Manažérstvo životného prostredia 2013 ♦ Management of Environment´2013
Zborník z XIII. medzinárodnej vedeckej konferencie, 18. - 19. apríl 2013, Bratislava
Proceedings of the 13rd International Conference, Bratislava, April 18-19, 2013
■ Žilina: Strix. Edícia ESE-14, 1. vyd., ISBN 978-80-89281-90-9 ■ Rusko, M. [Ed.] ■

A COMPARISON OF TWO DIFFERENT APPROACHES TO ESTIMATION OF INHALATION EXPOSURE TO MIST GENERATED DURING TURNING

MIROSLAV DADO – RICHARD HNILICA

ABSTRACT
Exposure by inhalation is a function of the concentration of the substance in the breathing zone atmosphere and is normally presented as an average concentration over a reference period. The traditional approach to characterizing worker exposure intensity to airborne contaminants is through personal or area monitoring. Different approach is based on mathematical modeling. In this study, we aim to evaluate the accuracy of Advanced REACH Tool (ART) model for predicting occupational exposure to metalworking fluid mist during turning process scenario through comparison between predicted exposure and actual measured data. The exposure scenario represented turning of cylindrical workpiece on horizontal lathe. There was good agreement between the results of the ART model and measured values.

Key words: *model, liquid aerosol, exposure, turning*

POROVNANIE DVOCH ODLIŠNÝCH PRÍSTUPOV PRI ODHADE INHALAČNEJ EXPOZÍCIE KVAPALNÉMU AEROSÓLU GENEROVANÉMU PRI SÚSTRUŽENÍ

ABSTRAKT
Inhalačná expozícia je funkciou koncentrácie látky v dýchacej zone človeka a zvyčajne býva vyjadrená prostredníctvom priemernej koncentrácie za referenčný čas. Tradičný prístup pri stanovení veľkosti inhalačnej expozície je pomocou osobného resp. miestneho odberu. Odlišný prístup je založený na matematickom modelovaní. Cieľom predkladanej štúdie bolo porovnať hodnoty hmotnostnej koncentrácie kvapalného aerosólu zistené na základe merania a predikčného modelu ART. Expozičný scenár reprezentoval sústruženie cylindrického obrobku na horizontálnom sústruhu. Výsledky štúdie indikujú dobrú zhodu medzi hodnotenými prístupmi.

Kľúčové slová: *model, kvapalný aerosól, expozícia, sústruženie*

INTRODUCTION

Metalworking fluid mist is important chemical/biological risk factor in working environment [1]. Exposure to metalworking fluids can result from inhalation of aerosols or from skin contact due to touching contaminated surfaces, handling of parts and equipment, splashing of fluids and settling of metalworking fluids aerosols on the skin [2].
Inhalation of metalworking fluids aerosols may cause irritation of the throat (e.g., sore, burning throat), nose (e.g., runny nose, congestion, and nosebleeds), and lungs (e.g., cough, wheezing, increased phlegm production, and shortness of breath). Metalworking fluids aerosol exposure has been associated with chronic bronchitis, asthma, hypersensitivity pneumonitis, and worsening of pre-existing respiratory problems [3].
Exposure by inhalation is a function of the concentration of the substance in the breathing zone atmosphere and is normally presented as an average concentration over a reference period. The severity of the exposure depends on a wide variety of factors. In general, the exposure will be higher if: the worker is in close proximity to the machine, the operation involves high tool speeds and deep cuts, machine is not enclosed, or if ventilation equipment was improperly selected or poorly maintained[4].
In addition, high-pressure and/or excessive fluid application, contamination of the fluid with tramp oils, and improper fluid selection and maintenance will tend to result in higher exposures.The traditional approach to characterizing worker exposure intensity to airborne contaminants is through personal or area monitoring. Different approach is based on mathematical modeling. Mathematical modeling is increasingly used by safety and health practicioners, but important caveats also pertain to the use of models: the model´s assumptions must reasonably match the workplace setting, only a few models have been rigorously validated, some settings may be so complex and variable that the only feasible approach is to directly monitor worker exposure levels [5]. When assessing the reliability and validity of exposure modeling tools, it is important to determine if the model accurately represented the exposure conditions in question and if the model could account for additional modifying factors or variables that would lead to a closer agreement between the predicted and actual airborne concentrations [6].

For estimation of inhalation exposure, the following preferential hierarchy should be applied to exposure data for estimation of exposure levels: measured data, including the quantification of key exposure determinants; appropriate analogous data, including the quantification of key exposure determinants; modelled estimates [7].
In this study, we aim to evaluate the accuracy of Advanced REACH Tool (ART) model for predicting occupational exposure to metalworking fluid mist during turning process scenario through comparison between predicted exposure and actual measured data.

MATERIALS AND METHODS

Simulated inhalation exposure scenario was established such that exposure could be evaluated using personal monitoring and then compared with results of ART model. The scenario represented turning of cylindrical workpiece (diameter: 30 mm and length: 400 mm) on horizontal lathe with following parameters: spindle speed of 800 rpm, MWF flow rate of 1.7 l/min. .
Synthetic fluid, mixed at 5% concentration with water, was applied via nozzle centered above the workpiece at a distance of 70 mm. Personal exposure to MWF mist was determined gravimetrically. Air samples were obtained using personal inhalable aerosol sampler (SKC Inc., model IOM). Personal sampler was sited in breathing zone of manikin representing operator of lathe. Sampler was attached to pump (A.P. Buck Inc., model No. L-4), which was operated at 2 l/min..The sampling flow rate was calibrated before and after each sampling event using field rotameter (SKC Inc., model No. 320-4A5).
Particles were collected on 25 mm diameter, MCE filters. Filters was conditioned in a temperature and relative humidity-controlled weghing room prior to taking pre-weight and again after sampling for the post-weight gravimetric measurements with microbalance (RADWAG, model XA 110).

Fig. 1. Photograph of experimental setup

The ART exposure model is a free web-based tool for the estimation of inhalation exposure at the workplace. ART combines a mechanistic model and a facility to update the estimates with the user’s own data. This integration of information is done using Bayesian statistics. The mechanistic model is based on a conceptual framework that adopts a source receptor approach.

Figure 2 shows a flow diagram of the ART mechanistic model, indicating the various modifying factors along the source-receptor pathway. The model allows for the calculation of total exposure from multiple activities within an 8-h work day and accounts for periods of non-exposure.

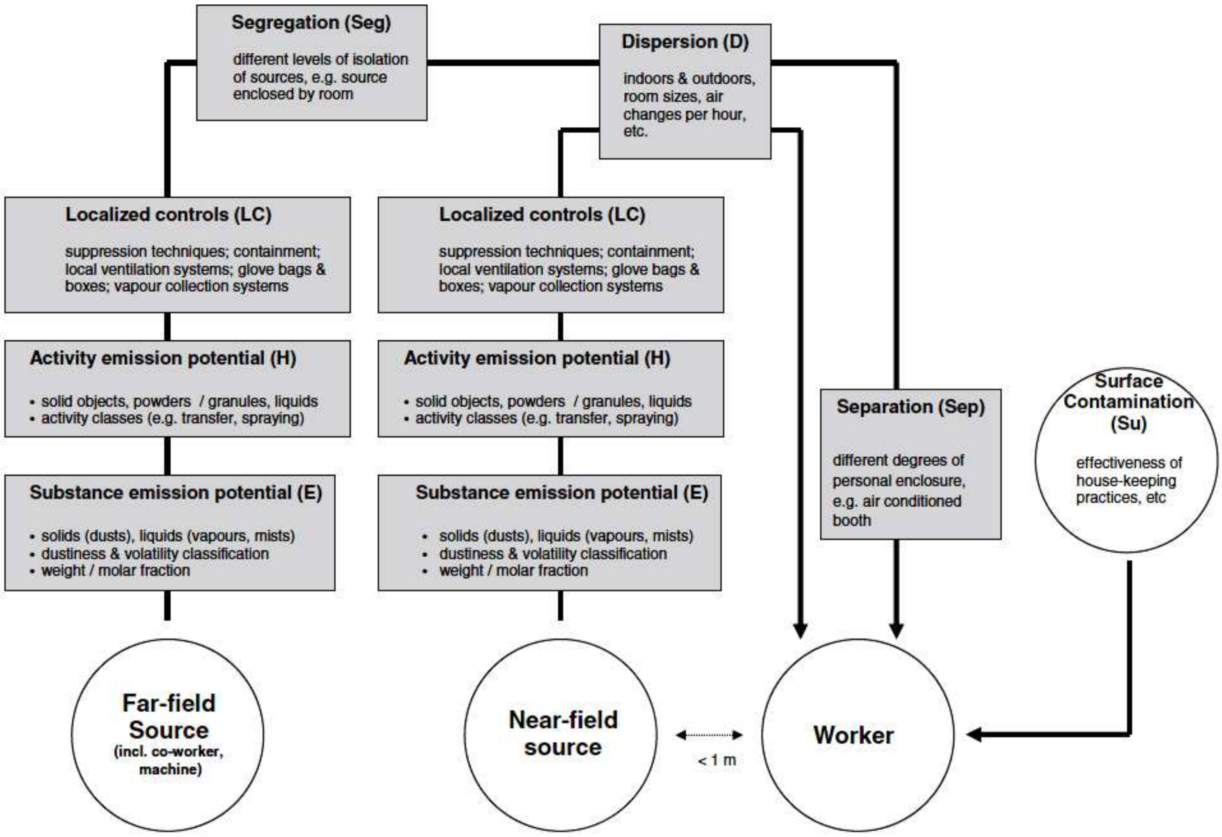

Fig. 2. Flow diagram of the ART model [6]

RESULTS

The results of personal sampling are summarized in Table 1. Time for every grab sample was 10 minutes and total sampling time was 120 minutes. The mass concentration of MWF mist ranged from 2 to 18.5 mg/m^3. The time-weighted average (TWA) mass concentration of MWF mist for a 8-hour workday is 1.9 mg/m^3.

Tab.1 Results of personal sampling

Number of sample	Difference between pre- and post-weight Δ m (mg)	Mass concentration c (mg/m^3)
1	0.18	9
2	0.37	18.5
3	0.11	5.5
4	0.13	6.5
5	0.15	7.5
6	0.16	8
7	0.07	3.5
8	0.04	2
9	0.04	2
10	0.04	2
11	0.31	15.5
12	0.18	9

A summary of input variables and associated exposure calculation for ART model is provided in Table 1. ART model overestimated metalworking fluid mist mass concentration in turning scenario by a factor 1.37.

Tab. 2 ART model inputs and exposure estimate

Scenario details	
Number of activities	1
Total duration	480 min.
Nonexposure period	80 min.
Emission source	Near field
Operational conditions	
Substance product type	liquid
Temperature of liquid	room temperature
Liquid weight fraction	main component
Viscosity	low
Activity emission potential	
Activity class	application of liquid in low speed process
Containment level	open process
Surface contamination	
Process fully enclosed?	no
Effective housekeeping practices in place?	no
General housekeeping practices in place?	yes
Dispersion	
Work area	indoors
Room size	100 m^3
Ventilation rate	no restriction on general ventilation characteristics
Predicted exposure level	
95th percentile full-shift exposure	2.6 mg/m^3
95% confidence interval	0.25 mg/m^3 to 70 mg/m^3

DISCUSSION AND CONCLUSION

MWF mist is present in the atmospheres of occupational environments as a result of numerous factors. These factors include high-speed dynamic forces involved in machining operations, the chemical composition of fresh fluids, and contaminants that enter fluids from extrinsic machinery sources [8]. Employee exposure to MWF mist generated during machining operations is affected by many variables. The type of MWF being used, the presence or absence of additives to reduce misting, the type of machining operations being performed, and the amount of general and local exhaust ventilation employed at the facility all affect the amount of MWF mist generated and released into the employee's breathing zone. Various studies indicate some of the important factors that influence mist generation, including tool spindle speed, size and location of the workpiece, speed, feed rate, and depth of cut, pressure of the applied fluid, and the proximity of the tool to the part [9]. Gunter and Sutherland [10] performed statistically designed experiments to determine the machining conditions that have the most significant effect on cutting fluid mist formation during a turning operation. The effects of spindle speed, nozzle diameter, workpiece diameter, fluid concentration and sampling location on mass concentration were investigated in experiment. A real-time aerosol monitor was used to measure MWF mist mass concentrations corresponding to the thoracic and respirable fractions. Results of this study showed that spindle speed is the most significant variable affecting mass concentration. Hwang and Chung [11] found out that the rotational speed of the workpiece and the fluid flow rate have great influence on the aerosol diffusion rate in turning operation. Sun et al. [12] developed and experimentally validated a model for cutting fluid mist formation that describes the interaction of the fluid with the rotating cylindrical workpiece during a turning operation. In machining operations performed with soluble oils, Piacitelli et al. [13] measured 242 total aerosol mass concentrations ranging from 0.07 to 2.41 mg/m^3 with a geometric mean of 0.34 mg/m^3 and a geometric standard deviation of 2.08. Simpson et al. [14] took 75 total inhalable particulate measurements where water-mixed MWFs were used. Concentrations varied from <0.01 to 1.82 mg/m^3 with a geometric mean of 0.07 mg/m^3 and a geometric standard deviation of 3.32. Our exposure results based on measurement was similar to the range of concentrations reported in studies mentioned above. The preferred method to estimate inhalation exposure is measurement of actual exposure concentrations in the breathing zone of worker at the workplace. In this study we estimated inhalation exposure level to metalworking fluid mist by applying two different methods: mathematical modeling and personal monitoring. There was good agreement between the results of the ART model and experimental values. However, the modifying factors applied to ART model could be refined further to produce a more accurate prediction.

ACKNOWLEDGEMENTS

The paper is based on work performed under research contract VEGA 1/0114/11 „Prediction models for workplace atmosphere contamination by metalworking fluid mist" which support is gratefully acknowledged.

REFERENCES

[1] SUJOVÁ, E. Contamination of the working air via metalworking fluid aerosols. Engineering Review, Vol. 32, Issue 1, pp. 9-15, 2012.

[2] ROSS, A. S., TESCHKE, K., BRAUER, M., KENNEDY, S. M. Determinants of exposure to metalworking fluid aerosol in small machine shops. Annals of Occupational Hygiene, Vol. 48, No. 5, pp. 383-391, 2004.

[3] LILLIENBERG, L., BURDOF, A., MATHIASSON, L., THÖRNBY, L. Exposure to metalworking fluid aerosols and determinants of exposure. Annals of Occupational Hygiene, Vol. 52, No. 7, pp. 597-605, 2008.

[4] NIOSH. What you need to know about occupational exposure to metalworking fluids. Retrieved 18/06/2013 from: http:// www.cdc.gov/niosh/docs/98-116/pdfs/98-116.pdf

[5] NICAS, M. Using mathematical models to estimate exposure to workplace air contaminants. Chemical Health and Safety, Vol. 10, No. 1, pp. 14-21, 2003.

[6] HOFSTETTER, E., SPENCER, J. W., HITESCHEW, K., COUTU, M., NEALLY, M. Evaluation of recommended REACH exposure modelling tools and near-fiels, far-field model in assessing occupational exposure to toulene from spray paint. The Annals of Occupational Hygiene, Vol. 57, No. 2, pp. 210-220, 2013.

[7] ECHA. Guidance on information requirements and chemical safety assessment: occupational exposure estimation. Retrieved 18/08/2013 from: http:// echa.europa.eu/documents/10162/13632/information_requirements_r14_en.pdf

[8] WHITE, E., LUCKE, W. Effects of fluid composition on mist composition. Applied Occupational and Environmental Hygiene, Vol. 18, Issue 11, pp. 838-841, 2003.

[9] SHEEHAN, M., HANDS, D. Metalworking fluid mist- strategies to reduce exposure:a comparison of new and old transmission case transfer lines. Journal of Occupational and Environmental Hygiene, Vol. 4, Issue 4, pp. 288-300, 2007.

[10] GUNTER, K., SUTHERLAND, J. An experimental investigation into the effects of process conditions on the mass concentration of cutting fluid mist in turning. Journal of Cleaner Production, Vol. 7, Issue 5, pp. 341-350, 1999.

[11] HWANG, J., HWANG, D., CHUNG, E. Analysis of cutting fluid atomization and environmental impact through spin-off mechanism in turning operation for environmentally conscious machining(II). International Journal of Precision Engineering and Manufacturing, Vol. 6, No. 3, pp. 3-7, 2005.

[12] SUN, J., JU, C., YUE, Y., GUNTER, K., MICHALEK, D., SUTHERLAND, J. Character and behavior of mist generated by application of cutting fluid to a rotating cylindrical workpiece, Part 2: Experimental validation. Journal of Manufacturing Science and Engineering, Vol. 126, Issue 3, pp. 426-434, 2004.

[13] O'BRIEN, D., PIACITELLI, G., SIEBER, W., HUGHES, R., CATALANO, J. An evaluation of short-term exposures to metalworking fluids in small machine shops. American Industrial Hygiene Association Journal, Vol. 62, Issue 3, pp. 342-348, 2001.

[14] SIMPSON, A., STEAR, M., GROVES, J., PINEY, M., BRADLEY, S., STAGG, S., CROOK, B.: Occupational exposure to metalworking fluid mist and sump fluid contaminants, Annals of Occupational Hygiene, Vol. 48, Issue 1, pp. 17-30, 2003.

AUTHORS´ ADDRESS:

Miroslav DADO, Ing., PhD., Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Študentská 26, 960 53 Zvolen, Slovak Republik, e-mail: miroslav.dado@tuzvo.sk

Richard HNILICA, Ing., PhD., Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Študentská 26, 960 53 Zvolen, Slovak Republik, e-mail: richard. hnilica@tuzvo.sk

REVIEWER:

Ružena KRÁLIKOVÁ, Assoc. prof., Ing., PhD., Technical University in Košice, Park Komenského 5, 04001 Košice, Slovakia, e-mail: ruzena.kralikova@tuke.sk