IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A CASE STUDY ON HAZARD CONTROL AND THE ENGINEERING EFFECTIVENESS AT PRODUCER GAS PLANT

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Background: The study was conducted at a Producer Gas Plant – old and new plants located in a giant public sector company. The various hazards like coal dust, carbon monoxide and the noise levels were studied in selected work stations. **Aim:** The object of this study is to identify and assess the prevailing occupational hazards in the plant. It is to assess the work room air and near the ambit of the workers, comparing the measured values with the recommended OELs and recommends engineering and administrative control measures and to assess the effectiveness of the implemented engineering measures. **Materials and Methods:** Employees of various levels were included in the sampling procedure. The follow up studies were carried out to evaluate the effectiveness of the recommended implementations by assessing the work exposures in both the plants. **Statistical Analysis:** Plant wise distribution analysis was done on the compiled database. The statistical tools IBM SPSS version-20 and the Mini-Tab Version-16 were used for the analysis of the data. One way ANOVA F Test and Paired t test were done to assess the effectiveness and the significance. **Results:** About 40 samples were collected with the 5% level of significance and 95% confidence interval level. Three work environmental factors were analyzed for the influence of risk to employees. The effectiveness of the measures was determined. **Conclusions and Implications:** This study has demonstrated that the work environmental factors were varying based on the operational variations such as plant load, air movement and other environmental factors and recommendations were given to mitigate those predominant factors to the management. It is concluded that there is a significant level of effectiveness ($p<0.05$) in the implemented control measures at by measuring the quantitative exposures to the pollutants in the work room air.

Key Words: *Industrial hygiene, Work Environment factor, Occupational hazards, Occupational exposure levels.*

1.0: INTRODUCTION

1.1: PG Plant Profile

The Producer Gas Plant is located in a major heavy engineering industry which comprises a number of process plants like Acetylene Plant, Oxygen Plant, Compressor house etc. to cater to its manufacturing activities. Producer Gas is used as a fuel for pre-heating, post-heating in various welding operations and in the gas-fired furnaces.

This Producer Gas Plants consist of 4 units of gas generators of capacity 4000 cubic metres per hour each. A coal crushing, sieving and conveying system is installed to size the coal to 12mm to 50mm. The sized coal is fed through bucket elevators and the belt conveyors to overhead bunkers and from there to gas generators. Producer Gas Plant consists of the following major equipments namely Gas generators, Pre-coolers, Electrostatic precipitators, Gas boosters, Final coolers, Final electrostatic precipitators and finally Yard torch (Flare Unit).

1.2: Gas Generation Process

The Producer Gas is made by blowing a mixture of air and steam through a bed of coal under such conditions that the combustible matter in it is converted to combustible gases. The producer gas will have a wide range of calorific value depending primarily on the coal used and the steam concentration in the blast. The producer gas generated from coal has the following composition namely Carbon monoxide (23.5 to 27%), Carbon dioxide (5 to 7%), Hydrogen (12 to 13%), Methane (2 to 3%), Nitrogen (50 to 58%) with the Calorific Value of 1250 K Cal/Nm3. The gas producer area has four zones namely Ash Zone, Oxidation Zone, Reduction Zone and Distillation Zone.

The main chemical reaction inside the gas producer area is as below:

C	+	O_2	=>	CO_2	- Oxidation Zone (+ O_2)
C	+	CO_2	=>	2 CO	- Reduction Zone (- O_2)
C	+	H_2O	=>	CO + H_2	- Distillation Zone
CO	+	H_2O	=>	CO_2+H_2	

The producer gas has the following properties

Colour	Colourless
Odour	Slightly Pungent
Specific Gravity	0.81 %
Vapour Density	0.97 %
Boiling Point	- 192 Deg C
Ignition Temperature	609 Deg C
Flammable Range	12.5 % to 74 %
Water Solubility	Nil
Calorific Value of cleaned gas	1250 to 1400 K Cal/Nm3
Gas Temperature at exit point	Ambient temperature
Gas Pressure at the exit point	400 mm of water column
Tar content of the gas at exit point	0 %
Dust in gas at exit point	0 %
Coal in ash	2 %

1.3: Health Hazards

Coal Dust

Coal dust size ranges from 0.1 to 25 microns. Particle upto 7 microns can do harm to the respiratory system and are called particles of respirable range. They freely enter the system during inhalation, particles below 5 microns size come out safely while particles between 5 and 10 microns size tend to stay in lungs and produce a condition called pneumoconiosis i.e. Hardening of the fibrous lungs. The threshold limit by ACGIH [8] for Coal dust is 2 mg/m3 in the atmosphere.

Carbon Monoxide

Producer gas is highly flammable gas. It has the flammable range of 12.5 to 74%. It gives rise to fire hazards as well as health hazards. Producer gas is highly toxic gas and it is a chemical asphyxiant. It contains 25 – 28% of Carbon Monoxide. Carbon Monoxide is easily absorbed through the lungs into the blood. It combines with haemoglobin of human body to form Carboxy Haemoglobin (CoHb). The affinity of haemoglobin for Carbon Monoxide is about 240 times that of its affinity to Oxygen. Carboxy Haemoglobin impairs the oxygen carrying capacity of haemoglobin to tissues. The severity of poisoning depends on the concentration of coal gas in the air, the exposure time and the individual susceptibility. On regaining consciousness, after severe exposure 50% of the victim have been reported as presenting an abnormal mental state manifested as irritability, restlessness etc.

Routes of Entry:
Inhalation, Eye contact

Points of Attack:
Heart, Blood Cells, Brain Cells, Respiratory system and Central Nervous System

First Aid:

Carbon Monoxide in the Coal gas does not accumulate in the body. It is completely exerted after each exposure if sufficient time in fresh air is allowed.

- The victim should be removed from Coal gas polluted area to a safe fresh air (open air)
- Administer oxygen if the victim is unconscious and call for medical help.

2.0: OBJECTIVES

The object of this study is to identify and assess the prevailing occupational hazards in all the sub processes in the plant. It is to assess the work room air and 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. An implementation team or steering committee members monitor the progress.

Hence the following objectives are identified for the purpose of the study:

- To identify and assess the prevailing hazards in the operations of the PG Plant.
- To determine and assess the engineering control effectiveness before and after the implementation of the measures.

The Following hypothesis is framed to study the above objectives:

H_0 1: There is no significant difference in the engineering control measures and its effectiveness before and after the implementations.

3.0: MATERIALS AND METHODS

Industrial hygiene audit is done by identifying the various occupational hazards, evaluating the exposures at static levels using gadgets and controlling the exposures by implementing one or more engineering and administrative measures. During the audit, samples were taken in selected areas of PG Plant (both old and new) and the sample size in each location was kept 40 before and after implementation of control measures. The data were carefully analysed and statistical analysis, paired t-test were done using IBM SPSS Version-20 and Mini-Tab Version-16 to compute the significant levels of engineering control measures. The areas sampled are peripherals, zero metre, 5.7 & 7 metre, 11.2 & 14 metre levels in both the PG Plants old and new. The peripherals here mentioned implies booster house and/or coal yard.

3.1: Industrial hygiene monitoring

Sampling for respirable Coal dust:

The particulate sampling instrument is a portable, personal sampling pump (SKC, USA) system consisting of a sampling head and a filtering medium to trap the particulates. Respirable fraction is collected on a pre-weighed Whatman glass fiber filter papers of diameter 37 mm and mean pore size of 5 um using single deck filter holders. The flow rate of the pump was set at 1.9 L/min and the duration of the sampling was for a period of 60 – 120 minutes. All the sampling equipment was initially calibrated for voltage and flow, and was used for sampling in the field for more accuracy. The weight of the filter paper was determined after sampling. In case of respirable dust, the gravimetric mass was determined and followed by X-Ray Diffraction method for free silica content. NIOSH analytical procedures and ILO encyclopedia [3] were adopted for all the sampling and chemical analysis. Then the values were computed for 8 hrs time weighted average exposures using the in-house developed IH software.

Sampling for Carbon Monoxide:

The gaseous pollutant viz., Carbon Monoxide was sampled using Drager Polymeter – Long term Detector. The principle of analysis was by chemical absorption technique. The pollutants were sampled in the long term detector tubes in the environment and near the source and then computed for 8 hours TWA using IH software.

Assessment of the ambient noise levels:

Sound level measurements were taken at places usually occupied by the employees in the area concerned. The continuous equivalent noise levels for a period of eight hours exposure were recorded. Precision Integrating sound level meters (B&K, Denmark and CEL, UK) were used to determine the ambient noise exposures. Frequency analysis of the noise emitting source was done by 1/3rd Octave filter sets (B&K, Denmark) using 1/3rd Octave selection. Both the sound level meters were calibrated using Acoustic Calibrators (B&K, Denmark and CEL, UK) before and after the survey.

4.0: RESULTS AND DISCUSSION

Figure -1, 2 & 3 indicates the hazard distribution before implementation of engineering control measures for chemical & physical hazards at the PG Plant (old). Figure – 4, 5 & 6 indicates the hazard distribution after implementation of engineering control measures for chemical & physical hazards at the PG Plant (new).

Table-1 indicates the One-way ANOVA F Test and Paired t test performed on data at PG Plant Old for the chemical and physical hazards studied before and after implementations of Engineering Control Measures. Table-2 indicates the One-way ANOVA F Test and Paired t test performed on data at PG Plant New for the chemical and physical hazards studied before and after implementations of Engineering Control Measures. The measured pollutant exposures were compared with Threshold Limit Values recommended by the American Conference of the governmental Industrial Hygienists (ACGIH), USA and the Permissible Exposure Levels by Occupational Safety and Health Administration (OSHA), USA. The recommended TLV and PEL values were shown in Table-3.

TABLE.1 :– ANALYSIS FOR PG PLANT – OLD

	BEFORE & AFTER IMPLEMENTATIONS			
	ANOVA-F TEST (F Value)		PAIRED T – TEST (p Value)	
PG Plant –Old -Coal dust	0.035	Significant	0.158	Significant
PG Plant –Old -Carbon Monoxide	0	Significant	0.023	Significant
PG Plant -Old- Noise	0	Significant	0.001	Significant

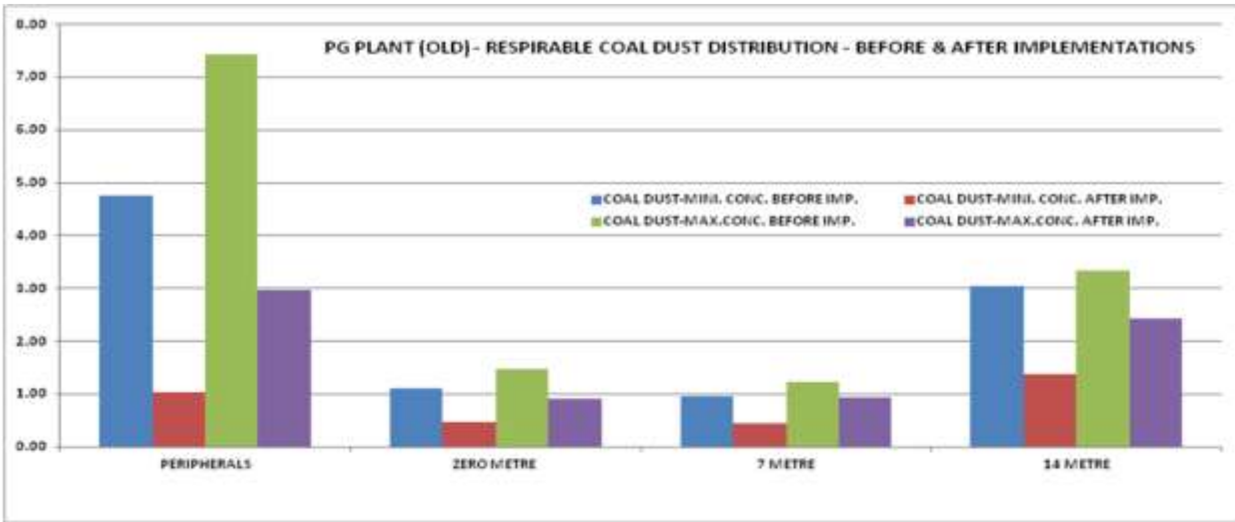
TABLE.2 :– ANALYSIS FOR PG PLANT – NEW

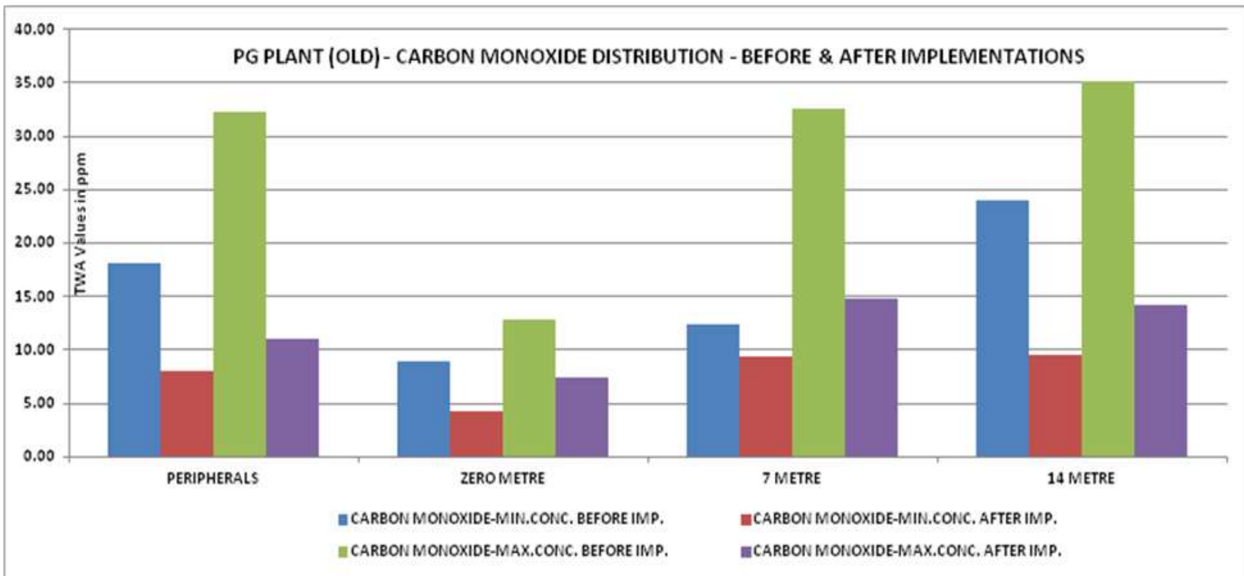
	BEFORE & AFTER IMPLEMENTATIONS			
	ANOVA-F TEST (F Value)		PAIRED T – TEST (p Value)	
PG Plant – New -Coal dust	0	Significant	0.024	Significant
PG Plant –New -Carbon Monoxide	0	Significant	0.028	Significant
PG Plant -New- Noise	0	Significant	0.017	Significant

TABLE.3 : OCCUPATIONAL EXPOSURE LIMITS

Respirable Coal dust	8 hrs TLV.TWA	2.0	mg/m3	ACGIH
Carbon Monoxide	8 hrs TLV.TWA	25.0	ppm	ACGIH
Noise	8 hrs Leq Level	90.0	dB (A)	OSHA, PEL

Fig.1, 2, 3: PGP-Old - Hazard Distribution – Before & after Implementations





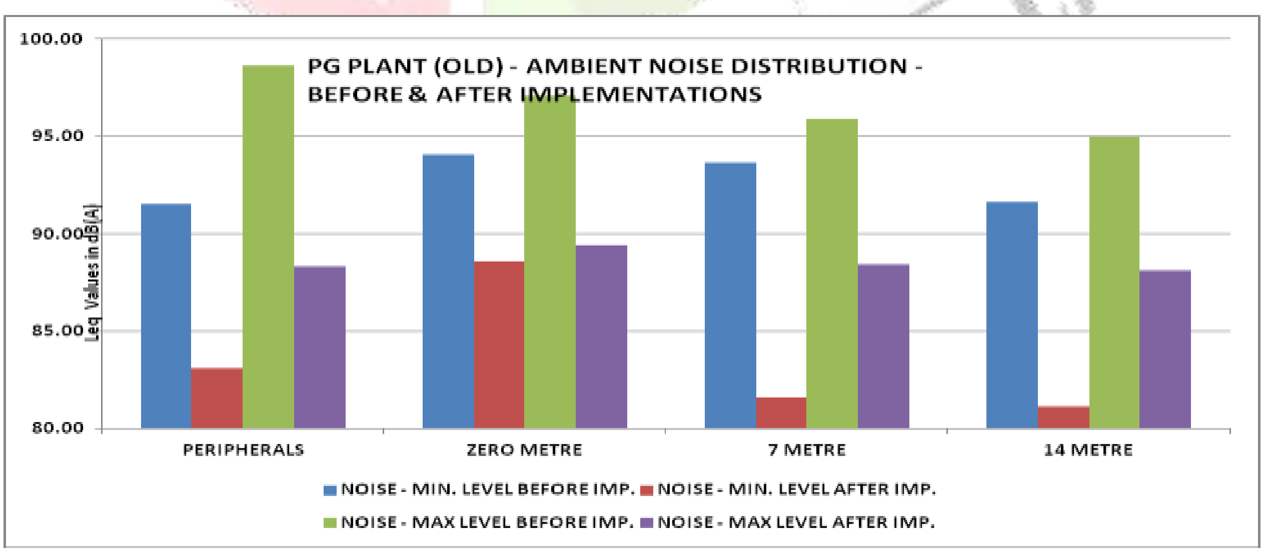
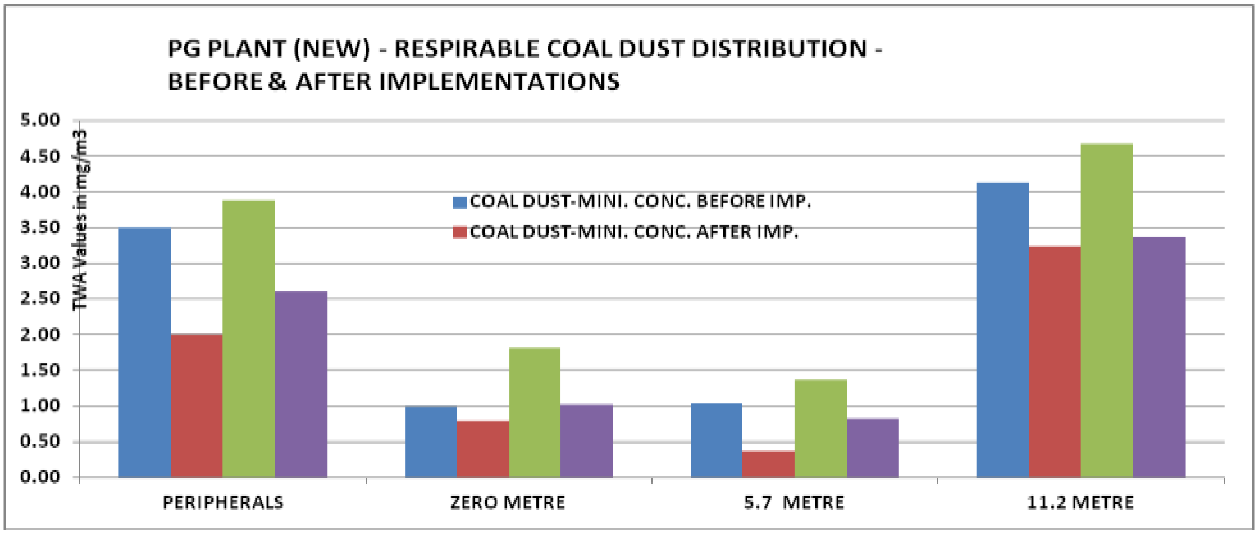
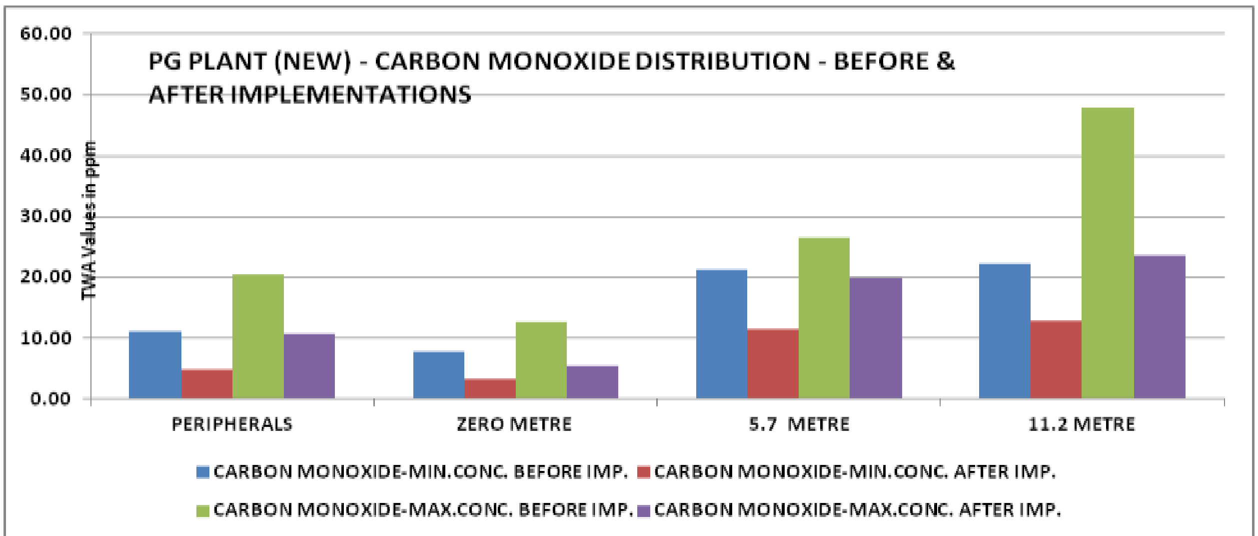
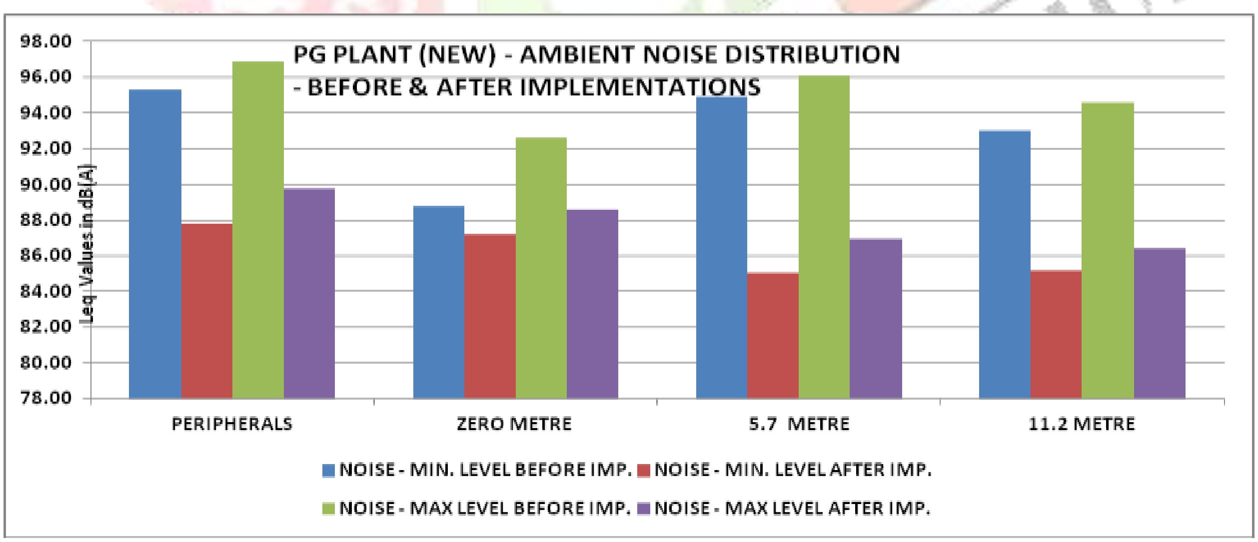


Fig.4, 5, 6: PGP-New - Hazard Distribution – Before & after Implementations







5.0: CONCLUSIONS AND RECOMMENDATIONS

This study revealed the following facts:

- The exposure levels for Carbon Monoxide exceeded the Threshold Limit Values in selected areas such as Booster House and 11.2 / 14m areas before implementations.
- The exposure levels for Coal dust exceeded the Threshold Limit Values in the selected areas such as Coal yard and 11.2 / 14 m areas before and after implementations.
- The exposure levels for noise exceeded the Permissible Exposure Levels in all the selected areas such as peripherals, zero metre, 5.7 / 7 m and 11.2 / 14m areas before implementations.
- All the other areas, the measured values are well within the recommended exposure levels.
- The ANOVA F Test results (Table 1 & 2) show that levels of chemical and physical pollutants belonging to various categories (coal dust, carbon monoxide, noise) before and after the implemented engineering measures differed significantly in their distribution (F (coal dust) = 402.688, $p < 0.05$; F (Carbon Monoxide) = 0.00, $p < 0.05$; F (Noise) = 0.00, $p < 0.05$).
- The results of the Paired t test indicated that since P < L in all the six situations, hence H_0 is REJECTED. It clearly indicates that the levels of chemical and physical pollutants before and after the implemented engineering measures differed significantly in their distribution (Table 1 & 2; $p<0.05$) and the implemented measures are found effective.

The following are the engineering and administrative control measures recommended and implemented.

Peripherals:

- In coal yard, water sprinkling system was suggested in raw coal bunker, crusher bottom and near vibrator
- Shovel cabin door is to be kept closed to minimize the dust exposures.
- Dust returned chute is to be redesigned and wet mechanism is to be applied.
- Periodic supply, use and maintenance of personal protective equipment such as goggles, dust respirators were insisted.
- General housekeeping in and around the yard is to be taken care.
- In booster house, bearing leak is to be arrested.
- Machinery vibration is to be arrested by periodic maintenance.
- Acoustic enclosure to the pump and booster unit is insisted.
- Gas washer room louvers are to be removed to provide more ventilation.
- Flame proof light duty exhaust fans are to be provided to minimize the gas exposures.

Zero Metre Level:

- Final cooler leak is to be arrested for dust and gas exposures.
- CDS bottom seal housekeeping is to be properly maintained.
- Sludge pump is to be isolated and enclosed.
- Generator motors are to be enclosed acoustically. Instead of pulley drawing system, chain drive system is to be adopted.

5.7 / 7 metre level:

- Heavy duty exhaust fans are to be installed in the walls to improve the ventilation in the working floor.
- The present ventilators are to be kept opened suitably to improve the ventilation.
- Poking point leaks are to be arrested. The washers are to be periodically changed.
- The coal feeder leak is to be arrested by repairing the buff in the coal feeder.
- The ambient noise is to be reduced by reducing the noise and damping the vibration of machineries such as coal feeder, pre-cooler etc., and by periodic maintenance.
- Pre-cooler top seal leak is to be arrested to reduce the escape of the gas in the environment.

11.2 / 14 metre level:

- The coal bunker lid is to be kept closed after each load of coal.
- Light duty exhaust fans are insisted on the walls.
- The glass louvers are to be kept opened.
- Roof extractors are to be planned to reduce the dust and gas levels.
- Periodic maintenance of the conveyor system, lubrication is insisted to reduce the noise levels. The source vibrations are to be arrested.
- Periodic supply, use and maintenance of personal protection such as ear muffs, dust respirators, gas masks is insisted.

Administrative Control Measures

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

6.0: 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 OHS department for giving permission to publish the results of the study. The technical help and criticism rendered by my friends are gratefully acknowledged.

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