Research Journal of Applied Sciences, Engineering and Technology 2(8): 710-719, 2010
ISSN: 2040-7467

Submitted date: August 17, 2010 Accepted date: September 22, 2010 Published date: December 10, 2010

Effects of Drilling Fluid Exposure to Oil and Gas Workers Presented with Major Areas of Exposure and Exposure Indicators

E. Broni-Bediako and R. Amorin
Petroleum Engineering Department, University of Mines and Technology, Tarkwa, Ghana

Abstract: Drilling fluid is any fluid which is circulated through a well in order to remove cuttings from a wellbore. They are used broadly in the oil and gas industry, on exploration rigs, and are critical to ensuring a safe and productive oil or gas well. During drilling, a large volume of fluids are circulated through the well and into open, partially enclosed or completely enclosed systems at elevated temperatures. When these drilling fluids are agitated during circulating process there is significant potential for chemical exposure to workers and subsequent health effects. This study seeks to identify major areas of drilling fluid exposure and health hazard associated with the use of drilling fluid. The study also presents some challenges in setting drilling fluid exposure standard which has always not been given the same attention or concern as effects and risk management of drilling fluid. Some exposure indicators are also presented.

Key words: BTEX (Benzene, Toluene, Ethylbenzene, Xylene), dermatitis, drilling fluids

INTRODUCTION

In deciding on the type of drilling fluid system to use in any drilling operations, there must be proper and an extensive planning of the well in order to select the best drilling fluid to drill holes that are usable, safe and of minimal cost. Safety should be the highest priority in the selection of the type of drilling fluid to use during and after drilling. Failure to stress crew safety has resulted in loss of life and burned or permanently crippled individuals (Chukwu, 2008).

Due to the nature of drilling operations in drilling environments, typically in the areas such as mud preparation, breaking out of pipes, addition of pipes to the strings and other related issues, drilling engineers need to conduct comprehensive risk assessments of drilling fluid systems, considering all its associated problems (James *et al*., 2007). This risk assessment includes health aspects, environmental and safety aspects, so as to be able to strike an appropriate balance between them so to minimize the exposure of drilling fluids to drilling operators, environmental effects and other related issues. This study seeks to identify potential areas of drilling fluid exposure, health hazard associated with the use of drilling fluid and some exposure indicators that could be used in place of the yet to be established health exposure standards of drilling fluids.

LITERATURE REVIEW

Drilling fluids and its functions: A drilling fluid, or mud, is any fluid that is used in a drilling operation in which that fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus ASME (2005) and Gardner (2003) as shown in Fig. 1 (HWU, 2009). According to Baker (1995), Darley and Gray (1988), drilling fluid must fulfil many functions in order for a well to be drilled successfully, safely, and economically. The most important functions are:

- Remove drilled cuttings from under the bit.
- Carry those cuttings out of the hole.
- Suspend cuttings in the fluid when circulation is stopped.
- Prevent the bore hole from collapsing or caving in.
- Protect producing formations from damage which could impair production.
- Clean, cool, and lubricate the drill bit etc.

Types of drilling fluid: According to OGP, (2003), and Neff *et al*. (2000), there are two primary types of drilling fluids: Water Based Fluids (WBFs) and Non-Aqueous Drilling Fluids (NADFs) or Non-Acqueous Base Fluid (NABFs).

Water Based Fluids (WBFs): WBFs consist of water mixed with bentonite, clay and barium sulphate (barite) to control mud density and thus, hydrostatic head. Other substances are added to gain the desired drilling properties. These additives include thinners (e.g., lignosulphonate, or anionic polymers), filtration control agents (polymers such as carboxymethyl cellulose or starch) and lubrication agents (e.g., polyglycols) and numerous other compounds for specific functions.

Corresponding Author: E. Broni-Bediako, Petroleum Engineering Department, University of Mines and Technology, Tarkwa, Ghana

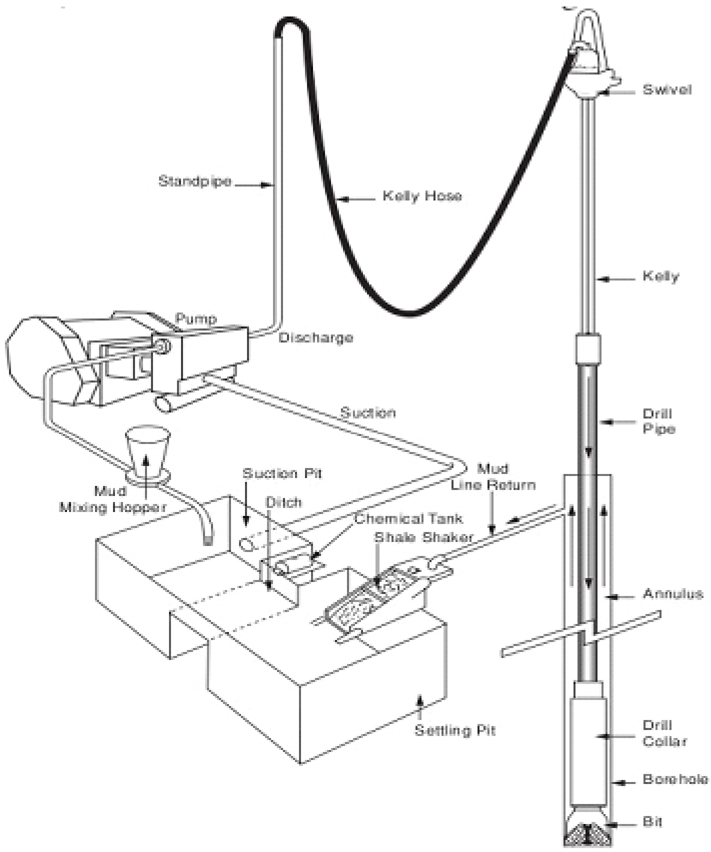


Fig. 1: Circulating system

Non-Aqueous Drilling Fluids (NADFs): NADFs are emulsions where the continuous phase is the Non-Aqueous Base Fluid (NABF) with water and chemicals as the internal phase. The NADFs comprise all non-water and non-water dispersable base fluids. Similar to WBFs, additives are used to control the properties of NADFs. Emulsifiers are used in NADFs to stabilise the water-in oil emulsions. Non-aqueous drilling fluid can further be group into 3 (James *et al*., 2007):

Group I: high-aromatic content fluids. This category includes crude oil, diesel and conventional mineral oils. These fluids are refined from crude oil and contain levels of total aromatics between 5 and 35%.

Group II: medium-aromatic content fluids. This category contains products produced from crude oil with levels of total aromatics between 0.5 and 5% and is often known as 'low toxicity mineral oil'.

Group III: low/negligible-aromatic content fluids. This group includes fluids produced by chemical reactions and highly refined mineral oils which contain levels of total aromatics below 0.5% and polycyclic aromatic hydrocarbon (PAH) levels below 0.001 %, according to the OGP definition.

RESULTS AND DISCUSSION

Field findings:

Workers mostly affected by drilling fluid exposure: Workers mostly affected by drilling exposure include the following:

Derrickman: These people are responsible for mixing and adding chemical to the drilling fluid and also collecting samples. They also monitor pumps and handle pipes tripping activities.

Mud engineer: Mud engineer may periodically check the mud by measuring its viscosity, density, and other properties.

Roughneck: These people make pipe connection during tripping activities from the drill neck, collect cores and cutting samples and also perform the general house-keeping.

Deep sea diver: People who make contact with discarded cuttings on the sea bed during operations.

Laboratory supervisor: Responsible for periodical checks on additives etc.

Motor Man: People responsible for all the motors, generators and general maintenance of equipment at the working area.

Major areas of drilling fluid exposure: Exposures are mostly encountered in a typical drilling environment during drilling operation. The following areas were identified during the study as the major areas of drilling fluid exposure:

- Shale shaker house
- Drilling floor
- Mud pit system
- Sack room
- Laundry services
- Deck operations

Shale shaker house: Workers may be exposed to drilling fluids either by inhaling aerosols and vapours/mist or by skin contact (Fig. 2). Other form of major exposure opportunities identified includes:

- Washing shale shaker with high-pressure guns using a hydrocarbon-based fluid
- Cleaning and changing shale shaker screens
- Checking the shaker screens for wears
- Solid and Liquid separation
- Mechanical agitation of the Shale shaker

Drilling floor: Contact with drilling fluids as well as lubricants, pipe dope, hydraulic oils, etc. by roughnecks and other personnel on the drill floor is predominantly dermal contact. This can be prolonged and repetitive due to the manual nature of the work involved. In most cases contact may be through manual handling of unclean pipes during breaking out of pipes, preparing to break out pipes, handling of tubular, lowering of drill pipe, sprays, and spills from cleaning operations and high pressure washing.

Mud pit system: The mud is monitored throughout the drilling process. A mud engineer and or the Derrickman may periodically check the mud by measuring its viscosity, density, and other properties. The mud engineer can be exposed to burns, or physical injury caused by contact with skin or eyes. Persons in the area are generally needed to perform less complicated tasks but on regular basis with the potential of inhalation hazard and also explosions or violent reactions from chemical mixed improperly (Fig. 3).

Fig. 2: Aerosol and vapour/mist exposure at shale shaker house

Fig. 3: Mud pit system

Fig. 4: Additive mixing at sack room

Sack room: Gardner (2003), reported that although base oils have attracted the most attention, workers are potentially exposed to a range of particulates, especially during powder handling of various additives especially barium sulphate in the sack room. The handling of these various powdered products can cause exposure of mud engineers and other operators in the sack room to both skin contact and inhalation. In practice, the potential problems of exposure and the opportunities for control are much the same as in comparable situations onshore (Fig. 4; Saleem and Ross, 2009).

Laundry: Ineffective cleaning of personal protective equipment may leave residues of drilling fluids on the clothes which may be exposed to the skin. Cauchi (2004) reported that detergent used by the rig laundry service may not be efficient or adapted to remove Oil Base Mud (OBM) or Non-Aqueous Drilling Fluid (NADFs) derivatives from the protective clothing, resulting in chemical accumulation into the clothing fibers.

Health effect associated with drilling fluids contact: The risk of adverse health effects from drilling fluids is determined by the hazardous components of the fluids, additives and by human exposure to those components. Skin irritation and contact dermatitis are the most common health effects observed from drilling fluids exposure in human beings, with headache, nausea, eye irritation, and coughing seen less frequently. The effects are caused by the physico-chemical properties of the drilling fluid as well as the inherent properties of drilling fluid additives, and are dependent on the route of exposure such as dermal, inhalation, oral and others.

Inhalation exposure: Gardner (2003) reported that the potential chemical changes in drilling during use and recycling can result in more toxic substance being released. Since drilling fluids are subjected to elevated temperatures and increased pressures, there has been a concern that organic components might break down, or chemical reactions might occur, to form more toxic substances. There was a particular concern that base oil high in aromatics might contain, or form Polycyclic Aromatic Hydrocarbons (PAHs), while muds (drilling fluids) based on alkyl benzenes might break down to yield free benzene.

OGP and IPIECA (2009) also reported that drilling fluids are often circulated in an open system at elevated temperatures with agitation that can result in a combination of vapours, aerosol and/or dust above the mud pit. In the case of water-based fluids the vapours comprise steam and dissolved additives. In the case of non-aqueous drilling fluids the vapours can consist of the low boiling-point fraction of hydrocarbons (paraffin, olefins, naphthenes and aromatics), and the mist contains droplets of the hydrocarbon fraction used. This hydrocarbon fraction may contain additives, sulphur, mono-aromatics and/or polycyclic aromatics. It should be noted that although the hydrocarbon fraction may contain negligible amounts of known hazardous constituents such as Benzene, toluene, ethylbenzene and xylenes (BTEX) at low boiling point, these will evaporate at relatively higher rates potentially resulting in higher concentrations in the vapour phase than anticipated.

McDougal *et al.* (2000), also reported that petroleum distillates such crude oil, diesel oil (Group I-Non Aqueous Fluids) have been associated with renal, hepatic, neurologic, immunologic, and pulmonary toxicity when they are inhaled or ingested. They are also irritating to the skin and mucus membrane. ATSDR (1999a) reported some health effects associated with inhalation exposure as:

- Neurological effects
- Carcinogenicity
- Haematological effect
- Immunological effect
- Lymphoreticular effects
- Pulmonary effects

Dermal exposure: Most chemicals are readily absorbed through the skin and can cause other health effects and/or contribute to the dose absorbed by inhalation of the chemical from the air. When drilling fluids are circulated in an open system with agitation, there is a high likelihood of dermal exposure resulting in dermatitis and skin irritation. The potential dermal exposure is not limited to the hands and forearms, but extends to all parts of the body. Actual exposure depends on the drilling fluid system and the use of Personal Protection Equipment (PPE). Many studies indicate that absorption of chemicals through the skin can occur without being noticed by the worker. In many cases, skin is a more significant route of exposure than the lung (OSHA, 2009).

Dermatitis and irritation: Skin contact with drilling fluids or mud can also cause inflammation of the skin, referred to as dermatitis. Signs and symptoms of dermatitis can include itching, redness, swelling, blisters, scaling, and other changes in the normal condition of the skin (Fig. 5, Anonymous, 2009). On the drill floor, in particular, skin contamination can be broad, but occasionally dermatitis also occurs in divers who make contact with discarded cuttings on the sea bed (Ormerod *et al.*, 1998).

Petroleum hydrocarbons will remove natural fat from the skin, which results in drying and cracking. These conditions allow compounds to permeate through the skin leading to skin irritation and dermatitis. Some individuals may be especially susceptibility to these effects. Skin

Fig. 5: Dermatitis of the hands

irritation can be petroleum hydrocarbons, specifically with aromatics and C8-C14 paraffins. Petroleum streams containing these compounds, such as kerosene and diesel (gas oil), are clearly irritating to skin. This is suggested to become malignant caused by the paraffins, which do not readily penetrate the skin but are absorbed into the skin, hereby causing irritation (McDougal *et al.*, 2000). Linear alpha olefins and esters commonly used in drilling fluids are only slightly irritating to skin, whereas linear internal olefins are not irritating to skin.

In addition to the irritancy of the drilling fluid hydrocarbon constituents, several drilling fluid additives may have irritants, corrosive or sensitizing properties (Cauchi, 2004). For example calcium chloride has irritant properties and zinc bromide is corrosive whereas a polyamine emulsifier has been associated with sensitizing properties. Although water based fluids are not based on hydrocarbons, the additives in the fluid may still cause irritation or dermatitis. Excessive exposure under conditions of poor personal hygiene may lead to oil acne and folliculitis (OGP and IPIECA, 2009). ATSDR (1997) concluded that it is reasonable to expect that adverse haematological and immunological effects might occur following dermal exposure to benzene.

Oral exposure: Oral exposure negligible as compared to the other exposure routes such dermal, inhalation and others. Oral exposure may occur when hands are not well washed before they are used to handle thing like cigarette.

Data for the oral route of exposure are less extensive. The BTEXs cause neurological effects, generally central nervous system depression, by the oral route. Renal and hepatic effects are also seen with oral exposure to these compounds. Renal effects are the basis for the intermediate. The hepatic effects tend to be mild, including increased liver weight and cytochromes. Benzene causes haematological effects by the oral route that is similar to those seen from inhalation exposure (ATSDR, 1999a).

Hierarchy of principle of control: If hazardous components of drilling fluids are identified at each stage of any drilling operation or areas where drilling fluids are likely to be exposed, together with a risk of exposure then, the following hierarchy of principles of controls should be considered:

- Elimination (not feasible)
- Substitution (low toxic base oils, WBFs)
- Engineering controls(greater enclosure)
- Administrative controls (rotate jobs, hygiene measures, education of Control of Substances Hazardous to Health (COSHH), skin management systems and improved laundry practices)
- Personal protective equipment (chemical resistant slicker suit and gloves)

Challenges in setting drilling fluid exposure standards: The health exposure standard of drilling fluid during oil and gas operations has always not be given the same attention or concern as its effects and risk management guidelines due to the following challenges:

- Drilling fluids are complex mixtures of variable composition
- It unclear about the longer term of health effect
- There is no scientific basis on which to set health exposure limit
- Exposure must be made up of all pertinent fractions such aerosol, vapour, etc., and all variation in composition
- Exposure should reflect the level that can be achieved using good practices

Exposure indicators: In spite of the challenges of setting health exposure standards of drilling fluid exposure to oil and gas workers, Agency for Toxic Substances and Disease Registry (ATSDR) has researched into the BTEXs which are released as a result of drilling fluids during agitation under high pressures and temperature. The study presents these findings by ATSDR as an Exposure Indicator or Lowest Observed Adverse Effect Level (LOAEL) for drilling fluid exposure to operators to help reduce the dangers of abnormal drilling fluids exposure. Appendices A and B showed for exposure indicators.

CONCLUSION

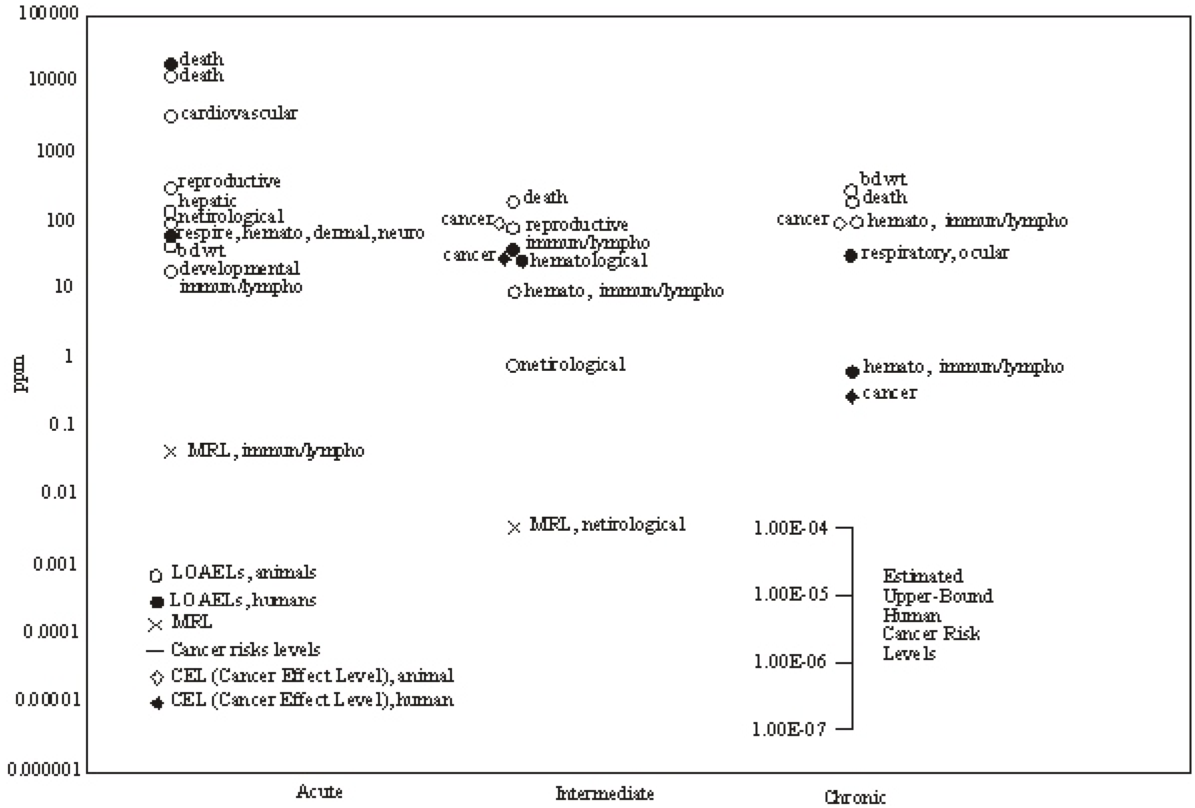
This study revealed the major areas of drilling fluid exposure as setting of pipe at the drill floor, manual handling of sack at the sack room and other related issues as major areas of drilling fluid exposure.

Findings also revealed that, the major health hazard such as dermatitis, body irritation, neurological effects etc., associated with drilling fluids exposure is mainly through inhalation, skin contact and oral exposure.

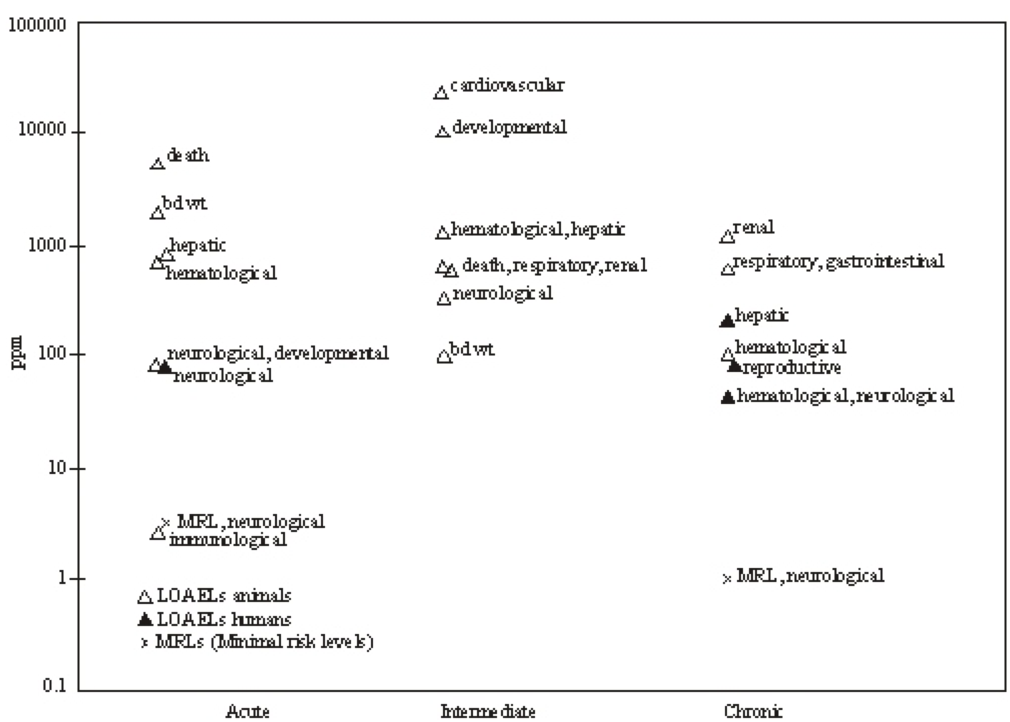
Exposure Indicator or LOAEL could serve as guidelines for oil and gas worker so as to prevent the dangers of abnormal exposure of drilling fluids.

Appendix A

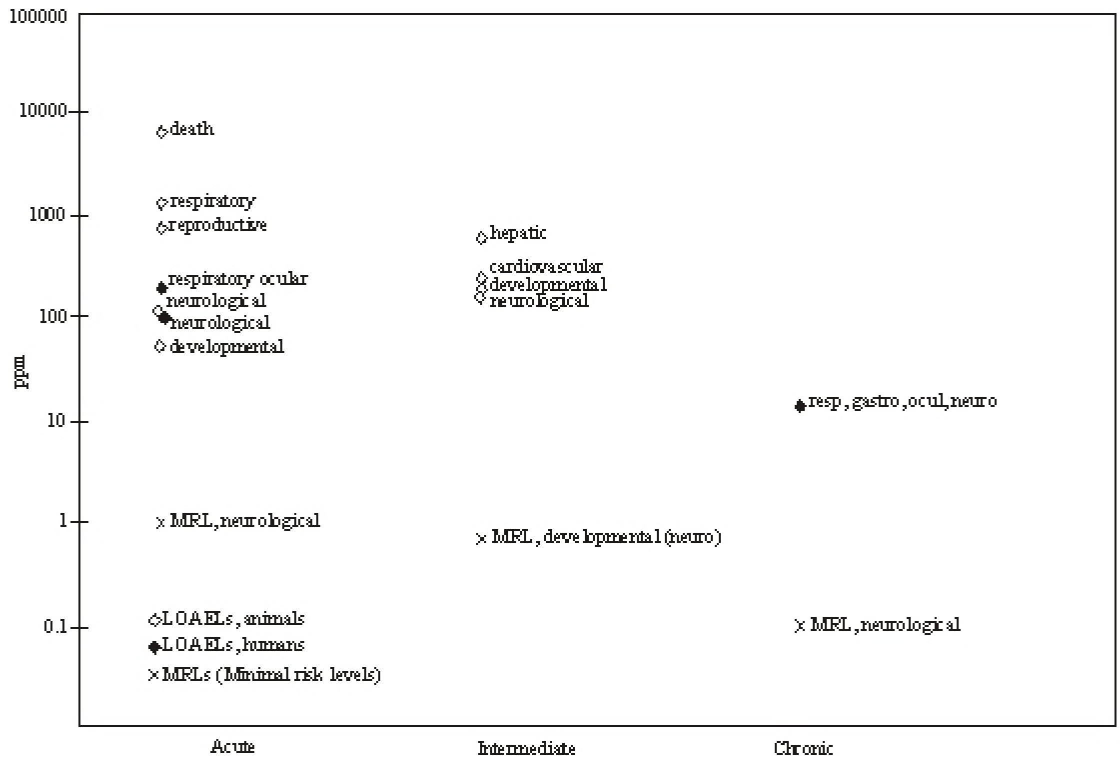
a: Aromatic EC_5-EC_9 exposures associated with health effects-inhalation-benzene, modified after ATSDR (1997)



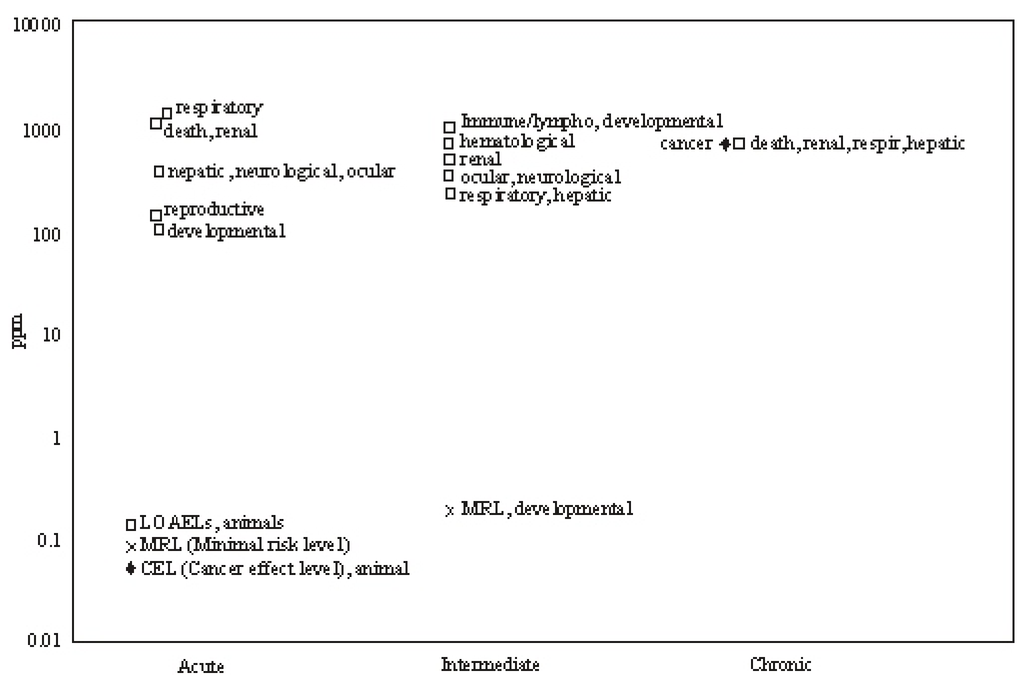
b: Aromatic EC_5-EC_9 exposures associated with health effects-inhalation-toluene, modified after ATSDR (2000)



c: Aromatic EC_5-EC_9 exposures associated with health effects-inhalation-mixed xylenes, modified after ATSDR (1999a)

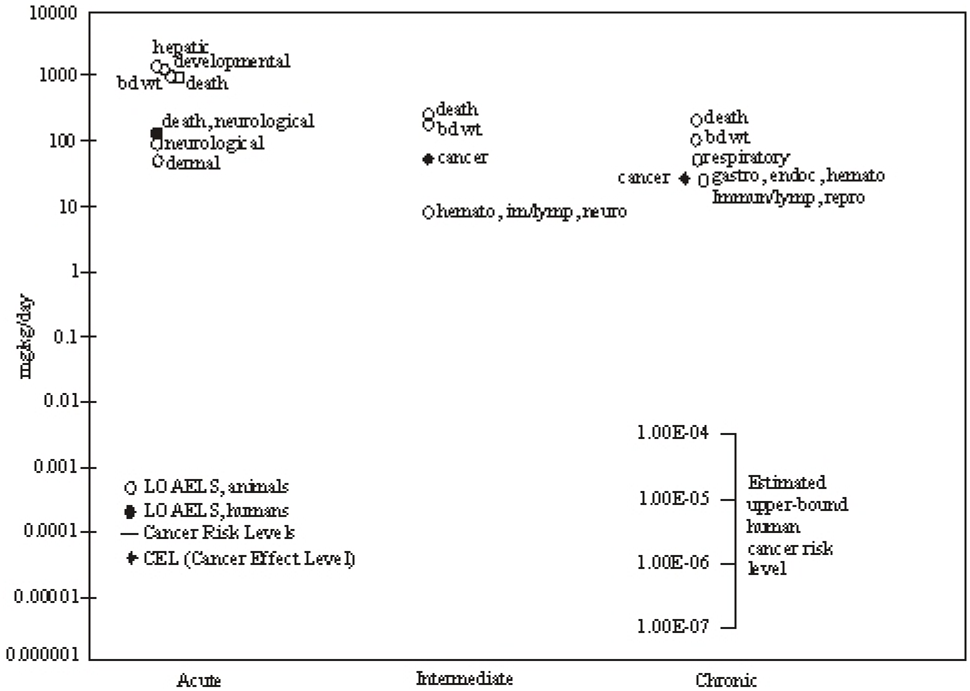


d: Aromatic EC_5-EC_9 exposures associated with health effects-inhalation-ethylbenzene, modified after (ATSDR, 1999b)

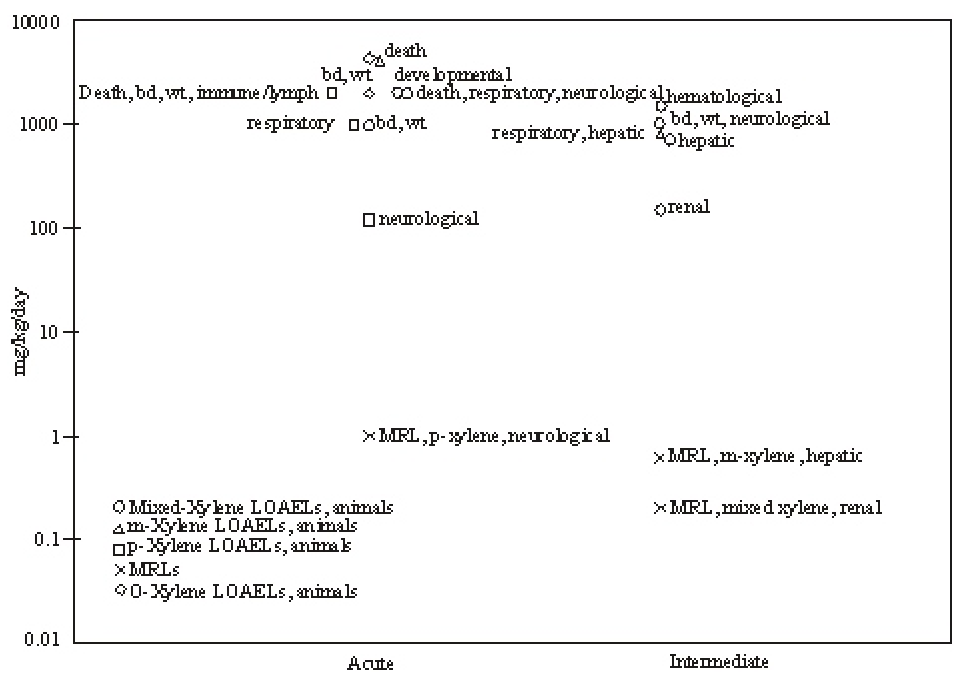


Appendix B

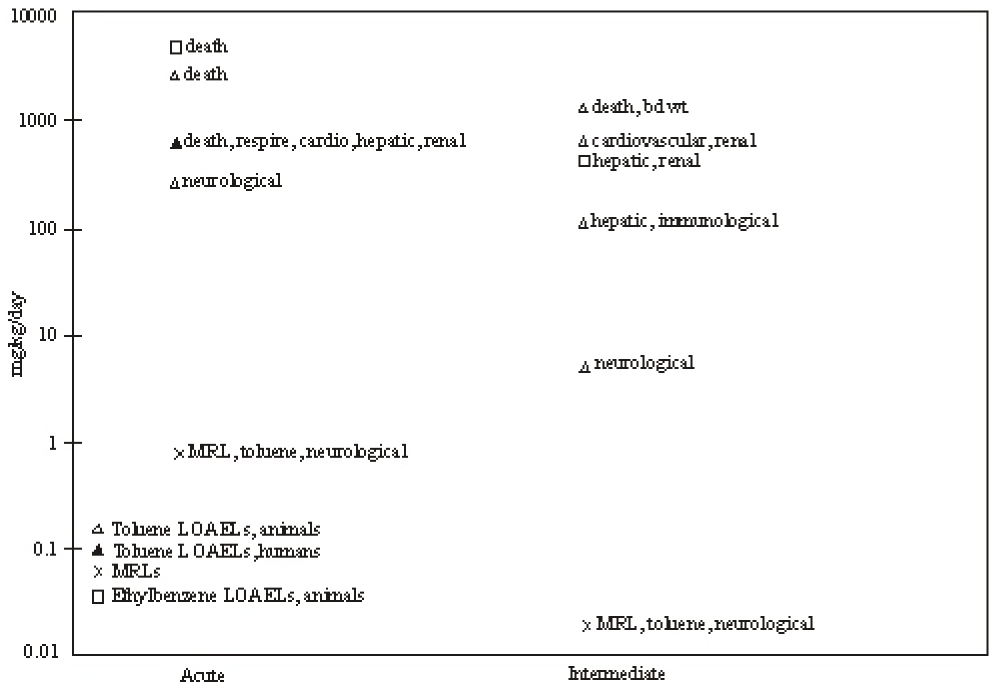
a: Aromatic EC_5-EC_9 exposures associated with health effects-oral-benzene, modified after ATSDR (1997)



b: Aromatic EC_5-EC_9 exposures associated with health effects-oral-xylenes, modified after ATSDR (1999a)



c: Aromatic EC_5-EC_9 exposures associated with health effects-oral –toluene and ethylbenzene, modified after ATSDR (1999a)



REFERENCES

Anonymous, 2009. Retrieved from: http://dermnetnz.org /dermatitis/img/hnd-dermatitis/index.html (Accessed on: August 27).

ASME, 2005. Drilling Fluids Processing Handbook, American Society of Mechanical Engineers, Shale Shaker Committee, Gulf Publishing Company, Burlington, USA, pp: 15-26.

ATSDR, 1999a. Toxicological Profile for Total Petroleum Hydrocarbons (TPH), Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA., 4: 102-114.

ATSDR, 1997. Toxicological Profile for Benzene, Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA., pp: 11-262.

ATSDR, 1999b. Toxicological Profile for Ethylbenzene, Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA., pp: 31-96.

ATSDR, 2000. Toxicological Profile for Toluene, Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA., pp: 11-168.

Baker, H., 1995. Drilling Engineering Workbook, A Distributed Learning Course, pp: 1-11.

Cauchi, G., 2004. Skin rashes with oil-base mud derivatives', safety, and environment in oil and gas exploration and production, calgary. SPE International Conference on Health, SPE 86865, pp: 1-2.

Chukwu, G.A., 2008. Drilling and Well Completion, Lecture Material, University of Alaska Fairbanks, USA (Unpublished), pp: 9-10.

Darley, H.C.H. and G.R. Gray, 1988. Composition and Properties of Drilling and Completion Fluids. 5th Edn., Gulf Publishing Company, Houston TX, pp: 1-10.

Gardner, R., 2003.Overview and characteristics of some occupational exposures and health risks on offshore oil and gas installations. Ann. Occup. Hyg., 47(3): 201-210.

HWU, 2009. Drilling Engineering, Lecture Material, Institute of Petroleum Engineering- Heriot Watt University, Edinburg, UK (Unpublished), pp: 358-363.

James, R., A. Nistov, C. Smulders, K. Walker, T. Schei, N. LeBlond, M. Sopko and T. Fonneland, 2007. Occupational Exposure Hazards Related to the use of Drilling Fluids Presented with Remedial Risk Management Guidelines, SPE Asia Pacific Health, Safety, Security and Environmental Conference and Exhibition, Bangkok, Thailand, SPE 108514, pp: 1-10.

McDougal, J.N., D.L. Pollard, W. Weisman, C.M. Garrett and T.E. Miller, 2000. Assessment of skin absorption and penetration of JP-8 jet fuel and its components. Toxicol. Sci., 55: 247-255.

Neff, J.M., S. McKelvie and R.C. Ayers, 2000. Environmental impacts of synthetic based drilling fluids. Report prepared for MMS by Robert Ayers and Associates, Inc., U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS, pp: 1-10.

OGP, 2003. Environmental aspects of the use and disposal of non aqueous drilling fluids associated with offshore oil and gas operations. International Association of Oil and Gas Producers (OGP), No. 342.

OGP and IPIECA, 2009. Drilling fluids and health risk management-a guide for drilling personnel, managers and health professionals in the oil and gas industry. International Association of Oil and Gas Producers (OGP), International Petroleum Industry Environmental Conservation Association, No. 342, pp: 396.

Ormerod, A.D., C.M. Dwyer and M.J. Goodfield, 1998. Novel Causes of Contact Dermatitis from Offshore Oil Based Drilling Muds. Contact Dermatitis, pp: 262-263.

OSHA, 2009. Safety and Health Topics, Dermal Exposure, United States Departments of labor, Occupational Safety and Health Administration. Retrieved from: http://www.osha.gov/SLTC/dermalexposure/index.html, (Accessed on: October 28).

Saleem, A. and L. Ross, 2009. Offshore Chemical Essentials. Retrieved from: http://stepchangeinsafety.net/stepchange/News/StreamContentPart.aspx?ID=4031, Power Point Presentation, pp: 1-26. (Accessed on: September 10).