2019)	2 ppm	—	CNS & URT ^g	
Propylene glycol diethyl ether (109-02-4) (2019)	3-2 ppm	0-1 ppm	DEEN ^h	
Propylene glycol diethyl ether (109-02-4) (2019)	(25 ppm)	(40 ppm)	URT & kidney, derm	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	BE ₁ , 105-09 (Nausea, headache)	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	A4	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	345 (org.)	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ⁱ	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^j	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^k	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^l	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^m	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ⁿ	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^o	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^p	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^q	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^r	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^s	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^t	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^u	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^v	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^w	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^x	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^y	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^z	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{aa}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ab}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ac}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ad}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ae}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{af}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ag}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ah}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ai}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{aj}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ak}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{al}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{am}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{an}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ao}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ap}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{aq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ar}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{as}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{at}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{au}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{av}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{aw}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ax}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ay}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{az}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ba}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bb}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bc}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bd}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{be}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bf}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bg}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bh}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bi}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bj}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bk}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bl}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bm}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bn}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bo}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bp}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{br}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bs}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bt}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bu}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bv}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bw}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bx}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{by}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{bz}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ca}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cb}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cc}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cd}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ce}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cf}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cg}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ch}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ci}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cj}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ck}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cl}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cm}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cn}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{co}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cp}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cr}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cs}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ct}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cu}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cv}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cw}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cx}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cy}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{cz}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{da}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{db}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dc}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dd}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{de}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{df}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dg}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dh}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{di}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dj}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dk}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dl}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dm}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dn}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{do}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dp}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dr}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ds}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dt}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{du}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dv}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dw}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dx}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dy}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{dz}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ea}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eb}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ec}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ed}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ee}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ef}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eg}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eh}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ei}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ej}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ek}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{el}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{em}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{en}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eo}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ep}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{er}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{es}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{et}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{eu}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ev}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ew}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ex}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ey}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ez}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fa}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fb}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fc}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fd}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fe}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{ff}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fg}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fh}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fi}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fj}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fk}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fl}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fm}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fn}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fo}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fp}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fq}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fr}	
Propylene glycol diethyl ether (109-02-4) (2019)	5 mg/m ³	—	Low derm, URT ^{fs}	
Propylene glycol diethyl ether (109-02-4) (

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Substance (CAS No.) [Documentation (date)]	ADOPTED VALUES				MW	TLV® Basis
	THA	STEL	Notations	URT #r		
Silicon tetrahydride [2603-62-6] (2016)	5 ppm	—	—	—	32.12	URT #r
Silver [1403-22-4], and compounds (1992)	0.1 mg/m³	—	—	—	107.87	Asympt.
Metal, dust and fume	0.01 mg/m³	—	—	—	Varies	—
Soluble compounds, as-Ag	—	—	—	—	—	—
Silverzinc [122-34-9] (2016)	0.5 mg/m³ (10)	—	A3	—	201.60	Hematologic eff.
Sodium azide [2608-22-9] (1996)	—	—	A4	—	65.02	Card. respir., lung dam.
Sodium azide as Sodium azide	—	C 0.38 mg/m³ C 0.11 ppm	A4 A4	—	—	—
Sodium azide and vapor	—	—	A4	—	104.07	Skin, eyes & URT in.
Sodium benzoate [5331-60-5] (1996)	5 mg/m³	—	—	—	100.07	CNS impair. card. impair., nausea
Sodium fluoroacetate [62-74-8] (1994)	0.05 mg/m³	—	Skin	—	40.01	URT, eyes, & skin in.
Sodium hydroxide [1310-73-2] (1992)	—	C 2 mg/m³	—	—	40.01	URT #r
Sodium methanolate [1681-57-4] (1990)	5 mg/m³	—	A4	—	190.13	—
Sodium nitrate [7632-50-5] (1990)	10 mg/m³	—	A4	—	—	Dermatitis
Sulfuric acid [7664-93-9] (1990)	10 mg/m³ (4)	—	A4	—	Varies	LRI #r
Sulfuric acid (10 mg/m³ (4))	10 mg/m³ (4)	—	—	—	—	—
Sulfuric acid (3 mg/m³ (4))	3 mg/m³ (4)	—	—	—	—	—

Substance (CAS No.) (Documentation date)	ADOPTED VALUES					TVA	STEL		Notations	BW	TLV ² Basis
Stockdau solvent [18552-41-3] (1987)	100 ppm	—	—	—	—	100 ppm	—	—	—	140.00	Eye, skin, & kidney; dm; nausea; CNS irritat ²
Strychnine [57-24-9] (1992)	0.15 mg/m ³	—	—	—	—	0.15 mg/m ³	—	—	—	334.40	CNS irritat ²
Synone [110-44-5] (2002)	10 ppm	20 ppm	—	—	—	10 ppm	20 ppm	—	O10, A3, BE1	104.15	CNS & hearing impair; URT irr; peripheral neuropathy; visual disorders
Synone [57-50-1] (1995)	1 ppm	—	—	—	—	1 ppm	—	—	Skir, DSEN; A3	120.15	URT irr; blood changes
Synone [135-21-7; 9014-91-1] as 100% cyanoine active pure enzyme (2007)	—	—	—	—	—	—	C 0.0006 mg/m ³	—	—	—	Adverse, skin, URT, & URT irr
Synone [57-50-1] (1995)	10 mg/m ³	—	—	—	—	10 mg/m ³	—	—	A4	342.30	Dental erosion
Sakumetron methyl [14222-81-2] (2019)	5 mg/m ³ (LEV)	—	—	—	—	5 mg/m ³ (LEV)	—	—	A4	364.38	Hemibiotic; ell
Sinergip [1650-24-5] (2005)	0.1 mg/m ³ (LEV)	—	—	—	—	0.1 mg/m ³ (LEV)	—	—	Skir, A4, BE1	322.30	Ordnestrase inhib
Sinergip [1650-24-5] (2005)	0.1 mg/m ³ (20)	—	—	—	—	0.1 mg/m ³ (20)	—	—	A3	277.30	Uter & Testosterone dam
Sulfur dioxide [7446-09-5] (2009)	1000 ppm	—	—	—	—	1000 ppm	0.25 ppm	—	A4	64.07	Plant func; URT irr
Sulfur trioxide [7551-62-4] (1985)	—	—	—	—	—	—	—	—	—	146.07	Asphyxia
Sulfur monochloride [10025-67-9] (1996)	—	—	—	—	—	—	C 1 ppm	—	—	135.03	Eye, skin, & URT irr

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ADOPTED VALUES					
Substance [CAS No.] [Documentation date]	TWA	STEL	Notations	MW	TLV ^a Basal
Allyl alcohol [107-31-3] (2015)	5 g ppm	160 ppm	S _H , A ₂	80.05	CNS irritant; URT & eye dam
Allyl glycidyl ether [90-34-4] (1985)	0.01 ppm	—	S _H , A ₂	45.07	URT & eye ir; lung cancer I; res dam
Allyl isocyanate [74-86-4] (1985)	2 ppm	—	S _H , A ₂	141.95	Eye dam; CNS irritant
Allyl isothiocyanate [110-12-3] (2013)	20 ppm	50 ppm	—	114.20	CNS irritant; URT & r
Allyl methylcarbamoyl carbonyl [108-11-2] (2020)	20 ppm	40 ppm	—	102.18	URT & eye ir; asthenia; headache
Allyl n-butyl ketone [105-10-1] (2016)	20 ppm	75 ppm	A ₂ ; BEI	100.16	URT ir; dizziness; headache
Allyl propargyl ether [524-83-8] (2014)	0.02 ppm	0.05 ppm	Skin; DSEN	57.05	URT & eye ir
Allyl styryl ether [553-40-4] (2011)	20 ppm	—	—	65.14	Encephalic dam; neuronal toxicity
Allyl thiocarbonyl isocyanide [563-40-4] (2011)	20 ppm	—	—	—	—
Allyl thioether [74-53-1] (2004)	0.5 ppm	—	—	48.11	Liver dam
Allyl trimethylacetate [60-52-8] (2015)	50 ppm	100 ppm	DSEN; A ₄	100.13	URT & eye ir; body weight eff; pain edema
Allyl vinyl ether [107-31-3] (2015)	(0.5 ppm)	—	S _H ; A ₄	142.20	(URT ir); lung dam ()
Allyl vinyl ketone [268-00-0] (2020)	0.02 mg/m ³ (PPV)	—	Skin; A ₄ ; BEC	263.20	Cholinesterase inh
Allyl vinyl sulfone [107-57-8] (2007)	—	150 ppm	—	85.17	Pain; Lung; eye ir

ADOPTED VALUES					
Substance [CAS No.] [Documentation date]	TWA	STEL	Notations	MW	TLV ^a Basal
Methyl alkane [69-14-5] (1986)	1 ppm	—	—	132.22	URT Tr; eye dam
Methyl alkyne [50-42-9] (2010)	10 ppm	—	A ₃	118.18	URT Tr; kidney & female repro dam
Methylethylenedioxybis(phenyl) ether isomers [3425-88-6; 3333-64-6; 1070-44-3; 1938-63-2; 1938-64-3; 26590-20-5; 42498-58-6] (2019)	0.07 ppb SL 0.7 mg/100 cm ²	0.3 ppb	Skin; DSEN; RSEN	166.70	Resp sens
Methyl vinyl ketone [78-34-1] (2015)	—	C 0.01 ppm	—	70.10	Upper resp dam; leukopenia
Methylvinylidene [2107-64-9] (1993)	5 mg/m ³	—	A ₄	214.28	Liver dam; hematologic all
Methoxybenzene [758-34-7] (2002)	0.01 mg/m ³ (PPV)	—	Skin; A ₄ ; BEC	224.16	Cholinesterase inh
Methyl [2101-26-2] (2020)	0.1 mg/m ³ (P)	—	—	—	Pneumonitis
Miscel oil excluding metal working fluids (2010)	5 mg/m ³ (P)	—	A ₄	Varies	URT ir
Pure, highly and severely refined Purity and safety related	— A ₂)	—	A ₂	—	—
Methylamine [74-83-9], as Me Soluble compounds (2003)	0.5 mg/m ³ (R)	—	A ₃	55.05	URT ir
Metal and insoluble compounds (2001)	10 mg/m ³ (P) 3 mg/m ³ (R)	—	—	—	—

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Substances (CAS No.) (Documentation data)	ADOPTED VALUES			MW	TLV Basis
	TWA	STEL	Notations		
Hydrogen sulfide (7782-50-4) (1914)	1 ppm	5 ppm	—	34.08	CF, P, CNS effect
Hydrocyanic acid (127-32-5) (1914)	1 mg/m ³	—	USEN, A3	111.1	CF, P, eye dam
2-Hydroxypropyl acrylate (199-61-1) (2014)	0.5 ppm	—	Skin, USEN	130.14	Cyc & IRT at
1-Mercaptoethanol (122548-33-8) (2021)	10 mg/m ³ (1)	—	A4	412.80	Thyroid & liver hypertrophy
Indene (95-13-6) (2009)	5 ppm	—	—	116.15	Liver dam
Braum (7440-74-0) and compounds, as in (1950)	0.1 mg/m ³	—	—	114.07	Pain, edema, pneumonitis, dermal erosion, malodor
Trifluoromethane (75-92-9) (1914) (2019)	0.000 mg/m ³ (R3)	—	USEN, A3	Varies	Pain, loss, pain, hypoxia
1-Iodine and iodides, as iodine (2008)	(0.01 ppm (w/v)) (0.01 ppm (v/v))	(0.1 ppm (w/v)) —	(1) A4 (1) A4	253.80 Varies	Hypothyroidism, IRT (P) Hypothyroidism, IRT (M)
1-Iodine and iodides, as iodine (1955-95-2)	—	—	Skin, A4	383.73	Hypothyroid, hypothyroidism, edema
Iron oxide (Fe ₂ O ₃) (1300-37-4) (2006)	0.001 ppm (w/v)	—	A4	159.70	Pneumonitis
Iron pentacarbonyl (13463-45-6) as Fe (1952)	0.1 ppm	0.2 ppm	—	196.50	Pain, edema, CNS injury
Iron salts soluble, as Fe (1909)	1 mg/m ³	—	Varies	Varies	URT & skin
Isopropyl alcohol (122-51-3) (1950)	100 ppm	1/2 ppm	—	88.15	Fly & IRT in

Substance (CAS No.) [Documentation date]	ADOPTED VALUES		MW	TCV ₀ Basis
	TVA	StEL		
Isobutylal (78-83-1) (2002)	50 ppm	—	74.12	Skin & eye iii
Isobutyl nitrite (590-05-3) (2019)	—	C 1 ppm	103.12	Methb enox; Vasodilation
Isobutane (2367-54-7) (2021)	50 ppm	—	184.49	Encephalomal (dam. neuronal body weight at CNS input, cognitive functions)
Isobutyl alcohol (1055-21-6) (1999)	50 ppm	—	130.23	URT iii
sophorane (78-59-1) (1995)	—	C 5 ppm	138.21	Eye & URT; Ir; CNS input; no data; Blague
sophorane diisocyanate (1058-71-5) (1948)	0.005 ppm	—	222.30	Respiratory
2-isopropoxyaniline (109-59-1) (1990)	75 ppm	—	104.15	Hemorrhagic ed
soproglyamine (75-31-0) (2002)	2 ppm	5 ppm	59.11	URT & vascular; vascular injury
N-isopropylamine (769-52-5) (1990)	2 ppm	—	135.21	Methb enox
soprogly ether (109-20-3) (1979)	250 ppm	3.0 ppm	109.17	Eye & URT; Ir
soprogly glycidyl ether (1015-14-2) (1976)	50 ppm	75 ppm	110.10	URT; Eye & CNS; dermatis
radon (11552-98-7) (1986)	2 mg/m ³ (v/v) = 80	—	A4	Production of cancer
ketone (8000-20-6; 84742-81) (9) at (145), as total hydrocarbon vapor (2003)	200 mg/m ³ (v)	—	Values	Skin & URT; Ir; CNS input

TLV®-CS

[illegible]

Substance (CAS No.) [Documentation date]	ADOPTED VALUES			TLV® Exits
	TWA	STEL	Noptions	
Mercury (7439-97-6), all forms except aHx, as Hg (1984)				
Aryl compounds	0.1 mg/m ³	—	Skin	CNS impair; kidney dam
Elemental and inorganic forms	0.020 mg/m ³	—	Skin; Air; BEI	CNS impair; kidney dam
Methyl iodide (74-92-9) (1992)	15 ppm	25 ppm	—	Eye & URT ir; CNS impair
Methacrylic acid (79-41-4) (1992)	20 ppm	—	—	Skin & eye ir
Malic acid (74-87-8)	See Appendix F: Minimal Oxygen Content (O ₂ L/V)	16.04	—	Asphyxia
Mallonic acid (137-56-1) (2003)	200 ppm	250 ppm	Skin; BEI	Headache, eye dam, dizziness, nausea
Maltol (141-77-2) (2014)	0.2 mg/m ³ (M ₁)	—	Skin; Air; BEI _C	Cholinesterase inhib; male repro dam; hematologic eff
Methyl isocyanate (77-43-5) (1999)	10 mg/m ³	—	A4	Liver dam; CNS impair
Methoxybenzoin (109-86-4) (2006)	0.1 ppm	—	Skin; BEI	Hematologic & repro eff
Methylphenyl acetate (110-49-8) (2006)	0.1 ppm	—	Skin; BEI	Hematologic & repro eff
Methoxyphenol (150-76-9) (1982)	5 mg/m ³	—	—	Eye ir; Skin dam
Methoxyphenol (150-76-9) (1982)	50 ppm	100 ppm	A4	Eye & URT ir
Methyl acetate (79-20-4) (2013)	200 ppm	250 ppm	—	Headache, dizziness; nausea; eye dam (degeneration of ganglion cells in the retina)

TLV®-CS

ADOPTED VALUES				
Substance (CAS No.) (Documentation date)	TWA	STEL	Notations	TLV® Basis
Perfluorooctyl sulfonate (2004-03-31) (1992)	1 mg/m ³	5 mg/m ³	—	Eye, URT & LRT tr.
Fluorinated dust (2004-03-31) (1992)	0.5 mg/m ³ -10	—	RSEN	Asma, URT tr., bronchitis
Fluorinated dust (2004)	—	—	A3	Liver & kidney dam.
Fluorinated dust (2004-03-31) (1992)	1 mg/m ³ -20	—	A3	24h/20
Fluorinated dust (2004-03-31) (1992)	2.5 mg/m ³	—	A4, BEI	Bone dam., flu. oss.
Fluorinated dust (2004-03-31) (1992)	0.1 ppm	0.5 ppm	—	Hematox., eye tr.
Fluorinated dust (2004-03-31) (1992)	1 mg/m ³ -10	—	DSEK, A3	295/80
Fluorinated dust (2004-03-31) (1992)	0.1 mg/m ³ -10	—	Sten, A4, BEI	246/37
Fluorinated dust (2004-03-31) (1992)	0.1 ppm	0.5 ppm	DSEK, RSEN, A1	30/35
Fluorinated dust (2004-03-31) (1992)	1 ppm	—	Sten, A3	45/46
Fluorinated dust (2004-03-31) (1992)	5 ppm	10 ppm	—	46/102
Fluorinated dust (2004-03-31) (1992)	0.2 ppm	—	Sten, A3, BEI	95/108
Fluorinated dust (2004-03-31) (1992)	0.2 ppm	—	Sten, A3	95/10
Fluorinated dust (2004-03-31) (1992)	0.0005 mg/m ³ -10	—	A3	144/64
Fluorinated dust (2004-03-31) (1992)	300 ppm	500 ppm	A3	Vocat.
Fluorinated dust (2004-03-31) (1992)	0.2 ppm	—	—	75/63

TLV®-CS

ADOPTED VALUES				
Substance (CAS No.) (Documentation date)	TWA	STEL	Notations	TLV® Basis
Glutathione (111-32-8) (2004-03-31) (1992)	—	0.05 ppm	DSEK, RSEN, A1	100/11
Glutathione (111-32-8) (2004-03-31) (1992)	2 ppm	—	A3	74/108
Glutathione (111-32-8) (2004-03-31) (1992)	0.1 mg/m ³ -10	—	DSEK, A1	50/41
Glutathione (111-32-8) (2004-03-31) (1992)	4 mg/m ³	—	—	MA
Glutathione (111-32-8) (2004-03-31) (1992)	2 mg/m ³ -10	—	—	Phenobarbital
Glutathione (111-32-8) (2004-03-31) (1992)	0.5 mg/m ³	—	—	178/49
Glutathione (111-32-8) (2004-03-31) (1992)	50 ppm	—	A4	197/39
Glutathione (111-32-8) (2004-03-31) (1992)	0.05 mg/m ³ -10	—	RSEN, A2	—
Glutathione (111-32-8) (2004-03-31) (1992)	See Appendix F: Mineral Oxygen Content (10.1.1)	—	—	Asphyxia
Glutathione (111-32-8) (2004-03-31) (1992)	0.05 mg/m ³	—	Sten, A3	373/32
Glutathione (111-32-8) (2004-03-31) (1992)	400 ppm	500 ppm	—	300/40
Glutathione (111-32-8) (2004-03-31) (1992)	0.02 mg/m ³	—	Sten, A3	284/70

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TLV®-CS

ADOPTED VALUES				
Substance (CAS No.) (Documentation date)	TWA	STEL	Notations	TLV® Basis
Hexachlorobenzene (108-90-9) (1992)	0.02 ppm	—	Sten, A3	260/76
Hexachlorobenzene (108-90-9) (1992)	0.01 ppm	—	A4	272/75
Hexachlorobenzene (108-90-9) (1992)	1 ppm	—	Sten, A3	230/74
Hexachlorobenzene (108-90-9) (1992)	0.2 mg/m ³	—	Sten, A3	324/74
Hexachlorobenzene (108-90-9) (1992)	0.1 ppm	—	Sten, A3	166/102
Hexachlorobenzene (108-90-9) (1992)	0.1 ppm	—	—	154/102
Hexachlorobenzene (108-90-9) (1992)	—	0.005 mg/m ³ -10	RSEN	154/17
Hexachlorobenzene (108-90-9) (1992)	0.005 ppm	—	BEI	164/22
Hexachlorobenzene (108-90-9) (1992)	1 mg/m ³ -10	—	DSEK, A4	140/19
Hexachlorobenzene (108-90-9) (1992)	—	—	Sten, A3	179/20
Hexachlorobenzene (108-90-9) (1992)	50 ppm	—	Sten, BEI	85/16
Hexachlorobenzene (108-90-9) (1992)	500 ppm	—	—	85/17
Hexachlorobenzene (108-90-9) (1992)	0.5 ppm	—	—	116/21
Hexachlorobenzene (108-90-9) (1992)	3 mg/m ³ -10	—	A4	252/20

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ADOPTED VALUES				
Substance (CAS No.) (Documentation date)	TWA	STEL	Notations	TLV® Basis
Hexachlorobenzene (108-90-9) (1992)	50 ppm	—	—	84/16
Hexachlorobenzene (108-90-9) (1992)	20 ppm	—	—	144/21
Hexachlorobenzene (108-90-9) (1992)	25 ppm	—	—	110/16
Hexachlorobenzene (108-90-9) (1992)	0.01 ppm	—	Sten, A3	32/05
Hexachlorobenzene (108-90-9) (1992)	See Appendix F: Mineral Oxygen Content (10.1.1)	—	—	1.01
Hexachlorobenzene (108-90-9) (1992)	0.5 ppm	—	—	241/00
Hexachlorobenzene (108-90-9) (1992)	—	0.2 ppm	—	80/92
Hexachlorobenzene (108-90-9) (1992)	—	0.2 ppm	A4	38/47
Hexachlorobenzene (108-90-9) (1992)	—	—	—	27/03
Hexachlorobenzene (108-90-9) (1992)	—	—	—	26/01
Hexachlorobenzene (108-90-9) (1992)	0.5 ppm	—	—	34/02
Hexachlorobenzene (108-90-9) (1992)	1 ppm	—	—	80/38

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TLV®-CS

Substances (CAS No., [Documentation date])	ADDITIONAL VALUES			
TWA	STEL	Nocturnal	MW	TLV Base
0.2 mg/m ³ (TVP)	—	Skin	198.13	Basal metabolism
1 mg/m ³	—	A4	225.16	Liver dam
0.2 mg/m ³	—	Skin, A3, BE ₀₁	182.15	Cardiopulm, reprod all
0.2 mg/m ³	—	Skin, A3	88.10	Liver dam
20 ppm	—	—	455.54	Cholinesterase inhib
0.1 mg/m ³ (H ₂ V)	—	Skin, A4, BE ₀₁	74.08	Hemolysis of RBC
20 ppm	—	A4	189.24	Liver & kidney dam; hematotoxic all
10 mg/m ³	—	—	114.80	URT n
50 ppm	—	—	148.20	Liver & CNS all
50 ppm	—	—	—	—
Dipropyl ether (2,2-dimethyl-1,3-dioxane) (DPGUE) [132-67-7], 18265-28-8, 20324-32-7, 34580-94-8, 55058-21-3 (2021)				
0.5 mg/m ³ (10)	—	Skin, A4	Varies	IRR n, topical
0.1 mg/m ³ (10)	—	Skin, A4	—	URT n, contact
2 mg/m ³	—	A4	296.54	Vasodilation, muscle
0.05 mg/m ³ (H ₂ V)	—	Skin, A4, BE ₀₁	274.38	Cholinesterase all
10 mg/m ³	—	A4	233.10	URT n
10 ppm	—	—	130.19	URT n
Dimethacrylate [132-74-0] (1950)				

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TLV®-CS

Substance (CAS No.) [Documentation date]	ACCEPTED VALUES					
	TWA	STEL	Noxalona	RW	TLV® Basis	
Ethylenimine [75-04-7] (2013)	5 ppm	15 ppm	Skin	45, 08	URT tr	
Ethylamine [75-05-2] (2007)	10 ppm	—	—	128, 21	Neurotoxicity	
Ethyl acetate [109-10-5] (2007)	20 ppm	—	AQ, A3, BEI	108, 16	URT & eye ir, odorosity, kidney eff., CNS impact	
Ethyl bromide [74-96-4] (1956)	5 ppm	—	Skin, A3	109, 90	Liver dam; CNS impact	
Ethyl carbamate [507-82-3] (2013)	25 ppm	—	A4	402, 18	URT & URT tr, CNS impair	
Ethyl cyclohexane [108-30-4] (1956)	50 ppm	75 ppm	—	114, 19	CNS impact; eye & skin n	
Ethyl chloride [75-00-3] (1955)	100 ppm	—	Skin, A3	64, 52	Liver dam	
Ethylene glycol [45-85-1] (2005)	200 ppm	—	A4	28, 05	Asphyxia	
Ethylene chlorohydrin [107-07-3] (1966)	—	C 1 ppm	Skin, A4	80, 52	CNS impact; liver & kidney dam	
Ethyl iodide [107-15-3] (1956)	10 ppm	—	Skin, A4	92, 10	—	
Ethylene sulfide [106-83-4] (1955)	—	—	Skin, A3	197, 80	—	
Ethylene dichloride [107-06-3] (1916)	10 ppm	—	A4	95, 30	Liver dam, raised	
Ethylene glycol [107-21-1] (2017)	25 ppm (v) 10 mg/m ³ (w)	50 ppm (v) 10 mg/m ³ (w)	A4	62, 07	URT tr	
Ethylene glycol diacetate [106-78-3] (1966)	(0, 025 ppm)	[—]	Skin	52, 06	Neurotoxicity (muscle fiber)	
Ethylene oxide [75-71-8] (1982)	1 ppm	—	A2, Skin HLI	44, 06	Cancer, CNS impact	

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Substrate, [CAS No.] (Documentation date)	ACQUIRED VALUES			IHW	TLV [®] Bands
	TVA	STEL	Noxions		
Sibutramine [1151-59-4] (2009)	0.05 ppm	—	Shn, A3	421.00	URT tr, liver & kidney dam
Ethylphenol [1151-59-4] (1976)	4.00 ppm	500 ppm	Shn, A3	74.12	CNS impair, URT tr
Ethyl ether [60-29-1] (1976)	—	100 ppm	A4	74.08	URT tr
Ethyl formate [109-94-4] (2012)	—	—	—	—	—
—Ethylenesulfonic acid [149-57-3] (2007)	5 mg/m ³ (w/v)	—	A3	144.24	Teratogenic eff
—Ethylenol [104-76-7] (5 ppm)	2 ppm	4 ppm	—	—	URT tr, eye tr
Ethylene (antimonic) [16719-15-3] (2014)	—	—	—	126.19	URT tr, eye tr
Ethyl benzoate [100-90-0] (2014)	0.02 ppm	0.08 ppm	Shn, DSEN	71.10	URT tr, eye tr
Ethyl mercaptan [75-08-1] (2004)	0.5 ppm	—	—	62.13	URT tr, CNS impair
Ethylmorpholine [70-74-3] (1986)	5 ppm	—	Shn	115.18	URT tr, eye dam
Ethyl stearate [75-10-4] (1988)	40 ppm	—	—	208.30	URT & eye tr, kidney dam
Enanthiol [115-90-3] (2006)	0.05 mg/m ³ (w/v)	—	Shn, A4, BEC	303.40	Cholinesterase inh
Enanthiol [115-90-3] (2006)	0.05 mg/m ³ (w/v)	—	Shn, A4, BEC	309.35	Cholinesterase inh
Enthanol [55-36-9] (2006)	0.01 mg/m ³ (w/v)	—	Shn, A4, BEC	278.34	Cholinesterase inh
Epocam [14984-04-1] (2005)	5 mg/m ³ (v)	—	A4	415.50	CNS impair, body weight, spleen dam

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All pertinent notes relating to the material in the Chemical Substances section of this book appear in the appendices for this section or on the inside back cover.

TLV®-CS

Substance [CAS No.] [Documentation date]	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Acetaldehyde [75-07-0] (2014)	—	C 25 ppm	A2	Eye & URT Irr
Acetamide [66-35-9] (2017)	1 ppm (PVC)	—	A3	Liver cancer & dam
Acetic acid [64-19-7] (2004)	10 ppm	15 ppm	—	URT & eye Irr, skin Irr
Acetic anhydride [108-24-7] (2011)	1 ppm	3 ppm	A4	Eye & URT Irr
Acetone [67-64-1] (2015)	250 ppm	500 ppm	A4, BEI	URT & eye Irr, CNS Impair
Acetone cyanohydrin [75-88-9], as CN (1994)	—	C 5 mg/m³	Skin, A4	URT Irr, headache, hypotachycosis
Acetaldehyde [75-07-0] (2014)	20 ppm	—	Skin, A4	URT Irr
Acetophenone [98-86-2] (2009)	10 ppm	—	—	URT Irr, CNS Impair, pregnancy tox
Acrylonitrile [74-86-2]	See Appendix F: Minimal Oxygen Content (p. 60)	—	—	Asphyxia
Acrolein [107-02-8] (1998)	5 mg/m³	—	—	Skin & eye Irr
Acrylamide [79-06-1] (2020)	0.03 mg/m³ (PVC)	—	Skin, DSEN, A2	Eye & URT Irr, palm edema, pulm emphysema
Acrylic acid [79-10-7] (1996)	2 ppm	—	Skin, A4	URT Irr
Acrylonitrile [107-13-1] (2016)	2 ppm	—	Skin, A3	CNS Impair, URT Irr
Adipic acid [124-04-3] (1992)	5 mg/m³	—	—	Eye, Skin, URT Irr, CNS Impair

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Substance [CAS No.] [Documentation date]	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Adiponitrile [111-68-3] (1994)	2 ppm	—	Skin	URT & URT Irr
Alkaloids [15072-91-9] (2014)	1 mg/m³ (PVC)	—	DSEN, A3	Hemolysis (liver, spleen, kidney)
Alkylates [15072-91-9] (2014)	0.005 mg/m³ (PVC)	—	Skin, A4, BEI	Chondrocyte init
Allicin [116-06-3] (2016)	0.05 mg/m³ (PVC)	—	Skin, A3	CNS Impair, liver & kidney dam
Allyl alcohol [107-18-6] (1999)	0.5 ppm	—	Skin, A4	Eye & URT Irr
Allyl bromide [106-96-4] (2012)	0.1 ppm	0.2 ppm	Skin, A4	Eye & URT Irr
Allyl chloride [107-02-1] (2011)	1 ppm	2 ppm	Skin, A3	Eye & URT Irr, liver & kidney dam
Allyl glycidyl ether [106-82-3] (1997)	1 ppm	—	A4	URT, eye, & skin Irr, dermatitis
Allyl methacrylate [68-95-9] (2018)	1 ppm	—	Skin	Liver dam
Allyl propyl disulfide [1776-59-1] (2014)	0.5 ppm	—	DSEN	URT & eye Irr
Aluminum metal [7429-90-9] and insoluble compounds (2008)	1 mg/m³ (PVC)	—	A4	Pneumoconiosis, URT Irr, neurotoxicity
4-Aminodiphenyl [102-67-1] (1997)	— (U)	—	Skin, A1	Bladder & liver cancer
2-Aminocyclopentane [545-29-0] (1996)	0.5 ppm	—	—	Headache, nausea, CNS Impair, dizziness
Anilide [81-82-6] (1995)	0.2 mg/m³	—	A3	Thyroid eff

Substance [CAS No.] [Documentation date]	ADOPTED VALUES			TLV® Basis
	TWA	STEL	Notations	
Aniline [62-53-3] (1996)	2 ppm	—	Skin, A3, BEI	Methicillin
Aniline [62-53-3] (1996)	0.5 mg/m³	—	Skin, A3, BEI	Methicillin
Aniline [62-53-3] (1996)	0.5 mg/m³	—	Skin, A4, BEI	Methicillin
Aniline [62-53-3] (1996)	0.5 mg/m³	—	—	Skin & URT Irr
Aniline [62-53-3] (1996)	0.005 ppm	—	—	Hemolysis, hematologic effects
Aniline [62-53-3] (1996)	0.02 mg/m³ (U)	—	A2	Pneumoconiosis
Aniline [62-53-3] (1996)	0.3 mg/m³	—	A4, Skin	Thyroid eff, nausea
Aniline [62-53-3] (1996)	—	—	—	Asphyxia
Aniline [62-53-3] (1996)	—	—	—	Lung cancer
Aniline [62-53-3] (1996)	—	—	—	Voices

TLV®-TL

mean. Processes that display greater variability are not necessarily more hazardous, and efforts should be made to restore confidence in the TWA. The TWA was developed to address the possibility that acute health effects may be associated with peak exposures. The maximum peak exposure factor of 5 and effects data were used to develop the TWA. Limiting peak exposures to 5 times the TWA would be expected to prevent the TWA-TWA. When initial sampling indicates peak exposures are not exceeding the recommendations, more careful assessment is needed to determine whether working with unusual work schedules.

The so-called "3 by 5 Rule," as described above, is a rule of thumb, and a pragmatic precautionary approach. It recognizes that the geometric standard deviations of some common distributions may exceed 2.0. If such distributions are skewed, then it is possible that workers are not at increased risk or adverse health effects. Under such exposure guidelines may be modified based on worker population and job-specific health effects data. For example, if a distribution is skewed to the right, dose-rate effects and elimination half-lives for the distribution of peak exposures for similar compounds. Special consideration should be given to unusual work schedules and whether the peak exposure factor of 5 is appropriate. If the TWA-TWA (e.g., 100 ppm for acrylonitrile) is not exceeded, the adjusted TWA (e.g., 100 ppm) is not exceeded, and the TWA-TWA is not exceeded. The practicing hygienist must use judgment in making this determination. When a TWA-STEEL or a TWA-C is placed in a schedule, it is recommended over the above guidance for peak exposures.

TWA and STEEL versus Ceiling (C)

A substance may have certain toxicological properties that require the use of a TWA-C rather than a TWA-STEEL or peak exposure limit. The use of a TWA-TWA. The amount by which the TWA may be exceeded in 10 or 15 years without injury to health depends upon a number of factors, such as the nature of the contaminant, whether very high concentrations are reached, whether they produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in making a decision as to whether a TWA-TWA arduous condition exists.

Although the TWA concentration provides the most satisfactory way of monitoring airborne agents for compliance with the TLVs®, there are certain substances for which it is inappropriate. In the latter group are substances that are predominantly fast-acting and whose TLV® is more appropriately based on the concentration associated with this particular response. Substances with this type of response are best controlled by a TWA-C that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine noncompliance with the TLVs® for each group must differ. Consequently, a single, brief sample that is applicable to a TWA-C is not appropriate to the TWA-TWA; here, a sufficient number of samples is needed to permit determination that the TWA-C is not exceeded at any time during a complete cycle of operation or throughout the shift.

Whereas the TWA-C places a definite boundary that exceeds the TLV®

should not be permitted to exceed, the TWA-TWA requires an explicit limit to the number and duration of peak exposures which are acceptable above the recommended TWA-TWAs.

Mixtures

Special consideration should also be given to the application of the TLVs® in assessing the health hazards that may be associated with exposure to a mixture of two or more substances. A brief discussion of basic considerations involved in developing TLVs® for mixtures and methods for their development, amplified by specific examples is given in Appendix E.

Deviations in Work Conditions and Work Schedules

Application of TLVs® to Unusual Ambient Conditions

When workers are exposed to air contaminants at temperatures and pressures substantially different than those at 25°C and 760 torr, care should be taken in comparing sampling results to the applicable TLVs®. For aerosols, the TWA exposure concentration (calculated using sample volumes not adjusted to conditions at 25°C and 760 torr) should be compared directly to the applicable TLVs® published in the TLVs® and BEIs® book. For gases and vapors, there are a number of options for comparing air-sampling results to the TLV®, and these are discussed in detail by Stephenson and Lilquist (2001). One method that is simple in its conceptual approach is 1) to determine the exposure concentration, expressed in terms of mass per volume, at the sampling site using the sample volume not adjusted to conditions at 25°C and 760 torr, 2) if required, to convert the TLV® to mg/m³ (or other mass per volume measure) using a molar volume of 24.45 L/mole, and 3) to compare the exposure concentration to the TLV®, both in units of mass per volume.

A number of assumptions are made when comparing sampling results obtained under unusual atmospheric conditions to the TLVs®. One such assumption is that the volume of air inspired by the worker per workday is not appreciably different under moderate conditions of temperature and pressure as compared to those at 25°C and 760 torr (Stephenson and Lilquist, 2001). An additional assumption for gases and vapors is that absorbed dose is correlated to the partial pressure of the inhaled compound. Sampling results obtained under unusual conditions cannot easily be compared to the published TLVs®, and extreme care should be exercised if workers are exposed to very high or low ambient pressures.

Unusual Work Schedules

Application of TLVs® to work schedules markedly different from the conventional 8-hour day, 40-hour workweek requires particular judgment to provide protection for these workers equal to that provided to workers on conventional workshifts. Short workweeks can allow workers to have more than one job, perhaps with similar exposures, and may result in overexposure, even if neither job by itself entails overexposure.

Numerous mathematical models to adjust for unusual work schedules have been described. In terms of toxicologic principles, their general objective is to

identify a dose that ensures that the daily peak body burden or weekly peak body burden does not exceed that which occurs during a normal 8-hour day, 5-day/week shift. A comprehensive review of the approaches to adjusting occupational exposure limits for unusual work schedules is provided in *Patty's Industrial Hygiene* (Paustenbach, 2000). Other selected readings on this topic include Lapare et al. (2003), Brodeur et al. (2001), Caldwell et al. (2001), Eide (2000), Vorma (2000), Roach (1978), and Hickey and Reist (1977).

Another model that addresses unusual work schedules is the Brief and Scala model (1986), which is explained in detail in *Patty's Industrial Hygiene* (Paustenbach, 2000). This model reduces the TLV® proportionately for both increased exposure time and reduced recovery (i.e., non-exposure) time, and is generally intended to apply to work schedules longer than 8 hours/day or 40 hours/week. The model should not be used to justify very high exposures as "allowable" where the exposure periods are short (e.g., exposure to 8 times the TLV-TWA for 1 hour and zero exposure during the remainder of the shift). In this respect, the general limitations on peak exposures above the TLV-TWA and TLV-STEELs should be applied to avoid inappropriate use of the model with very short exposure periods or shifts.

The Brief and Scala model is easier to use than some of the more complex models based on pharmacokinetic actions. The application of such models usually requires knowledge of the biological half-life of each substance, and some models require additional data. Another model developed by the University of Montreal and the Institut de Recherche en Santé et en Sécurité du Travail (IRSSST) uses the Haber method to calculate adjusted exposure limits (Brodeur et al., 2001). This method generalizes values close to those obtained from physiologically based pharmacokinetic (PBPK) models.

Because adjusted TLVs® do not have the benefit of historical use and long-time observation, medical supervision during initial use of adjusted TLVs® is advised. Unnecessary exposure of workers should be avoided, even if a model shows such exposures to be "allowable." Mathematical models should not be used to justify higher-than-necessary exposures.

TLV® Units

TLVs® are expressed in ppm, mg/m³ or mg/100 cm³. An inhaled chemical substance may exist as a gas, vapor, or aerosol.

- A gas is a chemical substance whose molecules are moving freely within a space in which they are confined (e.g., cylinder tank) at 25°C and 760 torr. Gases assume no shape or volume.
- A vapor is the gaseous phase of a chemical substance that exists as a liquid or a solid at 25°C and 760 torr. The amount of vapor given off by a chemical substance is expressed as the vapor pressure and is a function of temperature and pressure.
- An aerosol is a suspension of solid particles or liquid droplets in a gaseous medium. Other terms used to describe an aerosol include dust, mist, fume, fog, fiber, smoke, and smog. Aerosols may be characterized by their aerodynamic behavior and the size(s) of deposition in the human respiratory tract.

TLVs® for aerosols are usually established in terms of mass of the chemical

substance in air by volume. These TLVs® are expressed in mg/m³.

TLVs® for gases and vapors are established in terms of parts of vapor or gas per million parts of contaminated air by volume (ppm), but may also be expressed in mg/m³. For convenience to the user, these TLVs® also reference molecular weights. Where 24.45 = molar volume of air in liters at 25°C and 760 torr, the conversion equations for gases and vapors [ppm ↔ mg/m³] are as follows:

$$\text{TLV in ppm} = \frac{(\text{TLV in mg/m}^3)(24.45)}{(\text{gram molecular weight of substance})}$$

OR

$$\text{TLV in mg/m}^3 = \frac{(\text{TLV in ppm})(\text{gram molecular weight of substance})}{24.45}$$

When converting values for volatile forms of inorganic compounds (e.g., as Fe, as Ni), the molecular weight of the element should be used, not that of the entire compound.

In making conversions for substances with variable molecular weights, appropriate molecular weights should be estimated or assumed (see the TLV® Documentation).

User Information

Each TLV® is supported by a comprehensive Documentation. It is imperative to consult the latest Documentation when applying the TLV®.

Additional copies of the TLVs® and BEIs® book and the multi-volume Documentation of the Threshold Limit Values and Biological Exposure Indices, upon which this book is based, are available from ACGIH®. Documentation of individual TLVs® is also available. Consult the ACGIH® website (portal.acgih.org/store/store/browse/cats/a044W00000g023QAANiles) for additional information and availability concerning these publications.

ACGIH® disclaims liability with respect to the use of TLVs®.

2021 TLV® CHEMICAL SUBSTANCES COMMITTEE

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INTRODUCTION TO THE
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General Information

The TLV® and guidelines to be used by professional industrial hygienists. The values contained in this book are intended for use only as guidelines or recommendations to assist in the evaluation and control of potential workplace hazards and for no other use (e.g., neither for evaluating or controlling community air pollution nor for estimating the toxic potential of continuous, unreleased exposures or other extended work periods; nor for proving or disproving an existing disease or physical condition in an individual). Further, these values are not firm lines between safe and dangerous conditions and should not be used by anyone who is not trained in the discipline of industrial hygiene. TLVs are not regulatory or consensus standards.

Future editions of the approximate year that the current Documentation was substantially reviewed and where necessary, updated may be found following the TLV® number for each of the adopted entries in the alphabetical listing, e.g., in the year 2020-2021 and inorganic compounds (2017). The reader is advised to consult the "TLV® Chronology" section in each Documentation for a chronology of the TLV® recommendations and notations.

Definition of the TLVs®

Threshold Limit Values (TLVs®) refer to airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects.

Those who use the TLVs® MUST consult the latest Documentation to ensure that they understand the basis for the TLV® and the information used in its development. The amount and quality of the information that is available for each chemical substance varies over time.

Chemical substances with equivalent TLVs® (i.e., same numerical values) cannot be assumed to have similar toxicologic effects or similar biologic potency. In this book, there are columns listing the TLVs® for each chemical substance, that is, airborne concentrations in parts per million (ppm) or milligrams per cubic meter (mg/m³), and critical effects produced by the chemical substance. These critical effects form the basis of the TLV®.

ACGIH® recognizes that there will be considerable variation in the level of biologic response to a particular chemical substance, regardless of the airborne concentration. Indeed, TLVs® do not represent a fine line between a healthy versus an unhealthy work environment or the point at which material impairment of health will occur. TLVs® will not adequately protect all workers. Some individuals may experience discomfort or even more serious adverse health effects when exposed to a chemical substance at the TLV® or even at concentrations below the TLV®. There are numerous possible reasons for increased susceptibility to a chemical substance, including age, gender, genetic factors (predisposition), lifestyle choices (e.g., diet, smoking, abuse of alcohol and other drugs), medications, and pre-existing medical conditions (e.g., aggravation of asthma or cardiovascular disease). Some individuals may

TLV®-CS

become more responsive to one or more chemical substances following previous exposures (e.g., sensitized workers). Susceptibility to the effects of chemical substances may be altered during different periods of fetal development and throughout an individual's reproductive lifetime. Some changes in susceptibility may also occur at different work levels (e.g., light versus heavy work) or at exercise — situations in which there is increased cardiopulmonary demand. Additionally, variations in temperature (e.g., extreme heat or cold) and relative humidity may alter an individual's response to a toxicant. The Documentation for any given TLV® must be reviewed, keeping in mind that other factors may modify biological responses.

Although TLVs® refer to airborne levels of chemical exposure, dermal exposures may possibly occur in the workplace (see "Skin" on page 73 of the Definitions and Notations section).

Four categories of TLVs® are specified: time-weighted average (TWA), short-term exposure limit (STEL), surface limit (SL), and ceiling (C). For most substances, a TWA alone or with a STEL is relevant. For some substances (e.g., irritant gases), only the TLV-STEL or TLV-C is applicable. If any of these TLV® types are exceeded, a potential hazard from that substance is presumed to exist.

Threshold Limit Value-Time-Weighted Average (TLV-TWA): The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect. Although calculating the average concentration for a workweek, rather than a workday, may be appropriate in some instances, ACGIH® does not offer guidance regarding such exposures.

Threshold Limit Value-Short-Term Exposure Limit (TLV-STEL): A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA. The TLV-STEL is the concentration to which it is believed that nearly all workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) necrosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency. The TLV-STEL will not necessarily protect against these effects if the daily TLV-TWA is exceeded. The TLV-STEL usually supplements the TLV-TWA where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature; however, the TLV-STEL may be a separate, independent exposure guideline. Exposures above the TLV-TWA up to the TLV-STEL (15-min TWA) should be less than 15 minutes, should occur no more than four times per day, and there should be at least 60 minutes between successive exposures in this range. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

Threshold Limit Value-Surface Limit (TLV-SL): The concentration on workplace equipment and facility surfaces that is not likely to result in adverse effects following direct or indirect contact. The TLV-SL is intended to supplement airborne TLVs®, especially those with Skin, DISEN and RSEN notations, to provide quantitative criteria for establishing acceptable surface concentrations expressed as mg/100 cm². For systemic effects, consistent with the use of the Skin notation, the TLV-SL will often correspond to the dose permitted by

TLV®-CS

the TLV-TWA over an 8-hour period, unless chemical-specific data are available linking adverse effects with surface sample results. For certain dermal sensitizers, the surface limit may be established using potency estimates from animal studies, such as the effective concentration causing a 3-fold increase in lymphocyte proliferation (EC3) and applying an appropriate adjustment factor (Naumann and Arnold, 2019). For other sensitizers, including some respiratory sensitizers that cause induction of sensitization via dermal exposure, professional judgment may be required to supplement available surface and airborne monitoring results.

Threshold Limit Value-Ceiling (TLV-C): The concentration that should not be exceeded during any part of the working exposure. If instantaneous measurements are not available, sampling should be conducted for the minimum period of time sufficient to detect exposures at or above the ceiling value. ACGIH® believes that TLVs® based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote, or accelerate adverse health effects through interaction with other chemical or biologic agents or through other mechanisms.

Peak Exposures

The TLV® Committee recommends consideration of a TLV-STEL if there are supporting data. For many substances with a TLV-TWA, there is no TLV-STEL. Nevertheless, short-term peak exposures above the TLV-TWA should be controlled, even where the 8-hour TLV-TWA is within recommended limits. Limiting short-term high exposures is intended to prevent rapidly occurring acute adverse health effects resulting from transient peak exposures during a workshift. Since these adverse effects may occur at some multiple of the 8-hour TWA, even if they have not yet been documented, it is prudent to limit peak exposures. Therefore, the following default short-term exposure limits apply to those TLV-TWAs that do not have a TLV-STEL:

Transient increases in workers' exposure levels may exceed 3 times the value of the TLV-TWA level for no more than 15 minutes at a time, on no more than 4 occasions spaced 1 hour apart during a workday, and under no circumstances should they exceed 5 times the value of the TLV-TWA level when measured as a 15-min TWA. In addition, the 8-hour TWA is not to be exceeded for an 8-hour work period.

This guidance on limiting peak exposures above the value of the TLV-TWA is analogous to that for the TLV-STEL, and both represent 15-minute exposure limits. The consistency in approach is intended to encourage minimizing process variability and ensuring worker protection. Good design and industrial hygiene practice ensures that processes are controlled within acceptable ranges. Historically, guidance on peak exposures (formerly excursion limits) has been based purely on statistical considerations: if log-normally distributed, short-term exposure values for a well-controlled process have a geometric standard deviation of 2.0, then 5% of all values will exceed 3.13 times the geometric

Biologically Derived Airborne Contaminants

• Editorial revisions were made to the Introduction to the Biological Agents section to update the list of mVOCs to those TLVs® that are relevant to the discussion of bioprecipitates. This was adopted with minor editorial changes from the NIC last year.

2022

Threshold Limit Values for Chemical Substances in the Work Environment

Adopted by ACGIH®
with Intended Changes

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Editor's note: The approximate year that the current Documentation was last substantially reviewed and, where necessary, updated may be found following the CAS number for each of the adopted entries in the alphabetical listing, e.g., Chromium [7440-47-3] and inorganic compounds (2017). The reader is advised to refer to the "TLV® Chronology" section in each Documentation for a brief history of the TLV® recommendations and notations.

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ONLINE TLV® AND BEI® RESOURCES

In an effort to make the threshold limit values (TLVs®) and biological exposure indices (BEIs®) guideline establishment process more transparent, and assist ACGIH® members, government regulators, and industry groups in understanding the basis and limitations of the TLVs® and BEIs®, ACGIH® has an online TLV®/BEI® Resources Section on its website at acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations/tlv-bei-development.

The TLV®/BEI® Resources Section is divided into eight categories, each containing clear and concise information. The categories are:

- **Conflict of Interest Policy** — applies to the Board of Directors, Committee Chairs, and Committee members (including consultant members), and safeguards the integrity and credibility of ACGIH® programs and activities. The Policy, as well as ACGIH®'s oversight and review, each play an important part in the protection of ACGIH®'s programs and activities from inappropriate influences (acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations/conflict-of-interest-policy).
- **Notice of Intended Changes (NIC)** — a listing of the proposed actions of the TLV®/CS, TLV®/PA, and BEI® Committees. This Notice provides an opportunity for public comment. Values remain on the NIC for approximately one year after they have been ratified by ACGIH®'s Board of Directors. The proposals should be considered final values during the period they are on the NIC. If the Committee neither finds nor receives any substantive data that change its scientific opinion regarding an NIC TLV® or BEI®, the Committee may then approve its recommendation to the ACGIH® Board of Directors for adoption. If the Committee finds or receives substantive data that change its scientific opinion regarding an NIC TLV® or BEI®, the Committee may change its recommendation to the ACGIH® Board of Directors for the matter to be either retained on or withdrawn from the NIC (Note: In the Physical Agents section of this book, the term Notice of Intent to Establish (NIE) is used in addition to NIC. For the purpose of this process overview, only the term NIC is used.) (acgih.org/science/tlv-bei-guidelines/documentation-publications-and-data/notice-of-intended-changes).
- **TLV®/BEI® Policy Statement** — states what the TLVs® and BEIs® are and how they are intended to be used. While the TLVs® and BEIs® do contribute to the overall improvement in worker protection, the user must recognize the constraints and limitations subject to their proper use and bear the responsibility for such use (acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations/tlv-bei-policy-statement).
- **TLV®/BEI® Position Statement** — expresses ACGIH®'s position on the TLVs® and BEIs® process. ACGIH® is proud of the positive impact that the TLVs® and BEIs® have had on workers worldwide, and stands behind the hard work of its Committees to make the process more transparent and accessible. This section is presented in its entirety on pages vi through vii (acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations/tlv-bei-position-statement).

- **TLV®/BEI® Development Process** — gives an overview of the process the Committees go through when establishing a TLV® or BEI®. This section is presented in its entirety on pages vi through vii (acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations/tlv-bei-development).
- **Committee Operations Manuals** — portable data files (PDF) of the Threshold Limit Values for Chemical Substances, the Threshold Limit Values for Physical Agents, and the Biological Exposure Indices Committees' Operations Manuals. Each Manual covers such areas as the Committee's mission, membership in the Committee, Committee make-up, internal and external communications with the Committee, flow of information, procedures for development of symposia and workshops, etc. (acgih.org/about/volunteer-leadership/committees/committees-operations-manuals).
- **TLV®/BEI® Process Presentations** — stand-alone PowerPoint presentations from the annual American Industrial Hygiene Conference and Exposition (AIHce) are offered. These forums are open to all AIHce registrants and focus on the process used by ACGIH® and its TLV®, BEI®, and Biological Committees. These presentations are posted on the ACGIH® website (acgih.org/science/tlv-bei-guidelines/policies-procedures-presentations).
- **Under Study List** — consists of substances, agents, and issues that are being considered by the Committees. Each Committee solicits data, comments, and suggestions that may assist in their deliberations about substances, agents, and issues on the Under Study list (acgih.org/science/tlv-bei-guidelines/documentation-publications-and-data/under-study). Further, each Committee solicits recommendations for additional chemical substances, physical agents, and issues of concern to the industrial hygiene and occupational health communities.

REVISIONS OR ADDITIONS

FOR 2022

All pertinent endnotes, abbreviations, and definitions relating to the materials in this publication appear on the inside back cover.

Chemical Substances Section

- Proposed TLVs® that appeared on the 2021 NIC are adopted for the following substances:

Anlimony hydride	Iodoform
Benzoic acid and alkali benzoates	Isosulfurane
Clothianidin	2-Methyl-2-bulene
Cyclopentane	Phosgene
Cyromazine	Prometon
Dipropylene glycol methyl ether	Prometryn
Ethyl benzene	Titanium Dioxide
Imazosulfuron	Trimethyl benzene isomers
	Xylene

- The following substances and proposed TLVs® new to this section are placed on the NIC:

Benzoquinone	Tetrachlorvinphos
Divinylbenzene-ethyl styrene mixture	
2-Ethylhexanol	
Glycidyl Methacrylate	
Glyphosate	

- Revisions to adopted TLVs® are proposed for the following substances and placed on the NIC:

Benzene	n-Propyl Nitrate
Iodine and Iodides	Propylene glycol dinirate
Methylnaphthalene, all isomers	Silicon Carbide
Nitric Acid	Vinyltoluene, all isomers
Phenothiazine	

- The following substances are retained on the NIC without revised TLV® recommendations or notations:

Trimetaresyl phosphate
Triparaesyl phosphate

- The following substances are retained on the NIC with revised TLV® recommendations or notations:

Acalamiprid
Di(2-ethylhexyl) phthalate
Ethylene glycol dinirate

Biological Exposure Indices (BEIs®) Section

- The proposed BEIs® that appeared on the 2021 NIC are adopted for the following substances:

Cyclohexane

- The following substance and proposed BEI® new to this section is placed on the NIC:

Acrylamide

- Revisions to the BEIs® for the following are proposed and placed on the NIC:

2-Ethoxyethanol and 2-Ethoxyethyl Styrene
Acetate
Furfural

- Negative Feasibility Assessments were completed for the following substances:

Diethylhydroxylamine
Styrene oxide

Physical Agents Section

- The following agents that appeared on the 2021 NIC with proposed changes or revisions are adopted:

ULTRAVIOLET RADIATION

- Under the *Ergonomics* section, revision to the TLV® for the following is proposed and placed on the NIC:

UPPER LIMB LOCALIZED FATIGUE

- The reason for this NIC is to add language, including an equation to be applied over the range of the TLV®.

- Under the *Thermal Stress* section, revision to the TLV® for the following is proposed and placed on the NIC:

HEAT STRESS AND STRAIN

- Under the *Physical Agents* section, the following appendix is adopted: Appendix C: Statement on Fatigue and Its Management in the Workplace.

- Under the *Electromagnetic Fields 0-300 GHz* section, editorial revisions were made to the Radiofrequency/Microwave Radiation TLV® to update references reflecting revisions to IEEE and ICNIRP exposure limits.

regarding TLV® or BEI® values or notations, the committee may revise the proposal(s) and recommend to the ACGIH® Board of Directors that it be retained on the NIC.

Important Notice: The comment period for an NIC or NIE draft *Documentation* and its respective TLV(s)®, notation(s), or BEI(s)®, will be limited to a firm 4-month period, running from February 1 to May 31 of each year. ACGIH® has structured the comment period to ensure all comments are received by ACGIH® in time for full consideration by the appropriate committee before its fall meeting. Because of the time required to properly review, evaluate, and consider comments during the fall meetings, any comments received after the deadline of May 31 will not be considered in that year's committee deliberations regarding the outcome for possible adoption of an NIC or NIE. As general practice, ACGIH® reviews all submissions regarding chemical substances and physical agents on the Under Study list, as well as NICs or NIEs, or currently adopted BEI(s)® or TLV(s)®, All comments received after May 31 will be fully considered in the following year. Draft *Documentation* will be available for review during the comment period.

When submitting comments, ACGIH® requires that the submission be limited to 10 pages in length, including an executive summary. The submission may include appendices of citable material not included as part of the 10 page limit. It would be very beneficial to structure comments as follows:

- Executive Summary** – Provide an executive summary with a limit of 250 words.
- List of Recommendations/Actions** – Identify, in a vertical list, specific recommendations/actions that are being requested.
- Rationale** – Provide specific rationale to justify each recommendation/action requested.
- Citable Material** – Provide citable material to substantiate the rationale.

The above procedure will help ACGIH® to more efficiently and productively review comments.

- TLV®/BEI® and Adopted *Documentation*:** If the committee neither finds nor receives any substantive data that change its scientific opinion regarding an NIC, TLV® or BEI® (or notation), the committee may then approve its recommendation to the ACGIH® Board of Directors for adoption. Once approved by the committee and subsequently ratified by the Board, the TLV® or BEI® is published as adopted in the *Annual Reports of the Committees on TLV® and BEI®* and in the annual *TLV® and BEI®* book, and the draft TLV® or BEI® *Documentation* is finalized for formal publication.
- Withdraw from Consideration:** At any point in the process, the committee may determine not to proceed with the development of a TLV® or BEI® and withdraw it from further consideration. Substances or physical agents that have been withdrawn from consideration may be reconsidered by placement on the Under Study list (step 1 above).

Summary: There are several important points to consider throughout the above process:

- The appropriate method for an interested party to submit data to the TLV® and BEI® process is through the submission of peer-reviewed, peer-reviewed and published. ACGIH® strongly encourages interested parties to publish their studies and not to rely on unpublished studies as their input to the TLV® and BEI® process. Also, the best way to submit comments to ACGIH® is in the early stages of the TLV®/BEI® Development Process, preferably while the substance is on the Under Study list.
- An additional venue for presentation of new data is an ACGIH® sponsored symposium or workshop that provides a platform for discussion and scientific interpretation. ACGIH® encourages interested external parties for suggestions on symposia topics, including suggestions about sponsors, speakers and format. ACGIH® establishes several criteria to determine the appropriateness of a symposium. A key criterion is that the symposium must be the most efficient method of presenting the committee with information that will assist in the scientific judgment used for writing the *Documentation* and in setting a recommendation for TLV® or BEI®. A symposium topic should be suggested while the substance/agent is under study, as symposia require considerable time commitment, and resources to develop. Symposium topic suggestions submitted while a substance is on the NIC will be considered, but this is usually too late in the decision-making process. A symposium topic will not be favorably considered if its purpose is to provide a forum merely for voicing opinions about existing data. Rather, there must be ongoing research, scientific uncertainty about currently available data, or another scientific reason for the symposium. Symposium topic suggestions should be sent to the ACGIH® Science Group: science@acgih.org.
- ACGIH® periodically receives requests from external parties to make a presentation to a committee about specific substances or cases. This is strictly by exception that such requests are granted. While there are various reasons for this position, the underlying fact is that the committee focuses on data that have been peer-reviewed and published and not on data presented in a private forum. A committee may grant a request when the data is significantly new, has received peer review, is the best vehicle for receipt of the information, and is essential to the committee's deliberations. The presentation is not a forum to merely voice opinions about existing data. In order for a committee to evaluate such a request, the external party must submit a request in writing that, at a minimum, addresses the following elements: (a) a detailed description of the presentation, (b) a clear demonstration of why the information is important to the committee's deliberations, and (c) a clear demonstration of why a meeting is the necessary method of delivery. This request must be sent to the ACGIH® Science Group (science@acgih.org).

Also, the committee may initiate contact with outside experts (a) to meet with the committee to discuss specific issues or to obtain additional

al knowledge on the subject, and (b) to provide written input or review of a *Documentation*. This is only done on an as needed basis, and not as a routine practice.

- ACGIH® does not commit to deferring consideration of a new or revised TLV® or BEI® pending the outcome of proposed or ongoing research.

Important dates to consider throughout each calendar year of the TLV®/BEI® Development Process:

First Quarter:

- The *Annual Reports of the Committees on TLV® and BEI®* and the *TLV® and BEI®* book are published.

Year Round:

- Public comments are accepted. See Note below.
- Committees meet.

Note: It is recommended that comments be submitted as early as practical, and preferably no later than May 31st to allow sufficient time for their proper consideration/review. This is particularly important for an NIC TLV®/BEI®.

Important Notice: The comment period for an NIC or NIE draft *Documentation* and its respective TLV(s)®, notation(s), or BEI(s)® will be limited to a firm 4-month period, running from February 1 to May 31 of each year. (See Important Notice, step 3 above.)

Third Quarter:

- Two-tier Under Study list published on website (acgih.org/tlv-bei-guidelines/documentation-publications-and-data/under-study-list).

Fourth Quarter:*

- TLV®/BEI® Committees vote on proposed TLV®/BEI® for NIC or final adoption.
- ACGIH® Board of Directors ratifies TLV®/BEI® Committee recommendations.

*These actions typically occur early in the fourth quarter, but may occur during other periods of the quarter or year.

Endnote: Sample permission statement granting ACGIH® authorization to use, cite, and release unpublished studies:

[Name], [author or sponsor of the study] grants permission to ACGIH® to use and cite the documents listed below, and to fully disclose them to parties outside of ACGIH® upon request. Permission to disclose the documents includes permission to make copies as needed.

Example: Joseph D. Doe, PhD, co-author of the study, grants permission to ACGIH® to use and cite the document listed below, and to fully disclose the document to parties outside of ACGIH®. Permission to disclose the document includes permission to make copies as needed.

Effects of Quartz Status on Pharmacokinetics of Intratracheally Instilled Cristobalite in Rats, March 21, 2003.*

*This statement must be signed by an individual authorized to give the permission, and should include contact information such as title and address.

Last Revised: April 2012

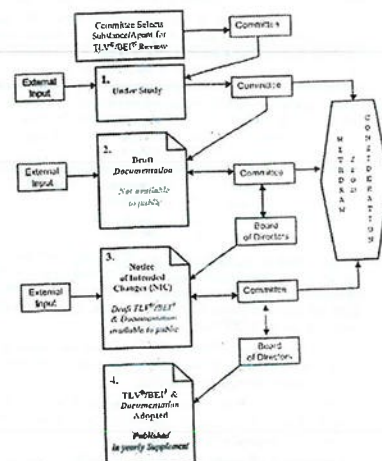


FIGURE 1. The TLV®/BEI® Development Process Flow Chart.

December 2012

not fine lines between safe and dangerous exposures, nor are they a relevant index of toxicology. The TLVs® and BEIs® are not quantitative estimates of risk at different exposure levels or by different routes of exposure.

Since ACGIH® TLVs® and BEIs® are based solely on health factors, there is no consideration given to economic or technical feasibility. Regulatory agencies should not assume that it is economically or technically feasible for an industry or employer to meet TLVs® or BEIs®. Similarly, although there are usually valid methods to measure workplace exposures at the TLVs® and BEIs®, there can be instances where such reliable test methods have not yet been validated. Obviously, such a situation can create major enforcement difficulties if a TLV® or BEI® was adopted as a standard.

ACGIH® does not believe that TLVs® and BEIs® should be adopted as standards without full compliance with applicable regulatory procedures, including an analysis of other factors necessary to make appropriate risk management decisions. However, ACGIH® does believe that regulatory bodies should consider TLVs® or BEIs® as valuable input into the risk characterization process (hazard identification, dose response relationships, and exposure assessment). Regulatory bodies should view TLVs® and BEIs® as an expression of scientific opinion.

ACGIH® is proud of the scientists and the many members who volunteer their time to work on the TLV® and BEI® Committees. These experts develop written Documentation that includes an expression of scientific opinion and a description of the basis, rationale, and limitations of the conclusions reached by ACGIH®. The Documentation provides a comprehensive list and analysis of all the major published peer-reviewed studies that ACGIH® relied upon in formulating its scientific opinion. Regulatory agencies dealing with hazards addressed by a TLV® or BEI® should obtain a copy of the full written Documentation for the TLV® or BEI®. Any use of a TLV® or BEI® in a regulatory context should include a careful evaluation of the information in the written Documentation and consideration of all other factors as required by the statutes which govern the regulatory process of the governmental body involved.

- ACGIH® is a not-for-profit scientific association.
- ACGIH® proposes guidelines known as TLVs® and BEIs® for use by industrial hygienists in making decisions regarding safe levels of exposure to various hazards found in the workplace.
- ACGIH® is not a standard-setting body.
- Regulatory bodies should view TLVs® and BEIs® as an expression of scientific opinion.
- TLVs® and BEIs® are not consensus standards.
- ACGIH® TLVs® and BEIs® are based solely on health factors; there is no consideration given to economic or technical feasibility. Regulatory agencies should not assume that it is economically or technically feasible to meet established TLVs® or BEIs®.
- ACGIH® believes that TLVs® and BEIs® should NOT be adopted as standards without an analysis of other factors necessary to make appropriate risk management decisions.
- TLVs® and BEIs® can provide valuable input into the risk characterization process. Regulatory agencies dealing with hazards addressed by a TLV® or BEI® should review the full written Documentation for the numerical TLV® or BEI®.

ACGIH® is publishing this Statement in order to assist ACGIH® members, government regulators, and industry groups in understanding the basis and limitations of the TLVs® and BEIs® when used in a regulatory context. This Statement was adopted by the ACGIH® Board of Directors on March 1, 2002.

TLV®/BEI® DEVELOPMENT PROCESS: AN OVERVIEW

Provided below is an overview of the ACGIH® TLV®/BEI® Development Process. Additional information is available on the ACGIH® website (acgih.org). Please also refer to the attached Process Flowchart (Figure 1).

1. **Under Study:** When a substance or agent is selected for the development or revision of a TLV® or BEI®, the appropriate committee places it on its Under Study list. Each committee determines its own selection of chemical substances or physical agents for its Under Study list. A variety of factors is used in this selection process, including prevalence, use, number of workers exposed, availability of scientific data, existence/absence of a TLV® or BEI®, age of TLV® or BEI®, input from the public, etc. The public may offer input to any TLV® or BEI® Committee by e-mail to science@acgih.org.

The Under Study lists serve as notification and invitation to interested parties to submit substantive data and comments to assist the committees in their deliberations. Each committee considers only those comments and data that address issues of health and exposure, but not economic or technical feasibility. Comments must be accompanied by copies of substantiating data, preferably in the form of peer-reviewed literature. Should the data be from unpublished studies, ACGIH® requires written authorization from the owner of the studies granting ACGIH® permission to (1) use, (2) cite within the Documentation, and (3) upon request from a third party, release the information. All three permissions must be stated/covered in the written authorization. (See endnote for a sample permission statement.) Electronic submission of all information to the ACGIH® Science Group at science@acgih.org is preferred and greatly increases the ease and efficiency with which the committees can consider the comments or data.

The Under Study list is published each year by February 1 on the ACGIH® website (acgih.org/tlv-bei-guidelines/documentation-publications-and-data/under-study-list), in the Annual Reports of the Committees on TLVs® and BEIs®, and later in the annual TLVs® and BEIs® book. In addition, the Under Study list is updated by July 31 into a two-for list.

- Tier 1 entries indicate which chemical substances and physical agents may move forward as an NIC or NIE in the upcoming year, based on their status in the development process.
- Tier 2 consists of those chemical substances and physical agents that will not move forward, but will either remain on, or be removed from the Under Study list for the next year.

This updated list will remain in two-tiers for the balance of the year. All updates to the Under Study lists and publication of the two-tier lists are posted on the ACGIH® website (acgih.org/tlv-bei-guidelines/documentation-publications-and-data/under-study-list).

2. **Draft Documentation:** One or more members of the appropriate committee are assigned the task of collecting information and data from the scientific literature, reviewing results of unpublished studies submitted for

review, and developing a draft TLV® or BEI® Documentation. The draft Documentation is a critical evaluation of the scientific literature relevant to recommending a TLV® or BEI®, however, it is not an exhaustive critical review of all studies but only those pertinent to identifying the critical effect and setting the TLV®. Particular emphasis is given to papers that address minimal or no adverse health effect levels in exposed animals or workers that deal with the reversibility of such effects, or in the case of a BEI®, that assess chemical uptake and provide applicable determinant(s) as an index of uptake. Human data, when available, are given special emphasis. This draft Documentation, with its proposed TLV® or BEI®, is then reviewed and critiqued by additional committee members, and eventually by the full committee. This often results in several revisions to the draft Documentation before the full committee accepts the proposed draft TLV® or BEI® and draft Documentation. The draft Documentation is not available to the public during this stage of the development process and is not released until it is at the Notice of Intended Changes (NIC) stage. Authorship of the Documentation is not disclosed.

3. **Notice of Intended Changes (NIC):**

[Notice of Intent to Establish (NIE): The Physical Agents section of the TLVs® and BEIs® book also uses the term Notice of Intent to Establish (NIE) in addition to NIC. An NIE follows the same development process as an NIC. For purposes of this process overview, only the term NIC is used.]

When the full committee accepts the draft Documentation and its proposed TLV® or BEI®, the Documentation and proposed values are then recommended to the ACGIH® Board of Directors for ratification as an NIC. If ratified, each proposed TLV® or BEI® is published as an NIC in the Annual Reports of the Committees on TLVs® and BEIs®, which is published in the ACGIH® newsletter, and is also available online for purchase at acgih.org store. At the same time, the draft Documentation is made available through ACGIH® Customer Service or online at www.acgih.org store. All information contained in the Annual Reports of the Committees on TLVs® and BEIs® is integrated into the annual TLVs® and BEIs® book, which is usually available to the general public in February or March of each year. Following the NIC ratification by the ACGIH® Board of Directors, interested parties, including ACGIH® members, are invited to provide data and substantive comments, preferably in the form of peer-reviewed literature, on the proposed TLV® or BEI® contained in the NIC. Should the data be from unpublished studies, ACGIH® requires written authorization from the owner of the studies granting ACGIH® permission to (1) use, (2) cite within the Documentation, and (3) upon request from a third party, release the information. All three permissions must be stated/covered in the written authorization. (See endnote for a sample permission statement.) The most effective and helpful comments are those that address specific points within the draft Documentation. Changes or updates are made to the draft Documentation as necessary. If the committee finds or receives substantive data that change its scientific opinion

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ACGIH® is a 501(c)(3) charitable scientific organization that advances occupational and environmental health. The organization has contributed substantially to the development and improvement of worker health protection. The organization is a professional society, not a government agency.

The *Documentation of the Threshold Limit Values and Biological Exposure Indices* is the source publication for the TLVs® and BEIs® issued by ACGIH®. That publication gives the pertinent scientific information and data with reference to literature sources that were used to base each TLV® or BEI®. For better understanding of the TLVs® and BEIs®, it is essential that the *Documentation* be consulted when the TLVs® or BEIs® are being used. For further information, contact The Science Group, ACGIH®. The most up-to-date list of substances and agents under study by the committees is available at acgih.org/tlv-bei-guidelines/documentation-publications-and-data-under-study-list.

Comments, suggestions, and requests for interpretations or technical information should be directed to The Science Group at the address below or to the following e-mail address: science@acgih.org. To place an order, visit our website at acgih.org/store, contact Customer Service at the address or phone number below, or use the following e-mail address: customerservice@acgih.org.

Help ensure the continued development of
TLVs® and BEIs®. Make a tax deductible donation to
the FOHS Sustainable TLV®/BEI® Fund today!

acgih.org/foundation/donate

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In the event significant errata are required, they will be listed on the ACGIH® website at acgih.org/tlv-bei-guidelines/policies-procedures-presentations.

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STATEMENT OF POSITION REGARDING THE TLVs® AND BEIs®

The American Conference of Governmental Industrial Hygienists (ACGIH®) is a private, not-for-profit, nongovernmental corporation whose members are industrial hygienists or other occupational health and safety professionals dedicated to promoting health and safety within the workplace. ACGIH® is a scientific association. ACGIH® is not a standards-setting body. As a scientific organization, it has established committees that review the existing published, peer-reviewed scientific literature. ACGIH® publishes guidelines known as Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) for use by industrial hygienists in making decisions regarding safe levels of exposure to various chemical and physical agents found in the workplace. In using these guidelines, industrial hygienists are cautioned that the TLVs® and BEIs® are only one of multiple factors to be considered in evaluating specific workplace situations and conditions.

Each year, ACGIH® publishes its TLVs® and BEIs® in a book. In the introduction to the book, ACGIH® states that the TLVs® and BEIs® are guidelines to be used by professionals trained in the practice of industrial hygiene. The TLVs® and BEIs® are not designed to be used as standards. Nevertheless, ACGIH® is aware that in certain instances the TLVs® and the BEIs® are used as standards by national, state, or local governments.

Governmental bodies establish public health standards based on statutory and legal frameworks that include definitions and criteria concerning the approach to be used in assessing and managing risk. In most instances, governmental bodies that set workplace health and safety standards are required to evaluate health effects, economic and technical feasibility, and the availability of acceptable methods to determine compliance.

ACGIH® TLVs® and BEIs® are not consensus standards. Voluntary consensus standards are developed or adopted by voluntary consensus standards bodies. The consensus standards process involves canvassing the opinions, views, and positions of all interested parties and then developing a consensus position that is acceptable to these parties. While the process used to develop a TLV® or BEI® includes public notice and requests for all available and relevant scientific data, the TLV® or BEI® does not represent a consensus position that addresses all issues raised by all interested parties (e.g., issues of technical or economic feasibility). The TLVs® and BEIs® represent a scientific opinion based on a review of existing peer-reviewed scientific literature by committees of experts in public health and related sciences.

ACGIH® TLVs® and BEIs® are health-based values. ACGIH® TLVs® and BEIs® are established by committees that review existing published and peer-reviewed literature in various scientific disciplines (e.g., industrial hygiene, toxicology, occupational medicine, and epidemiology). Based on the available information, ACGIH® formulates a conclusion on the level of exposure that the typical worker can experience without adverse health effects. The TLVs® and BEIs® represent conditions under which ACGIH® believes that nearly all workers may be repeatedly exposed without adverse health effects. They are

2022

TLVs® and BEIs®

Based on the Documentation of the

Threshold Limit Values

*for Chemical Substances
and Physical Agents*

&

Biological Exposure Indices



POLICY STATEMENT ON THE USES OF TLVs® AND BEIs®

The Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) are developed as guidelines to assist in the control of health hazards. These recommendations or guidelines are intended for use in the practice of industrial hygiene, to be interpreted and applied only by a person trained in this discipline. They are not developed for use as legal standards and ACGIH® does not advocate their use as such. However, it is recognized that in certain circumstances individuals or organizations may wish to make use of these recommendations or guidelines as a **supplement** to their occupational safety and health program. ACGIH® will not **oppose** their use in this manner, if the use of TLVs® and BEIs® in these instances will contribute to the overall improvement in worker protection. However, the user must recognize the constraints and limitations subject to their proper use and bear the responsibility for such use.

The Introductions to the TLV®/BEI® Book and the TLV®/BEI® Documentation provide the philosophical and practical bases for the uses and limitations of the TLVs® and BEIs®. To extend those uses of the TLVs® and BEIs® to include other applications, such as use without the judgment of an industrial hygienist; application to a different population; development of new exposure/recovery time models; or new effect endpoints, stretches the reliability and even viability of the database for the TLV® or BEI® as evidenced by the individual's Documentation.

It is not appropriate for individuals or organizations to impose on the TLVs® or the BEIs® their concepts of what the TLVs® or BEIs® should be or how they should be applied or to transfer regulatory standards requirements to the TLVs® or BEIs®.

Approved by the ACGIH® Board of Directors on March 1, 1999.

Special Note to User

The values listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations to assist in the control of potential workplace health hazards and for no other use. These values are *not* fine lines between safe and dangerous concentrations and *should not* be used by anyone untrained in the discipline of industrial hygiene. It is imperative that the user of this book read the Introduction to each section and be familiar with the Documentation of the TLVs® and BEIs® before applying the recommendations contained herein. ACGIH® disclaims liability with respect to the use of the TLVs® and BEIs®.

2022

TLVs® and BEIs®

Based on the Documentation of the

Threshold Limit Values

*for Chemical Substances
and Physical Agents*

&

Biological Exposure Indices



Signature Publications