International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 9 No. 1 Nov. 2014, pp. 377-386

http://www.ijias.issr-journals.org/

Implementing Process Safety Management (PSM) in Battery Manufacturing Industry: A case study

Shohanuzzaman Shohan, Md. Al-amin Hossain, and Fardim Sufiyan

Department of Industrial Engineering and Management,
Khulna University of Engineering & Technology,
Khulna-9203, Bangladesh

ABSTRACT: Process safety management (PSM) is the analytical tool which is used to prevent the unexpected release of toxic, reactive, or flammable liquids and gasses in various processes in industries worldwide. This regulation is promulgated by the U.S. Occupational Safety and Health Administration (OSHA). In this paper, the challenges and necessities are investigated in implementing the PSM process in the battery industries of Bangladesh. This paper shows that implementing the PSM tool in this area would result in a safer work environment and will assure environmental safety as well as increased productivity. The basic problems that occur in the process of storage, manufacturing and handling of highly hazardous chemicals in battery industries are also discussed. A case study was made in Hamko Batteries Company Ltd. Khulna, Bangladesh to observe the effects of implementing process safety management. The observed result showed a significant reduction in the number of accident frequency and increased productivity of the company. The three basic relationship between man, machine and environment are discussed in an industrial situation to ensure safety. The main aim of this paper is to identify the obstacles and challenges that would take place in implementing the PSM method and the requirements of practicing PSM method in the battery industries of Bangladesh.

KEYWORDS: Process Safety management, Safety Management, Industrial waste Management, Process Risk Reduction PSM implementation.

1 INTRODUCTION

Numerous facilities process and store highly hazardous materials, both toxic and flammable, below the PSM regulatory threshold. While these facilities are not required to comply with the rigorous requirements of PSM, because these facilities process highly hazardous materials they still have a responsibility to identify hazards associated with the process and ensure the facilities are designed, operated, and maintained to minimize hazards [1]. To meet this objective, many industries in Bangladesh have elected to implement PSM elements at the unregulated industries. For example, battery industries in Bangladesh process and transfer lead-acid battery which meet the definition of toxic and hazardous materials are subject to the OSHA PSM standard. In battery industries in Bangladesh like every other process industries, raw materials (lead and sulfuric acid) are converted into intermediate or final products using physical and/or chemical processes [2]. In these industries, production, storage, transportation, use and disposal of chemicals are inherently dangerous and the potential for catastrophic accidents is very high [3-4]. As accidents in these industries may lead to loss of life and damage to equipment, economic losses and environmental pollution [5-6], great efforts should be made to improve safety. This should be promoted by traditional safety measures and a passive approach toward developing preventive laws and regulations, such as the introduction of process safety management (PSM) [7].PSM was introduced in 1990 by the U.S. Occupational Safety and Health Administration (OSHA) and its final, complete version was published in 1992 [8, 9]. Process industries have since used this management system to limit and control chemical risks [10-11]. OSHA estimated that 6 to 10 years after the implementation of PSM, the risk of accidents had decreased 80% and nearly 264 deaths and 1,534 injuries or illnesses had been prevented each year [12].Considering the benefits which result from the establishment of good PSM in process

Corresponding Author: Shohanuzzaman Shohan

industries, this study was conducted in order to evaluate the requirements and Challenges of Implementing Process Safety Management (PSM) in Battery Manufacturing Industries in Bangladesh. All the information mentioned in this paper was taken from case studies in leading Battery manufacturer industries in Bangladesh.

2 PROCESS SAFETY INFORMATION

2.1 PROCESS FLOW DIAGRAM

All the lead-acid battery industries in Bangladesh follows almost similar process in their production process, transportation & storing. The process starts from gathering raw materials such as round lead (Pb) and concentrated H_2SO_4 and finishes the production process by making the final product as complete cell lead-acid Battery. Then the products are stored in inventory and thus transported to the dealers via various vehicles. As in this paper we focus on the PSM, the process flow diagram shows the production process only.

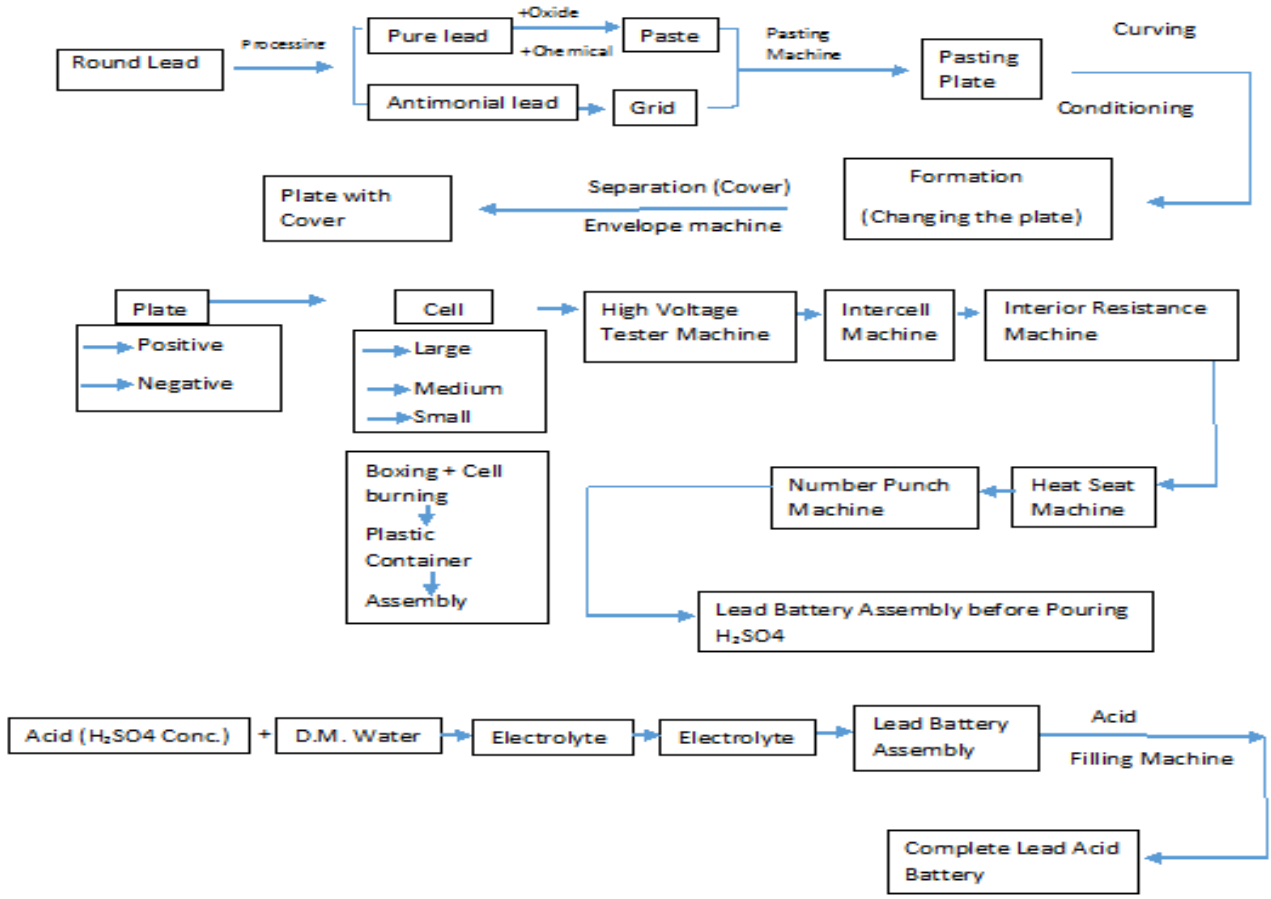


Fig. 1. Process Flow diagram of Hamko Batteries Company Ltd.

Fig. 1 shows the Process Flow diagram of Hamko Batteries Company Ltd.

2.2 PROCESS CHEMISTRY & ITS PROPERTIES

During the process of lead acid battery the following basic reactions are taken places particularly in cathode and anode [16].

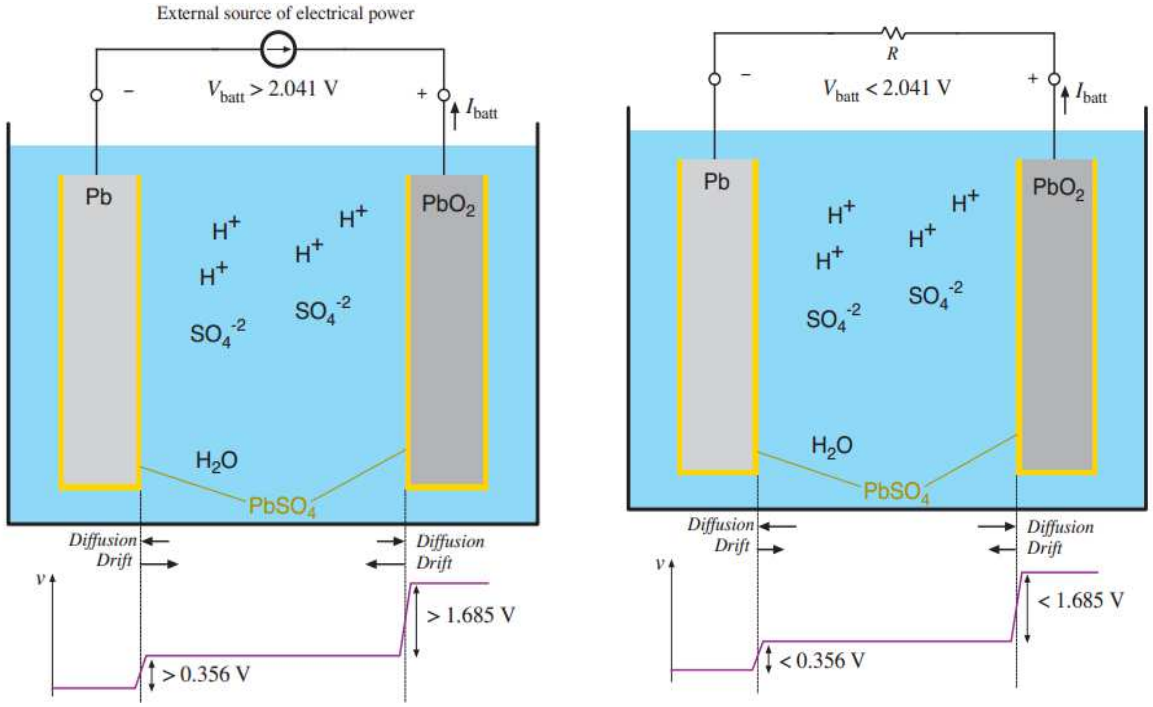
Anode: Pb + H2SO4 ↔ PbSO4 + 2H+ + 2e-

Cathode: PbO2 + H2SO4 + 2e-↔PbSO4 + 2OH-

→ Discharge

Pb + PbO2 + 2H2SO4 2PbSO4 + 2H2O

←charge



Discharging Charging

Fig. 2. Charging and discharging of lead-acid battery [17]

Fig.2 shows the charging and discharging mechanism of lead acid battery.

The aging mechanism of batteries are the actual chemical or mechanical events that cause battery's degradation. The battery will be affected in different ways depending on the conditions which is operated. All types of lead batteries will suffer from the same damage mechanism but in different degrees. The major aging process leading to [17]

- Gradual loss of performance and eventually to the end of service life
- Stratification of electrolyte
- Sulfating of electrodes
- Corrosion of electrodes
- Non cohesion of active mass

2.3 MAXIMUM INTENDED INVENTORY: (A CASE STUDY BASED ON HAMKO BATTERIES COMPANY LTD.)

The total demand of battery per month = 70,000 pcs
So the daily demand of battery = 2500 pcs
The minimum level of inventory is 10 times of daily inventory = 2500*10=25,000 pcs
The maximum level of inventory is 3 times of minimum level inventory= 25000*3=75,000 pcs

2.4 TOXICITY INFORMATION

A chemical or material is said to be toxic when it produce injury if it reaches a susceptible site or sites on or within the body. Other way of Toxicity may be defined as the inherent ability that all substances have to harm to body. [15]

The major type of toxic compounds/chemicals are classified as follows:

1. METALS - Lead
2. ACIDS - H2SO4

Table 1. Occupation exposure limits for inorganic lead

Inorganic Lead	Exposure units $\mu g/m^3$
OSHA PEL TWA	50
NIOSH REL TWA	100*
ACGIH TLVR TWA	150

*Air level to be maintained such that worker blood lead remains ≤ 60µ /100g

The degree of the toxic effect is not the same in all organs. Usually there are one or two organs which show the major toxic effect. These are referred as target organs of toxicity of the particular substance. The central nervous system is the target organs of toxicity most frequently involved in systemic effects. The blood circulation system, liver, kidneys, lungs, and skin follow in frequency of systemic effects. Muscle and bones are the target organs for a few substances. The male and female reproduction systems are vulnerable to many substances. [15]The major uses of lead is in lead-acid storage batteries. The majority of the lead used in batteries are recycled and during the melting process PbO is produced and released in the environment. [15] Sulfuric acid mist severely irritates the eyes, respiratory tract, and skin. Concentrated sulfuric acid destroys tissue due to its severe dehydrating action, whereas the dilute from acts as milder irritant due to acid properties. A worker sprayed in the face with liquid fuming sulfuric acid suffered skin burns of the face and body, as well as pulmonary edema from inhalation. Sequelae were pulmonary fibrosis, residual bronchitis, and pulmonary emphysema; in addition, necrosis of the skin resulted in marked scarring. In human subjects, concentrations of about 5 mg/m3 were objectionable, usually causing cough, an increase in respiratory rate, and impairment of ventilator capacity. Workers exposed to concentrations of 12.6 to 35 mg/m3 had a markedly higher incidence of erosion and discoloration of teeth than was noted in unexposed individuals. Splashed in the eye, the concentrated acid causes extremely severe damage, often leading to blindness, whereas dilute acid produces more transient effects from which recovery may be complete. Repeated exposure of workers to the mist causes chronic conjunctivitis, tracheobronchities, stomatitis, and dermatitis, as well as dental erosion. While ingestion of the liquid is unlikely in ordinary use, the highly corrosive nature of the substance may be expected to produce serious mucous membrane burns of the mouth and esophagus. [19]

3 CHALLENGES IN IMPLEMENTING PSM

In a developing country like Bangladesh, implementing any new practice or feature which is not mandatory for the production and doesn't earn extra profit for the industry are not welcome if it's not a must to do. So implementing PSM which is not directly involved with earning extra profit for the industry, could be subjected to the unwillingness of the managerial levels. The board of directors of the industry should realize their responsibility to identify hazards associated with the process and ensure the facilities are designed, operated, and maintained to minimize hazards. Though the practice of PSM method has not been well established till now, the top line of the battery industries should realize the importance and advantages of implementing PSM. Although PSM implementation costs are estimated to be high, most companies implemented it have achieved equal or higher benefits and are generally happy with it [13]. A study of chemical industries of South Korea found that seven years after the implementation of PSM, the number of deaths, injuries and "near misses" had been reduced by 62%, 58% and 82%, respectively. Additionally, quality and productivity had improved, and the number of emergency process shutdowns had decreased, as had damage to equipment [14].The unawareness of the worker in the battery industry is also one of the big challenges in the process of implementing PSM. They are not provided with any specific training program as the upper level of the industry think of the training program as an extra cost. If the safety regulations, provided by OSHA PSM is practiced in the industry, the number of accident will reduce dramatically as most of the accidents

happen due the unawareness and disobedience of the safety procedure. If the necessity of the PSM method can be realized by both the top line and bottom line of the industry, the challenges of implementing PSM can be resolved.

4 NECESSITY OF PSM IN BATTERY INDUSTRIES

4.1 TO PREVENT OPERATIONAL & TRANSPORTATION PROBLEMS

Both the raw materials used to produce battery in a lead-acid battery industry are toxic and reactive. Lead is a poisonous metal which has a deadly effect on human body. Lead binds strongly to a large number of molecules; such as: amino acids, hemoglobin, many enzymes, RNA and DNA, it thus disrupts many metabolic pathways. The effects of lead toxicity are wide ranging include impaired blood synthesis, hypertension, hyperactivity and brain damage.[15] Similarly, sulfuric acid is a very reactive agent which is deadly to human body. So safety precautions must be taken to handle these material in the production, transportation and storing process.

4.2 TO ENSURE PROPER RELATIONSHIP BETWEEN MAN, MACHINE & ENVIRONMENT

In an industrial situation there exists three basic relationship and any lagging or imbalance in the relations will result in accident. If these relationships are properly harmonized then accident can be reduced appreciably. [15] The three relationships are:

a) Man to Man (human) relationship.
b) Man and Machine relationship.
c) Man and Environment relationship.

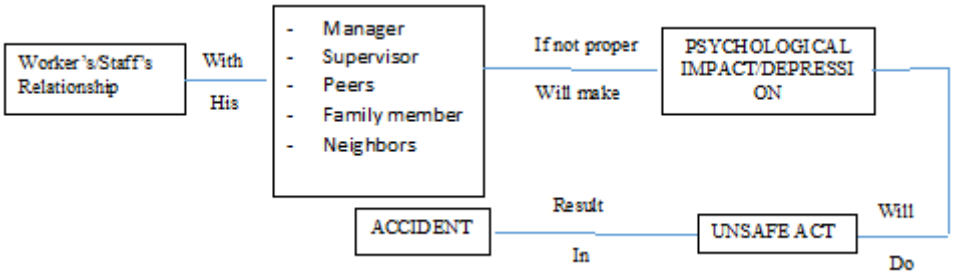


Fig. 3. Man to Man (human) relationship.

Fig. 3 shows the man to man relationship in an industrial situation.

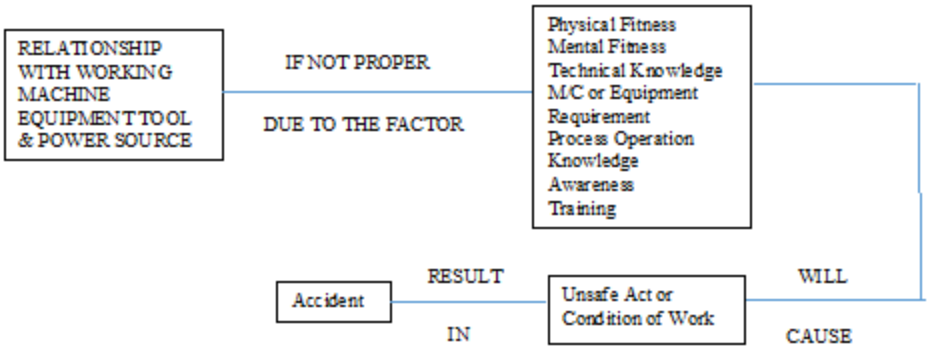


Fig. 4. Man and Machine relationship.

Fig. 4 shows the man and machine relationship in an industrial situation.

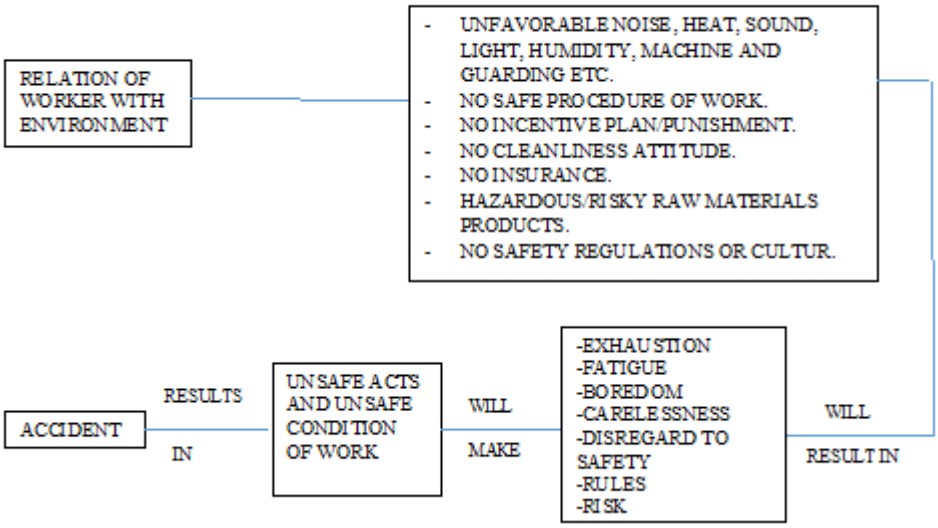


Fig. 5. Man and Environment relationship.

Fig. 5 shows the man and machine relationship in an industrial situation.

4.3 TO ENSURE BETTER WORK ENVIRONMENT FOR WORKERS

The work environment has a great effect on the worker's performance and dedication to work. A healthy and safer work environment will motivate the worker and increase his/her performance. This increased amount of motivation will lead to greater productivity of the industry. So implementing PSM is necessary to increase the work safety and sound environment in the industry area. Because PSM focuses not only on the safety issue but also on the sanitation system, medical treatments, emergency plan, workers training and much more.

4.4 SAFETY INCREASES PRODUCTIVITY

Safety is an important criterion increasing productivity. [16] Safety promotes productivity because of

- Uninterrupted production
- Keep people moral high
- No unplanned shut-down & production loss
- Better labor-management relationship

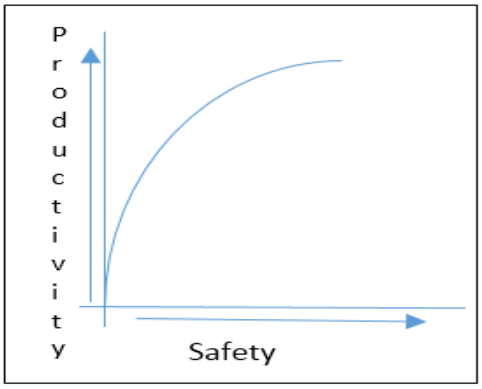


Fig. 6. Relationship between safety and productivity

Fig. 6 shows the relationship between safety and productivity in an industry.

4.5 PROMOTE COMPANY STANDARD

Successful implementation of process safety management secure the standard of any company. Because most accident and inequalities cause when any process is operated. When a process runs well, then the output of that process will be better. This will result in an increased reliability of the product as well as the company standard. This also secures better working condition and proper safety for workers that help to promote a company's standard.

4.6 REDUCE ACCIDENT RATE

"Accident does not happen-it is caused". Mr.Heinrich a U.S. safety expert in the year 1928 made an analysis with 75000 accident event and found that [16]

- 88% accidents were caused by unsafe acts.
- 10% accidents were caused due to unsafe work condition.
- 2% accidents were beyond human control.

To reduce the accident rate in the industry and to increase the occupational safety, PSM is very effective.

5 REQUIREMENTS FOR IMPLEMENTATION OF PSM IN BATTERY INDUSTRIES

To be eligible for the membership of OSHA organization and to implement PSM in the industry the battery industries must provide the following information about their process, raw materials and process technology: [9]

Information on the hazards of the highly hazardous chemicals in the process shall consist of at least the following:

- Toxicity,
- Permissible exposure limits,
- Physical data,
- Reactivity data,
- Corrosivity data, and
- Thermal and chemical stability data, and hazardous effects of inadvertent mixing of different materials.

Information on the technology of the process must include at least the following:

- A block flow diagram or simplified process flow diagram,
- Process chemistry,
- Maximum intended inventory,
- Safe upper and lower limits for such items as temperatures, pressures, flows or compositions, and
- An evaluation of the consequences of deviations, including those affecting the safety and health of employees.

Some of these required data has been discussed in this paper from a case industry in Hamko batteries, one of the largest battery manufacturer in Bangladesh.

5.1 ETP PLANT

When Lead Acid Batteries are replaced, they contain spent acid with some lead dissolved in it. These used batteries are sold in the open market to lead recyclers where they are drained before being put into the process of recycling. Further in many units, plastic containers of the batteries, after cutting and opening, are washed to remove any lead in them. The drained acid along with any washing effluent of the plastic scrap comprises of the effluent that needs treatment at the Effluent Treatment Plant (ETP). This ETP is also commonly called Acid Neutralization System.

If unchecked, these untreated effluent will sweep in to land and would lead to soil contamination, pollution in ground water table and their runoff may also lead to pollution of nearby eater sources. Hence, their proper treatment before disposal is necessary. [18]

Characteristics of Effluent before and after Treatment can be shown as the table below. The approved range of lead is 0.1 mg/l whereas before treatment it could be up to 30-40 mg/l.

Table 2. Characteristics of Effluent before and after Treatment

Parameter	Before Treatment	Approved Range
pH	3.0 - 4.0	6.5 - 8.5
Suspended Solids	600 - 800 mg/l	50 mg/l
Lead	30 - 40 mg/l	0.1 mg/l

5.2 EPP PLANT

A carefully Emergency Preparedness Plan (EPP) is vital for any plan that handles hazardous chemicals. The aim of EPP is to enable a quick and effective response to contain and minimize the effect if a catastrophic event to restore normality as soon as possible. [15]

In short, the objective of this plan:

- To provide essential information about the hazard any accident even because of certain equipment or process failure. Also to provide implication and remedial procedure.
- To form action group, for specific task during accident emergency.
- To provide information about emergency handling equipment, their functions and uses.
- To define procedure for evacuation of accident victims and their treatment.

5.3 SANITATION SYSTEM

Clothing which is contaminated with inorganic lead should be removed immediately and placed in closed contains for storage until it can be discard or until provision is made for the removal of inorganic lead from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of inorganic lead's hazardous properties. Change and shower rooms should be provided with separate locker facilities for street and work cloths. Skin that becomes contaminated with inorganic lead should be promptly washed with soap and water. [18] Skin that becomes contaminated with sulfuric acid should be immediately washed or showered to remove any sulfuric acid. [19]

5.4 APPROPRIATE MEDICAL FACILITIES

Medical facilities should be ensured for every worker. One or more specialized medical officer should be appointed according to the size of the total human resource. A regular checkup should be done for the identification of percentage of lead in the worker's body. Other medical tests like HIV test and blood test should be done periodically. A specific position of the industry should be allotted for the medical room and necessary fast aid instruments should be available all the time. Emergency transportation system like Ambulance should be available 24 hours a day in case of an emergency.

5.5 SAFETY COMMITTEE

In large organization, there may be safety committee for each department and a central committee for the whole undertaking. Safety committee should consist of representatives of both employers (management) and workers. The employer's representative should include staff members such as the Manager, Safety Engineer, Foreman, Factory Doctor and Personnel officer. The workers representatives should be as many as possible, preferably of different department and should be appointed for certain tenure of time, so as to allow other workers to become members. The workers members should be elected by them or nominated by the labor union, but sometimes nominated by the management also. It is expected always that educated, intelligent, logical, sincere and generally acceptable person from co-workers should be nominated or selected for the safety committee.

5.6 WASTE REMOVAL AND DISPOSAL

Bangladesh Environment Protection Agency, Department of Transportation, and state regulations should be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

Other issues like emergency evacuation system, air cleaning, dust cleaning, providing clean and cold water, providing standard training should be also taken care of to implement PSM in battery industries or battery manufacturing facilities.

6 CONCLUSIONS

Effectively applying PSM at battery manufacturing industries in Bangladesh presents numerous challenges due to unwillingness of managerial level to bear additional expenses associated with PSM implementation and geographic extent of facilities. If the top level of industries are informed with the advantages of implementing PSM in the industry. It will result in both occupational safety for the workers and environmental safety and productivity for the company. Recently, Hamko Batteries Company Ltd. has been a member of OSHA and started implementing Process Safety Management Procedure in their lead-acid battery manufacturing facility. This implementation of PSM has shown a significant effect in reducing the accident rate in various operation of battery manufacturing and assembling process. The occupational safety of the workers has increased, the productivity has increased due to less interruption in the manufacturing and assembling process. These results can be shown in the chart below:

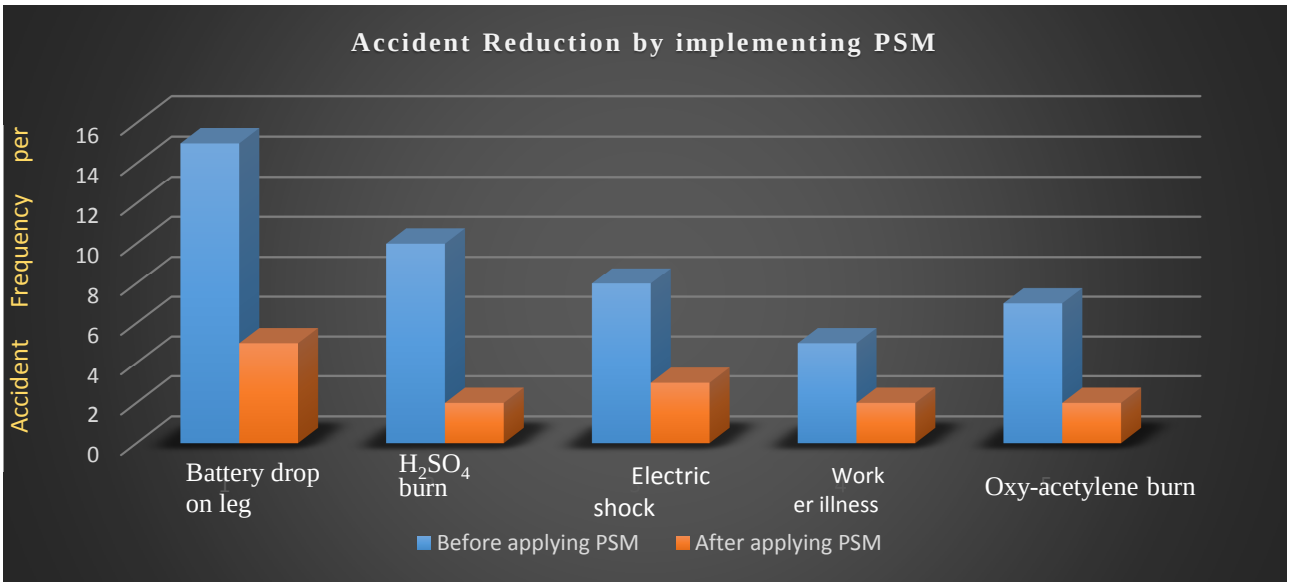


Fig. 7. Implementation of PSM in Hamko Batteries Company Ltd.

Fig. 7 shows the average number of accident happened in the industry due to various reasons before the implementation of PSM and after implementation of PSM.

Implementation of PSM not only protects workers but also protect the co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are impacted by the working place environment.

REFERENCES

[1] Kristin D. Norton, Michael B. Saura, Colin R. Scholtz. **"***Practical Implementation of Safety Management Systems at Unregulated Upstream Oil & Gas Facilities",* 9th Global Congress on Process Safety, April 28 – May 1, 2013, San Antonio, Texas

[2] Macza M, "*Canadian perspective of the history of process safety management"*, 8th International symposium, 2-3 September 2008; Cologne, Germany.

[3] Dowdsworth M, Connelly KE, Ellett CJ, Sharratt P., "*Organizational climate metrics as safety, health and environment performance indicators and an aid to relative risk ranking within industry*." *Process Saf Environ* 2007; 85(1): 59- 69.

[4] Philley J., "*Incident investigation - the center for chemical process safety approach",* ASSE Professional Development Conference and Exposition, 22-25 June 2003: Denver, Colorado.

[5] Kim T, Kim J, Kim Y, Kim K., "*Current risk management status of the Korean petrochemical industry", J Loss Prevent Proc* 2005; 15(4): 311- 318.
[6] Pitblado R. "*Real-time safety metrics and risk- based operations*", 11th International Symposium Loss Prevention, 2004: Prague, Czech Republic.
[7] Chang JI, Liang C. "*Performance evaluation of process safety management systems of paint manufacturing facilities"*, *J Loss Prevent Proc* 2009; 22(4):398- 402.
[8] Occupational safety and health administration (OSHA). Process safety management of highly hazardous chemicals.2000; Available: http://www.osha.gov/SLTC/ processsafetymanagement/
[9] Occupational Safety and Health Administration. *Process safety management of highly hazardous chemicals*. OSHA Report 3132. 2000; Available: http://www.osha.gov/SLTC/ processsafetymanagement/
[10] Mohamed HA. "*Process safety management to manage risk in occupancies other than chemical process facilities"*, 54th Canadian chemical engineering conference, 17-19 October 2005; Toronto, Canada.
[11] Arendt S. "*Continuously improvement PSM effectiveness- A practical roadmap*", *Process Saf Prog* 2006; 25(2): 86-195.
[12] Rosenthal I, Kleindorfer PR. Elliott MR. *"Predicting and confirming the effectiveness of systems for managing low-probability chemical process risks*", *Process Saf Prog* 2006; 25(2); 135-155.
[13] Bridges W. "*The cost and benefits of process safety management: Industry survey results", Process Saf Prog* 1994; 13 (1): 23-29.
[14] Kwon H. "*The effectiveness of process safety management (PSM) regulation for chemical industry in Korea"*, *J Loss Prevent Proc* 2006; 19(1):13-16.
[15] Acid Neutralization Effluent Treatment Plants, EROS ENVIROTECH PRIVATE LTD. Available: http://erosenvirotech.tradeindia.com/acid-neutralization-effluent-treatment-plants-1683491.html
[16] Mohammad Hafizur Rahman, Management of Occupational Safety Health & Environment, 1st Ed. Adorn Publication, 2009.
[17] K. BRICK, F. BEN AMMAR "*The Fault tree analysis of the lead acid battery's degradation",* Journal of Electrical System 4-2 (2008): 1-12
[18] The National Institute for Occupational Safety and Health (NIOSH), Occupational Health Guidelines for Chemical Hazards DHHS (NIOSH), January 1981,Publication Number 81-123; Available: http://www.cdc.gov/niosh/docs/81-123/pdfs/0368.pdf
[19] The National Institute for Occupational Safety and Health (NIOSH), Occupational Health Guidelines for Chemical Hazards DHHS (NIOSH), January 1981,Publication Number 81-123; Available: http://www.cdc.gov/niosh/docs/81-123/pdfs/0577.pdf