Iranica Journal of Energy & Environment 5 (2): 146-151, 2014
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2014.05.02.05

BUT

Predictive Statistical Model for Indoor Manganese Airborne Particles Affected by Psychrometric Parameters

Seyedtaghi Mirmohammadi

Department of Occupational Health, Faculty of Health, Mazandaran University of Medical SciencesSari, Iran

Received: May 2, 2014; **Accepted** in Revised Form: June 11, 2014

Abstract: Commonly, there are varieties of indoor airborne particles in the foundry factories. One of the main particle with emphasize on health effect on exposed human is manganese airborne particle. The current study considered correlation between indoor psychrometric parameters and manganese concentration in the workplace. Overall, fifty samples were collected by filter based on OSHA ID-121 method in the workplaces. SPSS V.20 was used to find a predictive model using linear regression model. The mean personal exposure to manganese was 1.626 mg/m^3. The mean measured psychrometric parameters for dry temperature, relative humidity and air velocity were 29°C, 52% and 1.2m/s, respectively. The correlations between personal exposures and indoor air parameters measurements showed a high significant relationship between personal exposure, dry temperature and wind speed in the factory ($P< 0.05$). This study concluded that controlling dry temperature and air velocity is the main effective parameters on airborne manganese concentration in the workplaces and decreased the personal exposure.

Key words: Manganese · Exposure · Dry temperature · Humidity · Foundry

INTRODUCTION

The melting process involves foundry, crushing and grinding of molding materials generates particulate matters (PM) and dust in the workplaces. The process at high temperature and inside the factories helps to generate variety of dust in hot workplaces. The polishing and finishing process, using sandblasting and drilling that are both environmentally pollutants for personals and factories. Particulate matters are relatively plentiful and variable component of the indoor atmosphere in the foundry factories. It is produced and emitted naturally to the atmosphere in the melting decomposition, combustion, and finishing process [1, 2]. One of the main element as airborne particulate matter in ferrous foundries is manganese particle, the workers are exposed to manganese (Mn) in the workplaces from both naturally occurring processes and processing activities. In such factories sources of Mn include furnaces, melting process, cars, lift trucks, sanding and combustion. Because of their small particle size, it tends to remain and suspending in the air for long periods of time (weeks or months). Usually, the health effects of Manganese (Mn) airborne particles are likely to depend on several parameters, including the ingredient of melting materials, duration of and level of exposure, size of the particles, and individual characterization of the exposed subject. Manganese is a necessary element, which is essential in small quantities but in higher doses might be a neurotoxic matter. High exposure to airborne manganese may lead to accumulation of the compound in the basal ganglia of the brain [3, 4], where it may create toxic condition [5]. Researchers reported that the neurological disorder of manganese (`manganism') that bears many similarities to Parkinson's disease [6, 7]. To prevent of related disease early indicators of the clinical effects and sensitive parameters of manganese exposure are needed. A time weighted average exposure for manganese airborne particulate concentration is about 1 mg/m^3 in workplaces. The manganese preclinical adverse effects have been observed to cause in the central nervous systems in workers exposed for less than 20

Correponding Author: Seyedtaghi Mirmohammadi, Department of Occupational Health, Faculty of Health, Mazandaran University of Medical SciencesSari, Iran. E-mail: t.mirmohammadi@mazums.ac.ir

Please cite this article as: Ghalekhani, G.R. and A.A.L. Zinatizadeh, 2014. Process analysis and optimization of industrial estate wastewater treatment using conventional and compartmentalized membrane bioreactor: A comparative study. Iranica Journal of Energy and Environment, 5 (2):

years [8, 9]. Studies have revealed basis subclinical intoxication which has been observed in manganese exposed workers with moderate (1±4 lg/l) increases in B-Mn [10, 11]. The foundry furnace-men are potentially exposed to manganese pollution during melting, weighting, transportation of recycled manganese-alloyed iron scrap from storehouse to furnace as well as manganese fumes exposure from the furnaces, especially during melting in the foundry workplace. The non-furnace workers may be potentially exposed to manganese during the handling of manganese-alloyed iron and preparing of the production and maintenance. There is a need to find personal exposure with manganese particles in foundry factory based on local psychrometric condition; it may improve our understanding of what humans are actually exposed to and how to reduce this exposure. The indoor air study assess factory pollutant problems can effect on human health with variety study models such as regression model or multiple model for pollution estimation with emphasis on particle matter in the workplaces. Similarly, the regression model was used before by other researchers in terms of pollution predictive model [12-16]. In the workplaces some raw material used in the production process such as cement factory the generation of particulate is predictable and they pass to the atmosphere through the exhaust. In the process activity of cement industry suspended particulate matter is inborn. For instance, the process activity of cement production generates pollutants such as suspended particulate matter, CO_X and NO_X [17-19]. The objective of this research is to find correlation between Mn pollution and psychrometric parameters such as dry bulb temperature (Td), relative humidity (RH), air velocity (or wind speed) and altitude in the foundry factory.

MATERIALS AND METHODS

Fifty workstations (in furnace, melting, molding, blasting, drilling, finishing and transporting task) were chosen for the air sampling during a working shift in the current study. Sampling, data collection and results documentation were conducted in accordance with the National Institute for Occupational Safety and Health guidelines and Standards.

Study Design: The study was conducted in Iran. Based on the study objectives, the indoor manganese particles (Mn) concentration was measured during a working shift in the foundry factory.

Sampling and Analytical Method: The measurement of Mn in ambient air was performed in the selected workstations in the factory. The air-Mn concentrations in the collected samples were determined by stationary samplers. The SKC samplers equipped with cellulose mixed-esters filters (filter diameter 37 mm, pore size 0.80 µm) at a low flow rate of 2 L/min over period of 2 h. The sampler distance from the smelting department was 2 m, and for other stations the sampler was placed from 2 to 3m from the furnaces. In the iron scrap recycling plant, the samplers were fixed next to the workers station. The analytical determination of manganese on the filters was performed by atomic absorption spectrometry.

Manganese concentration was measured by graphite furnace-atomic absorption spectrometry (GF-AAS). The cellulose ester filters were suspended in 2 ml of 35% hydrochloric acid and 65% nitric acid (40:60 v/v) and tempered at 90°C for 60 min. The samples were injected into a 4100-Z-AAS spectrometer (Perkin Elmer, UÈ berlingen, Germany) (wavelength 279.5 nm, lamp current 20 mA, gap 0.2 nm, 10 ll matrix modi®er) after another 24 h at room temperature. Interferences from the matrix were minimized by the use of the Zeeman-effect background compensation and automated standard addition calibration. The detection limit for manganese in air was 2 ng/m^3 under the conditions of the above-described sampling procedure. The dry thermometer and Asman hygrometer was used to measure dry bulb temperature and relative humidity. SPSS V.20 was used for statistical analysis for current study result.

RESULTS

Lots of fifty air samples were collected by stationary sampling method from workplace. The study sampling area included all production and supervisory workstations assigned to the melting process line. The study workstations also included maintenance employees working in the workplaces. Sampling zones were selected at random from within the corresponding frequency categories, because there were many workstations which workers working in the factory.

Indoor Air Sampling and Psychrometric Parameters Measurement: The analysis of the data from Table 1 shows, Mn concentration in the factory ranged from 0.25 to 3.61 mg/m^3; the average value for Mn pollutant concentration was 1.626 mg/m^3; relative humidity ranged from 41 to 56 %; the mean relative humidity was 52 %; dry bulb temperature ranged from 22 to 27°C and the mean dry

Table 1: Mean of indoor air variables in the foundry factories

Variables		Results
Mn, concentration (mg/m^3)	Max	3.61
	Min	0.25
	Mean	1.626
Relative Humidity, (%)	Max	56
	Min	41
	Mean	52
Dry bulb temperature, (°C)	Max	27
	Min	22
	Mean	24
Air velocity, (m/s)	Max	1.5
	Min	0.9
	Mean	1.2

NIOSH permissible exposure limit for Mn: 1 mg/m^3
OEL in Iran, 0.2 mg/m^3

Table 2: Regression correlation summary of Mn particulate matters

Model	R	r^2	Adjusted r^2	SE of the Estimate
	0.964	0.982	0.982	1.352

Predictors: (Constant), Relative humidity (%), Dry bulb temperature (°C), Air velocity (m/s), Altitude (m)

Table 3: Coefficients of regression correlation for Mn particle pollution and indoor psychrometric parameters

	Coefficients			
	------------------		t	
Model	B	SE	7.707	P value.
(Constant)	11.355	3.274	3.469	0.001
Relative humidity (%)	1.35	0.06	22.564	0.0001
Dry bulb temperature (centigrade)	0.218	0.088	2.481	0.014
Air velocity (m/s)	1.121	0.07	18.243	0.92
Altitude (m)	0.89	0.051	-8.107	0.713

Dependent Variable: Mn concentration (mg/m^3)

Table 4: Regression correlation test for Mn and indoor psychrometric parameters

Model	Sum of Squares	F	P value
Regression	20098.31	3457.655	< 0.0001(α)
Residual	428.687		
Total	20526.997		

(α) Predictors: (Constant), Relative humidity (%), Dry bulb temperature (°C), Air velocity (m/s), Altitude (m)
Dependent Variable: Mn Concentration (mg/m^3)

bulb temperature was 24°C. The indoor air velocity of the factory was between 0.9 to 1.5 m/s and altitude for the factory was 1700 m.

Table 1 shows the average of Mn concentration and other parameters in the factory. The mean Mn concentration was 1.626 mg/m^3 and this corresponds with mean relative humidity of 52%. Moreover, the result of Table 1 shows the mean Mn concentration is corresponds with mean dry bulb temperature of 24°C in the factory.

Table 2 showed that 98.2% of the Mn concentration can be attributed to any some or all of the independent variables (relative humidity, dry bulb temperature, air velocity and altitude) ($r^2 = 0.982$).

The correlation between psychrometric parameters (RH and Td) also air velocity and altitude and Mn concentration were studied to understand the behavior of indoor air Mn particulate matters with respect to indoor psychrometric parameters in the foundry factory. Linear regression analysis was used to assess the interactive behavior for Mn pollution and indoor air psychrometric parameters. The extracted factors for foundry factory showed that all of the evaluated parameters correlated with Mn concentrations are well defined in Table 3.

The multiple correlation coefficients (R) and the amount of variance (r^2,) are showed in Table 2. The following equation has been employed to stand for different parameters in order to measure the predictive regression correlation between psychrometric parameters and Mn concentration of this study. According to coefficients extracted from Table 3, indoor air velocity (1.121) and altitude (0.89) were no significant in the final regression model, therefore it can be ignored to include in the model.

Results of regression model test in Table 4 demonstrate that the independent variables are significant predictors of Mn pollution situation ($P< 0.05$) in the foundry factories.

The multiple correlation coefficients (R) and the correlation of model (r^2) are illustrated in Table 2. It implies that all of the predictors (indoor air velocity, relative humidity, dry bulb temperature and altitude change 98.2% dependent variables (Mn concentration) in the foundry workplaces.

DISCUSSION

The time weighted average (TWA) of the Mn concentration in the industries according to NIOSH standards for fine particulate matters in the factories should not exceed 1 mg/m^3 (NIOSH). Therefore, the concentration Mn in the foundry factory detected (expressed in milligram per cubic meter) in the factories is 1.626, when compared to NIOSH standard appear to be extremely high. The result of this present study was slightly high compared to that of the other factories in different countries [17, 18, 20].

While duration of work in the workplaces is important factor to determine of personal exposure to particles, it is supposed that health situation of subjects were different exposure condition compared to the general population and the exposure results are similar to other research finding in the other country [21].

A high personal exposure was found for Mn in the workplaces among subjects and it shown that there are high level of contamination of Mn compared to NIOSH permissible exposure limit, but the result of the current study is not comparable with other study was conducted by researchers [22, 23].

The correlation between the average of indoor air variables and personal exposures to indoor dust such as Mn was not strong and a straight relationship have seen between Mn pollution and condition of indoor psychrometric parameters such as relative humidity and dry bulb temperature. This finding if comparable with other results was obtained by other researchers [12, 14, 22-25].

The positive relationship between temperature and Mn n concentration can be expected as it was reported in the literature with emphasis on dust exposure [12, 15, 24, 26] where an exponential increase of fine particulate matters emission rate during curing of melting process. It was observed that in the range of typical room temperatures, 20-30°C, there was only small effect on emission. However, at temperatures greater than 30°C, a clear increase in emission was noticed. The dry bulb temperatures within the factory ranged from 22 to 27°C. The linear relationship between temperature and Mn concentration is acceptable since the indoor temperatures were not greater than 30°C where exponential increase of Mn particulate emission could occur [12, 15].

As for the effects of relative humidity on fine particulate matters concentration, researchers observed that dispersion of dusts during working process are inversely proportional to the relative humidity of the environment. The electromagnetic properties of the particle-based components studied were found to be strongly influenced by the presence of water vapor during the curing process, as evidenced by the significant difference in the real relative permittivity of samples cured in different RH environments [16].

The obtained regression predictive model in the current study is adapted with other finding that was achieved by researchers [12, 18, 21]. They illustrated that determined pollution were compared to the predictions of the thermodynamic models GFEMN [21] in order to estimate the contribution of particulate matters to water absorption. A direct comparison with the obtained particulate matters model is possible for the GFEMN and AIM models [18] calculated the amount of aerosol bound water based on the measured relative humidity and the $PM_{2.5}$ aerosol concentrations.

Researchers [3, 12, 13, 15] previously used the regression techniques to correlate pollutants indicators as a function of psychrometric parameters and other factors relevant to factory, such as dry bulb temperature, relative humidity, dimension of factory and altitude of factory. The correlation between airborne fine particulate matters and psychrometric variables can be understood better by using multiple regression correlations. The general approach is to correlate Mn concentration with independent variables, which include psychrometric data.

In this study, the use of multiple regression models to examine exposure distributions that embraced the data on a wide range of indoor air has not been previously reported in the occupational hygiene literature.

CONCLUSION

The result of this study illustrated that, the average concentration of manganese particles in the foundry factories is more than 1.626 mg/m^3 for time weighted average, this value is higher than that time weighted average of NIOSH (1 mg/m^3), it implies that the factory was studied is polluted with Mn. The obtained predictive regression model of Mn for foundry factory based on psychrometric parameters in this study shows that the relative humidity and dry bulb temperature are the main factors influenced on Mn concentration in the workplaces.

REFERENCES

1. Cheng, Y.H., 2008. Comparison of the TSI model 8520 and Grimm Series 1.108 portable aerosol instruments used to monitor particulate matter in an iron foundry. Journal of Occupational and Environmental Hygiene, 5(3): 157-168.
2. Meléndez, A., E. García, P. Carnicer, E. Pena, M. Larrión, J.A. Legarreta and C. Gutiérrez-Cañas, 2010. Fine and Ultrafine Emission Dynamics from a Ferrous Foundry Cupola Furnace. Journal of the Air and Waste Management Association, 60(5): 556-567.
3. Ansari, A.S. and S.N. Pandis, 2000. Water absorption by secondary organic aerosol and its effect an inorganic aerosol behavior. Environment Science Technology, 34(1): 71-77.

4. Dastur, D.K., D.K. Manghani and K. Raghavendran, 1971. Distribution and fate of 54 Mn in the monkey: studies of different parts of the central nervous system and other organs. Journal of Clinical Investigation, 50(1): 9.
5. Krieger, D., S. Krieger, L. Theilmann, O. Jansen, P. Gass and H. Lichtnecker, 1995. Manganese and chronic hepatic encephalopathy. The Lancet, 346(8970): 270-274.
6. Aschner, M. and J.L. Aschner, 1991. Manganese neurotoxicity: cellular effects and blood-brain barrier transport. Neuroscience and Biobehavioral Reviews, 15(3): 333-340.
7. Barbeau, A., 1984. Manganese and extrapyramidal disorders (a critical review and tribute to Dr. George C. Cotzias). Neurotoxicology, 5(1): 13-36.
8. Calne, D., N. Chu, C.M. Huang, C. Lu and W. Olanow, 1994. Manganism and idiopathic parkinsonism: similarities and differences. Neurology, 44(9): 1583-1586.
9. Grufferman, S., 1999. Complexity and the Hawthorne effect in community trials. Epidemiology (Cambridge, Mass.), 10(3): 209.
10. Lucchini, R., E. Bergamaschi, A. Smargiassi, D. Festa and P. Apostoli, 1997. Motor function, olfactory threshold and hematological indices in manganese-exposed ferroalloy workers. Environmental Research, 73(1): 175-180.
11. Mergler, D. and M. Baldwin, 1997. Early manifestations of manganese neurotoxicity in humans: an update. Environmental Research, 73(1): 92-100.
12. Mirmohammadi, M., M. Hakimi, A. Ahamd, O. Kader, M. Mohammadian and S. Mirashrafi, 2010. Evaluation of Indoor Air Pollution of Polyurethane Industries with Emphasis on Exposure with Methylene Diphenyle Diisocyanate (MDI). Iranica Journal of Energy and Environment, 1(2): 100-105.
13. Mirmohammadi, M., M.H. Ibrahim, A. Ahmad, M.O.A. Kadir, M. Mohammadyan and S. Mirashrafi, 2010. Indoor air pollution evaluation with emphasize on HDI and biological assessment of HDA in the polyurethane factories. Environmental monitoring and assessment, 165(1-4): 341-347.
14. Mirmohammadi, S., 2013. Indoor Air Quality Assessment with Emphasis on Flour Dust: A Cross-Sectional Study of a Random Sample from Iranian Bakeries Workers. Iranica Journal of Energy and Environment, 4(2): 150-154.
15. Mirmohammadi, S., S.E. Nejad, M. Ibrahim and J. Saraji, 2011. Relationships Between Indoor Air Pollution and Psychrometric and Effective Factors in the Polyurethane Factories with Emphasis on Methylene Diphenyl Diisocyanate. Iranica Journal of Energy and Environment, 2(4): 366-373.
16. Roels, H., P. Ghyselen, J.P. Buchet, E. Ceulemans and R. Lauwerys, 1992. Assessment of the permissible exposure level to manganese in workers exposed to manganese dioxide dust. British Journal of Industrial Medicine, 49(1): 25-34.
17. Clegg, S.L., J.H. Seinfeld and P. Brimblecombe, 2001. Thermodynamic modelling of aqueous aerosols containing electrolytes and dissolved organic compounds. Journal of Aerosol Science, 32(6): 713-738.
18. Demokritou, P., I.G. Kavouras, S.T. Ferguson and P. Koutrakis, 2001. Development and laboratory performance evaluation of a personal multipollutant sampler for simultaneous measurements of particulate and gaseous pollutants. Aerosol Science and Technology, 35(3): 741-752.
19. Mirmohammadi, S., M.H. Ibrahim and G. Saraji, 2009. Evaluation of Hexamethylene Diisocyanate as an Indoor Air Pollutant and Biological Assessment of Hexamethylene Diamine in the Polyurethane Factories. Indian Journal of Occupational and Environmental Medicine, 13(1): 38-42.
20. Subramanian, R., A.Y. Khlystov, J.C. Cabada and A.L. Robinson, 2004. Positive and negative artifacts in particulate organic carbon measurements with denuded and undenuded sampler configurations special issue of aerosol science and technology on findings from the fine particulate matter supersites program. Aerosol Science and Technology, 38(S1): 27-48.
21. Cabada, J.C., A. Khlystov, A.E. Wittig, C. Pilinis and S.N. Pandis, 2004. Light scattering by fine particles during the Pittsburgh Air Quality Study: Measurements and modeling. Journal of Geophysical Research: Atmospheres, (1984–2012), 109(D16).
22. Ellingsen, D.G., E. Zibarev, Z. Kusraeva, B. Berlinger, M. Chashchin, R. Bast-Pettersen, V. Chashchin and Y. Thomassen, 2013. The bioavailability of manganese in welders in relation to its solubility in welding fumes. Environmental Science: Processes and Impacts, 15(2): 357-365.