Assessment of Safety Culture in Three Selected Thermal Power Plants Situated in Sylhet, Bangladesh

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Abstract

Hazards, accidents and ill management in thermal power plants have a big impact on business, whether it's due to reduced productivity, lost sales, lower staff morale, or even closure. To prevent and/or mitigate workplace injuries, hazards, accidents and to improve productivity, it is needed to establish safety culture practice in the entire management system. Use of safety signs is one of the ways for controlling hazards in the work environment. Safety signs are widely used to effectively control workplace hazards. In this research, different safety culture factors were taken from OHSAS 18001:2007 standard. The objective of this study was to assess the safety culture factors in three selected thermal power plants namely Sylhet 150 MW Combined Cycle Power Plant, Fenchuganj 90 MW Combined Cycle Power Plant and Bibiyana South 400 MW Combined Cycle Power Plant. This research work describes the key factors of organizational health and safety management system. The research also measures the existing safety practice performance of the three selected thermal power plants. The collected data were analyzed to explore research findings. Lastly recommendations were made to take corrective actions to improve existing safety culture practice in the three selected thermal power plants situated in Sylhet, Bangladesh.

Keywords
Safety Culture, Safety Signs, Thermal power plant, Weighted average, OHSAS

1. Introduction

Work related accidents and injuries are a major occupational health problem in most of the industrialized countries. There are about 340 million occupational accidents and 160 million victims of work-related illnesses annually worldwide. These estimates are updated by ILO at intervals, and the updates indicate an increase of accidents and ill health [1]. Accident and ill-health record of the thermal power plants compares poorly to that of other economic sectors such as manufacturing, construction and railway. The 20th century has experienced a considerable amount of success in thermal power plants safety in India. To ensure workers safety as well as the safety of the facility, safety assessment and safety management in thermal power plants are necessary. An industrial facility that generates electric power is called a power plant. In thermal power plant mechanical power is generated by a heat engine that transforms thermal energy often from combustion of a fuel, into rotational energy. As most thermal power plants produce steam, these are called steam power plants. The World Bank added that, "Driven by industry, Bangladesh's economy continues to grow at an impressive rate. Bangladesh is among the five fastest-growing economies of the world, despite insufficient private sector investment, with a 7.3% GDP growth projection in the FY2019" [2]. To meet the huge demand of energy in industries power plants are increasing in a significant number. A large number of people are working in those sectors. To ensure their health & safety, no research work has been conducted so far on safety assessment in the thermal power plants based on an international standard like OHSAS 18001:2007 worldwide or in Bangladesh. If proper safety rules and regulations could be implemented in these plants, the number of accidents and incidents could be minimized to almost zero. This research work has tried to show the present scenario of the safety culture practicing in the selected three thermal power plants and has tried to identify the gap between the practicing culture and the standard cultured proposed in OHSAS 18001: 2007. Then the research work has tried to suggest a better safety practice

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for the selected thermal power plants. It is expected that, if the suggested actions are taken, this can significantly reduce the risks of accidents occurring.

2. Literature Review

Literature review means studying the existing studies relevant to proposed study. It is essential to make manifest the relevance of the resource of the mass of knowledge and to conduct the research work successfully. A literature review was conducted in this study by assessing different articles about safety culture related issues and topics. Vencislav Grabulov and Niculai Pasca in 2019 in their research titled " Risk assessment of thermal power plant", presented an application of risk-based inspection concept on boiler components from fossil power plant using Risk Based Inspection (RBI). It determined the risk matrix, which pointed out the failure probability and the failure consequences [3]. Dharmateja Bandlamudi and Sahithi Avirneni in 2013 in their research paper titled "Power Plant- A Scientific Disaster" emphasizes society's movement towards improvement of power sector as a pavement of luxury and on the benighted dark side of it. This research tried to give the detailed list of effects caused by the power plants mainly on coal fired, nuclear and hydroelectric power plants, their adverse effects on environment and in turn human life [4]. Stefan Mandic-Rajcevic and Milica Karanac in their research paper titled "Occupational Health and Safety Concerns in Coalfired Thermoelectrical Power Plant Workers" tried to identify the main sources of occupational exposure in coal-fired thermoelectrical power plants along with their health effects. This study found that specific tests should be carried out in the work environment to confirm the effect of coal pollutants, as well as follow-up studies to monitor the dose of exposure and health effects [5]. In the research paper entitled "Impact of Coal Based Thermal Power Plant on Environment and its Mitigation Measure", Ahmad Shamshad, Fulekar M.H., and Pathak Bhawana highlighted the problems associated with fly ash and mitigating measures for fly ash have also been emphasized in that research paper. This article gives the direction for the beneficial use of fly ash generated from coal combustion in power plants [6]. Ruchi Shrivastava, and Praveen Patel in their research paper titled "Hazards Identification and Risk Assessment in Thermal Power Plant" tried to identify physical, chemical, biological and environmental hazards in Thermal Power plant as well as analyzed the event sequences leading to those hazards and calculated the frequency and consequences of hazardous events [7]. Arghami Shirazeh,Pouya Kian Mostafa, and Goudarzi Rahim in their research paper titled "Identification of factors affecting safety culture in Iranian thermal power plants" identified 9 sets of parameters in achieving the safety culture [8].

2.1 Research Gap

The above section discussed the previous research works done so far in the field of safety culture. Issues related to safety culture has become major concern all over the world. A lot of research works have been carried out by many authors regarding safety culture.

Table 1: Summary of Studies on Safety Culture Practice.

Sources	Objectives	Methodology
Jiss Joy, and Dr.Nihal Siddiqui (2016)	To explore the perception of employees towards safety culture in a manufacturing industry by using safety climate questionnaire.	Empirical/Case Study
Arghami Shirazeh,Pouya Kian Mostafa, and Goudarzi Rahim (2016)	To investigate the parameters and factors influencing organizational safety culture in the Iranian thermal power plants industry.	Triangulation approach
James H. Warren, Jr (2015)	To provide an ongoing holistic, objective, transparent and safety-focused process to identify early indications of potential problems linked to culture using a cross-section of available data.	Multiple-criteria Decision Analysis (MCDA)
Fazli B, Ansari H, Zare H, Hami Mahkoyeh S (2015)	To show the effectiveness of the level of education, age, and work experience in promoting the culture of safety.	Cross-sectional study.

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Stefan Mandic-Rajcevic and Milica Karanac (2015)	To identify the main sources of occupational exposure in coal-fired thermoelectrical power plants along with their health effects.	Empirical/Case Study
Ruchi Shrivastava, and Praveen Patel (2014)	To identify physical, chemical, biological and environmental hazards in Thermal Power plant.	Risk Based Inspection (RBI)
Vishal Vasistha (2014)	To identify the effects of pollutants produced by thermal power plant on environment.	Empirical/Case Study
Dharmateja Bandlamudi and Sahithi Avirneni (2013)	To give the detailed list of effects caused by the power plants mainly on coal fired, nuclear and hydroelectric power plants, their adverse effects on environment and in turn human life.	Empirical/Case Study
K. Kant, K.L Mehta Dayanand and S.K Chakarvarti (2012)	To identify the impact of Coal Based Thermal Power Plant on Environment and its Mitigation Measure.	Empirical/Case Study
Seyed Ali Jozi And Amaneh Alsadat Pouriyeh (2011)	To examine the risks resulting from activities of the Yazd Combined Cycle Power Plant located in Iran.	Analytical hierarchy process
Vencislav Grabulov and Niculai Pasca (2009)	It determined the risk matrix, which pointed out the failure probability and the failure consequences of boiler components.	Risk Based Inspection (RBI)

From the above table 2.4, it is seen that no research work has been conducted so far on safety assessment in the thermal power plants based on an international standard like OHSAS 18001:2007 worldwide or in Bangladesh. This research work is the first one worldwide and also in Bangladesh, which is assessing the safety culture of the thermal power plants based on the OHSAS 18001:2007 standard. This research work has been conducted to assess the safety culture of the three selected gas turbine thermal power plants, which are situated in Sylhet division of Bangladesh.

3. Objectives of the Study

i. To assess the current safety practice and culture scenarios in the three selected thermal power plants situated in Sylhet division, Bangladesh.
ii. To suggest an improvement plan for the better safety of the selected thermal power plants.

4. Methodology

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. Before exploring the research methodology option, the type of research should be identified since the choice of methodology for the research follows on naturally for the clear definition of the research. To establish a credible and reliable methodology, relevant research works were reviewed. Also, methodology includes some steps such as action plan and tools and techniques that are used during the study.

4.1 Methodology

An action plan has been constructed so that logical and sequential progress can be made throughout the study. Action plan shown in figure.1 describes the stages involved in this study.

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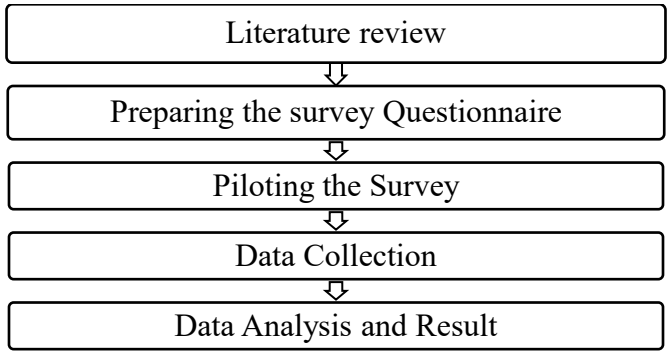

Figure 1: Action plan of this research.

4.2 Tools and Techniques Used

Different tools and techniques that were used in this research work are as follows:

A. Sample Size

If nothing is known about the attributes to be experimented of a population, Slovin's formula is used to determine a sample size. Slovin's formula is a random sampling technique formula to estimate sample size. It is used to calculate the sample size from given the population size and a margin of error [9].

$$n = \frac{N}{(1 + Ne^2)}$$

Where,

n = Sample size, N = Total Population, e = Error tolerance level.

Let, the confidence level of this research study be 82 percent. Which gives e = (1 – 0.82) = 0.18. The population is 57. So, putting the value in the formula, we get, n = 20.02. By rounding to a whole number, the sample size is found to be 20. It means that, 20 respondents need to be selected for data collection from survey questionnaire.

B. Likert Scale

In this section, the answers of the questionnaires were converted to numerical values using Likert scale. The Likert Scale is a rating scale that ranges from one extreme to another. A series of questions are asked to the customers. The answers given by the customers are then converted to the Likert scale. In this research, a 5-point Likert scale was used, where, 1 = Very Bad/Strongly Disagree/Very Poor, 2 = Bad/Disagree/Poor, 3 = Average/Neither Agree nor Disagree, 4 = Good/Agree, 5 = Very Good/Strongly Agree [11].

C. Average and Weighted Average

At first calculation of average values for each question under every safety factor was done. For example, the average value for 5 questions under the safety factor "policy" for Sylhet 150 MW Combined Cycle Power Plant, Kumargaon, Sylhet is calculated as below:

$$\text{Average value, } X_i = \frac{\sum X_n}{n}$$

Where,

X_n = The value of the Likert Scale rated by individual respondent against each question, n = Total number of respondents for each question. Then, average value of each question (Xi) was multiplied by their respective weight as shown in table 4.5 (b) and weighted average values were calculated using the following formula [12],

$$\text{Weighted average} = \frac{\sum W_i \times X_i}{\sum W_i}$$

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Where,

$\sum W_i$= sum of the weight and X_n = The value of the Likert Scale rated by individual respondent against each question.

4.3 Data Collection

Both primary and secondary data were collected for this research work. Secondary data were collected from newspapers, articles, journals, magazines etc. Primary data were collected from 60 respondents of Sylhet 150 MW, Fenchuganj 90 MW and Bibiyana 400 MW thermal power plants through a survey questionnaire. The respondents were selected randomly. Collected data were sorted and prepared for analysis using required software like Microsoft Excel. Junk data generates wrong information and misleads the research work. In order to avoid this, missing data was handled, and unwanted information was removed.

5. Result and Discussion

The values of weighted average for the five main safety factors called Policy, Planning, Implementation and operation, Checking and corrective action and Management review were calculated for the three thermal power plants namely Sylhet 150 MW Combined Cycle Power Plant, Kumargaon, Sylhet Fenchuganj 90 MW Combined Cycle Power Plant, Fenchuganj, Sylhet and Bibiyana South 400 MW Combined Cycle Power Plant, Bibiyana, Habiganj.

Table 2: Weighted average values for 5 key safety factors for the three selected thermal power plants.

Factor	Weighted average		
	Sylhet	**Fenchuganj**	**Bibiyana**
Policy	2.63	2.45	3.99
Planning	3.59	3.52	4.25
Implementation and operation	3.57	3.48	4.29
Checking and corrective action	3.14	2.81	4.18
Management review	1.65	1.88	3.81

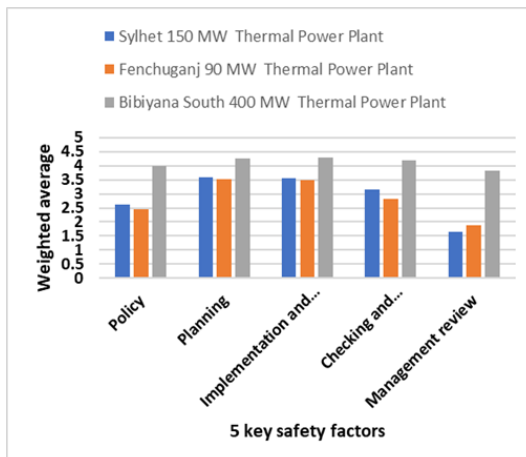

Figure 1: Comparison of 5 key safety factors among the three selected thermal power plants.

Major hazards and emergencies that arise in thermal power plants are presented below with existing practices of the three power plants to mitigate and/or to prevent those hazards and emergencies.

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Table 3: Major Hazards and Emergencies with the existing safety practices in the three selected thermal power plants.

Hazards and emergencies	**Description**	**Existing practice**		
		Sylhet 150 MW Power Plant	**Fenchuganj 90 MW Power Plant**	**Bibiyana South 400 MW Power Plant**
Slips and Trips	Slips and trips occurs in hydraulic oil tank area (slippery) and switch yard area (working at height).	Safety signs are used to warn the workers. Safety belts are also used while working at height.	Only safety signs are used but no safety belts are also used while working at height.	Safety signs are used to warn the workers. Safety belts are also used while working at height.
Leaking fuel cylinders or barrels	Fuel cylinders or barrels leakage is another common hazard in thermal power plants.	Regular inspection is conducted to check leakage in fuel cylinders or barrels.	Regular inspection is conducted to check leakage in fuel cylinders or barrels.	Regular inspection is conducted to check leakage in fuel cylinders or barrels.
Unsafe Electric Connections	There are numerous electric connections in thermal power plants. Any unsafe electric connection may result in severe electric shock.	Proper PPEs are used.	Proper PPEs are used.	Proper PPEs are used.
Noise	There are high intensity noise areas like generator room.	Noise reduction control programs are not implemented.	Noise reduction control programs are not implemented.	Noise reduction control programs are implemented.
Equipment damage	Damage of generator due to lack of lubrication in coupling shaft may occur. This might be catastrophic.	Proper inspection and lubrication are done to prevent such equipment damage.	Inspection and lubrication are done to prevent such equipment damage.	Proper inspection and lubrication are done to prevent such equipment damage.

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Unsafe use of Flammable substances	Diesel, Petrol, LPG etc.	Flammable substances. are carefully handled to prevent potential explosion or fire incident.	Flammable substances. are carefully handled to prevent potential explosion or fire incident.	Flammable substances. are carefully handled to prevent potential explosion or fire incident.
Unsafe use of Compressed Gas	Compressed carbon dioxide gas cylinders are used for firefighting purpose in thermal power plants.	Pressure tests are not done regularly for compressed carbon dioxide gas cylinders to prevent burst or explosion.	Pressure tests are not done regularly for compressed carbon dioxide gas cylinders to prevent burst or explosion.	Pressure tests are done regularly for compressed carbon dioxide gas cylinders to prevent burst or explosion.
Fall from height	Workers often need to work at height e.g. switch yard. Fall from height occurs sometimes.	Ladders, scaffolds, tower scaffolds etc. are not used to prevent fall from height.	Ladders, scaffolds, tower scaffolds etc. are not used to prevent fall from height.	Ladders, scaffolds, tower scaffolds etc. are used to prevent fall from height.
Fire and explosion	Fire and explosion in boiler, turbine due to cooling system failure may occur. This results in large number of injuries.	Maintenance and testing of safety devices are done to prevent such explosion.	Maintenance and testing of safety devices are done to prevent such explosion.	Operators are trained, maintenance and testing of safety devices are done, boiler equipment are upgraded.to prevent such explosion.
Explosion of gas cylinder	Acetylene gas cylinders are used for welding purpose in thermal power plants.	Periodic inspection and maintenance are done to avoid explosion of such gas cylinder.	Periodic inspection and maintenance are done to avoid explosion of such gas cylinder.	Regular inspection and maintenance are done to avoid explosion of such gas cylinder.
Electrocution	Electrodes used in generation panel can cause electric shocks and burns.	Awareness and training are conducted to prevent electrocution.	Awareness and training are conducted to prevent electrocution.	Shock resistant clothing are used to prevent such electrocution. Awareness and training are also conducted.

Table 3 shows the major hazards and emergencies with the existing safety practices in the three selected thermal power plants namely Sylhet 150 MW Power Plant, Fenchuganj 90 MW Power Plant and Bibiyana South 400 MW Power Plant. The table also describes the preventive measures taken by the three selected thermal power plants to eliminate, to prevent or to mitigate those hazards. It is seen from the table that Bibiyana South 400 MW Power Plant takes the

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most effective and preventive measures to prevent and mitigate the general hazards and emergencies. While the other two thermal power plants namely Sylhet 150 MW Power Plant and Fenchuganj 90 MW Power Plant are lacking in safety practices to prevent and mitigate the general hazards and emergencies.

Table 4: Condition of existing safety signs as in the three selected thermal power plants.

Safety Sign	**Description**	**Existing Practice**		
		Fenchuganj 90 MW Power Plant	**Sylhet 150 MW Power Plant**	**Bibiyana South 400 MW Power Plant**
	Name: DANGER. HIGH VOLTAGE. KEEP AWAY. Place of Application: High Voltage Area	Yes	Yes	Yes
	Name: DANGER. HOT STEAM PIPES. Place of Application: Places, where hot steam pipes pass though.	Yes	No	Yes
	Name: AVOID USING MOBILE PHONE Place of Application: Workplaces at a height.	No	No	Yes
	Name: Speed Limit. Place of Application: At necessary places by the roadside inside the plant area.	No	No	Yes
	Name: SMOKING IS PROHIBITED. Place of Application: Workplaces.	No	No	Yes
	Name: CAUTION. USE PPE. Place of Application: Different workplaces, where PPE is necessary.	Yes	Yes	No

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	Name: UNAUTHORIZED VEHICAL IS NOT PERMITTED. Place of Application: At the entrance of different workplaces, where necessary.	No	No	Yes
	Name: DANGER. SULFURIC ACID. Place of Application: Workplaces or storage of Sulfuric acid.	No	No	Yes
	Name: FIRST AID. Place of Application: Storage of First Aid.	Yes	Yes	No
	Name: WARNING. DO NOT WALK UNDER HANGING LOAD. Place of Application: Workplaces under heavy loads.	No	Yes	Yes

Table 4 compares the condition of existing safety signs scenarios of the three selected thermal power plants namely Sylhet 150 MW Power Plant, Fenchuganj 90 MW Power Plant, Enchain, Sylhet and Bib Iyana South 400 MW Power Plant situated in Sylhet division, Bangladesh. From the table, it is seen that, Bibiyana South 400 MW Power Plant uses maximum number of safety signs as required to warn the workers as other staffs about various potential hazards. Then the safety condition of Sylhet 150 MW Power Plant is comparatively better than that of Fenchuganj 90 MW Power Plant, Fenchuganj, Sylhet.

6. FINDINGS

The major findings of this research for three selected thermal power plants namely Sylhet 150 MW Power Plant, Kumargaon, Sylhet, Fenchuganj 90 MW Power Plant, Fenchuganj, Sylhet and Bibiyana 400 MW Power Plant, Bibiyana, Habiganj in relation to OHSAS 18001:2007 standard are discussed below one by one:

6.1 Findings of Sylhet 150 MW Power Plant, Kumargaon, Sylhet

A good number of fire extinguishers are found in all the workplaces. All the fire extinguishers were found with validity of date to use. Some of the workers use PPE, though they are not enough to mitigate risks and accidents. A good number of safety signs are displayed in several places. A computer-based control room is there to control and monitor the problems and hazards. Fire sprinkler system is associated with all the rooms of the administrative building. No

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documented OH&S management system is existing in Sylhet 150 MW Power Plant. There is no OH&S management organogram in Sylhet 150 MW Power Plant. Absence of OHSAS organogram is the key weakness of Sylhet 150 MW Power Plant. There exist no OH&S objectives for achieving continual improvement of the OH&S Performance in Sylhet 150 MW Power Plant. Insufficient availability of Health and safety hardware (e.g. PPEs), Health and safety training, Health and safety incentives etc. in Sylhet 150 MW Power Plant. There are a large number of compressed CO_2 vessels are without inspection and pressure test in Sylhet 150 MW Power Plant. Housekeeping is generally poor in Sylhet 150 MW Power Plant in some areas. Light and sound intensity are not measured as per Factory Rule 2015 in Sylhet 150 MW Power Plant.

6.2 Findings of Fenchuganj 90 MW Power Plant, Fenchuganj, Sylhet.

A wheel career is used to move the fire extinguishers quickly and easily. Safety signs are posted in different places. The workers use PPE. Automatic fire detector is found in all the buildings. An MBBS doctor is remain standby always to provide medical support. No documented OH&S management system is existing in Fenchuganj 90 MW Power Plant. There is no OH&S Management Organogram in Fenchuganj 90 MW Power Plant. No OH&S objectives for achieving continual improvement of the OH&S Performance were found in Fenchuganj 90 MW Power Plant. Availability of Health and safety hardware (e.g. PPEs), Health and safety training, Health and safety incentives etc. are inadequate in Fenchuganj 90 MW Power Plant. In Fenchuganj 90 MW Power Plant it was noted that lifting equipment and pressure vessels have not been tested. Light and sound intensity are not measured as per Factory Rule 2015 in Fenchuganj 90 MW Power Plant. In Fenchuganj 90 MW Power Plant many sites do not have separate emergency evacuation paths and mock drills conducted are not adequate as emergency preparedness programs. Very few safety sings are available at Fenchuganj power plant to warn the people about potential hazards. Housekeeping is generally poor in Fenchuganj 90 MW Power Plant in some areas. Adequate PPE (earmuffs, helmets etc.) is not available, and employees do not use them in Fenchuganj 90 MW Power Plant. No routine health check-up is done for employees, specially eye test, hearing test in Fenchuganj 90 MW Power Plant. In Fenchuganj Power Plant, trees and other vegetation are in lavish growth and they are in proximity of live conductors, transformers and other equipment.

6.3 Findings of Bibiyana South 400 MW Thermal Power Plant, Habiganj, Sylhet

Documented OH&S management system is existing in Bibiyana South 400 MW Thermal Power Plant. Bibiyana South 400 MW Power Plant has an OH&S management organogram as per OHSAS guidelines. OH&S objectives is seen to be practiced for achieving continual improvement of the OH&S Performance in Bibiyana South 400 MW Thermal Power Plant. A large number of Health and safety hardware (e.g. PPEs), Health and safety training, Health and safety incentives etc. are found in Bibiyana South 400 MW Thermal Power Plant. Bibiyana South 400 MW Power Plant maintains a regular safety training for the workers, staffs and employees. Bibiyana South 400 MW power plant has vertigo test structures and arranges vertigo training regularly so that the workers can work at higher without facing any vertigo problem. Light and sound intensity are measured as per Factory Rule 2015 in Bibiyana South 400 MW Thermal Power Plant. Bibiyana South 400 MW power plant arranges fire drills once in every month. Bibiyana South 400 MW power plant has mock drill facility and arranges mock drill regularly in response to emergencies. Color code is practiced in Bibiyana South 400 MW power plant. Different color-coded bins are used for collecting different types of wastes separately. In Bibiyana 400 MW Power Plant there is an organogram which shows the responsibility of

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different individuals in case of emergencies. Bibiyana South 400 MW Thermal Power Plant has emergency preparedness facilities. Most of the sites have separate emergency evacuation paths and large number of mock drills are conducted. Routine health check-up is done for employees, specially eye test, hearing test.

7. CONCLUSION

This study has tried to assess the current safety culture scenarios in three selected gas turbine thermal power plants. As for Sylhet 150 MW Power Plant, OH&S management system, OH&S management organogram and OH&S objectives are missing in this power plant. Those are few prime necessities for establishing a good safety culture in Sylhet thermal power plant. Health and safety hardware (e.g. PPEs), Health and safety training, Health and safety incentives etc. should also be increased in this power plant. All equipment need to be tested periodically as per the Factory act 2015. Emergency evacuation paths should be established, and mock drills conducted should be increased. In Fenchuganj 90 MW thermal power plant, OH&S management system, OH&S management organogram and OH&S objectives Should be established. Number of fire drill, mock drill and vertigo training should be increased in Fenchuganj 90 MW thermal power plant. Trees and other vegetation closer to live conductors, transformers and other equipment should be trimmed and cleared. Light and sound intensity need to be measured as per Factory Rule 2015. Management review of the existing safety culture practice is also necessary for continuous improvement of safety culture in Fenchuganj 90 MW thermal power plant. Bibiyana South 400 MW Power Plant has the best safety culture practice among the three studied thermal power plants. This power plant is OHSAS 18001:2007 certified and has EHS policy award too.

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