

EXPOSURE AND RISK ASSESSMENT BTEX IN A PETROCHEMICAL DEPOT AT HEIDELBERG, SOUTH AFRICA

Abstract

Background

The International Labour Organization estimated 2.2 million workers are dying yearly from work-related accidents and occupational diseases, whilst about 270 million suffer serious injuries, and 160 million become ill due to their work. It is further estimated that work-related accidents and diseases cause 4% of annual Global Gross Domestic Product or US \$1.25 trillion due to lost working time, workers' compensation, the interruption of production, and medical expenses. In 2005, the ILO estimated that 440 000 people died throughout the world because of exposure to hazardous chemicals.

In 2018 chemicals production was the second largest production sector in the world. Chemicals are indispensable and critical part of life. Their visible positive outcomes are quite palpable. They are well recognized for instance pesticides improve the quality of food production, pharmaceuticals cure illness, cleaning products help to establish hygienic living conditions. Chemicals are key development of final products that make life little easy for human beings, etc. Controlling employees 'exposure to chemicals and preventing or minimizing emissions remains a significant challenge in workplaces throughout the world.

The production, storage, and handling of petrochemical products particularly BTEX emissions are known and associated with potential harm to human and aquatic organisms. Some of the health effects associated with exposure to BTEX are the health effects on hematopoietic system, including pancytopenia. The benzene exposure leads to an acute myelogenous leukemia. The exposure to toluene, ethylbenzene, and xylene have been linked to the damaging the central nervous system and irritation of the respiratory system. Benzene and ethylbenzene are confirmed carcinogens (Benzene is classified as a Group 1 and ethylbenzene is a Group 2 B carcinogens).

Purpose

To characterize, assess exposure and health risk assessment to benzene, toluene, ethylbenzene, and xylene (BTEX) at the petrochemical depot at Heidelberg in Gauteng, South Africa.

Methods

Exposure sampling was done using a MiniRAE 3000 Photoionization detector (PID). The PID (equipment) was calibrated before the commencement of the monitoring program following the manufacturer's operating manual. The PID equipment was used to collect the BTEX samples. The PID was mounted on a marked tripod stand at 1.5 m above ground and approximately 0.2 m to 0.5 m in the microenvironment (Exposure scenario) of the depot workers (Controllers and/or laboratory assistant) with the probe extended or placed within 30cm of the breathing zone of the depot workers.

Sampling was conducted at three different exposure scenarios (workstations) i.e., density huts, laboratory, and during plant equipment cleaning in the plant (strainer removal) over three days period. The sampling started from 08h00 to 17h00. One workstation was sampled per day. The sampling of BTEX per workstation took 30 minutes per hour over ten hours, every hour BTEX was sampled for a duration of 30 minutes and in totality ten samples were collected per 12-hour shift, a total of 30 BTEX samples were collected over the 3 days period. Additionally, the measured BTEX concentrations were used to obtain dose estimates. Data from the equipment was exported to a Microsoft Excel spreadsheet. All outliers were removed from the data and a correction factor was applied to derive the final concentration. Thereafter, statistical tests using student F-test and Test were performed to evaluate for significant differences amongst paired comparisons.

Results

The highest average BTEX concentrations were measured in the laboratory, followed by density huts and the least was measured during the removal of the strainer (plant equipment cleaning). The activity areas (exposure scenarios) served as direct sources for the BTEX vapours. The average benzene concentrations measured in three activity areas ranged from 469 ppm to 542 ppm. The highest benzene concentration was found to be 542 times higher than the current South African Occupational Exposure Limits of 1ppm. The average toluene concentrations measured ranged from 1335 pm to 1542 pm; the highest toluene concentration was found to be more than 30 times above the South African Occupational Exposure Limits of 50 ppm. The average ethylbenzene concentrations measured ranged from 433 ppm to 500 ppm; the highest concentration was found to be 5 times above the South African Occupational Exposure Limits of 100 ppm. The average xylene concentrations measured ranged from 1372

ppm to 1584 ppm, the highest concentration was found to be more than 15 times above the South African Occupational Exposure Limits of 100 ppm. All the measured BTEX compounds were found to be above their respective South African Occupational Exposure Limits.

The cancer risk was determined to be 13×10^{-2} (male) and 10×10^{-2} (female), 14×10^{-2} (male) and 11×10^{-2} (female), 16×10^{-2} (male) and 13×10^{-2} (female), 12×10^{-3} (male) and 10×10^{-3} (female) for the workers in the density huts, laboratory, strain remover (plant equipment cleaning), respectively.

In all exposure scenarios (male and female) the cancer risk was found to be higher than the acceptable risk levels of $1E^{-4}$. There were 13 males and 10 females in the population of 100 controllers who were likely to develop cancer when working density huts environment. In the laboratory work environment, 14 males and 11 females in a population of 100 controllers were likely to develop cancer, whereas 16 males and 13 female laboratory workers were likely to develop cancer in a population of 100 laboratory workers, and during plant equipment cleaning 12 males and 10 female controllers were likely to develop cancer in a population of 1000.

Therefore, the potential of developing cancer was heightened by working in the laboratory and density huts. The risk of the number of employees who were likely to develop cancer was reduced when doing plant equipment cleaning. In all three activity areas, cancer risk for males was higher than for their female counterparts. This finding denotes that male were more vulnerable than females even though the exposure concentration is the same. The higher number of males who were likely to develop cancer in all the activity areas were influenced by two factors i.e., males have a shorter average life expectancy and higher average body weight versus their females' counterparts.

A hazard quotient was used to determine the non-carcinogenic health effects, a hazard quotient of greater than 1 was used as a reference value. A value greater than 1 denoted a higher possibility that depot workers will get health effects from exposure to the Toluene, ethylbenzene, and xylene (TEX). The hazard quotient for males ranged from 4.6 to 577.5, the highest hazard quotient was more than 577 times above the HQ reference value. The lowest was at density huts for xylene and the highest was at the laboratory for a chemist for xylene. The hazard quotient for females ranged from 3.15 to 399.00, the highest hazard quotient was more than 399 times above the HQ reference value. The lowest was at density for xylene and the highest was at the laboratory for laboratory assistant. From the results, both males and

females had a hazard quotient far above 1 which means health effects arising from TEX exposure were anticipated.

Conclusion

The results showed highest constant BTEX concentrations in the three exposure scenarios over the 12 hours shift. The BTEX emissions were generated by activities that were performed by the depot workers. Highest BTEX concentrations were measured at laboratory, followed by density huts and the least was measured during the removal of the strainer (plant equipment cleaning). The lack of effective vapour recovery system and natural ventilation in the laboratory and in density huts also contributed to the high BTEX concentrations measured in these areas. Individual BTEX component results measured in the three activity areas indicated concentrations that were far above the South African Occupational Exposure Limits for individual BTEX. The cancer risk score was found to be far above the reference USEPA cancer risk value and denoting that depot workers were likely to develop cancer. The hazard quotient for the three exposure scenarios was also found to be greater than the reference value of 1 which indicates the potential to develop non-carcinogenic health effects due to exposure in three exposure scenarios.

Recommendations

The following recommendations are made to assist management of the depot to control employees' exposure to BTEX emissions per activity area:

Density huts

The practicality of introducing a vapour recovery system on workbenches to extract the VOCs generated during sample collection and from density measuring jugs should be investigated or alternatively, the introduction of an online fuels and density analysis should be investigated or the practicality of introducing sample bombs to collect fuel samples should be investigated. Keep the windows opened to promote an ingress of fresh air and allow BTEX emissions to escape. A practicality of introducing a controlled mechanical ventilation to blow vapours away from the breathing zone of the depot workers should be investigated.

Laboratory

The practicality of automating or modifying the GC equipment in the laboratory to be able to conduct an online petrochemical analysis to control employees' exposure should be investigated. The tasks that require rinsing of testing tubes with fuels, refilling of the testing tubes, and discarding of superfluous samples should be performed under controlled conditions, the practicality of introducing a vapour recovering system to control vapours emissions should be investigated. The current practice of keeping the decanting drum open should be discontinued to prevent the accumulation of vapours in the laboratory or alternatively, it should be kept under a vapour recovery system. The practicality of keeping the retained fuel samples under the vapour recovery system in the laboratory storage should also be investigated. The fume hood and two extraction units should be serviced on a regular basis.

Cleaning of plant equipment (strainer removal)

The practicality of automating the removal and lifting the strainer to be cleaned to increase the distance between the strainer and receptors (controllers) should be investigated. The practicality of putting the clogged-up strainer in degreaser bath to remove and clean the strainer with the view of automating the task to prevent employees' exposure to VOC emissions.

Recommendations applicable to all activity areas

Employees exposed to BTEX including the other petrochemicals should undergo a risk-based medical surveillance program including biological monitoring to evaluate the efficacy of the

existing controls and as part of a preventative medical surveillance program. Provide information, instruction, and training at regular interval about: - petrochemicals (BTEX) that employees are potentially exposed to at workplace and duties of persons who are likely to be exposed to VOCs vapour. The names and potential harmfulness of the BTEX at the workplace and the employees who are likely to be exposed. Significant findings of the BTEX exposure assessment (an occupational health risk assessment survey). Information on how to access the relevant safety data sheets and information that each part of an SDS provides. The work practices and procedures that must be followed for the use, handling, storage, transportation, spillage, and disposal of samples, in emergency situations, as well as for good housekeeping and personal hygiene. The necessity of personal exposure air sampling, biological monitoring, and medical surveillance; The need for engineering controls and how to use and maintain them. The need for personal protective equipment, including respiratory protective equipment, and its use and maintenance. The precautions that must be taken by an employee to protect themselves against health risks associated with exposure, including wearing and using protective clothing and respiratory protective equipment. The necessity, correct use equipment, maintenance and potential of safety facilities and engineering control measures provided. Supervisor/Line Manager must give written instructions of the procedures to be followed in the event of spillages, leakages, or any similar emergency situations to employees. Once the aforementioned information, instruction and training have been provided, enforce the wearing of the prescribed PPE including ABEK respirator and no employee should be allowed to enter and remain in respiratory zone without the prescribed PPE and respiratory protection equipment (ABEK respirator).