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Mini Review

Occupational Diseases in the Petrochemical Sector and Offshore Upstream Petroleum Industry

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Abstract

In this mini-review occupational diseases (ODs) in the offshore oil and gas industry and the petrochemical sector are discussed. A disappointing number of publications during half a century yields a picture of hearing noise damage,musculoskelatal disorders (MSDs), debated cancers and dermatitis as main ODs. Crucial information about exposures at work places, working history and life styles to establish causal relationships is missing. Little attention is paid to job stress and mental health, addictions and COPD at the work place.

Introduction

Chemicals are used extensively both in industry and in our daily lives. Occupational disease (OD) refers to any disease contracted as a result of exposure to factors arising from work (ILO 2011)-(1). Diagnosis of OD requires establishment of the causal relationship between exposure in a specific working environment or work activity and a specific disease and the disease occurs among exposed persons with a frequency above the average morbidity of the rest of the population. The list of ODs prepared by the International Labour Organization (ILO) has four main groups [1]. ODs caused by exposure to agents arising from work activities (such as chemical, physical and biological agents), ODs by target organ systems occupational cancers and other diseases. Chemical agents account for 41 of the ODs that are caused by exposure to agents from work activities. They are the commonest occupational hazard that can result in OD. In addition, chemical agents are also the main contributor to ODs classified by target organ systems especially respiratory and skin diseases as well as occupational cancers.

Toxicology is the study of poisons and how they affect the body. Toxicity is an inherited property of a chemical that causes bodily injury or disease to a living organism as a result of physiochemical interaction with living tissue. All substances including chemicals are potentially poisons. However, all chemicals can be used safely if exposure is kept below tolerable limits. There are various factors that influence the toxicity and the health effects of a chemical agent. These include its physical state, dose or concentration, route of absorption, duration of exposure and presence of other chemicals. Personal factors also determine the effects of a chemical. These include genetic factors, age, gender, health status, hypersensitivity, personal habits and hygiene and pregnancy and lactation.

Chemicals can also be classified on the base of hazards.The Globally Harmonized System (GHS) divides hazardous chemicals in the workplace into different categories; physical hazards,health hazards and environmental hazards (GHS 2007) [2]. Not surprisingly,noise -induced hearing loss (NIH) represents the most frequent occupational disease (25.3%) in the petrochemical industry followed by the musculoskeletal diseases (MSDs) with 22.9% [3]. Malignant tumors of the pleura and peritoneum follow with a proportional rate of 19%, six times higher than that recorded for the total industrial sectors (3.6%). Disease of the respiratory system are clearly proportionally more frequent (16.5%) compared to data reported from the total industrial sectors (6%) [3]. The management of health hazards in the off-shore upstream petroleum industry has its own specific problems [4]. In this mini-review the specific health problems in both sectors will be discussed.

Noise-induced hearing loss (NIHL)

Hearing loss due to noise exposure in the workplace is a significant health problem with economic consequences. NIHL is the OD most frequently reported by the Norwegian Labour Inspection Authority and the Petroleum Safety Authority. Every year the two authorities receive close to 2000 and 600 new reports of NIHL respectively accounting for 60% of all reported work-related diseases in a working-population of 2.7 million [5,6]. Occupational noise exposures causes between 7 and 21% of the hearing loss among workers in general lowest in industrial countries,where the incidence is going down and highest in the developing countries [6]. It is difficult to distinguish between NIHL and age-related hearing loss at an individual level. Most of the hearing loss is age-related.

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Men lose hearing more than women do. Heridity also plays a role. Socio-economic position, etnicity and other factors such as smoking, high blood pressure, diabetes, vibration and chemical substances may also affect hearing. Impulse noise seems to be more deleterious than continuous noise. Hearing loss is decreasing in industrialized countries due to preventive measures [6].

Morken et al. [7] examined the incidence of NIHL,among offshore workers on the Norwegian continental shelf reported to the Petroleum Safety Authority (PSA) from 1992-2003. The study revealed a significant increase from 1/1000 employed in 1992 to 9/1000 in 2003. The majority of cases were reported among mechanics, surface treatment workers, electricians, process technicians and rough necks, most of them aged 50-59 years [7]. In 2002, Zachariasen et al. [8] stated that there is a problem with high noise exposure in the Norwegian Offshore. Nistov et al. [9] in a later study reported that there is a high noise exposure level a risk of NIHL and a need for preventive measures in this industry. Ross et al. [10] however found that offshore workers exept for divers had a normal hearing and so did Johnson and Gann in a former study [11]. There is a great deal over the noise exposure and the perceived risk of NIHL in the offshore sector. The number of studies is limited but the evidence suggests that offshore workers as a group have a relaively normal hearing. More and larger longitudinal studies are needed.

In addition to noise workers in the petrocemical industry may be exposed to solvents toxic to the inner ear, cochlear and/or vestibular apparatus, temporarily or permanently. Several studies have demonstrated that chemical compounds like metal fumes (lead, mercury, manganese, cobalt and arsenic) asphyxiant gases (carbon monoxide, nitrate or butyl and tetrachloride or carbon) and organic solvents (toluene, xylene, styrene, n-hexane, tetachloroethylene and disulfide or carbon) may cause hearing loss either alone or when interacting with noise [12,13]. However, data are scarce and current available scientific literature does not establish a causal relationship between the occupational activity in the petrochemical sector and hearing loss [14].

Loukzadeh et al. [15] looked in a cross-sectional study at 99 workers in the petrochemical industry with exposure to a mixture of solvents whose noise exposure was lower than 85dB (decibel) and compared them with 100 unexposed contols. The mean hearing treshold at all frequencies among petrochemical workers was normal (below 25dB). They did not observe any significant association between solvent exposure and high-frequency or low-frequency hearing loss [15]. Exposure standards for chemicals and noise have not yet been altered to take account of increased risk to hearing. Until revised standards are established it is recommended that the 8 hour equivalent continious noise level of workers exposed to the above mentioned solvents should be reduced to 80dB or below accordng to a statement of the Government of Australia, Departments of Mines, Industry Regulation and Safety [16]. Hearing loss due to ototoxic chemicals is mostly sensorineural of origin [14,17].

Musculoskeletal disorders (MSDs)

Since 1992, physicians have reported work-related diseases among workers in Norway's offshore petroleum industry to the PSA, as required by law. Morken et al. [18] analysed the number of reported work-related MSDs and risk factors (occupation and reported exposure) from 1992-2003. During the 12 years 3131 new work-related MSDs were reported and this was the category of work-related disease most frequently reported (47%). The number of work-related MSDs varied substantialy from year to year. Disorders of the upper limb accounted for 53% and back disorders for 20% of all work-related MSDs. Lower limb disorders accounted for 16% of which knee disorders dominated (12% of all cases). The dominant occupational categories were maintenance work (40%) and catering (21%). Frequently reported types of exposure were high physical workload, repetitive work and walking on hard surfaces/climbing stairs and ladders, probably contributing to knee disorders.

Jensen and Hedegaard Laursen performed an epidemiological review study in 2014 of injuries in the oil and gas offshore [19]. Only a few papers were found published between Jan 1 2000 or before and 2013 after an extensive search in PubMed, Cochrane, Embase, Google Scholar and Web of Science data bases. Only 2 studies were found that included incidence rates. The first incidence rate study analysed the fatal injuries in the USA oil and gas production, based on data from 1988-1990 and 2003-2004 [20]. The oil and gas extraction employed approximately 380.000 workers on approximately 1300 drilling rigs in 2006. CDC (Centers for Disease Control and Prevention) analysed the data and found an annual fatality rate of 30.5 per 100.000 workers (404 fatalities during 2003-2006) approximately 7 times higher than the rate for all workers (4.0 per 100.000 workers). Nearly half of the fatalities were attributed to high-way motor vehicle crashes or being struck by machinery or equipment [20].

The CDC previously analysed the 1988-1990 incident reports from the international association of drilling contractors, an industry wide international trade association representing 95% of the world's oil and gas companies. The over-all non-fatal incidence rate was 1.2/100 full-time equivalents and the over-all fatal incidence rate was 7.5/100.000 full-time equivalents [21]. A study of non-fatal injuries from Greece covers 6 years from 1997-2003 of 5000 people from which more than 3000 were employees at the production and storage sites [22]. There were 1024 major injuries during the 6 years and the rough estimate is 57 injuries/100.000 workers. According to work -related MSDs only three studies were found.

Offshore workers from a Chinese oil company were invited to complete a self-administered questionnaire providing information on socio-demographic characteristics,occupational stressors,social support,coping style,health related behaviours,past injuries and musculoskeletal pain [23]. The prevalence of musculoskeletal pain over the previous 12 months varied between 7.5% for elbow pain and 32% for low back pain.At least 56% of the workers had one complaint. Significant associations were found between various psychosocial factors and musculoskeletal pain in different body regions after adjusting for potential confounding factors. Occupational stressors in particular stress from safety, physical environment and ergonomics were important predictors of musculoskeletal pain.

The prevalence of MSD was assessed in a cross sectional study in 2000 among employees in the UK oil and gas industry predominantly on offshore installations [24]. Assessed by the Nordic Musculoskeletal Questionnaire (n=321), 80% of the sample reported that they had experienced some form of MSD in the past 12 months; 37% reported that they experienced one or more problems over the past seven days. Low back pain was the most frequently reported (51%) and 17% of them in the last week. The prevalence rate of neck, shoulders and upper back MSD was also 17%. Mental health, workload, physical environment stressors and body mass index predicted MSD with a different relative importance across different body areas.

A Norwegian review of epidemiological studies on health conditions among offshore petroleum workers include a few publications but none with data illustrating incidences or prevalence rates after 2000 [24-27]. The authors expressed a doubt whether the prevalence of MSD differs from that among onshore workers. They propose that the main risk factors are physical stressors and a fast pace of work.

The work-related diseases from Norway's offshore petroleum industry notified by the physicians to the PSA were analysed [28]. For the period from 1992-2003 there were 6725 cases of work-related diseases out of which 3131 were MSDs (47%). The other large groups were hearing loss (25%) and skin diseases (15%). Among the MSDs upper limb disorders accounted for 53%, back disorders for 20% and lower limb disorders for 16% of which knee disorders dominated (12% of all cases). The authors of the Norwegian review of MSDs expressed doubt like the British study authors whether the prevalence of MSDs differs from that of onshore workers [24,28].

Cancers

Offshore production of crude oil and natural gas developed in the North Sea from the late1960's onwards. In Norway, cancer incidence has been reported from 2 cohorts of offshore workers both of about 28.000 workers. Stenehjem et al. [29] merged these 2 cohorts to one in order to update the analysis of cancer incidence in a largerand more complete sample of Norwegian offshore workers with a follow up extended to 2009. In this large group of offshore workers they found an overall cancer incidence in line with expected numbers for men and a slightly elevated incidence (17% in excess of expected) for women. There was an excess risk of pleural cancer in male workers and an excess of AML (acute myeloid leukemia) in women which was a novel finding. There was no sign of any overall excess of lymphohaematopietic cancers in men. There was a doubled risk of malignant melanoma and a 69% increase of lung cancer in women, while in male workers a 25% increase of bladder cancer was observed [29]. Lack of information on exposure work history and life style factors hampers the identification of possible causal factors.

All 21 pleural cancers were mesotheliomas and asbestos exposure the most likely explanation may have taken place when asbestos was used offshore as a drilling mud additive (until 1980) and in derrick brake bands (until 1991). However a similar increased risk was found in workers employed after 1985, suggesting that exposure outside the offshore may have played a part at least for the seven cases in the latter group. Excess mortality and incidence from pleural cancer have been reported in UK and Australian petroleum workers, both ascribed largely to asbestos exposure in oil refineries [30,31]. In women a significant increased risk of AML was found but based on 5 cases only. Further clarification of the possible role of offshore work in cancer etiology requires information on exposure and potential confounders [29].

However, Stanehjem et al. [32] found an increased risk for AML, MM (multiple myeloma) and suggestively for CLL (chronic lymphocytic leukemia) between cumulative and intensity metrics of low level benzene exposure in a cohort subanalysis of 25.000 Norwegian men working offshore beween 1965 and 1999. These findings are generally in line with other studies conducted in petroleum workers. Kirkeleit et al. [33] reported a three-fold increased risk of AML in Norwegian upstream operators employed before 1985. An Australian study reported a seven-fold increased risk of CML among petroleum workers exposed to >8p.p.m./years [34]. Further, a study in UK petroleum marketing and distribution workers reported increased risks of AML or monocytic leukemia in relation to cumulative, duration and intensity metrics of benzene [35].

A pooled analysis of Canadian, Australian and UK data, comprising a total of 60 AML cases showed an elevated risk of AML according to cumulative, intensitivity, duration and peak metrics of benzene exposure [36,37]. A study of leukemia risk in relation to gasoline Spill in Pennsylvania, USA, suggested a dose-response relationship between atmospheric benzene levels <1p.p.m. and AML [38]. Moreover, recent studies have detected genotoxic effects and altered gene expression linked to leukemia among workers exposed to low levels of benzene (i.e. <1p.p.m.), which supports a biological plausability for a dose-response relation between average benzene levels [39-41]. Although benzene exposure during ordinary and high activity seems to be low in the processing area on a production vessel, cleaning of tanks and performing maintainance work in a cleaned tank have a potential for high exposure [42]. Other studies also observed an elevated risk of CLL in relation to benzene exposure [34,35,43].

There is an increased risk of multiple myeloma for all exposure metrics with a statistically trend test for cumulative exposure [32]. These findings are in accordance with those published by Kirkeleit et al. [33] of increased risk of MM in upstream operators employed offshore before 1985 and with similar findings of two meta-analyses [33,44,45]. In their most recent evaluation of benzene as a carcinogen the IARC (International Agency for Research on Cancer, WHO, Lyon, France) pointed out that NHL (Non-Hodgkin Lymfoma) is a heterogenous group of histological subtypes and that a few cohort studies have reported benzene-related risks of NHL [46]. Measurements of benzene exposure are mainly conducted since the year 2000 [47,48].

Dermatitis

Skin contact with drilling fluids or mud can cause inflammation of the skin referred to as dermatitis. Signs and symptoms of dermatitis include itching, redness, swelling, blisters, scaling and other changes in the normal condition of the skin. 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 [49]. 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 individual may be especially susceptible to these effects. Skin irritation can be petroleum hydrocarbons, specifcally with aromatics and C8-C14 paraffins. Petroleum streams containing these compounds such as kerosene and diesel (gas oil) are clearly irritating to the skin. This is suggested to become malignant caused by the paraffins which do not readily penetrate the skin but are absorbed in the skin hereby causing irritation [50]. Linear alpha olefins and esters commonly used in drilling fliuds are only slightly irritating to the skin whereas linear internal olefins are not irritating to the skin.

In addition to the irritancy of the drilling fluid hydrocarbon constituents several drilling fluid additives may have irritants, corrosive or sensitizing properties [51]. 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 additive in the fluid may still cause irritation or dermatitis. Excessive exposure under conditions of poor personal hygiene may lead to oil acne and folliculitis [52]. ASTDR concluded that it is reasonable to expect that adverse haematlogical and immunological effects might occur following dermal exposure to benzene [53]. The use of PPE (personal protection equipment) and barrier creams might reduce the incidence of contact dermatitis. However, the use of barrier creams requires careful monitoring since in some cases, they were regarded as a form of PPE [28].

Inhalation risks

Although base-oils have attracted the most attention, workers are potentially exposed to a range of particulates esecially during powder handling in the sack room (various additives, especially barium sulphate) and at the shale shaker (aerosols from mud and the strata being drilled). With respect to the sack room few exposure data have been published. Hansen et al. [54] published detailed elemental analysis of airborne dust from 16 static samples from a shale shaker room during drilling using a water based mud. Total airborne dust concentrations at the working area were in the range of 0.05-0.7mg/cubic meter. Barium sulphate was the major component of the mud and not surprisingly the element found in the highest concentration was barium. The concentrations were equivalent to 0.4-0.5mg/cubic meter. Current accepted levels for respirable and total inhalable dust are 4 and 10mg/cubic meter respectively [54]. Studies about the prevalence and incidence of COPD (chronic obstructive pulmonary disease in offshore petroleum workers and workers in the petrochemical sector are not available.

Conclusion

Half a century of occupational medicine in the offshore petroleum industry and the petrochemical sector yielded a disappointing number of scientific publications. With thanks to the Norwegian government instituting a compulsory reporting requirement by law in 1992 some valuable publications are available. A picture is rising of hearing noise, musculoskelatal disorders, dermatitis and debated cancers as the main ODs in these sectors. Attention for job stress and mental health, addictions and COPD have been minimal. Information about exposures at work places, working history and life styles to establish causal relationships is missing. Part of the problem is the historical bad communication between occupational physicians and the curative sector and vice versa, in providing each other information [55]. The inflow of occupational physicians and the esteem is low. Nevertheless, people spend a great deal of their lives at working places and deserve more and better occupational medicine. After half a century more questions are open than being answered.

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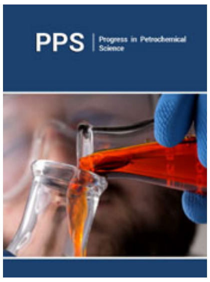

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