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ORIGINAL ARTICLE

Application of Hazard and Operability Study (HAZOP) in Evaluation of Health, Safety and Environmental (HSE) Hazards

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ABSTRACT

Risk assessment and management techniques are used in industrial activities to reduce accidents by applying preventive and protective methods. In this article a preventive approach called Hazard and Operability Study (HAZOP) was used. The application of HAZOP, a process hazard identification and control method, has been demonstrated in the fatty acid unit of Golnar Oil Company, northwest of Tehran Province. The results of the study identifies 58 types of hazard of which 45.6% were unacceptable, 27.1% were unsafe, 18.6% were acceptable but needed reconsideration, 8.7% were acceptable with no need for any corrective action. To prevent any catastrophic consequences, we recommend: (1) installing pressure switch and flow switch on the product-receiving lines, and (2) conducting regular and periodic HSE audit.

Keywords: *Hazard, Chemical industries, HAZOP, Safety*

INTRODUCTION

The development of industry and technology while providing essential support for wellbeing has threatened human life [1]. The tragic events such as Feyzin, Mexico City, Piper Alpha (UK) or Chemobyl (Russia), have caused human suffering, environmental pollution and finally disturbance in ecosystem [2]. The consequences of extreme events make us think deeply and seriously in offering health, safety and environment (HSE) controls [3]. Comparing tragic incidences in different countries, regardless of their development status, show that they are somehow similar. The analysis of these incidents points to factors such as human errors, too much reliance on the safety of machinery, problems in design of the plant, unprepared to face and cope with critical situations and lack of HSE rules (specifically in under-developed countries) [4]. Other factors, natural or man-made, can also contribute or intensify the problem. Examples are global warming, mass water pollution, depletion of ozone layer, and extinction of certain animals [5]. All the factors mentioned do exist in a country like Iran. Traditionally, safety incorporated in the design of chemical plants based upon the application of codes of practices well as checklists prepared by experienced and knowledgeable professionals and specialists in this industry [6]. However, such approach can only deal with problems that have surfaced before. With ever increasing of complexity in modern chemical plants, these traditional approaches are likely to miss some major issues which need to be considered at the design stage of a project [7]. To overcome these shortcomings, health and safety

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Table 1. Major process parameters

Parameter	Deviation	Parameter	Deviation
Level	High or low level	Flow	No flow, reversed flow, low or more
Corrosion	More or low	Pressure	More, low or no pressure
PH	More or low	Temperature	More or low
Contaminate	More or low	Tune up & maintenance danger	More
Training	No or less	Material mixed with another one	More

professional have come up with new ideas. Based on experience from using safety-related techniques and related to the development of risk analysis articles and handbooks, we evaluated methods such as Layer of Protection Analysis (LOPA), Event Tree Analysis (ETA), Fault Tree Analysis (FTA), Failure Mode Effect Analysis (FMEA) and hazard as well as Operability studies (HAZOP) etc for use in the fatty acid unit of a vegetable oil Company [8, 9]. Regarding the identification of chemical safety threats, conclusion was that the HAZOP principle seemed well suited, assuming that adequate guidewords could be established [10].

HAZOP, developed by Imperial Chemical Industries (ICI) during the 1960s as a technique to systematically identify potential hazards and operability problems in newly designed chemical and petrochemical plants [7]. It is also used in reviewing and modifying existing processes.

This report deals with the HSE assessment and risk management of a fatty acid unit in a vegetable oil company by HAZOP technique. Piping lines, storage tank, and distillation and splitting shops likely to have a high risk on employees' health, safety and environment. It is obvious that even a small leakage from these operations can be problematic for employers and their environment and wasteful of valuable materials. These operations are assumed to be the critical points of mass transportation in the Unit and need serious safe approach such as the HAZOP. In this article the preventive approach of HAZOP was used

MATERIALS AND METHODS

Location

The qualitative study was conducted at the fatty acid unit of Golnar Oil Company in the station in northwest of Tehran Province using HAZOP technique. Fatty acid unit has 700 m² shop-floors with 16 employees working in day and night shifts. It is a 5-floor building which consists of three operations of acidulation, distillation and splitting. This unit produces fine fatty acid. The raw material is washed by sulfuric acid and water (acidulation stage). In splitting plant, it is separated into fatty acid and glycerin. Fatty acid is transferred into distillation plant to get purified fatty acid which is the final product.

HAZOP technique

A hazard and operability study (HAZOP) is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation [11]. The HAZOP technique was initially developed to analyze chemical process systems, but has later been extended to other types of systems and also to complex operations and to software systems [12]. The analysis is performed using a set of guidewords and attributes. A HAZOP study is typically conducted by a team consisting of four to eight persons with a detailed knowledge of the system to be analyzed. The HAZOP leader of the group will normally be an occupational safety and health engineer with extensive training in the use of HAZOP and other hazard analysis methods. The analysis itself is done by going systematically through all system components identifying possible deviations from intended behavior and investigating the possible effects of these deviations. For each deviation the team sets out to answer a series of questions to decide whether the deviation could occur, and if so, whether it could result in a hazard. Where potential hazards are detected, further questions are asked to decide when it might occur and what can be done to reduce the risk associated with the hazard [13].

Documents

Initially, all the required documents including maps, details of operations and systems, piping and instruments diagrams, technical details and directions for implementation of systems were obtained by main team members who were familiar with the design of fatty acid unit. The nodes of the processes including entry of raw material till the entrance of the fatty acid, tanks of the materials, filters, high pressure pumps, acid discharges and acid tanks were located and reviewed.

The cases of process deviation from the standards were also documented by the research team members using guiding words such as No, More than, Less than, As Well as, Part of, Reverse, Other than and Process Parameters (Table 1). The risk prioritization and estimation of the qualitative hazards, risk management in the form of risk assessment matrix were also explored [4, 14]. The risk factors were also classified in three following stages and then results were entered in the HAZOP worksheet: Probability of consequences of deviation from standard in 5 groups were determined as "frequent" to "rare" [15]. Severity of accidents was

Table 2. Sample of the Hazop Results Summary

Deviation	Possible causes	Consequences	Action required
Low pH	Manual pH measurement	Piping corrosion, leakage,	Monitoring system of corrosion, installation of PH meter, PM program
More flow	Manual filling of tanks, malfunction of safety and control valve, out of repairing the pump of the fatty acid, malfunction of FRC (flow record control)	Environmental pollution, disorder in the process of distillation column,	FCA installation, Calibration of the appliances and PI system,
More level	Manual filling	Over filling of acid tanks, sever danger to the workers, environmental pollution, death	LCA, FRCA installation, personnel training,
Low pressure	Malfunction of high pressure pump, leakage of the packing, technical problem of boiling tank, steam condensing,	Malfunction in the process, boiler column and its function, inadequate steam for the process, delay to reach desired time, waste of time and energy, coil steam damages	PI installation, regular examine, PM program
Low Maintenance and services danger	Entering gas in to the column while repairing,	workers, poisonous steam in the column, changing the nature of chemical fatty acid, disorder in the process of the column	Test poisonous steam before going in to the column,

classified into 4 groups as “catastrophic” to “marginal.” Severity and probability in each situation is combined to determine the risk levels to set priority of control measures [16, 17].

RESULTS

A total of 3 systems and 14 nodes were recognized, evaluated and then documented as summarized in Table 2. The operational problems were the main focus by team members, but more attention was paid to the deviations with negative impact on the financial loss and personal injuries [18]. Totally 58 deviations were identified; of those 12% were related to nodes from the entry of fat to entry of the distillation column, 10% from the entry of 56 bar steam to entry of the distillation column, 10% related to distillation column, 6.8% to light ends passage and 3.4% to splitting column. Considering that one deviation can have several causes and effects, 110 causes of deviation were identified. Some of the causes are as follows: failures in the level measurement instrument, non regulation of the pump, performance of production process manually, corrosion of the acid path way, blockage of the path ways, defective check valves, mechanical problems of check valves, leakage of the pipes, and presence of air in the system. 45.6 % of all risks were unacceptable, 27.1% unsafe, 18.6 % acceptable but needed reconsideration, and 8.7% acceptable with no need for any corrective action.

DISCUSSION

This study has been designed to examine and manage HSE risks of a fatty acid unit in a vegetable oil company. Fifty eight hazards were identified by this study; showing that 27.1% of identified issues were unsafe with severe human, economic and environmental sufferings. The root cause of 31.4% was unacceptable behavior. In consistent with the findings of Habibi [19] and Puly [20], more than 30% of the identified hazards followed by operator errors.

The highest level of unacceptable risk was related to deviation in node 3 (56 bar steam passage to distillation tower) and needed to be abated immediately. Some of their high risk deviation was: a) malfunctioning of high voltage pump of boiler b) obstruction of the passage of the water in the boiler would result in pipe bursting, damage to workers and decreased efficiency of the boiler c) packing leakage which causes malfunction in boiler and processing of the column. The finding is consistent to the results of Shafaghi [21]. For prevention of deviations, attention should be, therefore, focused on the application of instructions for regular inspections and maintenance of systems.

In general, designing and implementing a preventive program is very effective in identifying and controlling these types of risk [22]. Major suggestions for further improvement are change the manual control to PLC (Programmable Logic Controllers) one, regular PM monitoring, change or improve the equipment, train the workers who may face problems such as over filling chemical tanks (like acid sulfuric, etc), regular monitoring and calibration of equipments.

CONCLUSION

Hazop technique was suitable and effective in the unit studied to assess risk and offer solutions.

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REFERENCES

1. Jin HU, Zhang LB, Liang W, Wang Z. Quantitative HAZOP Analysis for Gas Turbine Compressor based on Fuzzy Information Fusion. *Syst Eng Theory Pract* 2009; 29 (8): 153-159.
2. Bartolozzi L, Castiglione A, Picciotto M. Qualitative models of equipment units and their use in automatic HAZOP analysis. *Reliab Eng Syst Saf* 2000; 70 (1): 49-57.
3. Rossing NL, Lind M, Jensen N, Jorgensen S. A functional HAZOP methodology Original. Comput. *Chem Eng* 2010; 34 (2): 244-253.
4. Dunjo J, Fthenakis V, Vílchez JA, Arnaldos J. Hazard and operability (HAZOP) analysis. A literature review. *J Hazard Mater* 2010; 173 (1–3): 19-32.
5. Wang F, Gao J, Wang H. A new intelligent assistant system for HAZOP analysis of complex process plant. *J Loss Prev Process Ind* 2012; 25 (3): 636-642.
6. Khan FI, Abbasi SA. Major accidents in process industries and an analysis of causes and consequences. *J Loss Prev Process Ind* 1999; 12(5): 361-78.
7. Johnson RW. Beyond-compliance uses of HAZOP/LOPA studies. *J Loss Prev Process Ind* 2010; 23 (6): 727-733.
8. Mata JL, Rodriguez M. Functional modeling applied to HAZOP automation. COMP AID CH 2012; 31: 255-259.
9. Noakes N, Chow CCL, Ko E, McKay G. Safety education for chemical engineering students in Hong Kong: Development of HAZOP Study teaching module. *Educ Chem Eng* 2011; 6 (2): 31-55.
10. Rossing NL, Lind M, Jensen N, Jorgensen S. A Goal Based HAZOP Assistant Original. COMP AID CH 2009; 26: 1129-1134.
11. Kitajima T, Fuchino T, Shimada Y, Naka Y, Yuanjin L, Iuchi K, Kawamura K. A New Scheme for Management-of-Change Support Based on HAZOP Log. COMP AID CH 2010; 28: 163-168.
12. Preisig HA, Manenti F HAZOP - an automaton-inspired approach. COMP AID CH 2012; 30: 1242-1246.
13. Reza A, Christiansen E. A case study of a TFE explosion in a PTFE manufacturing facility. *Process Saf Prog* 2007; 26(1): 77-82.
14. Kwamura K, Naka Y, Fuchino T, Aoyama A, Takagi N. Hazop support system and its use for operation. COMP AID CH 2008; 25: 1003-1008.
15. Mata JL, Rodriguez M. HAZOP studies using a functional modeling framework COMP AID CH 2012; 30:1038-1042.
16. Labovsky J, Lassak P, Markos J, Jelemensky L. Design, optimization and safety analysis of a heterogeneous tubular reactor by using the HAZOP methodology. COMP AID CH 2007; 24: 1241-1246.
17. Kletz TA. Hazop-past and future. Reliable Eng Sys Safety 1997; 55(3): 263-6.
18. Mearns K, Whitaker S, Flin R. Benchmarking safety climate in hazardous environments: a longitudinal, inter-organizational approach. *Risk Anal* 2001; 21(4): 771–786.
19. Habibi E, Zare M, Barkhordari A, Mirmohammadi SJ, Halvani GhH. Application of a Hazard and Operability Study Method to Hazard Evaluation of a Chemical Unit of the Power Station. *J Res Health Sci* 2008; 8(2); 13-20.
20. Pully AS. Utilization and results of hazard and operability studies in a petroleum refinery. *Process Safety Prog* 1993; 12(2):106-10.
21. Shafaghi A, Cook FB. Application of a hazard and operability study to hazard evaluation of an absorption heat pump. *IEEE Trans on Rel* 1998; 37(2):159- 66.
22. Jeerawongsuntorn C, Sainyamsatit N, Srinophakun T. Integration of safety instrumented system with automated HAZOP analysis: An application for continuous biodiesel production. *J Loss Prev Process Ind* 2011; 24 (4): 412-419.