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Biological monitoring of benzene exposure during maintenance work in crude oil cargo tanks

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Abstract

We investigated the association between the individual concentrations of benzene in the breathing zone and the concentrations of benzene in the blood and urine among workers maintaining crude oil cargo tanks. Benzene exposure was measured during three consecutive 12 h work days among 13 tank workers and 9 unexposed referents (catering section). Blood and urine samples were collected pre-shift on the first day, post-shift on the third day, and pre-next shift on the following morning. The workers used half-mask air-purifying respirators, but not all workers used these systematically. The individual geometric mean benzene exposure in the breathing zone of tank workers over 3 days was 0.15 ppm (range 0.01–0.62 ppm). The tank workers' post-shift geometric mean benzene concentrations were 12.3 nmol/l in blood and 27.0 nmol/l in urine versus 0.7 nmol/l for both blood and urine among the referents. Benzene in the work atmosphere was highly correlated with the internal concentration of benzene both in post-shift blood ($r = 0.87$, $P < 0.001$) and post-shift urine ($r = 0.90$, $P < 0.001$), indicating that the varying use of respirators did not explain much of the variability in absorbed benzene. The results showed that, despite low benzene exposure in this work atmosphere and the use of personal protective equipment to a varying degree, the tank workers had a significant uptake of benzene that correlated highly with benzene exposure. The internal concentration of benzene was higher than expected considering the measured individual benzene exposure, probably due to an extended work schedule of 12 h and physical strain during tank work. Control measures should be improved for processes, which impose a potential for increased absorption of benzene upon the workers.

Keywords: Benzene; Crude oil; Biological monitoring; Tank work; Extended work shift

1. Introduction

Benzene, a known carcinogenic [1,2] and hematotoxic agent [3], is a natural component of crude oil. Thus, benzene exposure is a potential hazard in the petroleum industry. During ordinary operation, most of the processes on an oil production facility are confined in closed systems, and the overall exposure to benzene is low [4,5]. However, whenever the processing system is opened there might be potential for high benzene exposure. In a previous study [5], we reported that cleaning and maintaining tanks containing residues of crude oil is associated with individual benzene exposure ranging from 0.004 to 16.8 ppm, with a geometric mean of 0.28 ppm. Similar concentrations of individual benzene

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exposure have been reported during cleaning [6] and gauging the content [7] of crude oil vessels.

During occupational exposure to benzene, the most important route of uptake is inhalation. Reports [8–10] indicate that humans absorb 30–52% of the inhaled benzene, depending on the benzene concentration, length of exposure and pulmonary ventilation. Traces of unmetabolized benzene, reported to be about 0.1% of absorbed benzene in humans [11], is eliminated unchanged in the urine. Benzene in urine has been recommended as a biomarker of choice at air concentrations below 1 ppm benzene because it is a non-invasive, specific and sensitive method [12–14].

Crude oil production vessels store crude oil in cargo tanks before offloading and transport onshore. Cargo tanks are prone to degradation by corrosion and are periodically emptied for internal inspection of the walls to detect pitting, general corrosion and cracks. If such damage is found, the tank must be repaired to avoid leaks. Tank work offshore has several characteristics that may modify the uptake of benzene both through inhalation and dermal exposure. While most standards for chemical exposure in the work environment assume 8 h work days 5 days a week, Norwegian offshore workers have in general 12 h shifts 7 days a week for 2 weeks with 28 days of leave between the tours. In addition, the physical strain of tank work presumably increases the uptake through all routes and might modify the distribution and biotransformation of hydrocarbons [15–18]. Further, although the use of half-mask air-purifying respirators with a cartridge for organic solvents is mandatory during tank work, their efficiency of protection under high workload is questioned. However, given this potential chemical hazard, benzene has previously not been biologically monitored among offshore tank workers. This might partly be due to logistic constraints, such as the need for helicopter transport, the unpredictability in planning of tasks and the priorities for personnel due to the limited number of beds offshore.

The objective of this study was to investigate the relationship between the individual concentrations of benzene in the breathing zone and the concentrations of unmetabolized benzene in blood and urine both before, at the end of the 12 h work shift and on the following morning among workers maintaining crude oil cargo tanks.

2. Methods

2.1. Study population

The study was performed in July 2004 during inspection of one cargo tank and in April 2005 during repair of two cargo tanks on a crude oil production vessel located on Norway's continental shelf. The maintenance work in the cargo tanks (volume 5000–7800 m^3) included tank inspection, scaffold-building and welding. The study population aimed at including 13 men performing tank work, and 9 referents not expected to be exposed to benzene. Referents were mainly recruited from the catering section on the same vessel. All workers who planned to perform tank work in the given study periods and all catering personnel with a shift schedule matching those of tank workers were invited to participate. No subject declined. Before the study period, the length of stay of the participants on the production vessel varied from 1 to 15 days. In that period they only performed ordinary jobs with minor benzene exposure. In a previous study on the same production vessel we reported an arithmetic and geometric mean benzene exposure of 0.02 and 0.004 ppm, respectively, during ordinary activity [5].

Before the maintenance work started, the tanks were cleaned with hot oil and water and purged with inert gases and fresh air. The tanks were ventilated with fresh air as long as work was in progress. The workers used half-mask air-purifying respirators with a combination filter containing both a particle and an organic gas filter. However, the use of the respirators varied between the workers and the workers replaced the filter with varying frequency. The use of respirators was not systematically recorded. The participants completed a self-administered questionnaire including questions on age, gender and whether they were current smokers during the study period. Smoking was prohibited on the production vessel, but the living quarters had a limited number of designated smoking rooms. Since alcohol consumption is completely banned on offshore oil and gas installations, no participant consumed alcohol during the study period.

Informed written consent was obtained from all participants. All subjects were informed about their own results. The study protocol was approved by the Western Norway Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services. The Ministry of Health and Care Services gave permission to establish a biobank and to transfer the biological material abroad for analysis.

2.2. Monitoring of individual exposure to benzene

The study period for all workers comprised three consecutive work shifts. All tank workers were monitored for individual benzene exposure by using organic vapor passive dosimetry badges (3M 3500®). The badges were