**FUNDAMENTALS OF INDUSTRIAL HYGIENE, 6TH ED.**

**HOMEWORK #1**

**INDIVIDUAL CALCULATION OF TIME-WEIGHTED AVERAGES**

**Name: KEY *35 pts. possible***

**EXERCISES:** Perform the calculations identified below. Show your work neatly and clearly in a manner similar to the examples provided above (i.e., write the formula, define each variable in the formula, show steps of your calculations).

**Part I: Duration – Calculation of Time-Weighted Averages**

Calculate the 8-hour time-weighted average (TWA) of worker exposure based on the information provided below. *(6 points)*

**Compound:** Calcium sulfate (PEL-TWA = 15 *mg/m3* (total), 5 *mg/m3* (resp), TLV-TWA = 10 *mg/m*3)

 **Time Period Contaminant**

**Period Duration Concentration**

 **(*T*) (*C*) (*Tx  Cx*)**

 1 0.5 *hr* 12 *mg/m*3 *6* *hr mg/m*3

 2 0.5 *hr* 9 *mg/m*3 *4.5* *hr mg/m*3

 3 0.5 *hr* 16 *mg/m*3 *8 hr mg/m*3

 4 0.5 *hr* 7 *mg/m*3 *3.5* *hr mg/m*3

 5 0.5 *hr* 5 *mg/m*3 *2.5* *hr mg/m*3

 6 0.5 *hr* 6 *mg/m*3 *3 hr mg/m*3

 7 0.5 *hr* 18 *mg/m*3 *9 hr mg/m*3

 8 0.5 *hr* 23 *mg/m*3 *11.5* *hr mg/m*3

 9 0.5 *hr* 4 *mg/m*3 *2 hr mg/m*3

 10 0.5 *hr* 2 *mg/m*3 *1* *hr mg/m*3

 11 0.5 *hr* 6 *mg/m*3 *3* *hr mg/m*3

 12 0.5 *hr* 17 *mg/m*3 *8.5* *hr mg/m*3

 13 0.5 *hr* 8 *mg/m*3 *4* *hr mg/m*3

 14 0.5 *hr* 3 *mg/m*3 *1.5* *hr mg/m*3

 15 0.5 *hr* 9 *mg/m*3 *4.5* *hr mg/m*3

 16 0.5 *hr* 2 *mg/m*3 *1* *hr mg/m*3

 Σ = ***8* *hr***  Σ = ***73.5* *hr mg/m*3**

Formula: $TWA= \frac{C\_{a}T\_{a}+ C\_{b}T\_{b}+ . ..C\_{n}T\_{n}}{8 hrs (480 min)}$

where: ***Cx* = concentration of contaminant during a specific time period**

 ***Tx* = time of exposure period (in hours)**

Calculation: $TWA=\frac{73.5 hr mg/m^{3}}{8 hr}$

 $TWA=9.2 mg/m^{3}$

Carbon tetrachloride is a colorless liquid with a sweet smell that can be detected at low levels. Once widely used as an industrial solvent, a dry-cleaning solvent, and as a refrigerant, its use has been greatly reduced. Carbon tetrachloride is one of the most potent hepatotoxins (toxic to the liver). Prior to the Montreal Protocol, large quantities of carbon tetrachloride were used to produce chlorofluorocarbon refrigerants . . . potent ozone depleting substances. Carbon tetrachloride is also a greenhouse gas. Prior to its use being discontinued, workers employed in a dry-cleaning facility that operated on 8-hour days (40 hours/week) began complaining of light-headedness and dizziness. The company installed ventilation hoods over the tanks of carbon tetrachloride where garments were soaked, and performed air quality monitoring to evaluate the effectiveness of their efforts. The table below provides the results of sampling conducted in the breathing zone of one of its workers.

Calculate the 8-hour time-weighted average (TWA) of worker exposure based on the information provided below to determine if the worker has been exposed above the OEL. *(8 points)*

**Compound:** Carbon tetrachloride (PEL-TWA = 10 *ppm*, TLV-TWA = 5 *ppm*)

 **Time Period Contaminant**

**Period Duration Concentration**

 **(*T*) (*C*) (*Tx  Cx*)**

 1 15 *min* 6 *ppm* *90 min ppm 1.50 hr ppm*

 2 20 *min* 9 *ppm* *180 min ppm 3.00 hr ppm*

 3 15 *min* 8 *ppm* *120 min ppm 2.00 hr ppm*

 4 45 *min* 11 *ppm* *495 min ppm 8.25 hr ppm*

 5 35 *min* 7 *ppm* *245 min ppm 4.08 hr ppm*

 6 20 *min* 6 *ppm* *120 min ppm 2.00 hr ppm*

 7 40 *min* 9 *ppm* *360 min ppm 6.00 hr ppm*

 8 20 *min* 13 *ppm* *260 min ppm 4.33 hr ppm*

 9 30 *min* 7 *ppm* *210 min ppm 3.50 hr ppm*

 10 25 *min* 5 *ppm* *125 min ppm 2.08 hr ppm*

 11 15 *min* 10 *ppm* *150 min ppm 2.50 hr ppm*

 12 20 *min* 7 *ppm* *140 min ppm 2.33 hr ppm*

 Σ = ***300 min (5 hr)***  Σ = ***2495 min ppm 41.62 hr ppm***

Formula: $TWA= \frac{C\_{a}T\_{a}+ C\_{b}T\_{b}+ . ..C\_{n}T\_{n}}{8 hrs (480 min)}$

where: ***Cx* = *concentration of contaminant during a specific time period***

 ***Tx* = *time of exposure period (in minutes)***

Calculation: $TWA=\frac{2505 min ppm}{480 min}$ $TWA=\frac{41.62 hr ppm}{8 hr}$

$TWA=5.2 ppm$

Was this worker exposed to this chemical above the PEL-TWA? ***No***

Was this worker exposed to this chemical above the TLV-TWA? ***Yes***

Cresols are widely occurring natural and manufactured aromatic organic compounds having a yellowish to brownish red tint, a distinctive “coal tar” aroma, and melting points near room temperature. The name cresol (creosol) reflects their traditional source, creosote. One isomer (*m*-Cresol) is a precursor to two commercially and widely used pesticides. A worker in the bagging plant for a pesticide manufacturer is exposed to airborne particulates containing cresol. The employee works four 10-hour days. An air monitoring device that sampled air in the breathing zone was attached to the worker during a typical work day and produced the results illustrated

Calculate the 8-hour time-weighted average (TWA) of worker exposure based on the information provided below to determine if the worker has been exposed above the OEL. *(8 points)*

**Compound:** Cresol (PEL-TWA = 22 *mg/m*3, TLV-TWA = 20 *mg/m*3)

 **Time Period Contaminant**

**Period Duration Concentration**

 **(*T*) (*C*) (*Tx  Cx*)**

 1 40 *min* 17 *mg/m*3 *680 min mg/m3 11.33 hr mg/m3*

 2 45 *min* 21 *mg/m*3 *945 min mg/m3 15.75 hr mg/m3*

 3 35 *min* 29 *mg/m*3 *1015 min mg/m3 16.92 hr mg/m3*

 4 35 *min* 17 *mg/m*3 *595 min mg/m3 9.92 hr mg/m3*

 5 25 *min* 25 *mg/m*3 *625 min mg/m3 10.42 hr mg/m3*

 6 15 *min* 21 *mg/m*3 *315 min mg/m3 5.25 hr mg/m3*

 7 35 *min* 24 *mg/m*3 *840 min mg/m3 14.00 hr mg/m3*

 8 45 *min* 23 *mg/m*3 *1035 min mg/m3 17.25 hr mg/m3*

 9 30 *min* 15 *mg/m*3 *450 min mg/m3 7.50 hr mg/m3*

 10 35 *min* 19 *mg/m*3 *665 min mg/m3 11.08 hr mg/m3*

 11 30 *min* 26 *mg/m*3 *780 min mg/m3 13.00 hr mg/m3*

 12 25 *min* 17 *mg/m*3 *425 min mg/m3 7.08 hr mg/m3*

 13 35 *min* 13 *mg/m*3 *455 min mg/m3 7.58 hr mg/m3*

 14 40 *min* 24 *mg/m*3 *960 min mg/m3 16.00 hr mg/m3*

 15 25 *min* 25 *mg/m*3 *625 min mg/m3 10.42 hr mg/m3*

 16 20 *min* 13 *mg/m*3 *260 min mg/m3 4.33 hr mg/m3*

 17 30 *min* 12 *mg/m*3 *360 min mg/m3 6.00 hr mg/m3*

 Σ = ***545 min (9.1 hr)*** Σ = ***11030 min mg/m3 183.83* *hr mg/m3***

Formula: $TWA= \frac{C\_{a}T\_{a}+ C\_{b}T\_{b}+ . ..C\_{n}T\_{n}}{8 hrs}$

where: ***Cx* = *concentration of contaminant during a specific time period***

 ***Tx* = *time of exposure period (in minutes)***  *\*REM: Worst-case scenario!*

 [11030 – (315 + 260 + 360)] = 10095

Calculation: $TWA=\frac{10095 min {mg}/{m^{3}}}{480 min}$ $TWA=\frac{168.25 hr {mg}/{m^{3}}}{8 hr}$ [183.83 – (5.25 + 4.33 + 6.00)] = 168.25

 $TWA=21.0 {mg}/{m^{3}}$

Was this worker exposed to this chemical above the PEL-TWA? ***No***

Was this worker exposed to this chemical above the TLV-TWA? ***Yes***

**Part II: Exposure to Mixtures**

Cosmetics and fragrances contain many chemical compounds that are known to have detrimental health effects. While concentrations are typically quite low in the final commercial product, in the factories where these compounds are stored and mixed, concentrations may be far higher. A worker in a blending room was exposed to multiple chemical airborne contaminants simultaneously. Fortunately, the worker was wearing an air-sampling device, so there is a record of the exposure concentrations for each contaminant. The table below represents these results.

Perform the required calculations *using the ACGIH TLV-TWA* values to determine the combined effect so you will know if the worker was exposed above the TLV. *(5 points)*

 **Chemical Chemical OEL Exposure**

 **Compound Function (PEL, TLV) Concentration**

diethyl phthalate (DEP) Solvent used to bind PEL-TWA (*none*) 0.4 *mg/m*3

 cosmetics and fragrances. TLV-TWA (5 *mg/m*3)

1,4-Dioxane A carcinogenic contaminant PEL-TWA (360 *mg/m*3) 14 *mg/m*3

 of cosmetics. TLV-TWA (72 *mg/m*3)

diethanolamine (DEA) Used in cosmetics to adjust PEL-TWA (*none*) 0.6 *mg/m*3

 pH. TLV-TWA (2 *mg/m*3)

triethanolamine (TEA) Ionic surfactant. PEL-TWA (*none*) 1.4 *mg/m*3

 TLV-TWA 5 (*mg/m*3)

Formula: $\frac{C\_{1}}{TLV\_{1}}+ \frac{C\_{2}}{TLV\_{2}} . . . \frac{C\_{n}}{TLV\_{n}}= ?$

where: ***Cx* = *observed atmospheric concentration***

 ***TLVx* = *the TLV that corresponds to the contaminant***

Calculations:

$$\frac{0.4}{5} + \frac{14}{72} + \frac{0.6}{2}+ \frac{1.4}{5}= ?$$

$$0.08 + 0.19+ 0.30 + 0.28 = ?$$

**0.85**

Was the worker’s exposure greater than the TLV? ***The TLV was not exceeded.***

During painting operations, keeping oil-based paints the proper consistency is often accomplished through the addition of a thinning liquid. There are a variety of paint thinners, each utilizing a different mixture of solvents. During the mixing process and during application, particularly when an air applicator is used, there is the potential for workers to be exposed to vapors. A worker uses a combination of three different paint thinning agents; naphthalene, dimethylformamide (DMK), and ethylbenzene. The worker then applies the paint using a spray gun inside a room that has been closed off from adjoining rooms by plastic sheets to prevent overspray and migration of odors, as well as to keep dust from entering the room. The observed concentrations of each thinning agent are identified in the table below.

Access the chemical sampling database on the OSHA website:

https://www.osha.gov/dts/chemicalsampling/toc/toc\_chemsamp.html

Click on the “Index of Chemical Sampling Information”

Use the alphabetical buttons across the top of the page to find the chemical sampling information for each of the chemicals identified above: Naphthalene, Dimethylformamide (DMK), and Ethylbenzene.

When you have accessed each page, record the PEL-TWA (in *ppm*) for each compound and record it in the table below. *(3 points)*

 **Observed PEL-TWA**

 **Substance Concentration (for substance)**

 Naphthalene 2 *ppm* ***10 ppm***

 Dimethylformamide 3 *ppm* ***10* *ppm***

 Ethylbenzene 62 *ppm* ***100* *ppm***

Perform the required calculations *using the OSHA PEL-TWA* values to determine the combined effect so you will know if the worker was exposed above the PEL. *(5 points)*

Formula: $\frac{C\_{1}}{PEL\_{1}}+ \frac{C\_{2}}{PEL\_{2}} . . . \frac{C\_{n}}{PEL\_{n}}= ?$

where: ***Cx* = *observed atmospheric concentration***

 ***PELx* = *the PEL that corresponds to the contaminant***

Calculations:

$$\frac{2 ppm}{10 ppm} + \frac{3 ppm}{10 ppm} + \frac{62 ppm}{100 ppm} = ?$$

$$0.20 + 0.30+ 0.62 = ?$$

**1.12**

Was the worker’s exposure greater than the PEL? ***The PEL was exceeded.***