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Rice, arsenic and health: an article review

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ABSTRACT

Arsenic exposure to humans through various sources, such as contaminated ground water and other human activities, has become a significant global concern. This is because arsenic has been shown to exhibit extreme toxicity potential with serious health implications. Arsenic accumulation has caused great problems due to changes in climate. An increase in CO2 leads to an increase in temperature, which results in high arsenic levels. Recently, the increase in carbon dioxide emissions will affect the earth; as the Earth continues to warm, arsenic levels will also increase in plants such as rice. Inorganic arsenic is a toxic compound. Inorganic arsenic in brown rice is known as a human carcinogen. They are monitored in different foodstuffs, such as rice, vegetables, and fish. Rice is considered the main food source for many people, so measuring the total arsenic level in rice to reduce the toxicity limit of the present arsenic has great scope interest in this article. The study of arsenic compounds and their nature, the different levels of arsenic in rice that depend on the rice type and other factors, and treatment methods such as cooking preparations are discussed in detail, and some scientific directions are also presented.

Keywords: Rice, arsenic metal, properties, toxicity, treatment method

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INTRODUCTION

Climate, arsenic and rice:

Arsenic accumulation has caused great problems due to changes in climate. An increase in CO2 leads to an increase in temperature, which results in high arsenic levels. Recently, increasing carbon dioxide emissions have affected the earth; as the earth continues to warm, arsenic levels have increased in plants such as rice.

High emissions of CO2 increase in temperature by two degrees, and CO2 levels increase by an additional 200 parts per million between 2025 and 2050. However, it does provide a snapshot of what may happen to rice crops in the future if carbon emissions are not reduced.

Because rice is important as the main food source worldwide and food for more than half of the global population, it is consumed on a daily basis by more people than other grains, such as wheat and maize, so the presence of rice in pure form is highly important. In addition, rice contains 75% starch; some glucose, sucrose, and dextran; and the protein of rice is rich in arginine amino acids compared with that of other cereals **(Ahsan., 2014).**

The presence of arsenic in rice has long been known to be a problem, as almost all rice contains arsenic. Harm naturally occurring chemicals can accumulate in the soil of paddy fields and leach into the grains of rice growing there, but the amount of rice can vary considerably from field to anther **(Zhoe., 2013).**

Humans have known for hundreds of years that arsenic is toxic. Its tasteless, colorless, and odorless nature has even made it a preferred method for dissipating enemies in ancient Rome and medieval Europe but in single doses at trace amounts if the dose does not cause poisoning **(Figure 1**). Some properties of arsenic metal are shown.

In recent decades, it has been discovered that even lower amounts of arsenic can cause health impacts when exposure occurs chronically over a lifetime. This is particularly true of inorganic arsenic, which is more readily accessible to biomolecules in the human body, where it can cause harm. The naturally occurring inorganic arsenic in rocks and soil can also be a product of various activities, such as glass making, wood preservative, mining, coal burning, and other industrial semiconductors **(Blauoch., et al, 2012**). Inorganic arsenic is found in industry in copper chroma-ted arsenic treated lumber and in private well water. The organic arsenic found in food is generally considered toxic.

Arsenic is distributed in the atmosphere most often in combination with oxygen, sulfide and chlorine. Only a low level of arsenic is present in the atmosphere. High quantities of arsenic are present in ores containing silver (Ag)-gold (Au) and Nickel (Ni)-cobalt (Co)-antimony, such as Arsenennaargentite (Ag_3As), Domskite (Cu_3As) and cobaltite (COASs).

The estimated amount of arsenic in the Earth's crust is approximately $4.01x10^{16}$ kg. **(Bissen and Frimmel, 2003)**, as shown in **Figure 1.**

Inorganic arsenic is particularly prevalent in ground water in a number of regions, so more than 7% of private well owners or 2.1 million people drink dangerous levels of inorganic arsenic worldwide. Others are 140 million people who drink water with an arsenic level above the WHO recommendation guidelines **(Figure 2).** Arsenic is distributed in regions worldwide **(Li., 2009: Hansen ., et al, 2011).**

Drinking arsenic-contaminated water can lead to acute and chronic poisoning, and there are no specific symptoms of acute arsenic poisoning. The symptoms of this nonspecific poisoning associated with chronic poisoning include weariness, colitis, loss of reflexes, weight loss, weakness, anorexia, gastritis, and hair loss. Moreover, experimental evidence has implicated prolonged arsenic poisoning in the pathogenesis of diseases such as cardiovascular disease, hyperkeratosis, disturbances in the nervous system-hyperpigmentation, circulatory disorders, and hepatic and kidney disorders **(Balali-Mood et al., 2021).**

In addition, outside of drinking water, the main source of dietary exposure to arsenic worldwide is rice. In regions that tend to have little arsenic in their ground water, such as Europe, rice is the single largest source of dietary exposure to inorganic arsenic. The problem comes down to how approximately 75% of world's supply of rice is grown in irrigated paddy fields, arsenic concentration relate to rice and other food matrix shown in table 1. **(Williams., et al. 2007).**

Time of rice and arsenic:

Rice tends to be chocked out by weeds, but rice can grow in water, whereas weeds cannot. This gives rice a large advantage over weeds, and it does not need a spray or hoe.

However, because the soil is flooded, when the soil shifts to have less oxygen, the microbiota of the soil changes in such a way that bacteria become more prolific, which leads to a lower temperature, and the CO2 level in the atmosphere increases, allowing bacteria in the soil to obtain more carbon, become warmer, and become more active. This effect was observed for more than 90% of the 28 different types of rice**. Table 2** shows the arsenic levels in the different types of rice matrix. **(Raab, et al., 2015).**

Arsenic and health problems:

Heavy metals include arsenic, which pollutes water, air, food and soil as a result of contamination. Toxic metalloids constitute a major risk to the entire ecosystem **(Balali-Mood et al., 2021)**. The most potent toxicant is arsenic, which has a complex metabolic pathway; it is an environmental agent that is known to be toxic to both animals and plants (Rahman and Singh, 2019). Arsenic displays varying toxicity in mammals according to several factors, including the form of organic or inorganic arsenic—the valence state—the rate of absorption and subsequent elimination, solubility and particle size **(John and Jelili, 2022).** Chronic exposure to trivalent forms is considered to have greater toxic potential than exposure to pentavalent forms. In mammals, inorganic arsenic is metabolized to methylated metabolites. The methylation process is considered a detoxification process until more toxic methylated trivalent compounds are detected in human urine. **(Chen and Rosen, 2020).** In most animal species following oral exposure, inorganic arsenic is metabolized by hepatic enzymes followed by urinary excretion. During the process of arsenic metabolism, pentavalent arsenic is first reduced by two electrons sequentially to form trivalent arsenic. Trivalent arsenic is in turn oxidatively methylated to form organic arsenic **(Chen and Rosen, 2020).**

The major diseases that are linked to arsenic poisoning are diabetes, hyperkeratosis, cancer, hypertension, and neurodegeneration. Some of these poisonings are mentioned as follows:**(1) Oxidative stress;** Arsenic causes an imbalance in the redox system, leading to oxidative stress. **(2) Epigenetic changes;** Arsenic can cause DNA hypomethylation by affecting the supply of S-adenosylmethionine and influencing the expression of DNA methyltransferase genes **(Dieter., et al., 2024) (3) Platelet reactivity;** Arsenic-induced changes in actin dynamics can increase platelet reactivity, potentially increasing the risk of thrombosis. **(4) Metabolic effects;** Arsenic exposure is associated with an increased risk of developing diabetes. **(5) Skin problems**; Chronic exposure often manifests with pigmentation changes and skin lesions, which are precursors to skin cancer. **(6) Cancer**; Arsenic is known as a human carcinogen and is linked to skin, lung, bladder and liver cancers.

The consumption of 0.13 micrograms per kg of body weight inorganic arsenic per day, or 7.8 micrograms per kg, increases the risk of developing bladder cancer by approximately 3% and diabetes by 1% **(Allen, et al., 2020).**

In those who eat a large amount of rice, these small risks can add up. This could significantly impact disease in populations that depend on rice as a mean food over several decades. The amount of inorganic arsenic in rice varies enormously, but the global median amount is 66 micrograms.

Inorganic As is a genotoxic carcinogen, both threshold and non-threshold mechanisms could apply to different genotoxic effects of iAs and its trivalent (111) and pentavalent (v) methylated metabolites. Thus, the guidance value varies, and rich characterization of the induction of genomic instability by iAs is needed. **Table 3** shows the name and chemical structure of arsenic compounds in the metabolic state **(Ameer., 2017: Andrew., 2009).**

The reported risk characteristic of IAs and harm reference points due to the CONTAM portal is 0.06 micrograms/kg BW per day for skin cancer, which is in the range of the mean dietary exposure estimates for iAS in adults (0.03–0.15 micrograms/KG BW per day) and below any of the 95th percentage exposure estimates in adults (0.07–0.33 micrograms/KG BW per day). For adults, the MOEs range between 2 and 0.4 for mean consumers and 0.9 and 0.2 at the 95th percentile-exposure-respectively.**(Dieter-Schrink.,2023)**

The EU set a limit in 2023 on inorganic arsenic in rice at 200 micrograms per KG of rice. Consume 0.13 micrograms per KG of body weight of inorganic arsenic per day, compared with the consumption of non-inorganic arsenic. An additional 129 0 trout of 10,000 individuals develop bladder cancer, an additional 100 out of 10,000 individuals develop lung cancer, an additional 110 per 10,000 individuals develop ischemic heart disease **(Schoof.,1999: Mehraj.,2008: Arab.,2021: Argos., 2014)**, and an additional 129 0 trout of 10,000 individuals develop diabetes.

Food table without rice:

Pretend that going to take rice from tables, as well as important food traditionally. Rice is important to people in poverty, some of whom obtain up to half of their daily calories from rice alone. Therefore, increasing the arsenic concentration in rice is very important. The following paragraphs describe possible methods for reducing the arsenic level in rice.

Ways of treatment:

Many studies have focused on reducing arsenic toxicity via cultivation and cooking methods. The concentration of As in food depends on the cultivation conditions, such as the soil type, irrigation conditions, pesticide use, and cultivation practices. Some studies focus on how to irrigate rice by completely flooding the field, which may be replaced by partial flooding and then drained and flooded again; this approach seems to reduce the amount of inorganic arsenic but increases the amount of other metals, such as cadmium, that can cause many dangerous diseases.

Cultivating in a pure environment to reduce CO_2 and pure water for irrigation via the use of filters that absorb arsenic as charcoal coconut filters will reduce the amount of arsenic absorbed by crops in fields or spray natural materials that absorb arsenic in irrigated fields of rice. Additionally, the ability of rice to absorb arsenic can be reduced via fundamental changes in the management of rice. Given that some types of rice accumulate less inorganic arsenic than others do, the exploration of their cultivation is of interest. Breeding varieties of rice that take less inorganic arsenic, but this has not yet panned out **(Petursdottir,2015**).

Children are particularly susceptible to environmental exposure, and they are the individuals most affected by arsenic poisoning because of their immature metabolic and excrement pathways. Moreover, during the maturation, differentiation and growth stages, their organs and systems may be more vulnerable to damage, so the use of sensitive and specific biomarkers associated with environmental kidney toxicity caused by arsenic exposure may allow early diagnosis and facilitate prompt intervention strategies than can prevent irreversible health effects in children later in life **(Cardenas-Gonzalez et al., 2016).**

Cooking treatment:

Similarly, some types of rice are more inorganic than others are. White rice has a lower arsenic effect than brown rice does. Cooking removes more than 50% of the arsenic material from brown rice and 74% of white rice. Preboiling the rice in preboiled water for 5 min before draining, fresh water is added, and the rice is cooked with lower heat to absorb all the water **(Gray., 2015: Hajeb., 2014).**

Rice can be rinsed before cooking and then boiled in six parts of water to one part of rice before being dragged and rinsed again, but all these preparations require more research on the nutritional value of rice after the starch water is discarded, although the As level is reduced.

Discussion and directions:

Plants absorb AS as a methylated species, methyl arsenate MA and dimethyl arsenate DMA, accumulate arsenic in leaves, roots, and shoots of grains, and the ability of soil microbes to methyl-arsenic-is-related-to-the-percentage-of-As.

arsenate bound to a group of peptides or proteins in food, which is converted to arsenate and arsenate. These two compounds represent ways of analysis by summing the quantified arsenate and arsenate in food, such as (in mg AS/kg wet weight: ww), referred to as inorganic total arsenic (iAs). In natural water or drinking water, all of these forms appear as arsenate and arsenate, whereas organic arsenic forms are rare in water **(Hensen.,2011: Aposhian., 2004: Barter., 2011).**

In humans, 45%-80% of As is rapidly absorbed after ingestion, is distributed in the body to all organs, and crosses the placental barrier. Arsenic is methylated by reduction, oxidation, methylation, thiolation and glutathiolation, and the degree of methylation is critical for its toxic effects.

IAS is eliminated via urine in the form of iAs and its methylation metabolism, with a half-life of approximately 2--3 days. There are no universally accepted biomarkers for chronic exposure to iAs, but measurements of blood and urine represent inorganic and organic arsenic compounds. Measuring the accumulation of As in hair and nails may provide biomarker assessments, but it is not used regularly **(Lai., 2004).**

The arsenic concentration in rice is often a factor of 10 higher than that in other grains because of the high accumulation efficiency from soil and anaerobic cultivation conditions, with the value of commercial rice ranging between 0.08 mg kg-1 and 0.47 mg/kg WW. Other species, such as algae, differ in their ability to detoxify the arsenic content via reduction–oxidation methylation. Mushrooms take up 14 mg/kg as a high concentration of As, present as DMA, MA and nontoxic arscenobetaine **(Rose., 2007: Popowish., 2016: Nearing .,2014: Garcia.,2012).**

Although rice has the ability to contain high As concentrations, the concentrations of total As and As species in the raw matrix are greater than those in the laboratory between the concentration of As in rice and the food matrix, as shown in Table 1. This is due to the moisture concentration in these matrices, which tends to mask high As concentrations.

Food preparation influences the moisture concentration of the food matrix, which can impact the interpretation of the data when the results are expressed on a fresh weight basis. Most studies have focused on concentrations on a dry weight (DW), which allows distinguishing between As release from foodstuffs and changes in water concentration and As release caused by food preparation **(Gray., 2016).**

The impact of food preparation on As release in the food matrix of rice and the decrease in the As content in rice resulting from washing depend on the rice type and washing procedure. When an average decrease in As of 33%-35% is discarded, rice is cooked to dryness to reduce the As concentration **(Karlein., et al., 2017).** Similar reductions in As concentrations were reported for other food matrices because of the impact of food preparation compared with that of rice. The % DW increased in boiled rice, the %DW decreased in boiled carrot but increased in steamed rice, and the %DW increased during the frying of anions because of the loss of water **(Natio., 2911).**

Hydration by soaking or boiling impacts a percentage of 6% DW that decreases from 90% to 6.2% DW in hydrated seaweed or to 2% in soup. High temperatures increase the impact of As release. Heat treatments improve As release ability, accelerate the breaking of bonds between arsenic and the food matrix and facilitate solubilization.

The significant potential for effectively removing heavy metals from water (over 90%) is due to the high magnetic characterization, high specific surface area, surface active sites, and high chemical stabilization of magnetic nanoferrites. All these characteristics indicate the application of magnetic ferrities (MFe_2O_4 -M=CO, Mg, and Ni) for removing heavy metals from water. This research aims to address water pollution as well as the factors influencing adsorption performance and health effects for future research **(Zohrabi, 2023).**

In the end, some methods could be used to reduce the As concentration in plants, especially rice. In addition, cultivating types with lower arsenic contents should be increased. prefer white rice for meals. Fundamental changes in the management of how rice is currently being grown are important for treating this problem.

Regarding the dietary exposure assessment for IAs, which is still valid, further investigations are needed to address the mechanisms that impact the methylation of As.

Figures and Tables

Figure .1 some properties of arsenic metal. (Dieter, et al., 2024)

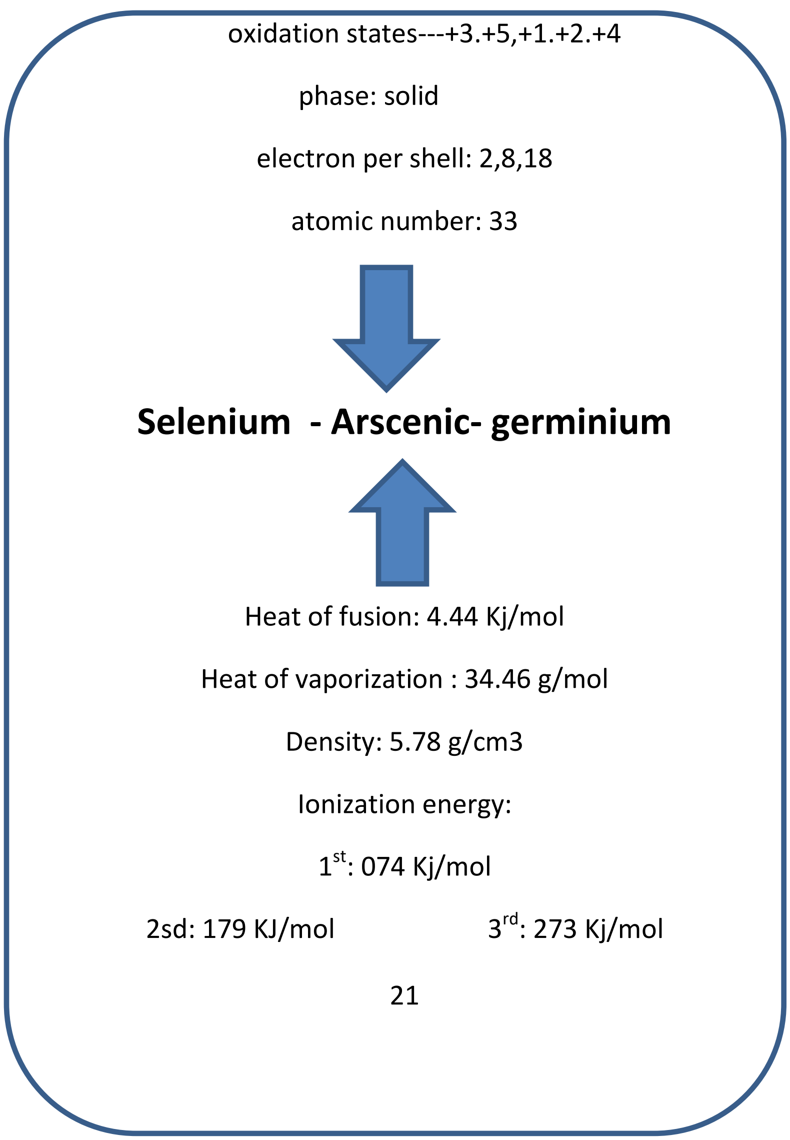

Figure 2. distribute arsenic in regions (Hansan, et al., 2011, Bissen and Frimmel, 2003)

-German soil 2.5-15mg /kg of As.

-China has 0.01-626mg/Kg of As.

-USA has 1 to 20mg/kg of As.

-Italy has 1.8-60mg/kg of As

Table 1: Total arsenic content in different matrix species (As in mg/Kg : ww) **(William., etal., 2007)**

Name of matrix food	concentration
Rice	0.12-0.17
Vegetables	0.16-0.39
Mushrooms	0.03-0.4
Hijiki	90.8
Other matrix	Up to 0.13

Table 2: levels of inorganic AS in different rice types (Arab.,2021)

Rice type	As in mg/Kg (max level)
Rice flour	0.25
Rice crackers, rice cakes	0.30
Rice designated for young children	0.1
Non –alcoholic rice-based drink	0.03
Placed on market as powder	0.02
Placed on market as liquid	0.01
Baby food	0.02
Salt	0.5

Table 3: different forms of arsenic compounds (Ameer., et al., 2017)

Name	Abbreviation	Chemical structure
Methyl arsonate,- monomethylarsconic acid	MMA (V)	CH3As O (OH)2
Methyl aesconite, monomethyl arsconous acid	MMA(111)	CH3As (OH)2
Dimethylarsinate, dimethyl arscinic acid	DMA(V)	CH3)2AsO (OH)
Thiomethylarscenate- thiodimethyl arscinic acjd	thio-DMA	CH3)2As S (OH)
Dimethyl monothioarscinate	thio-DMA (V)	DMMTA(V)
MMA sum of	MMA(111)and MMA(V)	
DMA sum of	DMA (111) and DMA (V)	

111: for arsenate species in oxidation state +3**, V:** for arsenic species in pent oxidation state

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