Toxicology and Applied Pharmacology 276 (2014) 83–94

Contents lists available at ScienceDirect

Toxicology and Applied Pharmacology

journal homepage: www.elsevier.com/locate/ytaap

Invited Review Article

Current understandings and perspectives on non-cancer health effects of benzene: A global concern

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ARTICLE INFO

Article history:
Received 28 November 2013
Revised 2 February 2014
Accepted 19 February 2014
Available online 1 March 2014

Keywords:
Benzene
Disease
Glucose homeostasis
Hepatotoxicity
Hematotoxicity
Immunotoxicity
Nephrotoxicity
Neurotoxicity

ABSTRACT

Objective: Benzene, as a volatile organic compound, is known as one of the main air pollutants in the environment. The aim of this review is to summarize all available evidences on non-cancerous health effects of benzene providing an overview of possible association of exposure to benzene with human chronic diseases, specially, in those regions of the world where benzene concentration is being poorly monitored.
Methodology: A bibliographic search of scientific databases including PubMed, Google Scholar, and Scirus was conducted with key words of "benzene toxic health effects", "environmental volatile organic compounds", "diabetes mellitus and environmental pollutants", "breast cancer and environmental pollution", "prevalence of lung cancer", and "diabetes prevalence". More than 300 peer reviewed papers were examined. Experimental and epidemiologic studies reporting health effects of benzene and volatile organic compounds were included in the study.
Results: Epidemiologic and experimental studies suggest that benzene exposure can lead to numerous non-cancerous health effects associated with functional aberration of vital systems in the body like reproductive, immune, nervous, endocrine, cardiovascular, and respiratory.
Conclusion: Chronic diseases have become a health burden of global dimension with special emphasis in regions with poor monitoring over contents of benzene in petrochemicals. Benzene is a well known carcinogen of blood and its components, but the concern of benzene exposure is more than carcinogenicity of blood components and should be evaluated in both epidemiologic and experimental studies. Aspect of interactions and mechanism of toxicity in relation to human general health problems especially endocrine disturbances with particular reference to diabetes, breast and lung cancers should be followed up.

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Abbreviations: AChE, Acetyl cholinesterase; ADA, Adenosine deaminase; ALP, Alkaline phosphatase; ALT, Alanine aminotransferase; AST, Aspartate transaminase; BUN, Blood urea nitrogen; DNA, DeoxyRibo Nucleic Acid; DOPA, Dopamine; EDCs, Endocrine disrupting chemicals; ERK1/2, Extracellular signal-regulated kinases 1 and 2; Hb, Hemoglobin; IL-2, Interleukin 2; Kg, kilogram; LDH, Lactate dehydrogenase; LINE-1, Long interspersed nuclear element-1; MCHC, Mean Corpuscular Hemoglobin Concentration; MPV, Mean platelet volume; Mg, Milligram; OSHA, Occupational Safety and Health Administration; ROS, Reactive oxygen species; VOCs, Volatile Organic Compounds; WBCs, White blood cells.

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http://dx.doi.org/10.1016/j.taap.2014.02.012
0041-008X/

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Introduction

Benzene (C_6H_6) is an organic hydrocarbon commonly used as a solvent in industries. Benzene is one of the most widely used chemicals in the synthesis of various polymers, resins, and synthetic fibers (Velasco Lezama et al., 2001).

Human exposure to benzene

Human life is surrounded by a wide range of environmental volatile organic compounds (VOCs) among which benzene has been known to have deleterious health effects (Karakitsios et al., 2007). Benzene is released to our environment from industry effluents, combustion of gasoline and other petrochemicals used in our cars and industries. Cigarette smoke is the main source for indoor benzene exposure (Wallace, 1996a,b). Being extensively used chemical in petroleum industries, and due to its subsequent presence in the environment from other sources, human exposure to benzene is unavoidable and the possible adverse health effects associated with benzene chronic or acute exposure remain a matter of great concern for public (Snyder, 2012). Humans are exposed to benzene most frequently through inhalation of vapors in the workplace and environment and by eating processed foods such as smoked and canned fish (Medeiros Vinci et al., 2012). Apart from above-mentioned sources, an additional quantity of approximately 10 kg/ton of benzene is released to our environment during manufacturing, transferring and storage (Etzel and Ashley, 1994).

Occupations associated with prominent benzene exposure

Occupations dealing with leather, petrochemicals (refining, service station operators), scientific laboratories, rubber industries, coal based coke production, steel manufacturing, printing and plastic manufacturing industries have a possibility of their personnel to be highly exposed to benzene (Galbraith et al., 2010).

Benzene as human carcinogen

Benzene has long been known to act as carcinogen of human blood components. A first case of "benzene associated lymphoma" was reported by French researchers in 1947. According to recent studies, benzene at 3.19 mg/m^3 exposure in air has been accounted to induce hematological effects in humans (Lan et al., 2004; Qu et al., 2002). It has been reported from China, Italy, and Turkey that occupational benzene exposure in the range of 638.8 to 5110.8 mg/m^3 has caused acute myeloid leukemia, myelodysplastic syndrome, non-Hodgen lymphoma and possibly childhood leukemia (Brandt, 1992; Eden, 2010; McHale et al., 2012).

Current global regulations on benzene gasoline ratio

Aromatic hydrocarbons are added to gasoline for maintaining high octane number and for best anti-knock properties. Refined petroleum products generally contain 2–3% benzene by volume (Wong and Fu, 2005). Due to hazardous effects of lead (Pb) on human health, the content of its additives in gasoline has been reduced and almost eliminated since the last decade, but for anti-knocking purposes, benzene is mixed with gasoline, so that the contents of benzene in gasoline have reached to more than 5% in some countries (Verma and des Tombe, 2002; Karakitsios et al., 2007). In the USA, Australia, and Europe the concentration of benzene in gasoline has been reduced to 1% by volume (Verma and des Tombe, 2002), but in other regions like Russia, India, Malaysia, UAE, Bangladesh, Saudi Arabia, Egypt, Libya and some African countries, concentration of benzene in gasoline is estimated to be in the range of 3–7% volume. Pakistan, Iran, Iraq, Turkmenistan, Uzbekistan, Syria, and Sudan are the countries where no monitoring is exercised over benzene contents and any standard for benzene concentration in gasoline has not been set yet (Fig. 1). Information regarding benzene gasoline ration in different parts of the world taken from "International Fuel Quality Center, August 2013 and Hart Energy Research and Consulting" have been brought in Table 1.

As recommended by the U.S. Environmental Protection Agency, current threshold limit for benzene is 1.59 mg/m^3 at workplace and