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HAZOP STUDY ON OIL REFINERY WASTE WATER TREATMENT PLANT IN KARACHI

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ABSTRACT

The disposal of Refinery wastewater has various hazards before and after treatment which needs to be properly analyzed by using different risk assessment tools. The main purpose of this work is to study the oily waste water from one of the biggest Refinery located in Karachi, Pakistan by applying Hazard and Operability Study (HAZOP) on it in hypothetical scenario. HAZOP is one of the best tools used in various oil Refineries globally based on guide words for all hazardous conditions with strong recommendation. For authentic HAZOP study whole process design was done on the basis of Process flow diagram (PFD), Piping and Instrumentation diagram (PID) and standard guide words. In this case study about (14) deviations were documented with (37) causes and (26) consequences. However for safer system design, the group analyze propose about 21 actions whereas most of them about (60%) will need to install new devices. This indicate that the HAZOP studies act as an efficient tool for enabling reasoning to reveal potential hazards in safety critical operations.
Keywords: AZOP, Wastewater Treatment, Process flow diagram (PFD), Piping and Instrumentation diagram (PID), guide words, deviations.

INTRODUCTION

The analysis of risk associated with hazard is the main aspect of oil industry. Risk assessment or risk analysis is carried out throughout the use of many suitable methods of study. The method involves Qualitative and Quantitative Risk Assessment. Qualitative or Historical risk analysis is preliminary risk assessment, while Quantitative risk analysis i.e. HAZOP is used in severe cases in various industries [1].

A petroleum refinery provides the most needed fuels for everyday use for industrial, commercial and domestic purposes. Processing crude oil in refinery requires large percentage of oil which is contaminated and requires some level of treatment [2].

Technological development, creativity, studying "what went wrong" and "how to implement the lessons learnt" have provided a new paradigm with an approach where safety is integrated into the complex system resulting from the network of typical industrial process interactions [3].

HAZOP is a complete, systematic and relatively easy to apply technique for analyzing risks and deviations. The procedure involves evolution of waste water treatment technologies and several techniques including Primary (physical) and Secondary (biological) treatment. This study involves identification of the main systems used for the treatment and their main characteristics [4].

Safety analysis are generated after a detailed study of HAZOP worksheet results, having lists of identified deviations with their causes and effects, as well as recommendations, suggestions and comments. The HAZOP of batch procedures need time consuming or classified guidewords (Early, delayed, Before, After quickly, slowly) which can be employed by incorporating in a meticulous fault of a working procedure [5, 6].

The HAZOP has been widely used for various kinds of industry especially in oil. In the case of Brazil, started to be used from the 90's in segment the oil and natural gas. In Brazil some oil refineries has successfully implemented HAZOP and other tool for analysis of hazards [7]. In this sense the use of HAZOP in the oil business like refinery process can be applied.

As per literature review HAZOP technique is a very operational tool for identifying the causes of deviation from set parameter and to determine all major hazards and operability problems associated with these deviations, however the unexpected events does not included in the detailed HAZOP [8].

The main objective of this work is to identify the hazards only related to oily waste water treatment plant. The disposal of waste water from the refinery as per National Environmental Quality Standards (NEQS) is the very serious problem in Pakistan. Therefore oily waste water treatment facility should be hazard free before and after treatment. To make the system safer with all respect HAZOP study is necessary for all Refineries of Pakistan. The HAZOP study is carried out for safety, reliability and to optimize the instrumentation in the Refinery.

MATERIALS AND METHODS

According to this study first of all deviation of various process variable of oil refinery waste water (RWW) unit has been identified to minimize the associated risk. After identifying deviation the next step is to check all realistic cause of this deviation. If there is, the consequences must be considered. They may be trivial or significant. If significant, they must be evaluated to see if they constitute a hazard then all the necessary action is recommended to make the process free from hazard. It is based on detailed study of the PFD (Process Flow Diagram) / P&ID's (Piping & Instrumentation) not only during the Design phase but after the implementation of project. In table 1 more than five guide words are given with specific function which is mostly utilized during HAZOP Study.

TABLE 1: BASIC GUIDE WORDS FOR HAZOP STUDY

Guide word	**Explanation**
NONE	No forward flow when there should be, i.e. no flow or reverse flow.
MORE OF	More of any relevant physical property than there should be, e.g. higher flow (rate or total quantity), higher temperature, higher pressure, higher viscosity, etc.
LESS OF	Less of any relevant physical property than there should be, e.g. lower flow (rate or total quantity), lower temperature, lower pressure, etc.
PART OF	Composition of system different from what it should be, e.g. change in ratio of components, component missing, etc.
AS WELL AS MORE THAN	More components present in the system than there should be, e.g. extra phase present (vapor, solid), impurities (air, water, acids, corrosion products), etc.
REVERSE	A parameter occurs in the opposite direction to that for which it was intended e.g. reverse flow.
OTHER THAN	Complete substitution e.g. sulphuric acid was added instead of water.
EQUIPMENT WORDS "OTHER"	What else can happen apart from normal operation, e.g. start-up, shutdown, uprating, low rate running, alternative operation mode, failure of plant services, maintenance, catalyst change, etc.

The HAZOP a qualitative survey is done for the largest oil refinery wastewater treatment plant (WWTP) of Pakistan. The capacity of the treatment plant is 90m^3/hr from different areas of refinery, mostly from utilities crude oil storage tanks, blow down water from cooling tower etc. having a huge hazardous operational factors are analyzed by HAZOP technique .

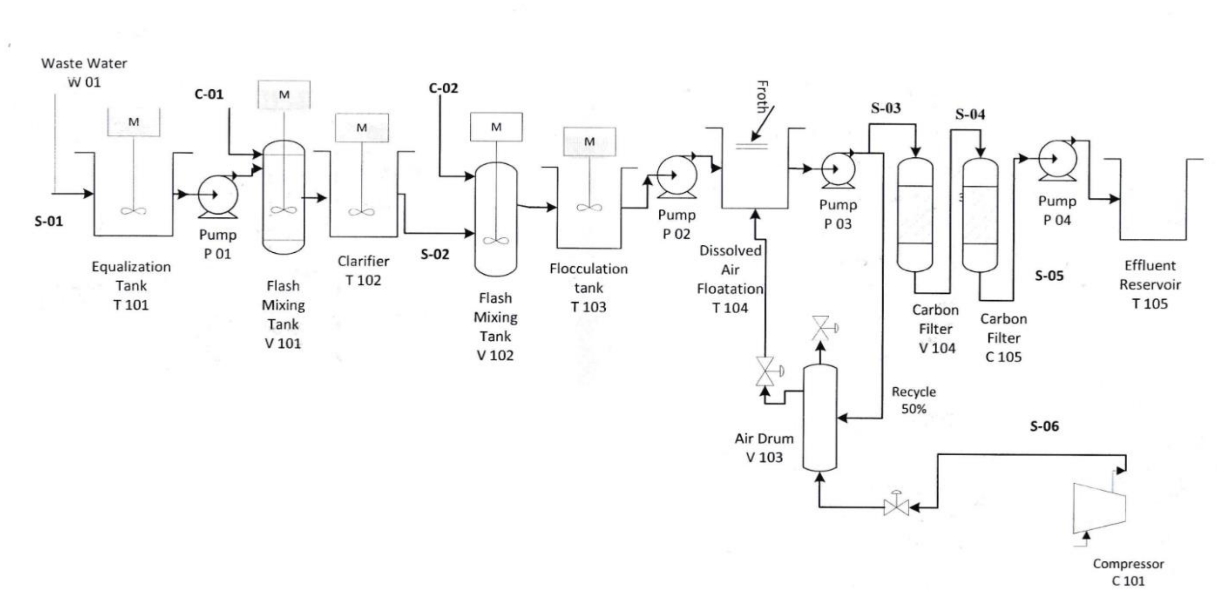

Fig. 1. Process flow diagram of Oily Wastewater Treatment Plant

According to (figure 1) the effluent wastewater first process in a clarifier and DAF (Dissolved Air Floatation) for the removal of oil and other impurities as illustrated in (Table 2).

Table-2: HAZOP features of equipment used in treatment of oily waste water of Refinery of Karachi.

Name of Equipment	**Possible HAZOPS reported by Team leader**
Equalization tank	The influent is directly entering in equalization tank therefore it can create different hazards to the material and human health, which can be overcome by installing the level sensors, flow meters and temperature measuring devices.
Clarifiers	There is always a danger for oil of achieving the flash point temperature, which explode or burn the plant and could be danger for human health, therefore proper vigilance is required in clarifiers.
Dissolved air floatation unit(DAF)	It has an ability to remove the 80% of oil content, that's why there is no danger of catching fire after this process. But proper vigilance monitoring & control are required in its various parts like compressor and air drum, which can rupture or blast at high pressure. Mainly employed as a second step in a WWTP in oil refineries. The process contains a physical-chemical separation. The DAF feed water is dosed with a coagulant and flocculent. According to some literature the flotation operation has efficiency ranges from 70% to 85% removal of oil and grease and 50 % to 85% of suspended solids.
Activated carbon filters	If influent stream of carbon filter contains high amount of suspended solid (SS) then there is a danger of blockages in filters, otherwise it is not hazardous. Activated carbon filtration process is a kind of adsorptive process, the oil and grease droplets are adsorbed onto the surface of carbon particles. The oil removal efficiency of activated carbon filtration is about 75% to 95%.
API Separators	It is a first primary treatment based on gravimetric. Mainly used to reduce the overloading of oil, grease and suspended solids in the subsequent downstream processes of WWTP. The removal efficiency of API separator is up to 33% to 68%. These separators are normally designed to remove oil droplet of size as small as 150 microns

To conduct the HAZOP organized by a team of the Engineers belongs to multiple disciplines. The team comprises of team leader/Chairman with complete knowledge of health, safety and environment (HSE), Maintenance, Process and Instrumentation Engineers.

The team has identified existing hazard of the WWTP then made control of entity/equipment after analyzing the consequential effects on overall system.

Revealing the fact that most of the accidents occurs due to deviation of the process variables like pressure, Temperature level from the standard level as per (Table 3).

Table-3: Summarized Table of Hazard and Operability (HAZOP) Study of oily waste water treatment plant of Refinery of Karachi.

Deviation From operating conditions	Possible causes	Consequences	Action Required
More flow of waste water	1.Valve malfunction 2.Pump malfunctioning 3. Control valve fails open. 4. Air inlet filter damage of compressor. 5. Production Loss. 6. Rain/ storm.	Liquid carried to the Overhead section of tank. Flooding may occur. More flow to pump causing Damage to pump. High velocity may lead to Erosion.	Regular checking and maintenance of valve Install high level liquid alarm. Install FCV. Proper monitoring of Pressure differential Across filter.

		Abrasion. Carbon comes along with water in Granular Activated Carbon filter.	Install block and Bleed arrangement at compressor. Use high abrasion number carbon in carbon filter.
No flow	1. Inlet Line rupture. 2.Pump malfunction 3.Scaling in pump suction line 4. Flow control valve before pump malfunction 5..FIC fails closing FCV 6.LIC fails closing LCV	Pump Cavitation. Deadhead Pump Plant shutdown Pressure in line increases	Proper inspection and maintenance of line Should be implemented. Install bypass loop for feed pump. Use alarm
Less flow	1.Inlet Valve malfunction 2. Blockage of line Scaling or corrosion in line. 3. Flow Transmitter malfunctions. 4. Three way valve failure.	Pump Cavitation. Damage to pump Incorrect information transmitted to FIC. Channeling in V-104 & V-105	Regular checking and maintenance of valve Connect a stand by pump and start it. Use supporting valves with LCV
High PH	Sources may contain basic Contamination	Coagulating and Flocculating agent may not work	Use pH controller
Lower PH	Sources may contain acidic contamination	Coagulating and Flocculating agent may not work	Use pH controller
Maintenance	Accumulation in tank.	Resulting in corrosion.	Regular inspection should be done.
More Composition in Granular Activated carbon	Carbon is spent in the train of carbon filters in operation. (Either V-106 & V-107 OR V-104 & V-105)	Poor adsorption resulting in high contaminants in effluent stream CW-041.	Periodic backwashing. Using parallel train of carbon filters V-106 & V-107
More Speed	1. speed of agitator Increases. 2.Motor malfunctioning	Improper effect of separation Floc may destroy	use specialized metallurgy Use alarm.
Low speed	Motor malfunctioning	Floc may not form	Use alarm
More pressure	1.Back flow occurs in pump, if pressure at discharge of pump increases 2. PSV-101 fails. 3.Compressor control Malfunction	Voids implode and generate Intense shockwave. Damage to pump Excessive agitation, vigorous bubbling in tank T-104	Use pressure indicator and controller. Use pressure controller to shut down compressor C-101. Use alarm.
Less Pressure	1. Inlet line chocked. 2. Compressor C-101 fails. 3. Blockage of Air filter in compressor. 4. FCV partially closed or malfunction	Pump failure Plant shutdown No or low bubbling in tank-104. Deferred Production	Use pressure indicator and controller Proper monitoring Periodic maintenance. Use alarm
High Level	1. LCV fails open. 2.Increase in discharge pressure 3.outlet valve of separator Choked.	Flooding may occur. Production loss.	Install high level liquid alarm. Use LIC. Proper monitoring should be done.
Low Level	1. Pump fails. 2. Level gauge Malfunction.	V-101 dry out. Production loss.	Use LIC to operate Pump. Proper monitoring Periodic maintenance.

More temperature	1. FCV malfunctions causing increase in temperature of fluid entering in vessel. 2.Compressor give gas of high temperature 3.Too much Compression 4.Fire case	Settling efficiency may effect. Seals, gaskets of compressor Melts. Tank may Rupture.	Install temperature indicator Feed temperature should be adjusted previous before it enters the vessel. Proper monitoring Of vessel. Use proper Cooling. Use alarm.

Deviations from the set values highlighted by some specific guide words. In some cases excess pressure may exist in a line. Firstly, it must be established if there is a realistic cause of this deviation. If there is, the consequences must be considered. They may be trivial or significant. If significant, they must be evaluated to see if they constitute a hazard. In the example of line over-pressure, the excess may be within the line rating. This consequence is trivial. If the rating is exceeded, however, rupture may result. This is obviously a hazardous occurrence. The study procedure may be broken into various steps and as shown in (Table 2). Therefore the scope and selection of team is very necessary to conduct any type of HAZOP study. Finally a detailed record of the study is also necessary; but now we will consider the “Application of the Guidewords” to a particular “Section” or “Study Node”.

Based on the PFD system is divided into 10 specific sections called nodes which are shown in (Fig 1).
According to Metcalf & Eddy (2003), is a flotation operation which has efficiency ranges from 85% to 90% removal of oil and grease [9]. This type of technology is present in all Brazilian’s oil refinery WWTP.

RESULT & DISCUSSION

As per process flow diagram the node starting from American Petroleum Institute(API)separator to Dissolved Oxygen Flotation Unit (DAF) then activated Carbon filter unit as per (Fig 1).The main operational problem were highlighted by HAZOP team was due to deviation in temperature in WTTP due to which water and oil separation becomes critical. Leakages from WWTP also critical parameter identified by team. In case of NRF (Non return Valve) not operated created big hazardous problem may be created fire so it is suggested to install NRF with bypass adjustment.PH should be control within 8-9 in WWTP plant if not maintain organic and suspended solid increased. Level control within range to avoid another hazard. The whole system not pressurized from initial step to final step in case of any mal functioning /human error then heavy leakages from the line. Maintenance of WWTP is highly recommended to avoid any hazardous situation.

Even though HAZOP analysis is a well-accepted tool for risk assessment in many industries very little has been published on a theoretical basis for HAZOP studies. HAZOP studies are used to identify hazard and its effects on plant. To identify hazard first the whole system is divided into its essential parts or auxiliary equipment. When process parameter change from the normal operating conditions or the design intent means the deviation from the system occurred. Then it describes the type of deviation, it causes, consequences and recommended actions required. The study relate to the goal of the system while the process represents the means for achieving these goals. Therefore it seems highly significant to develop a HAZOP assistant based upon means-ends modeling combined with whole-parts concepts to grasp the different levels of abstraction when needed. Thus models based on these concepts, such as functional models will form a suitable basis for an HAZOP assistant. The HAZOP assistant developed in this work uses a functional model to combine the system goal structure with the means to achieve these goals [10].

By severe questioning and continuous monitoring of plant possible deviations during the HAZOP study are generated then series of standard ‘‘guidewords’’ applied to the intended design [11]. The results of this procedure present a wide multi-dimensional view of the oil refinery plant safety. This information could directly serve to the examination of the industrial equipment safety, or may be used as a vigorous basis for a subsequent ordinary HAZOP study.

CONCLUSION AND RECOMMENDATIONS

The major concern of the industries of developing countries including Pakistan is to emphasize on the occupational health and safety (OHS), improving worker’s productivity and increasing plant efficiency. Some common difficulties like inadequate work design, non-organized jobs, mismatch between worker skills and job which worker demands, severe environment, poor human and machine system and inappropriate management. These aspects lead to workplace threats, poor workers health, injuries and increase cost. Ergonomics or human factor can minimize or improve worker’s productivity, OHS and satisfaction. Overall performance is affected by these factors either directly or indirectly. It would very difficult for any company to attain its objectives unless it has attained the proper consideration for ergonomics.

The facility should design and monitor properly based on legal requirements, design/engineering codes, industry standards and good engineering practices.

All equipment should be well maintained, appropriate instrument and control system test procedures will be followed. Alarm and shutdown set points will not be set out of range or disconnected to avoid nuisance trips or other problems. Control valve bypasses will not be used unless the control valve is blocked out.

Recommendations include design, operating, or maintenance changes that reduce or eliminate Deviations, Causes and Consequences. Recommendations identified in a hazard analysis are considered to be preliminary in nature. Requests for additional information or study can also be recommended. After each recommendation has been reviewed, the resolution of each recommendation should be recorded in a tracking document such as a spread sheet, and kept on file.

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