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Mini Review

Overview of Arsenic in the Environment and its Impact on Human Health

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Abstract

Arsenic is a known carcinogen and its presence in water, soil, products and produce is a cause of concern for human health. This article includes a brief review on arsenic presence and forms in the environment, regulations for permissible presence of arsenic, its effects on human health and preventative measures to reduce arsenic exposure.

Keywords: *Arsenic; Environment; Human Health*

Introduction

Arsenic is an element found in nature in many forms and has historically been used as poison due to its toxicity to humans. Arsenic has been famously rumoured to have killed Napoleon Bonaparte, who was found to have excessive arsenic present in his hair samples. However, recent studies suggest that, while Napoleon may have succumbed to a stomach ulcer, various environmental factors might have caused him to have higher than normal exposure to arsenic [1]. In the 19th century, arsenic was very commonly used in household products. Wallpapers dyed bright green with copper arenite became popular during the Victorian age. Pigments containing arsenic were used in soaps, candles, clothes and many other items. Arsenic was also used as a medicine for many conditions. 'Fowler's Solution', is a tonic containing 1% potassium arenite and was used to treat psoriasis, eczema, asthma, syphilis, and other ailments, but due to its toxicity, its usage declined over time [2,3]. The toxic effects of arsenic, however, presented themselves leading it to be recognized as a carcinogen with the help of modern science.

What is arsenic?

Arsenic is a metalloid and it occurs in organic and inorganic forms in nature. Inorganic forms include arenite and arsenate, which are the most abundant forms found in the environment. The majority of arsenic in aerated soils exists as $H_2AsO_4^-$ (acid soils) or $HAsO_4^{2-}$ (neutral species and basic) [4]. Arsenic is present in the environment in different states of valency, however, the pentavalent and trivalent states of arsenic present in groundwater, soil and rocks, play a major role in the environment and are especially relevant to arsenic toxicity. Arsenite and Arsenate occur in -III valency states. Although humans are exposed to both pentavalent and trivalent oxidation states of arsenic, trivalent arsenic is higher in toxicity due to its reactivity with sulphur and oxygen. Arsenic is usually present in three allotropic forms – black, yellow and grey. On heating, it rapidly oxidizes to form the highly toxic arsenic trioxide and emits a garlic like odour [9].

Presence of arsenic in the environment and its causes

The extent of arsenic present in soil, freshwater and water reserves can fluctuate due to underlying geothermal and geological conditions. Naturally occurring arsenic reserves can permeate groundwater. However, the percentage of arsenic in soil and water is heavily affected by usage of pesticides containing arsenic, lumbar (Copper Chromated Arsenate) [8] as well as mining and fracking.

Inorganic arsenic compounds were previously used in pesticides, mainly in cotton, orchard and rice fields. Although the usage of inorganic arsenic pesticides like lead arsenate has been banned, organic arsenic compounds such as monosodium methyl arsenate (MSMA), disodium methyl arsenate (DSMA) and cacodylic acid are still in usage [3].

Arsenic present in industrial waste (especially lumbar industrial waste) has polluted water bodies and soil as sediment. Shellfish concentrate arsenic in seawater, but it exists in the organic forms such as arsenobetaine, which has proven to be less harmful than inorganic arsenic and thus of no harm to humans, this type of organic arsenic is also rapidly excreted.

Arsenic toxicity and its effects

Considering how commonly arsenic is present in environmental factors an important question is how much arsenic is poisonous for adult humans. According to WHO guidelines, 10 micrograms per litre of arsenic is permissible in drinking water [11,12]. The U.S. Food and Drug Administration (FDA) has established tolerance levels for arsenic for by products of animals given veterinary drugs. These levels range from 0.5 ppm in eggs and uncooked edible tissues of chickens and turkeys to 2 ppm in certain uncooked edible by products of swine [10-23].

While arsenic does not cause changes to gene sequence, it has been studied to induce changes in DNA that eventually lead to changes in genes that supress tumours, greatly increasing the risk of cancer and thus has immense carcinogenic effects These effects usually take about 10 to 14 years to emerge. Cancer in the bladder, kidney, lungs and skin has been observed to be related to increased arsenic exposure. Arsenicosis is caused due to prolonged arsenic exposure. Increased risks of skin lesions, lung cancer and bladder cancer are studied to be related to drinking water containing 50 micrograms of arsenic per litre. Inhalation of arsenic has been linked to lung cancer and tobacco consumption is observed to be interactive with arsenic towards increased risks of lung cancer. Long term exposure to arsenic in Taiwan, in combination with poor nutrition has caused Blackfoot disease (which severely damages blood vessels) and has also caused other types of blood vessel diseases in other countries. Evidence also suggests that arsenic exposure may be linked to higher blood pressure, cardiac arrests and other circulatory conditions. Higher doses of arsenic have severe gastrointestinal effects which cause nausea and vomiting and can be lethal. If not lethal, it can severely damage nerves, blood vessels and cause brain damage [9,24].

Arsenic in produce

Arsenic is also present in orchard produce, rice, and leafy vegetables. Such crops, if irrigated with arsenic polluted groundwater and grown in soil with higher arsenic content, contain greater levels of arsenic [16]. Although few guidelines and limitations exist for arsenic limitations in vegetables, few government agencies have recommended arsenic limits close to 0.1 mg kg^{-1}. According to a study conducted in 2013 on crops grown in lead and arsenic contaminated soil, arsenic uptake in root and leaf tissue of plants with soil containing 220 mg kg^{-1} of total arsenic was relatively high (near 10 mg kg^{-1} arsenic as per dead weight basis) and exceeds the WHO guidelines for arsenic (by fresh weight) [7].

Rice is the crop with the highest amount of inorganic arsenic present [20]. Rice is grown under flooded conditions and is hence more susceptible to arsenic accumulation. Data suggests that rice far exceeds the arsenic concentrations limitations of 50 microgram per kg by reaching up to levels of approximately 400 microgram per kg. However, washing rice thoroughly with water has the potential to remove up to 57% of arsenic according to a study [17,21,22].

Arsenic poisoning in effect

The presence of arsenic in our everyday environment is a major cause of concern for public health. Furthermore, poverty struck regions are likely to be affected on a larger scale to the carcinogenic effects of arsenic. Lack of proper nutrition adds to the harm caused by arsenic exposure to the health of the public. The contamination of groundwater in Bangladesh has had immense effects on a large scale across Bangladeshi populations due to the prevalence of usage of tube wells which contained high levels of arsenic [6]. The results of this poisoning were slow and severe. Several people developed conditions such as skin lesions and cancer. Children and older adults were at a higher risk [14].

Conclusion and Remedies for Arsenic Pollution

While arsenic exposure is worrisome, measures can be taken to reduce it. Switching out brown rice for white rice, rinsing and cooking rice in excessive water leads to reduced arsenic consumption through rice. Root vegetables contain most of their arsenic in their skins, therefore peeling them is a good measure. Buying wooden products and lumbar treated with arsenic preservatives can be avoided. For home gardeners, the arsenic levels in soil should be tested as precaution. If the main water supply comes from tube wells in a region, the arsenic levels in the water should be tested to avoid ill effects of excessive arsenic if any is present. Government bodies, on arsenic detection must take the appropriate measures of tube well screening and further determine which methods to reduce arsenic concentration from the tube well is deemed suitable. Phytoremediation is an emerging technology for making arsenic contaminated soil fit for use again and phytostablization has shown to successfully confine arsenic in its inert form in soil [26]. Phyto filtration is used to treat water with high arsenic concentrations. Development of technology providing more remedies for arsenic pollution shows promise.

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