68. Recognition of Potential Risk Factors with Suitable Hazard Reduction Measures for Well Control Operation for On and Offshore Oil and Gas Drilling: A Quantitative and Qualitative Risk Assessment Accession

Muhammad Mujtaba Asad[a,b*], Razali Hassan[a], Qadir Mehmood Soomro[b,c], F.Sherwani[d], Muhammad Zubair Hingoro[e]

[a]*Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, Batu Pahat 86400, Malaysia*
[b]*OSHTC, Occupatioanl Safety and Health Training & Consultancy, Hyderabad 71000, Pakistan*
[c]*Faculty of Enviromental Sciences,University of Sindh, Jamshoro 76080, Pakistan*
[d]*Faculty of Electrical and Electronics Engineering,Universiti Tun Hussein Onn Malaysia, Batu Pahat 86400,Malaysia*
[e]*Institute of Petroleum and Natural Gas Engineering, Mehran University of Engineering and Technology, Jamshoro 76080, Pakistan*
**E-mail address: mujtabaasad11@gmail.com*

Abstract

Over the last decade hundreds of people have been died and thousands have been injured due to insufficient management of well control at oil and gas drilling and production activities. Major causes which have been reported in previous studies include huge blowout and failure of blowout preventers (BOPs). These on and offshore blowout disasters not only harm the work force also critically affect the environment and marine life. In this paper, a detailed survey and qualitative risk assessment (RA) has been carried out for assessing the potentially hazardous activities associated with well control along with their appropriate controls and risk reduction factors and measures in Middle East and south East Asian countries. What- If analysis approach has been adopted in this study, because it provides in-depth information from health and safety environment experts. Suitable hazard controlling measures have been also recognized based on engineering, administrative and personal protective equipment control (PPEC).The overall, quantitative results based on the response from Saudi Arabian well control crew is highly hazardous then Malaysian and Pakistani industries. Likewise, findings from what if analysis approach demonstrate that the drilling crew members have repetitively faced life threatening hazards which have (safety and chemical) during well control on and offshore operation due to oil base mud, confined space at site, pinch points and falling during working on blow out preventers. According to the overall result, respondents have highly recommended engineering and administrative hazard controlling measures as most suitable for the elimination of safety and chemical hazards during well control drilling and oil and gas production activities.

Keywords:
Risk Assessment Practices, Well Control Operation, Hierarchy of Control, Oil and Gas, Qualitative Analysis, What-If Analysis.

1. Introduction

Well control operation during oil and gas well drilling activity is considered as most important task which starts from actual petrochemical extraction and end on production phase [1]. Every year numerous accidents and causalities have been reported at on and offshore drilling sites due to large number of oil spills or uncontrollable pressure from hydrocarbons [2]. In year 2010, eleven (11) peoples have been died and several injured during offshore blowout in the Gulf of Mexico [3]. The most common incidents which have been reported are due to improper and insufficient safety measures which lead to huge and uncontrollable disasters [4]. From year 2010-2015 more than 50 blowout and fire explosion accidents has been reported due to improper well control operation [5].

Most of the drilling crew members have been reported with critical burns and bone fractures due to fire and falling from blowout preventers during maintenance [6]. Accordingly, successful well control operation is only possible by competent and well experienced well controlling crew and adopting effective hazard elimination factors and controls [7]. Thus, this paper discusses about the hazardous activities and their associated hazards with their most appropriate controls and measures for accident prevention during on and offshore well control operation.

2. Problem Statement

Oil and gas drilling operation is highly correlated with health and safety risks due to improper handling and safety precautions and measures [8]. Most of the major hazardous incidents in past five years from 2010-2015 have been occurred due to insufficient and well control operation which had caused large number of casualties and property damage [9]. In year 2005, 27 peoples were died and seven reported as missing during fire explosion due to blowout and leakage of hydrocarbons at skikda offshore plant [10]. Whereas, numerous offshore disaster have been reported due to large amount of deep water of oil spills [11]. While, faulty blowout preventers and negligence of safety measures during maintenance of blowout preventers cause explosion at offshore sites [11].

Therefore, there is sheer need of implementation and safety protocols and standards at on and offshore well control activities [12]. Also, effective hazards identification and assessments can help to reduce potential hazards at on and offshore drilling sites [12]. Thus, this paper focus to recognize hazardous activities and potential hazards at on and offshore well control operation with their appropriate hazard controlling measures by adopting what-if analysis approach.

3. Research Objectives

The Main objectives of this study are listed below:

1. To asses the hazardouness of well control activities at on and offshore drilling operation among Malaysian, Saudi Arabian and Pakistani oil and gas industries.

2. To identify the potential hazards associated with hazardous well control activities at Malaysian, Saudi Arabian and Pakistani oil and gas industries.

4. Research Question

Two research questions have been designed to achieve the answers of proposed objectives are:

1. What are the most hazardous nature of well control activities among on and offshore oil and gas industries in Malaysia, Saudi Arabia and Pakistan?

2. What are the potential hazards associated with well control activities among on and offshore oil and gas industries in Malaysia, Saudi Arabia and Pakistan?

5. Methodology

In this paper, explanatory research approach has been adopted to achieve proposed research objectives and questions. Eighty (80) drilling crew members have been randomly selected from Malaysian (PETRONAS), Saudi Arabian (Saudi Aramco) and Pakistani (OGDCL) oil and gas industries for qualitative research (Survey Instrument) as shown in table 1. While for qualitative research (Semi Structure interview) three health and safety professionals has been selected based on their working experience in oil and gas drilling operation. For analysing quantitative data, descriptive statistic methods such as mean and standard deviation have been utilized through SPSS 22.Whereas, What-If assessment and thematic analysis approach has been used for analysing quantitative findings.

Table 1. Respondents of Study

Country	Industry	No of Respondent	
		Quantitative	Qualitative
Malaysia	PETRONAS	80	03
Saudi Arabia	Saudi Aramco	80	03
Pakistan	OGDCL	80	03
Total		240	09

6. Quantitative Findings and Analysis

To answer of first research question, a table of specifications is adapted from Landlell 1997 as guide to measure the appropriateness level of mean range of hazardous activity during well control operation at on and offshore oil and industries in Malaysia, Saudi Arabia and Pakistan as shown in table 2 [13].

Table 2. Appropriate Level

Category	Mean Range	Level
1	1.00-2.33	Low
2	2.34-.3.67	Moderate
3	3.68-5.00	High

As per table 3, Malaysian oil and gas industries based on questionnaire survey response from respondents its shows that testing of blowout preventer activity has considered most hazardous during onshore with mean score 3.27.Whereas, installation of blowout preventer activity has reported more risky at offshore well control operation which is lying under moderate range of hazardousness with mean 3.45.

Table 3. Response on Well Control Operation at Malaysia

Activities	Onshore	Offshore
Monitoring Mud System	Mean=3.22 SD=0.659	Mean=3.35 SD=0.662
Installation of BOPs	Mean=3.25 SD=0.669	Mean=3.45 SD=0.503
Testing of BOPs	Mean=3.47 SD=0.598	Mean=3.37 SD=0.585
Total	**3.31**	**3.39**

Respondents from Pakistani oil and industry considered that monitoring and maintaining mud system is most hazardous and major cause of injuries at onshore with moderate level of mean score, 3.57 as indicated in table 4. As per the response from offshore operation during installation of blowout preventers and choke manifold mostly hazards has been reported, during this activity as per mean score which is 3.52 and lying under moderate level of mean score range.

Table 4. Response on Well Control Operation at Pakistani

Activities	Onshore	Offshore
Monitoring Mud System	Mean=3.57 SD=0.500	Mean=3.42 SD=0.675
Installation of BOPs	Mean=3.40 SD=0.708	Mean=3.52 SD=0.598
Testing of BOPs	Mean=3.55 SD=0.597	Mean=3.45 SD=0.677
Total	**3.50**	**3.46**

In the context of Saudi Arabian oil and gas industry based on quantitative response from respondents as shown in table 5, its indicates that the more hazard and risk are involved during installation of blowout

preventers and during maintenance of surface control system as per quantitative response from drilling crew and safety officers at Pakistani oil and gas industry with mean score 3.70 and 3.72, both of them are under high level of mean range. Whereas, for offshore well control operation most of the hazards and risks are involved during monitoring and maintaining mud system with moderate level of mean score, 3.57.

Table 5. Response on Well Control Operation at Saudi Arabian

Activities	Onshore	Offshore
Monitoring Mud System	Mean=3.62 SD=0.627	Mean=3.57 SD=0.594
Installation of BOPs	Mean=3.70 SD=0.563	Mean=3.55 SD=0.552
Testing of BOPs	Mean=3.55 SD=0.597	Mean=3.47 SD=0.640
Total	**3.62**	**3.53**

7. Qualitative Findings and Analysis

For the qualitative data analysis thematic analysis with what if analysis risk assessment approach has been adapted for semi structure interviews. In this study every respondent have been assigned confidential code number for recognizing the industry and country based on designation during data analysis and interpretation, as shown in table 6.

Table 6. Respondent of Study

S.NO	Malaysia	Saudi Arabia	Pakistan
1	MY01	SA1	PK1
2	MY02	SA2	PK2
3	MY03	SA3	PK3
Total	**03**	**03**	**03**

7.1. Safety Hazards Associated with Monitoring and Maintaining Mud System

In order to find out hazards related with monitoring and maintaining mud system during well control operation, interview participants from MY, SA and PK have indicated that the confined space and limited movement on the mud pump unit and mud tank is a major cause of fatalities due to lack of ventilation in confined space or drop and fall hazard if working on limited space. Generally, workplace is sometimes isolated whereby little recognition can cause hazardous incidents in on and offshore. Participant MY2, SA2 and PK in offshore domain has mentioned during interview, that working in confined space is always consider as on high risk during well control operation, therefore complete proper safety system and equipment are essential before performing any activity.

Moreover, overall interview respondents also pointed out chemical hazards due to in contact with oil base mud during monitoring and maintaining mud system. Participant MY3 from Malaysia and PK3 from Pakistan also mentioned about fire hazard due to oil base mud monitoring activity at onshore operation. Although participant PK2 and PK3 from Pakistan and SA2 and SA3 from Saudi Arabia have reported hazards at both on and offshore such as respiratory problems, lungs infections and skin problems due to interaction with oil base mud.

Fig 2.Block Diagram of Hazards Associated with Mud Monitoring Activity

7.2. Hazard Controlling Factors and Measures for Monitoring and Maintaining Mud System

7.2.1. Administrative and Engineering Hazard Control for Confined Space

- **Preventive Maintenance Program and Confined Space Permit: Malaysian Context**

In the perspective of Malaysian oil and gas industry, interview participant MY1 nominated that, by establishing the specific preventive practical training session or program from drilling crew, which will train and guide them regarding monitoring and maintaining mud system in sufficient way for controlling risk and hazards at on and offshore sites. Likewise, participant MY2 in the context of offshore have suggested that, only those crew members are allowed to perform duties and tasks for mud monitoring they have work permit for confined space after full filament of all safety requirements.

- **Ventilation System Installation and Personal Protection: Saudi Arabian Context**

As drilling health and safety expert SA2 from Saudi Arabia specified that, the setting up of air ventilation and purification system at well control area can overcome the hazards due to lack of oxygen and shortness of breathing at offshore well control site. While, participant SA3 have pointed out for on and offshore well control monitoring, that workers should enter in confined space only if ventilation system is provided and they have wear respiratory protective mask to protect themselves from toxic gases and hydrocarbon near mud system.

- **Installation of Exhaust Ventilation and Visual/Audible Alarms: Pakistani Context**

Participant PK2 has recommended the installation of exhaust ventilation for confined space to avoid any misshape due to shortage of oxygen in that congested area of well control at both shores. He also suggested that, to install visual warning because if there is a nose of mud circulating system or other equipment then visual alarm will notify the crew for caution. Similarly, audible indications in different languages should install, because most of the time workers neglected to read any information which is displayed, therefore audio alarms are more suitable for this scenario.

7.2.2. Engineering and Personal Protective Equipment (PPE) Hazard Control for Oil Base Mud

- **Utilize Water Base Mud and Protection Shields: Malaysian Context**

According to the participant MY2 have specified personal protective equipment hazard control, by wearing face and eyes protection shields during using and interacting with oil base mud to avoid oil base mud splashes which can cause severe eye irritation and skin problems on long term bases. While, interview participant MY3 suggested engineering by utilizing water base mud instead of oil base for the elimination of fire related hazards at offshore domain.

- **Eyes and Hands Protection: Saudi Arabian Context**

For shunning the risk of physical injuries and burns, participant SA1 have highly recommended safety goggles for eyes protection from oil base mud splashes and protective hand gloves to overcome skin problems and rashes due to in contact with mud during on and offshore mud monitoring activity.

- **Respiratory Mask and Installation of Fire Fighting System: Pakistani Context**

Health and safety experts PK1 from Pakistani oil and gas industry have suggested of weaning respiratory mask or to reduce breathing and lungs problems due to inhalation of mud dust as suitable hazard control. Whereas, interview participant PK3, suggested engineering control for on and offshore, by installing fire fighting system near oil base mud champers for the eradication of fire and explosion hazards due to toxic oil bas mud.

7.3. Safety Hazards associated with Installation of Blowout Preventers (BOPs)

During installation of blowout preventers (BOPs) fall hazard is considered as one of the source for injuries according to the mutual perspective of participants from Malaysia, Saudi Arabia and Pakistan. Two participants MY1 and MY2 from Malaysian industry and PK1 from Pakistan have indicated the fall hazard during installation of BOPs at onshore, although participant SA1 from Saudi Arabia notified fall hazard during installation and working on upper and lower units of BOPs which cause skull injuries and bone fractures.

Secondly, pinch point hazard which leads to hand and fingers when tighten the nuts of BOPs units during installation at both domains of drilling operation is also indicated by most of interview respondents. Participant MY3, SA1 and PK1 mentioned about injures during onshore operation during tightening nuts of blowout preventers units as shown in table, but on other side participant PK1 specified about pinch point hazard at offshore and it's also happen during maintenance of BOPs.

Fig 3.Block Diagram of Hazards Associated with Installation of BOPs

7.4. Hazard Controlling Factors and Measures for Installation of Blowout Preventers (BOPs)

7.4.1. Engineering, Administrative and PPE Hazard Control for Falling from BOPs

- **Use Lifters during Installation of BOPs and Wear Safety Harness: Malaysian Context**

Interview participant MY1 from Malaysian oil and gas industry have nominated, by utilization of lifting crane or any lifting equipment during installation of upper accessories of blowout prevent (BOP) at on and offshore well control activity to avoid falling person and object hazards. Similarly, participant MY2 has advised to attire safety harness prior to performing onshore BOP installation activity.

- **Utilize Work Positioning System: Saudi Arabian Context**

To overcome the falling hazards at on and offshore BOP installation activity, participant SA1 from Saudi Arabia recommended by utilization the work positioning system which is designed to support and hold a worker in the event of a fall and have potential to carry maximum weight of human body.

- **Conduct BOPs Fall Hazard Risk Assessment: Pakistani Context**

As participant PK3 from Pakistani on and offshore oil and gas industry have advised and suggested to always conduct fall person and object hazard risk assessment specifically for blowout preventers (BOPs) installation task to identify the most potential hazards.

7.4.2. Administrative and PPE Hazard Control for Pinch Point

- **Ensure Workers use all necessary PPE: Malaysian Context**

In the context of Malaysian on and offshore oil and gas industry, participant MY3 have considered that workers should wear required protective equipment's such as body harness, high performance gloves and foot wear before starting designated task of nut tightening and heavy load lifting, to control risk and hazards due to pinch point in BOP installation activity in well control operation.

- **Tool Box Meeting for Lifting Accessories: Saudi Arabian Context**

Administrative hazard control is the most suitable control for controlling pinch point hazards during on and offshore sites as recommended by participant SA3 from Saudi Arabian oil and gas industry. Interview participant SA3, have suggested to conduct tool box meetings for load lifting tasks in which all the experts should discuss issues related to pinch point related hazards, which not only injured the figures also effect on the spinal code during load lifting.

- **Use Appropriate Equipment and Tools: Pakistani Context**

According to the drilling health and safety expert PK3 from Pakistan, have recognized that, through utilizing of accurate and specified equipment tool which is design for connecting and tightening the parts during blowout preventer accessories installation. This information can be accrued by referring to the blowout manufacturer log book or technical and engineering personnel's on drilling rig or platform.

7.5. Safety Hazards Associated with Testing BOPs

In this study, participants from targeted on and offshore oil and gas industries highlighted hose burst hazards during testing blow out preventers and chock manifolds and have potential to critical injured or even cause death. While attempting to clear the blockage the hose burst just near the cyclone inlet. The force of the burst hose resulted in the cyclone moving very rapidly, breaking the retaining rope and striking the driller with considerable force. According Participants PK1 from Pakistan reported theses hazards during onshore sites and Participant SA2 experienced hose burst hazards during offshore well control operation. Further, interview participants from onshore and offshore MY, SA and PK oil and gas industries has revealed that the lack of competent person is one of the cause of accidents at on and offshore drilling sites. Participant PK3 pointed out that many accidents due to loose of well controls are due to lack for proper and incompetent supervision has been recorded and resulting everyone has to suffer due to this issue. Similarly participant SA1 from Saudi Arabia and MY3 from Malaysia are also agreed that, well control even all operations are highly successful when there is technically efficient and knowledgeable management work together
with drilling workforce.

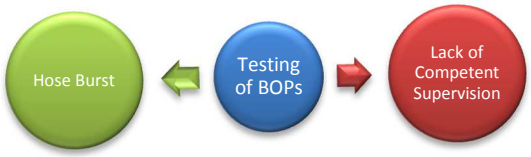

Fig 3.Block Diagram of Hazards Associated with Testing Blowout Preventers

7.6. Hazard Controlling Factors and Measures for Testing Blowout Preventers (BOPs)

7.6.1. Administrative Control for Hose Burst

- **Well Control Exercise and Regular Maintenance: Malaysian Context**

For controlling the hazards due to burst hose and damage or leak BOPs, participant MY1 have nominated that, by providing well control training exercise through recognized trainer will be effective for eliminating life threatening hazards at onshore and offshore site. Participant MY1 have also

recommended and advised that, through proper and regular maintenance of blowout preventer accessories will also reduce the chances of hose bursting.

- **Danger Zone Declaration: Saudi Arabian Context**

As interview participant SA2 have reported that through indicating or highlighting an area within the 500 meters of the well on the down wind direction as danger zone several hazards can be controlled. Participant further added that, through nominated red zone area workers will be cautioned to enter in that premises which will reduce the unnecessary trafficking of workers at well control location.

- **Pressure Line Clearance: Pakistani Context**

Participant PK2 from Pakistan have suggested to clean up the pressure line after monitoring on the system, if the pressure of the line is exceeded to its normal range, then there should be some chocking or blockage in that line. Drilling expert has recommended doing maintenance with all safety precautions for that particular chock line before blowout happened at both shores.

7.6.2. Administrative Control for Lack of Competent Supervision

- **Qualified and Well Experienced Supervisor: Malaysian Context**

According to the interview respondent MY2 have pointed out, onshore industry should appoint a well-qualified person which have obtained all relevant international certification for well control assessment and management. While participant MY3 have suggested assigning well control task to those personnel they have broad experience of handling and dealing with wild wells and have strong experience profile.

- **Technical and Functional BOPs Knowledge: Saudi Arabian Context**

In the context of Saudi Arabian oil and gas industries, participant SA1 indicated for controlling safety hazards due to lack of supervision or unskilled well controller can be eradicate by hiring those professional they have mechanical and operational knowledge regarding blowout preventers. Otherwise train the current employees for well control management for the elimination of potential risk during testing blowout preventers.

- **Regular Maintenance and Inspection of BOPs: Pakistani Context**

As per interview participant PK3 from Pakistani on and offshore industry recommended and highlighted that, hazards due to human error or mistake can be controlled through management officials or well control safety experts which have IADC/IWCF certification by inspecting the well control operation and also follow-up the routine maintenance of BOPs and its accessories.

8. Conclusion

According to the overall qualitative and quantitative results from targeted countries, it is highlighted that all three well control activities are considered risky and hazardous particularly at on and offshore domain according to the respondents. While, participants from Saudi Arabian on and offshore oil and gas industries consider well control operation as more hazardous operation as compared to other targeted industries, with a total mean range, 3.62 for onshore and 3.53 for offshore site both lying under upper level of moderate mean range, and associated with potential safety and hazard during on and offshore operation. As per the overall results of What-If analysis, respondents of the study have mutually suggested engineering and administrative hazard controlling measures as most appropriate and effective for the reduction of safety and chemical hazards during well control operation at o and offshore drilling domains.

References

[1] Blackley DJ, Retzer KD, Hubler WG, Hill RD, Laney AS. "Injury rates on new and old technology oil and gas rigs operated by the largest United States onshore drilling contractor," *American journal of industrial medicine*, vol 57(10), pp.1188-92 Oct 2016.

[2] Witter RZ, McKenzie L, Stinson KE, Scott K, Newman LS, Adgate J. "The use of health impact assessment for a community undergoing natural gas development," *American journal of public health*, vol 03(6),pp.1002-10,Jun 2013.

[3] Gibson M. Risk Impact Analysis Maximises Safety. "Efficiency & Drilling Cost Effectiveness: Vital in Today's Oil Price Era," *In IADC/SPE Asia Pacific Drilling Technology Conference*, vol 22, Aug 2016.

[4] Esswein EJ, Snawder J, King B, Breitenstein M, Alexander-Scott M, Kiefer M."Evaluation of some potential chemical exposure risks during flow back operations in unconventional oil and gas extraction: preliminary results," *Journal of Occupational and Environmental Hygiene*, vol 11(10), pp.74-84, Oct 2014.

[5] The world's worst offshore oil rig disasters,2014,retrived from: www.offshoretechnology.com

[6] Caldwell B, Hinton J. "Data Drilling: Changing the Way the Oil and Gas Industry Manages Safety and Risk," *In SPE E&P Health, Safety, Security and Environmental Conference-Americas*, Mar 2015.

[7] Arifin K, Mustaffa F, Zakaria SZ, Razman MR, Aiyub K, Jaafar MH."Implementation of the fire safety programme: A case study on the oil and gas industry in Terengganu,," *Journal of Food, Agriculture & Environment.*, vol 12(2),pp 861-6. Apr 2014.

[8] Bamberger M, Oswald RE. "Impacts of gas drilling on human and animal health. New solutions," *Journal of environmental and occupational health policy*, vol 22(1), pp 51-77, May 2012.

[9] Penning, T. M., Breysse, P. N., Gray, K., Howarth, M., & Yan, B. (2014). Environmental health research recommendations from the inter-environmental health sciences core center working group on unconventional natural gas drilling operations. *Environmental Health Perspectives (Online)*,*122*(11), 1155.

[10] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development. *Environmental science & technology*, *48*(15), 8307-8320.

[11] Abimbola, M., Khan, F., & Khakzad, N. (2014). Dynamic safety risk analysis of offshore drilling. *Journal of Loss Prevention in the Process Industries*, *30*, 74-85.

[12] Asad, M. M., Asad, M. M., & Hassan, R. (2015). Development of KBES with hazard controlling factors and measures for contracting health and safety risk in oil and gas drilling process: a conceptual action plan.

[13] Landell K. 1997. "Management by Menu." London:Wiley and Sons Inc.