IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

WORK PLACE EXPOSURE ASSESSMENT OF CHEMICAL WORK ENVIRONMENTAL FACTORS AND ITS RELATIONSHIP IN A CAST IRON FOUNDRY

Dr G.S Swaminathan*

*Retired Corporate HSE Head & Business Consultant, Chennai

Background: The study was conducted in a melting and casting foundries located in South India. The studies were conducted in Plant-1 (old) and 2 (new). The various hazards like metallic dusts, fumes, oil mist, silica dust, carbon monoxide and sulfur dioxide were studied in selected work stations. **Aim:** This study was initiated to explore and assess the prevailing chemical work environmental factors / hazards in the plant as well as the distribution of these hazards in the plants with two different process and control technologies. It is to assess the quality of the work room air near the ambit of the workers, comparing the measured values with the recommended OELs and recommends engineering and administrative control measures. **Materials and Methods:** A cross sectional study was conducted among 33 Operators working in various hot and peripheral operations in two Casting Plants old and new. Systematic random sampling method was adopted to collect 32 dust samples and 33 fumes, gases, vapours samples. The work exposures were compared for compliance with the occupational standards. **Statistical Analysis:** Plant wise and operation-wise distribution analysis was done on the compiled data. The data was analyzed by using the IBM-Statistical Package for the Social Sciences software statistical tools version-20 and the Mini-Tab Version-16, and the results were tabulated using $p<0.05$ as statistically significant. Paired t tests, Chi Square tests, Pearson's correlation and one-way ANOVA were performed. **Results:** The measured data on various chemical work environmental factors were compared with the Threshold Limit Values. Only for dusts and Total fumes in two different plants, Correlation and association analysis is done and it is found to be at 5% level of significance and 95% confidence interval level. **Conclusions and Implications:** This study has demonstrated that the chemical work environmental factors were varying based on the operational conditions and variations such as plant load, Plant design, technology change, air movement and other environmental factors. It is concluded that there is a significant level of association ($p<0.05$) in these two plants with the improved process and control technologies adopted in the new plant than the old plant.

Key Words: *Industrial hygiene, Chemical Work Environment factor, Threshold Limit Values, Occupational exposure levels.*

1.0: Introduction

New technological developments in industry today produce seven times more goods than it did some fifty years ago. While industrial developments have brought obvious benefits, it has also frequently increased risk of damage to the human health and environment. Foundry industry gives direct employment to about 25% of all industrial labors. So problems of comfort and health of foundry workers are of paramount importance. The work place environment influences significantly the health status of workers.

In the previous study More and Sawant (2001) have observed that the workplace environment in foundry was extremely adverse due to high concentration of coal dust, silica dust, extremely high temperature and noise. In foundry industries, thousands of workers was working in various sections like sand plant, core shop, moulding section, furnace section and fettling shop, performing repetitive identical cycles of operations. The socioeconomic study of workers reveals that most of the workers working in foundry are illiterate, smoker, alcoholic and earning less for work done. Work environment was extremely adverse with prevalence of high temperature, high noise intensity, dust concentration, poor ventilation, and variety of fumes as well as excessive work load. These conditions make it extremely difficult to maintain the appropriate level of health status of foundry workers.

The foundry division under study is engaged in cast iron products employing a workforce of around 1500. The foundry has got two plants and the second one started recently in a decade with advanced technological processes and controls. The unit operations of the plant are metal melting, metal holding, pouring and die casting, fettling, sand plant, core shop, Permanent Mould Foundry (PMF Plant), etc. In the present study efforts have been made to correlate the chemical work environmental hazards like dust, fumes, gases, and vapours in two different foundries of different control technologies. There is a need for industrial hygiene specialists and safety professionals to increase the production output without compromising the health and safety of the workmen.

2.0: Objectives

The general objective was to identify and assess the prevailing chemical work environmental factors/ hazards in all the selected sub processes in the plant. It is to assess the quality of the work room air near the ambit of the workers, comparing the measured values with the recommended occupational exposure levels and recommends engineering and administrative control measures to Management to mitigate the impact of the hazards. Also to compare associations in the existing control measures in two different plants focusing on dusts and fumes levels.

Hence the following objectives are identified for the present study:

- To identify and assess the prevailing chemical work environmental factors in the Plant-1&2.
- To determine the association of dusts exposures in the work room air between the Plants 1 & 2.
- To determine the association of total fumes exposures in the work room air in Plants 1 & 2.

3.0: Materials and Methods

The occupational environment was assessed for the airborne dust and particulates, metal fumes, gases and vapours. The object of the study is to determine the various work environmental hazards such as dusts and particulates, metal fumes and gases near the breathing zone of the operators. A total of 33 samples were collected for each pollutant in various operations in particular shift timings over a period of three months. One sample is rejected in dusts (only 32) due to practical inconvenience. The following are the locations sampled: metal melting, pouring, holding, transfer, pouring sample collection areas; Peripheral areas such as casting conveyor areas, shot blasting, fettling areas; Permanent Mould Foundry (PMF) Plant – Bizerba scale area, cupola furnace area, HMR tilting, metal transfer, annealing furnace and die cast areas; Pattern & Die shop areas – Babbitt furnace operation, Babbitt grinding, Aluminium melting furnace, CNC Machine areas. The various hazards such as dusts, fumes, gases, vapours, oil mist were studied. Only dusts and total fumes data were focused for correlation studies to meet the objectives 2&3.

3.1: Assessment of dusts and particulates

The breathing zone sampling was done using AFC 123 Personal Air Sampling System (Casella, London) and SKC Samplers. The respirable metallic dust was collected on Whatman Glass Fibre filters of diameter 37 mm and mean pore size of 0.8 um supported in a Cyclone Pre Collector heads of size 37 mm. The total dust was collected on a Whatman Glass fibre filters of diameter 37mm and mean pore size of 0.8 um supported in an open face filter holder. The flow rate of the pump was set at 1.9 – 2.0 litres per minute and the duration of the sampling period ranged from 2 – 4 hours. All the sampling equipment was initially calibrated for flow rate and voltage. Sampling heads were attached to one or the other overall lapel, for breathing zone sampling (within 30 cm around the nose of the employee) and the pump units hung on a belt or put in a pocket. These were joined together by a flexible tube. The filter papers were pre weighed before sampling on a sensitive single pan electronic balance and weighed again with dust after sampling. Then the gravimetric mass was scanned by X-Ray Diffraction technique to assess the percentage of respirable free silica in the mass. Then the time weighted average concentrations were computed for the eight hours exposures using our in-house developed software for computation. The measured values for the dusts and particulates in peripheral operations of Plant-1 & 2 are given in mg/m3 and shown in Table-1.

3.2: Assessment of Metallic fumes and mist

Metallic fumes mainly emanated from the raw material, additive powders and castings. Fume particles are usually in submicron size and so remain airborne, making it necessary to sample near the breathing zone of the operators. AFC 123 Casella air sampling equipment and SKX Air sampling pumps were used to collect the metallic fumes. The metallic fumes and oil mist were collected on Millipore PVC membrane filters of size 37 mm and the mean pore size of 0.8 um supported in an open face filter holder. The flow rate of the pump was set at 1.9 – 2.0 litres per minute and the duration of the sampling period ranged from 2 – 4 hours. All the sampling equipment was initially calibrated for flow rate and voltage. The filter papers were weighed before and after sampling. The collected metallic fume samples were gravimetrically analysed for total fumes and subsequently analysed for elemental analysis using Atomic Absorption Spectrometry and Plasma Emission Spectrometry. Then the time weighted average concentrations were computed for the eight hours exposures using our in-house developed software for computation. The measured values for the metallic fumes are given in mg/m3 and shown in Table-2 for Plant-1 & 2 respectively. Fig.1 shows the distribution of total fumes in hot operations of Plant-1 & 2. Table-3 shows the distribution of fumes, dusts and mist in Pattern shop environment.

3.3: Assessment of Gases and Vapours

Most of the hot operations viz., metal melting, holding, pouring operations emanate gases like carbon monoxide, sulfur dioxide into the work environment. Some of the vapours like formaldehyde are emanated from the annealing furnaces, die casting and metal transfer operations. Drager Polymeter – Long Term Detector was used for the evaluation of gases. The gases and vapours are collected into the respective long term detector tubes. The long term detector tubes were held near the breathing zones using lapel clips. Then the time weighted average concentrations were computed for the eight hours exposures using our in-house developed software for computation. Table-4 shows the distribution of pollutants in Permanent Mould Foundry (PMF) shop including the gases and vapours given in ppm.

4.0: Results and Discussions

The present study aimed to explore the association between the dust levels in the old and new plant melting and pouring operations as well as the association of total fume levels in these operations. Various researchers have previously studied the work environment in cast iron foundries and the association of hazards in various operations. However, the present study focused on the association of chemical work environmental factors in two different plants with different design, process and control technologies.

The results of the present study indicate a significant positive association between the operations of the plants in the domains of dust level exposures and the total fume level exposures.

That one-way ANOVA test in Table-5 showed the mean dust levels and total fumes levels in the plants-1&2 had a significant difference ($p < 0.05$).

The paired t-test results in Table- 6 & 7 showed that there is a significant and straight correlation relationship among dust levels in both the plants. Similarly significant for total fume levels in the old and new plant operations. ($p < 0.05$).

The result in Table-8 indicates that there is correlation between dust levels as well as the total fume levels in both the plants. Relationship between plant-1 and plant-2 levels observed to have high correlation.

Pearson Chi-Square value in the Chi-square test Table-9 showed that there was a significant and direct correlation relationship (r = 2.240E2) between dust levels in the old and new plant operations. ($p < 0.05$).

Pearson Chi-Square value in the Chi-square test Table-9 showed that there was a significant and direct correlation relationship (r = 1.320E2) between total fume levels in the old and new plant operations. ($p < 0.05$).

Table-10 shows the descriptive statistics values for dust levels and total fume levels in both the plants.

Table- 1: Dust Variance in Peripheral Operations			Plant-1		Plant-2	
Peripheral areas	**Operation**	**Pollutants**	**Mean**	**Std.Dev**	**Mean**	**Std.Dev**
Casting Conveyor area	Casting Conveyor operation	Total Dust	2.1225	0.9679	1.0923	0.8697
		Respirable Dust	0.3135	0.1969	0.2331	0.1440
Shot Blasting	Shot Blasting	Total Dust	4.7425	1.4618	3.2374	1.1125
		Respirable Dust	0.6625	0.2469	0.3466	0.2115
Fettling Area	Derisering	Total Dust	6.2200	0.9539	5.1452	0.6595
		Respirable Dust	0.9133	0.4826	0.6691	0.3348
Fettling Area	Fettling	Total Dust	3. 1700	0.0000	2.5672	0.1112
		Respirable Dust	0. 4750	0.0000	0. 3747	0.0000

[Mean values are given in mg/m3 – TWA; n = 32]

Table- 2: Distribution of metallic fumes in Plant-1						
	Iron	Manganese	Chromium	Nickel	Lead	Total Fumes
Melting Furnace	2.4660	0.0840	0.0496	0.0694	0.0046	2.4660
Holding Furnace	2.6800	0.0707	0.0507	0.0649	0.0031	2.5550
Metal Transfer-Manual	2.5180	0.0960	0.0180	0.0860	0.0014	2.5180
Metal Pouring-Manual	1.2466	0.0424	0.0126	0.0244	0.0032	1.2466
Sample Collection-Pouring	0.6420	0.0640	0.0000	0.0280	0.0000	0.6420
Distribution of metallic fumes in Plant-2						
	Iron	Manganese	Chromium	Nickel	Lead	Total Fumes
Melting Furnace	0.7788	0.0460	0.0183	0.0288	0.0032	0.7788
Holding Furnace	0.5788	0.0420	0.0178	0.0263	0.0030	0.5788
Metal Transfer-Manual	0.3940	0.0510	0.0038	0.0000	0.0000	0.3710
Metal Pouring-Manual	0.2620	0.0381	0.0017	0.0000	0.0000	0.2620
Sample Collection-Pouring	0.1282	0.0364	0.0000	0.2230	0.0000	0.1282

[Values are given in mg/m3 – TWA; n = 33]

Table-3: Distribution of Hazards in Pattern Shop				
Location	**Operation**	**Pollutants**	**Mean**	**Std.Dev**
Pattern Shop	Babbitt Furnace oprn	Lead in Fumes	0.0010	0.0000
	Babbitt Grinding	Respirable Dust	0.3280	0.0000
	Aluminium melt Furnace	Aluminium – Fumes	0.5400	0.0000
	CNC Machine	Oil Mist	5.8800	0.0000

[Mean values are given in mg/m3 – TWA; n = 32]

Table-4: Distribution of hazards in PMF Plant									
	Iron	Manganese	Chromium	Nickel	Lead	SO2	CO	HCHO vap.	Total Fumes
Bizerba Scale	5.1800	0.0190	0.0000	0.1680	0.0080	0.0000	10.5000	0.0000	5.1800
Cupola Furnace	2.9200	0.0130	0.0020	0.0087	0.0600	0.1767	10.6667	0.0000	2.9200
HMR Tilting	2.6800	0.0460	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	2.6800
Metal Transfer	0.8200	0.0140	0.0000	0.0160	0.0008	0.1800	12.0000	0.1400	0.8200
Annealing Furnace	2.5550	0.0046	0.0014	0.0045	0.0000	0.1050	8.5000	0.0900	2.5550
Die Cast	2.5250	0.0064	0.0056	0.0860	0.0000	0.2000	14.0000	0.1500	2.5250

[Values of elements are given in mg/m3-TWA; Values of gases, vapour are given in ppm-TWA.; n =33]

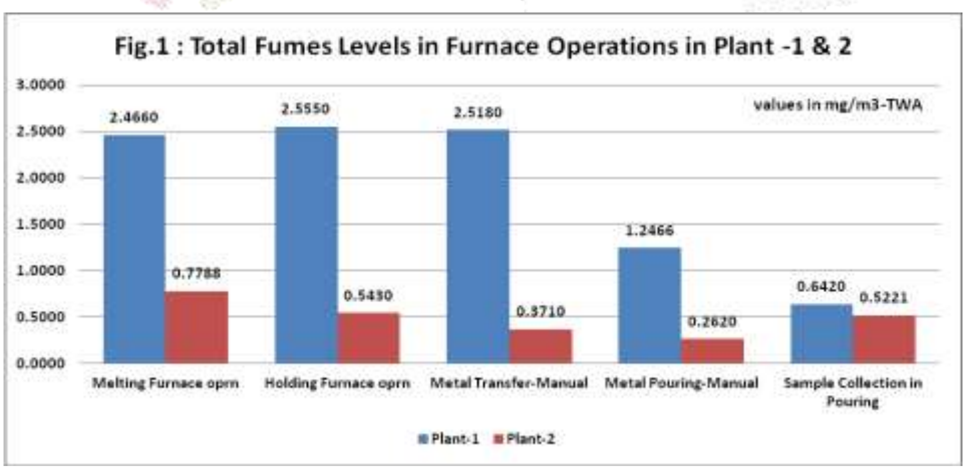

Table-5: ANOVA – Dust Levels

PLANT-1					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	135.983	7	19.426	5.530E33	.000
Within Groups	.000	24	.000		
Total	135.983	31			

ANOVA – Total Fumes

PLANT-1					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19.916	4	4.979	5.667E32	.000
Within Groups	.000	28	.000		
Total	19.916	32			

Table-6: Paired Samples Statistics-Dust Levels

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PLANT-1	2.327413E0	32	2.0944089	.3702427
	PLANT-2	1.708200E0	32	1.6908277	.2988989

Paired Samples Correlations-Dust Levels

		N	Correlation	Sig.
Pair 1	PLANT-1 & PLANT-2	32	.987	.000

Paired Samples Statistics-Total Fumes

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PLANT-1	1.942564E0	33	.7889139	.1373323
	PLANT-2	.437618	33	.2335136	.0406495

Paired Samples Correlations-Total Fumes

		N	Correlation	Sig.
Pair 1	PLANT-1 & PLANT-2	33	.803	.000

Table-7: Paired Samples Test-Dust Levels

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PLANT-1 & PLANT-2	.6192125	.5020935	.0887584	.4381885	.8002365	6.976	31	.000

Paired Samples Test-Total Fumes

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PLANT-1 – PLANT-2	1.5049455E0	.6172392	.1074475	1.2860820	1.7238089	14.006	32	.000

Table-8: Correlation Analysis –Dust Levels

		PLANT-1	PLANT-2
PLANT-1	Pearson Correlation	1	.987**
	Sig. (2-tailed)		.000
	N	32	32
PLANT-2	Pearson Correlation	.987**	1
	Sig. (2-tailed)	.000	
	N	32	32

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation Analysis –Total Fumes

		PLANT-1	PLANT-2
PLANT-1	Pearson Correlation	1	.803**
	Sig. (2-tailed)		.000
	N	33	33
PLANT-2	Pearson Correlation	.803**	1
	Sig. (2-tailed)	.000	
	N	33	33

**.Pearson's Correlation is significant at the 0.01 level (2-tailed).

Table-9: Chi-Square Test Statistics – Dust Levels

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.240E2[a]	49	.000
Likelihood Ratio	133.084	49	.000
Linear-by-Linear Association	30.171	1	.000
N of Valid Cases	32		

a. 64 cells (100.0%) have expected count less than 5. The minimum expected count is .50.

Chi-Square Test Statistics – Total Fumes

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.320E2[a]	16	.000
Likelihood Ratio	106.039	16	.000
Linear-by-Linear Association	20.643	1	.000
N of Valid Cases	33		

a. 25 cells (100.0%) have expected count less than 5. The minimum expected count is 1.09.

Table-10: Descriptive Statistics-Dust Levels

	N	Mean	Std. Deviation	Minimum	Maximum
PLANT-1	32	2.327412E0	2.0944089	.3135	6.2200
PLANT-2	32	1.708200E0	1.6908277	.2331	5.1452

Descriptive Statistics-Total Fumes

	N	Mean	Std. Deviation	Minimum	Maximum
PLANT-1	33	1.942564E0	.7889139	.6420	2.5550
PLANT-2	33	.437618	.2335136	.1282	.7788

5.0: Conclusions and Recommendations

The following are the process conditions and the control measures existing in the hot metal handling areas in Plant-1 (old):

Heavy duty general exhaust fans are available on the walls of the melt shop. There is a frequent leak of metal fumes in the melting and holding furnaces due to poor ceramic lining of the furnace walls. There was a poor practice by workmen to keep the furnace lid open after loading. There is an infrequent practice of wearing personal protective equipment such as fume respirators.

The Plant-2 (new) has the following process and control advantages in the metal handling areas.

Heavy duty general exhaust fans are made available on walls. Natural roof extraction system is available on the shop roof areas. Since the furnaces are slightly new and ceramic linings are perfect, the metal fumes leak is not evidenced. There is a canopy type extraction or local extraction system is available in the metal tapping and the melting and holding furnaces which reduces the dust and fume exposures in and near the working platform and the ambient air. The furnace lid has the automatic sensor which ensures the closure of the lid. The production and HSE team is very active in displaying safety slogans, safety awareness on PPE usage and maintenance. The hot molten metal are carried and transferred in closed ladles. The proximity of the consecutive hot metal operations is slightly nearby which contributes to less pollutant levels.

The other recommendations for the peripheral operations are the provision of "down-draft" ventilation system on sorting conveyor system for the capture of silica dust at the generated during handling of castings. Dust leakages to the shot blasting machine be rectified on priority basis and the machine be maintained on a regular basis. Local exhaust system is provided for the derisering and fettling activities. There should be a portable system adjusted for those cutting machine in operation or centralized dust exhaust system with the provision of extraction points for each cutting machine. Installation of real-time carbon monoxide monitoring system to be located at critical points like cupola furnace, die-casting workstations in PMF plant and metal pouring points. Periodic maintenance of the engineering control measures is to be ensured for the provided Bag filter system etc.,

Employee development program in specific disciplines like use and maintenance of personal protective equipment, health hazards, material handling etc., are to be provided. Periodic medical screening for the exposed group is to be planned by the OHS team.

6.0: Conflicts of Interest

Author does not have any conflicts of interest to declare.

7.0: Acknowledgement

I sincerely thank all the workers and supervisors/executives who participated enthusiastically and also provided all the facilities and help during my study. I also thank the management of the Company and HSE department for giving permission to publish the results of the study. The technical help, software assistance and the criticism rendered by Prof. Dr. K. Hari and the colleagues are gratefully acknowledged.

References

1) American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical and Physical agents and biological exposure indices. Cincinnati: ACGIH; 1998.

2) Gomes J, et al. Dust exposure and impairment of lung Functions at a small iron Foundry in a rapidly developing country. Occ. & Env. Med 2001; 58: 656-662.

3) Govindarajulu, Pillai RM, et al. Indian Foundry- Current outlook and future scenario. Foundry Engineering, 1st ed., London: Utility Publications;1989

4) Gupta JS, et al. Physiological responses during work in hot humid environment. Indian J. Physiol & Pharmacol. 1984, 25: 339-347.

5) Hawkins NC, *et al.* A strategy for occupational exposure assessment. Akron: American Industrial Hygiene Association; 1991.

6) Hittman A, Baseline data environmental assessment of a large coal conversion complex. Washington: Energy Research and Development Administration; 1975.

7) International Labour Office. Encyclopedia of Occupational Health and Safety. 2nd ed., Vol. 1 & 2. Geneva: ILO; 1998. P. 171 – 200.

8) Kohn J, et al. Fundamentals of Occupational safety and health. Rockville: Govt. Institute Press; 1996.

9) Koo JW, et al. The effect of Silica dust on ventilator functions of foundry workers. J Occup Health 2000; 42: 251-257.

10) Low I, et al. Respiratory diseases in foundry workers. Br J Ind Med 1985; 42: 101-105.

11) Mathew KC, Air pollution in foundries. Indian Foundry Journal, 1984; 30: 11-19.

12) More RB, M.Phil. Thesis: Physiological studies on foundry workers in relation to work and stress submitted to Shivaji University, Kolhapur: 2003.

13) Xu X, et al. Exposure response relations between occupational exposures and chronic respiratory illness: a community based study. Am Rev Resp Dis. 1992; 146: 413-418.