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Analysis of arsenic in rice and domestic water supply in Baguio City, Philippines

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Abstract

Numerous studies have found that rice and water, as components of the human diet, are potential pathways of arsenic exposure in humans. Due to the negative health effects linked with arsenic exposure, the quality of drinking water and rice samples must be continually monitored. This research was carried out in Baguio City, a small urban center in the Philippines. Following microwave digestion, arsenic in rice and water samples were determined using Atomic Absorption Spectrometry. The results showed that the National Food Authority (NFA) rice samples had arsenic content below the detection limit, indicating that this commercially available rice does not pose any health risk to Filipino consumers in terms of arsenic exposure. The arsenic value in other rice samples ranged from 8 µg/L to 27 µg/L, with the lowest and highest values found in organic brown rice and white rice varieties, respectively. Despite detectable arsenic in all 20 rice samples, all values were less than the maximum contaminant level (MCL) of 150 µg/L. Despite higher arsenic content in mixed rice than in white and organic colored rice, the mean differences are not significant, as proven by the Kruskal Wallis Test. All drinking water samples bought from water refilling stations had no detectable arsenic, while eight of the 18 (44%) of the spring water samples showed detectable amounts but are far below MCL of arsenic in drinking water. The findings suggest that the amount of arsenic in rice and spring water samples are too low to pose health risks over a short period of time.

Keywords: *arsenic, rice, water samples, health risks, atomic absorption spectroscopy*

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1. Introduction

Metals in the environment are transported by natural processes as well as human activities, where they may enter the food chain and bioaccumulate. This increases the possibility of metal contaminants being ingested by humans, resulting in a variety of health problems. Toxic contaminants in food are regarded as a significant public health challenge for the twenty-first century, as they can cause disorders in a variety of body systems (Hensawang & Chanpiwat, 2017).

Arsenic, an odorless and tasteless metalloid, is a prevalent environmental contaminant, originating from natural geologic processes and pollution (Davis et al., 2017). It has the potential to enter the food system through contaminated soil or water. Inorganic arsenic (i-As) is classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and the US Environmental Protection Agency (EPA) (Lai et al., 2015). High exposure to i-As can lead to adverse health effects, including certain cardiovascular diseases, cancers, diabetes and respiratory conditions (IARC, 2004; Sharma et al., 2014; WHO, 2011). For these reasons, arsenic is one of the ten substances that the World Health Organization (WHO) considers to be a major public health concern.

Arsenic contamination presents a significant dietary concern, with research revealing its prevalence across various sources. Costa et al. (2016) highlighted that 32% of studies on dietary arsenic contamination are linked to fish sample analysis, 39% to food samples like rice, and 29% to drinking water. The primary source of inorganic arsenic (i-As) exposure for humans stems from the consumption of unregulated contaminated water, impacting an estimated 140 million people globally (States et al., 2011; Meharg & Zhao, 2012).

The World Health Organization (WHO) has continuously adjusted guidelines to address arsenic exposure, recommending a maximum arsenic level of 50 µg/L in drinking water since 1963. However, due to the correlation between low arsenic concentrations and cancer risk, the WHO lowered the guideline to 10 µg/L in 1992 (WHO, 2018). Various countries, including the United States, Taiwan, and the European Union, have set similar maximum allowable arsenic concentrations in drinking water. However, some nations maintain a national standard of 50 µg/L, underscoring the global disparity in arsenic regulation.

Rice, a staple cereal crop, has emerged as a major concern due to its ability to accumulate arsenic, particularly in regions with contaminated water sources. Studies indicate that rice grains in arsenic-endemic areas contain approximately 90% inorganic arsenic, making rice a primary dietary source of arsenic exposure in many countries (Chowdhury et al., 2020; Joardar et al., 2020). Even in areas with arsenic-safe drinking water, rice consumption alone can exceed safe thresholds, especially with the rise of global food trade, potentially exposing millions to excessive arsenic levels through imported rice and rice-based meals (Mridha et al., 2022).

Rice's significance in global diets is indisputable, being a staple for more than half of the world's population and cultivated extensively across more than 100 countries, with Asia contributing a staggering 90% of the total production (Hoang et al., 2021). Its popularity, notably among children, stems from being a high-calorie, cost-effective food with a relatively low allergic potential and high iron content (Signes-Pastor et al., 2016). However, the ubiquitous cultivation of rice presents a significant health concern, particularly in regions where the crop is grown on contaminated land, leading to the uptake and accumulation of toxic elements, notably arsenic, in edible plant parts (Hoang et al., 2021).

Recent studies highlight rice as a significant source of inorganic arsenic in human diets alongside drinking water (Costa et al., 2016; Sobel et al., 2020). With rice serving as the primary food for approximately half of the world's population, particularly in Asia, its contribution to global caloric intake is substantial (Majumder & Banik, 2019). Arsenic accumulation in rice grains is facilitated by its unique physiology and anaerobic growth conditions, where silicon transporters carry arsenic from flooded soil into the plant, resulting in higher arsenic concentrations in rice compared to other grains like wheat or barley (Lai et al., 2015). Recent research highlights the mobility of arsenic in rice, contributing to its elevated transfer from soil to grain (Rokonuzzaman et al., 2022).

Significant variations in total and inorganic arsenic concentrations in rice across different geographic regions have been observed, with studies indicating higher levels in European and US rice compared to Asian varieties (Chen et al., 2017). Investigations by the US Food and Drug Administration revealed elevated arsenic levels in a considerable portion of rice products sold in the US, posing potential health risks (USFDA). Epidemiological studies have further associated higher rice consumption with increased risks of chronic conditions such as type 2 diabetes and cardiovascular diseases, emphasizing the importance of addressing arsenic contamination in rice (Karagas et al., 2019).

The researches conducted in various countries shed light on the presence of potentially toxic metal(loid)s, including arsenic (As), in rice grains and its implications for human health. For instance, Soe et al. (2023) examined white rice samples from rain fed paddy fields in Myanmar, revealing concentrations within acceptable limits for most metals, but with arsenic as a concern, particularly for consumers in areas without groundwater irrigation. Similarly, Jayasumana et al. (2015) found arsenic contamination in rice cultivated in Sri Lanka, emphasizing the need for safer rice varieties. Shraim (2017) expanded this concern globally, highlighting hazardous levels of arsenic and other toxic elements in rice sold in Saudi Arabia. Studies in Vietnam (Nguyen et al., 2020), Bangladesh (Agence France-Press [AFP] News, 2013), and rural Bengal (Biswas et al., 2021) further emphasized the health risks associated with arsenic exposure from rice consumption. The study by Watson and Gustave (2022) found that 2% of rice samples in the Bahamian market had an estimated i-As concentration above WHO's allowable limits. Additionally, Nunes et al. (2022) quantified the global trade flow of arsenic in rice, showing how importing countries may face increased cancer risks. The Philippines, although reported to have low arsenic levels in rice by the FDA (Rettner, 2013), still requires monitoring for potential long-term health risks.

In terms of arsenic pollution in water, studies conducted in various regions, including Italy, Malaysia, Pakistan, and the Philippines, underscore its pervasive nature. For instance, Nuvolone et al. (2023) highlighted the association between chronic exposure to low-level arsenic in drinking water and adverse health outcomes, including mortality and hospitalization, in the volcanic region of Mt. Amiata, Italy. Similarly, Ramly et al. (2023) conducted a comparative cross-sectional study in Malaysia, revealing high arsenic concentrations in drinking water and hair samples, leading to the prevalence of arsenicosis in exposed communities. These findings resonate with broader concerns outlined by Uppal et al. (2019), who emphasized the extensive population exposure to arsenic-contaminated water in Southeast Asia and its link to various health conditions.

Moreover, regional studies, such as those conducted in Pakistan (Abbas & Cheema, 2019) and the Philippines (Apostol et al., 2022), provide localized insights into arsenic contamination patterns and associated health risks. Abbas and Cheema (2019) reported a positive correlation between arsenic levels in drinking water and blood samples of females in District Sheikhupura, Pakistan, emphasizing the systemic health implications of arsenic exposure. Meanwhile, Apostol et al. (2022) explored arsenic contamination in groundwater surrounding Taal Volcano in the Philippines, highlighting the need for continuous monitoring and risk communication to safeguard public health. These studies collectively underscore the global significance of arsenic contamination in drinking water and underscore the imperative for evidence-based policies to mitigate its adverse effects and protect vulnerable populations.

The literature presents extensive evidence highlighting the pervasive nature of arsenic pollution in both rice and water sources and its significant implications for public health globally. However, there remains a notable gap in the literature regarding arsenic contamination specifically in water sources within Baguio City, Philippines. Despite the well-documented risks associated with arsenic exposure, including various adverse health outcomes, there is a lack of localized studies addressing this issue in Baguio City. Given the unique environmental and geographical characteristics of Baguio City, there is a pressing need to conduct a study to assess arsenic levels in water samples and understand the extent of contamination in this region. Such research is crucial for informing evidence-based policies and interventions to mitigate arsenic exposure risks and protect the health of vulnerable populations in Baguio City.

2. Methodology

2.1 Design and Locale of the study

The study used of descriptive-analysis method. Specifically, it analyzed the level of As from drinking water and rice samples using Atomic Absorption Spectroscopy.

The study was conducted in Baguio City, a small urban center in the Philippines located approximately 250 kilometers North of Metro Manila and 1,500m above sea level. Baguio City’s water supply comes from springs, wells, surface diversions, and a rain basin (Ciencia et al., 2015). Baguio Water District (BWD) administers the city's water supply system. Seven of the city's 129 barangays are not directly connected to the Baguio Water District (BWD). Moreover, not all households in the remaining 122 barangays are connected to the BWD's pipe system.

The Philippines has three types of potable water systems. Level I water system includes stand-alone water points such as hand pumps, shallow wells, and rainwater collectors. Level II water system covers piped water with a communal water point such as borewell and spring system. Level III water system includes piped water supply with a private water point, such as a house connection (Israel, 2009). In Baguio City, most of the barangays rely on Level III water system with BWD as the water service provider. On the other hand, a significant number of Baguio residents still rely on 'natural' water sources (e.g., springs) or Level II water systems due to the absence of water line from BWD or in the event of a disruption in the water distribution services of the BWD (Ciencia et al., 2015).

The current study was conducted in barangay Lucnab, Baguio City. Its population, as determined by the 2015 Census was 2,120, representing 0.61% of the total population of Baguio (Philippines Statistics Authority). Out of the four Puroks (*district or zone*), only Purok 1 residents have water connections to the BWD's pipeline system. Thus, Puroks 2, 3, and 4 were specifically chosen for this study to assess the quality of water used by the residents, which are from springs and private water delivery trucks.

In terms of Baguio's rice supply, there are some 120 accredited National Food Authority (NFA) outlets in the Baguio-Benguet area that distribute rice to hundreds of retailers in the different public and private markets (See, 2020). The NFA is a Philippine government agency responsible for ensuring food security for the country, as well as rice supply and price (National Food Authority, 2020). Starting November 2018, rice retailers are required by the NFA to sell four varieties of rice labeled only as "regular-milled", "well-milled", "whole grain," and "special" (Layug, 2018). The special rice varieties are either organic or heirloom. Regardless of rice varieties, the white rice samples are all classified by the National Food Authority of the Philippines as well-milled rice. Most of the commercially available rice in the Philippines are sold as well-milled rice.

2.2 Data gathering procedures

The preliminary survey was conducted to gather baseline data on common drinking and household water sources, and common rice varieties consumed among Puroks 2, 3, and 4 residents. The pre-survey employed convenience sampling in the aforementioned areas where a total of 92 completed questionnaires were collected.

The survey revealed that the source of drinking water for the majority (58.7%) was spring water. On the other hand, 41.3% got their drinking water from water refilling stations. Springwater was used for cooking, washing, and other household tasks by the majority (69.6%) of the respondents. A majority of the respondents, or 81.5 percent, consumed commercially available rice, while the rest consumed homegrown rice. The top five most commonly purchased rice varieties included: NFA (30.4%), Sinandomeng (17.4%), Jasmine (10.9%), RC-18 (8.7%), and Bordagol (6.5%).

Twenty-eight (28) water samples were collected from strategic locations in Puroks 2, 3, and 4. Ten (10) were purified while 18 were spring water samples. The purified water samples collected from the households were bought by the residents from Water Refilling Stations and were used as drinking water. On the other hand, spring water samples collected were used mainly by the residents for cooking, cleaning, and other household activities. The study also analyzed 22 rice samples consisting of organic rice, homegrown rice, and commercially available rice of different varieties. The varieties include Angelica, Jasmine, Sinandomeng, Dinorado, R160, Bordagol, and NFA rice. For comparison purposes with commercially available rice, the collected samples included organic rice and homegrown rice.

2.3 Sample collection and preservation

Polyethylene bottles were used to collect spring water and purified water samples from selected households. Upon collection, the samples were treated immediately with 3-5 drops of analytical grade nitric acid. Most trace metals are preserved by acidification to below pH=2. This decreases precipitation and sorption losses to the container walls. An icebox containing a mixture of water and ice was used to maintain the temperature from 10C to 40C (EPA, 2000). The samples were kept at this condition during transport to the laboratory. In addition, around 20 g of rice were collected from the volunteer residents and immediately placed in zip-lock plastic containers.

2.4 Analysis of water and rice samples using Atomic Absorption Spectrometry

The rice and water samples were brought to the Department of Science and Technology laboratory for arsenic analysis using Atomic Absorption Spectrometry after Microwave digestion. The methods used were based on the official methods of analysis of AO/AC International (20th ed) (2016) and in accordance with Milestones Microwave and PinAAle 900Z Methods Manual.

2.5 Data processing and Statistical analysis

The Philippines has not set a maximum arsenic level for rice yet. Australia and New Zealand (1000 µg/L or ppb of total cereal arsenic), and China (150 ppb of inorganic arsenic for rice and rice products) established limits. For purposes of interpretation, the study adopted the limit set by China. Thus, if the mean concentration of As detected from the rice samples is higher than 150 ppb, the value is interpreted as high level, otherwise, it is interpreted as low. The maximal allowable concentration of As in drinking water set by WHO is 10 µg/L (or ppb). Thus, if the determined mean concentration of As in drinking water is above the allowable limit, it will be interpreted as high; otherwise, the mean will be interpreted as low.

Kruskal Wallis (KW) test was used to determine if there was a significant difference in the level of As according to rice varieties. All statistical analyses conducted in this study were two-tailed at a significance level of 0.05, using SPSS software.

3. Results and Discussion

3.1 Levels of arsenic in different rice varieties

Table 1 shows the arsenic content of the rice samples collected from 22 households. The two NFA rice or the so-called "cheap" rice in the Philippines had an arsenic content below the detection limit, which means that, apart from being affordable, this commercially available rice does not pose any health risk to Filipino consumers in terms of exposure to arsenic. For the remaining 20 rice samples, the arsenic value ranged from 8 µg/L to 27 µg/L, with the lowest and highest values found in organic brown rice and white rice varieties. Despite detectable arsenic in the 20 rice samples, all values were below the maximum contaminant level of 150 µg/L. The results imply that the arsenic levels in rice are low to pose health risks over a short period. The results underscore the importance of monitoring arsenic levels in rice varieties, given rice's status as a staple food in the Philippines. While the detected arsenic levels may not pose immediate health risks, the potential for long-term health effects cannot be ignored, especially considering rice's role as a dietary mainstay for Filipinos. The ability of arsenic to bioaccumulate in the body over time raises concerns about cumulative exposure, particularly among vulnerable populations such as pregnant women, infants, and adolescents.

Table 1

Arsenic analysis of different rice varieties using Atomic Absorption Spectrophotometry

Sample no.	Rice Varieties	Arsenic content, µg/L or ppb	Interpretation
White Rice			
1	Angelica	14.8	Low
2	Bordagol	11.0	Low
3	Dinorado	15.7	Low
4	Jasmine	9.30	Low
5	Jasmine	10.8	Low
6	Jasmine	8.80	Low
7	Jasmine	12.3	Low
8	Jasmine	9.60	Low
9	Jasmine	17.0	Low
10	Jasmine	27.0	Low
11	RC 160	12.0	Low
12	Sinandomeng	12.0	Low
13	Sinandomeng	8.10	Low
14	Sinandomeng	13.2	Low
15	Sinandomeng	11.2	Low
16	Sinandomeng	13.4	Low
17	NFA 1	ND	Low
18	NFA 2	ND	Low
Mixed (White and Red)			
19	White and Red Rice	14.2	Low
20	Sinandomeng and Red Rice	17.1	Low
Organic Rice			
21	Organic Brown	8.00	Low
22	Organic Red	10.7	Low

The IARC (2004) and the National Research Council (2001) have highlighted the significant health risks associated with exposure to low levels of arsenic, including cancer, skin lesions, diabetes, cardiovascular disease, peripheral neuropathy, and other hematologic, liver, and kidney issues. The studies of Lai et al. (2015), Liao et al. (2018) and Rettner (2013) likewise highlight the potential long-term health risks of arsenic in rice, particularly for pregnant women and infants. Younger populations, particularly adolescents, are at higher risk due to their early years of life and development. Despite rice's low concentrations, the LCR values are beyond the acceptable upper limit. The US Food and Drug Administration (2016) underscores children's greater potential for long-term exposure due to the long latency period of iAs-related cancer. Children, including adolescents, are in a critical window of development, have a high calorie per unit body weight diet, and are more exposed to contaminants unique to specific foods due to selective and less diverse dietary patterns.

3.2 Comparison of the level of arsenic according to rice varieties

For comparison, the 20 rice samples with detectable arsenic content were grouped into white rice, organic colored rice varieties, and mixed rice (white and non-organic red rice). Among the three groups presented in table 2, the lowest arsenic level was from organic rice (M = 9.30, SD = 1.91). The conventionally-grown white rice varieties showed a mean arsenic level higher than the organic rice but lower than the mix of white and colored non-organic rice. The result connotes that organic farming has reduced the amount of arsenic in rice, making the resultant rice crop healthier.

Table 2

Mean levels of arsenic in different rice varieties

	N	Mean	SD
White Rice	16	12.9	4.50
Organic Colored Rice	2	9.35	1.91
Mixed (White and Non-Organic Red Rice)	2	15.7	2.05
Total	**20**	**12.8**	**4.30**

Conventional methods of rice production use agrochemicals, which can release arsenic into the soil and water, leading to arsenic accumulation in rice grains (Interra International 2018). Organic farming uses bio-fertilizers and other organic nutrient sources to minimize exposure to harmful chemicals like arsenic. Organic rice does not involve synthetic raw materials, transgenic plants, animals, or microorganisms, maintaining the organic integrity and quality of products (National Bureau of Agricultural Commodity and Food Standards Ministry of Agriculture and Cooperatives, 2010). Organic products, like organic brown rice, are less processed than non-organic foods, containing fewer artificial colorings, sweeteners, flavorings, and preservatives, which may be harmful to health (George, 2018).

A common drawback with organic foods, given the known health benefits, is cost, as organic foods can cost considerably more than their traditional counterparts (George, 2018). The operating costs for organic and heirloom rice are more expensive than the typical rice paddy with its seasonal, lower yields, thus, driving up the price (Castro, 2019). Because of these, most Filipinos still consume white rice. Mixtures of white and colored rice sold on the market can balance health benefits and economic factors.

Table 2 further shows that the highest mean level of arsenic was from mixed rice (*M* = 15.65, SD = 2.05), potentially due to the addition of non-organic colored rice to white rice. This finding aligns with the 2013 findings of the Philippine Food and Drug Administration (FDA), which reported that instant rice had low amounts of arsenic while brown rice had higher levels. Additionally, Meharg and Zhao (2012) found that bran, the hard outer layer of the grain present in brown rice, accumulates more arsenic than white rice, as white rice production involves removing this layer, thereby reducing arsenic levels. Furthermore, Hensawang and Chanpiwat (2017) discovered that brown jasmine rice contained considerably more As than white jasmine and white glutinous rice. In terms of As exposure produced by different forms of rice consumption, brown jasmine rice intake caused around 1.7 to 2.3 times greater As exposure rates compared to other types of rice consumption. Moreover, Su et al. (2023) emphasize the greater concentration of arsenic in brown rice compared to white rice and caution against advocating for brown rice over white rice without considering the potential risks and benefits. Additionally, Yim et al. (2017) found that brown rice contained the highest amount of total arsenic compared to white rice with varying degrees of polishing.

Considering that arsenic accumulates in the bran, post-harvesting methods such as polishing raw rice grains have been found to decrease total As content in cooked rice (Kumarathilaka et al., 2019). This explains why the average values of the white rice varieties analyzed in the current study are lower than the white and colored non-organic rice mixtures. Notwithstanding the varieties of rice, white rice samples are all classified as well-milled rice by the National Food Authority of the Philippines. Most of the commercially available rice in the Philippines is sold as well-milled rice, equivalent to polished rice. The United Nations Food and Agriculture Organization (FAO) defines well-milled rice as rice grain that has had the hull, germ, outer bran layers, and the majority of the inner bran layers removed. In contrast to conventional milled rice, which permits for the existence of bran layer streaks in up to 30% of the kernels (GMA News Online, 2013).

Despite higher arsenic content in mixed rice compared to white rice and organic colored rice, the mean differences are not significant, as proven by the Kruskal Wallis Test,

χ^2 (2) = 5.22, and p=.074. The non-significant differences in arsenic levels among the rice groups imply that, from an arsenic exposure perspective, consumers may not face significantly different health risks when consuming mixed rice, white rice, or organic colored rice. This finding suggests that, in terms of arsenic content, all three types of rice may be considered relatively safe for consumption. Consumer Reports (2014) suggest that white or brown rice offers significant health benefits, outweighing arsenic trace levels. Sun et al. (2010) discovered that substituting 50 grams of white rice for brown rice resulted in a 16 percent lower risk of type 2 diabetes. For improved diets, Healthline (2019) underlines the need of selecting particular rice types.

However, the discussion on organic brown rice adds a layer of complexity. While George (2018) suggests that organic foods, including brown rice, may contain fewer agricultural pollutants than conventional crops, the health benefits of organic foods compared to conventional ones remain inconclusive. Nevertheless, it highlights that organic brown rice may offer greater health advantages compared to non-organic rice. In the broader context of risk-benefit assessment in food safety research, Assunção et al. (2019) highlight the importance of evaluating both the risks and benefits of consuming specific foods or food components. Applying this approach to rice consumption would involve assessing the potential health risks associated with arsenic exposure alongside the nutritional benefits of different rice types, ultimately guiding consumers toward informed dietary choices.

3.3 Levels of arsenic in different water samples

The cost of domestic water purifiers and bottled water has grown in recent years due to the rise in demand for cleaner water. The distribution of around 3,000 water filling stations across the Philippines has made it a reliable supply of clean, affordable drinking water for the nation. These water refilling stations offer filtered water of equal quality to bottled water at a lesser cost (Magtibay, 2018). Water refilling stations now supply clean water in 5-gallon containers right to people's homes. More and more Filipinos are purchasing their drinking water from water filling stations due to price and convenience. For example, in the locality of the current study, 41.3 percent of barangay Lucnab residents buy their drinking water from the water refilling stations.

Table 3 shows that all ten drinking water samples bought from water refilling stations had no detectable amounts of arsenic-based on AAS analysis. The results imply that the water refilling stations follow the Philippine National Standards for Drinking Water (PNSDW). The highest arsenic level allowed in drinking water is 10 μg/L (Department of Health, 2017). The Philippine National Standards for Drinking Water (PNSDW), which establishes standards and procedures for the quality of drinking water in order to safeguard the public's and consumers' health, was released by the Department of Health (DOH) in 2017. These requirements are in line with the WHO's enhanced framework for safe drinking water.

Table 3

Arsenic analysis of different water samples using Atomic Absorption Spectrophotometry

Sample No	Source	Arsenic content, μg/L	Interpretation
1	Spring Water	0.0012	Low
2	Spring Water	0.00116	Low
3	Spring Water	0.00105	Low
4	Spring Water	ND	Low
5	Spring Water	ND	Low
6	Spring Water	ND	Low
7	Spring Water	ND	Low
8	Spring Water	0.00065	Low
9	Spring Water	ND	Low
10	Spring Water	ND	Low
11	Spring Water	ND	Low
12	Spring Water	ND	Low
13	Spring Water	0.00083	Low
14	Spring Water	0.00158	Low
15	Spring Water	0.00150	Low
16	Spring Water	0.00003	Low
17	Spring Water	ND	Low
18	Spring Water	ND	Low
19	Purified Water	ND	Low
20	Purified Water	ND	Low
21	Purified Water	ND	Low
22	Purified Water	ND	Low
23	Purified Water	ND	Low
24	Purified Water	ND	Low
25	Purified Water	ND	Low
26	Purified Water	ND	Low
27	Purified Water	ND	Low
28	Purified Water	ND	Low

Notes: RdL – Required detection limit or drinking water is 0.000016 microgram/L while 0.000014 microgram/L for spring water.
ND – Not Detected

There is no health risk from exposure to arsenic, according to the findings, but there may be dangers from other types of contamination. Even though water filling stations employ effective water purification methods to provide water that is superior to the quality of traditional water systems, Magtibay (2018) has noted that the possibility of contamination is likely if the handling procedures are not carefully examined. For the residents of Barangay Lucnab, contamination may occur during the transfer or storage of the purified water at home.

Table 3 further shows that eight of the 18 (44%) spring water samples showed detectable amounts but are far below the MCL of arsenic in drinking water. Since arsenic naturally appears as a trace component in many rocks and sediments, bedrocks may be the source of the spring water's low arsenic levels. Arsenic found in the mineral deposits and rock easily dissolves in a nearby groundwater (WHO, 2014). As a result of human activities including mining and its various industrial uses, animal feeds, wood preservatives, and pesticides, arsenic can also leach into groundwater. The very low levels of arsenic may not have come from such operations because there have been no known mining activity, little vegetation, and no rice paddies in barangay Lucnab, which may imply the usage of pesticides. In a related study conducted in the Malaysian state of Perak, Rahmanian et al. (2015) claimed that the elevated As levels in the communities of Ipoh (IP) and Seri Iskandar were brought on by the usage of chemical fertilizers in the neighboring rice fields. Geographically, the IP's closeness to the Kinta small-medium industrial sector may have contributed to increased levels of As in the sample under investigation. Aside from the production of semiconductors, other sources of As include waste runoff from glass and electronics manufacturing facilities, orchard runoff, natural deposit erosion, and semiconductor manufacturing.

The low amounts of arsenic in spring water samples used by the residents posed no significant health risks associated with arsenic exposure. The finding presents a better picture than the research findings in other parts of the world and the Philippines positing that threat to public health comes from arsenic-contaminated groundwater. Inorganic arsenic is naturally present in groundwater at high concentrations in a number of nations, including Mexico, Argentina, Bangladesh, Chile, China, India, Mexico, and the United States of America. The three main sources of contamination are food prepared with contaminated water, crops irrigated with it, and drinking water (WHO, 2018). Sharp geographic, socioeconomic, and cultural divides occur between rural and urban areas as well as inside towns and cities, where residents of low-income, informal, or illegal settlements typically have less access to improved drinking-water sources than other residents (WHO, 2019).

In contrast, the study of Delos Reyes et al. (2017) found that groundwater samples from the Inayawan Landfill in Cebu, Philippines, showed an arsenic level of 72 µg/L, exceeding the World Health Organization's 10 µg/L limit. The majority of respondents had low exposure to arsenic-contaminated water, with a low prevalence of skin diseases. Similarly, the study of Magalona et al. (2019) showed that some of the groundwater samples from Bulacan, Batangas, and Laguna exceeded the maximum allowable limit set by EPA and WHO. The results are alarming, as people use groundwater for drinking, cooking, and personal needs. Epidemiological studies are recommended to assess the incidence of cancer, diabetes, and cardiovascular diseases.

4. Conclusion

The analysis of arsenic levels in various rice varieties available in Baguio City, Philippines highlights the importance of continued monitoring and awareness of arsenic exposure risks, particularly in staple foods like rice. While the levels detected in the studied rice samples were generally below the maximum contaminant level, the potential for long-term health effects, especially among vulnerable populations, necessitates ongoing vigilance. Organic farming practices appear to contribute to lower arsenic levels in rice, suggesting potential health benefits, although cost considerations remain a challenge. Additionally, the arsenic levels in drinking water samples indicates that water refilling stations generally provide safe drinking water, aligning with national standards. However, attention should still be paid to potential contamination risks during storage and handling.

Based on these findings, it is recommended to prioritize efforts in promoting organic farming practices for rice cultivation to minimize arsenic exposure. Government subsidies or incentives could help mitigate the cost barrier associated with organic products, making them more accessible to the general population. Furthermore, continuous monitoring and enforcement of water quality standards, especially in areas reliant on groundwater sources, are essential to ensure safe drinking water for all. Public awareness campaigns on proper water handling and storage practices can also help reduce the risk of contamination.

Additionally, further epidemiological studies are warranted to better understand the health impacts of arsenic exposure in communities with elevated levels of contamination.

References

Abbas, M., & Cheema, K. J. (2019). Correlation studies of arsenic level in drinking water and blood samples of females in district Sheikhupura, Pakistan. *Journal of Environmental Science and Management*, *22*(2), 1–5. https://doi.org/10.47125/jesam/2019_2/01

Agence France-Press (AFP) News (2013). *Largest study widens rice, arsenic link in Bangladesh.* http://ph.news.yahoo.com/largest-study-widens-rice-arsenic-bangladesh-184854774.html?.tsrc=globe

Apostol, G. L. C., Valenzuela, S., & Seposo, X. (2022). Arsenic in groundwater sources from selected communities surrounding Taal Volcano, Philippines: An exploratory study. *Earth*, *3*(1), 448–459. https://doi.org/10.3390/earth3010027

Assunção, R., Pires, S. M., & Nauta, M. (2019). Risk-Benefit assessment of foods. *EFSA Journal*, *17*. https://doi.org/10.2903/j.efsa.2019.e170917

Biswas, B., Chakraborty, A., Chatterjee, D., Pramanik, S., Bhaswati, G., Majumdar, K. K., Nriagu, J. O., Kulkarni, K. Y., Bansiwal, A., Labhasetwar, P., & Bhowmick, S. (2021). Arsenic exposure from drinking water and staple food (rice): A field scale study in rural Bengal for assessment of human health risk. *Ecotoxicology and Environmental Safety*, *228*, 113012. https://doi.org/10.1016/j.ecoenv.2021.113012

Castro, J. (2019). *These are all the different kinds of rice you can buy in the Metro*. https://www.yummy.ph/lessons/prepping/where-to-buy-heirloom-rice-a00261-20190405-lfrm

Chen, Y., Han, Y.-H., Cao, Y., Zhu, Y.-G., Rathinasabapathi, B., & Ma, L. Q. (2017). Arsenic transport in rice and biological solutions to reduce arsenic risk from rice. *Frontiers in Plant Science, 8*. https://doi.org/10.3389/fpls.2017.00268

Chowdhury, N., Das, A., Joardar, M., De, A., Mridha, D., Das, R., Rahman, M. M., & Roychowdhury, T. (2020). Flow of arsenic between rice grain and water: Its interaction, accumulation and distribution in different fractions of cooked rice.

Science of the Total Environment, 731, 138937. https://doi.org/10.1016/j.scitotenv.2020.138937

Ciencia, A. Jr., Mendoza, L. Cruz, G., Calde, N., Cabalfin, M. & Peñalba, M. (2015). Towards establishing water security and urban resilience in the city of Baguio. *Asian Cities Climate Resilience Working Paper Series 27.* https://pubs.iied.org/pdfs/10754IIED.pdf

Consumer Reports (2014). How much arsenic is in your rice? https://www.consumerreports.org/cro/magazine/2015/01/how-much-arsenic-is-in-your-rice/index.htm

Costa, B., Coelho, L., Araújo, C., Rezende, H., & Coelho, N. (2016). Analytical strategies for the determination of arsenic in rice. *Journal of Chemistry*, 1-11. https://doi.org/10.1155/2016/1427154

Davis, M., Signes-Pastor, A. J., Argos, M., Slaughter, F., Pendergrast, C., Punshon, T., Gossai, A., Ahsan, H., & Karagas, M. R. (2017). Assessment of human dietary exposure to arsenic through rice. *Science of the Total Environment*, 586, 1237–1244. https://doi.org/10.1016/j.scitotenv.2017.02.119

Delos Reyes, J., Flores, S. M. and Winona, M.T. (2017). *Exposure to Arsenic contaminated water and its association to skin disease prevalence in Inayawan, Cebu.* Thesis. http://www.herdin.ph/index.php/herdin-home?view=research&cid=69557

Department of Health (2017, December 22). *DOH launches Philippine National Standards for Drinking Water of 2017*. https://www.doh.gov.ph/node/12121

Department of Health (2017). *Philippine National Standards for Drinking Water.* https://www.foodshap.com/PNSDW2017.pdf

George, S. (2018.). What are the benefits of organic brown rice? https://www.leaf.tv/6764390/what-are-the-benefits-of-organic-brown-rice/

GMA News Online (2013, July 21). *NFA now selling well-milled rice*. https://www.gmanetwork.com/news/money/content/318506/nfa-now-selling-well-milled-rice/story/

Healthline (2019). *What is the healthiest type of rice*? https://www.ecowatch.com/healthiest-rice-2633703792.html

Hensawang, S. & Chanpiwat, P. (2017). Health impact assessment of arsenic and cadmium intake via rice consumption in Bangkok, Thailand. *Environmental Monitoring Assessment*, 189, 599. https://doi.org/10.1007/s10661-017-6321-8

Hoang, A. T., Prinpreecha, N., & Kim, K. (2021). Influence of mining activities on arsenic concentration in rice in Asia: a review. *Minerals*, *11*(5), 472. https://doi.org/10.3390/min11050472

International Agency for Research on Cancer (IARC) (2004). Some drinking-water disinfectants and contaminants, including arsenic. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, 84*, 1–19.

Interra International (2018). Organic rice – the healthy option. https://interrainternational.com/2018/11/organic-rice-the-healthy-option/

Israel, D. (2009). The cases of Dumaguete City and Agusan del Sur. *Philippine Institute for Development Studies Policy Notes No. 2009-01*. https://core.ac.uk/download/pdf/6506005.pdf

Jayasumana, C., Paranagama, P., Fonseka, S., Amarasinghe, M. D., Gunatilake, S., & Siribaddana, S. (2015). Presence of arsenic in Sri Lankan rice. *International Journal of Food Contamination*, *2*(1). https://doi.org/10.1186/s40550-015-0007-1

Joardar, M., Das, A., Mridha, D., De, A., Chowdhury, N., & Roychowdhury, T. (2020). Evaluation of acute and chronic arsenic exposure on school children from exposed and apparently control areas of West Bengal, India. *Exposure and Health*, *13*(1), 33–50. https://doi.org/10.1007/s12403-020-00360-x

Karagas, M. R., Punshon, T., Davis, M., Bulka, C. M., Slaughter, F., Karalis, D., Argos, M., & Ahsan, H. (2019). Rice intake and emerging concerns on arsenic in rice: a review of the human evidence and methodologic challenges. *Current Environmental Health Reports*, *6*(4), 361–372. https://doi.org/10.1007/s40572-019-00249-1

Kumarathilaka, P., SamanSeneweera, S. SikOk, Y. Meharg, A. & Bundschuh, J. (2019). Arsenic in cooked rice foods: Assessing health risks and mitigation options. *Environment International*, 127, 584-591.

Lai, P., Cottingham, K. Steinmaus, C., Karagas, M. & Miller, M. (2015). Arsenic and rice: Translating research to address health care providers' needs. *The Journal of Pediatrics*, *167*(4), 797–803. https://doi.org/10.1016/j.jpeds.2015.07.003

Layug, M. (2018, October 10). *NFA sets just 4 labels for rice.* GMA News. https://www.gmanetwork.com/news/money/economy/670805/nfa-sets-just-4-labels-for-rice/story/

Liao, N., Seto, E., Eskenazi, B., Wang, M., Li, Y., & Hua, J. (2018). A comprehensive review of arsenic exposure and risk from rice and a risk assessment among a cohort of adolescents in Kunming, China. *International Journal of Environmental Research and Public Health*, *15*(10), 2191. https://doi.org/10.3390/ijerph15102191

Magalona, M., Peralta, M., Lacsamana, M., Sabularse, V., Pelegrina, A. & de Guzman, C. (2019). Analysis of Inorganic Arsenic (As(III) and Total As) and some physicochemical parameters in groundwater samples from selected areas in Bulacan, Batangas, and Laguna, Philippines. *KIMIKA*, *30*(2), 28-38. https://doi.org/10.26534/kimika.v30i2.28-38

Magtibay, B. (2018). *Water Refilling Station: An alternative source of drinking water supply in the Philippines.* https://businessdiary.com.ph/835/water-refilling-station-study/

Majumder, S., & Banik, P. (2019). Geographical variation of arsenic distribution in paddy soil, rice and rice-based products: A meta-analytic approach and implications to human health. *Journal of Environmental Management*, *233*, 184–199. https://doi.org/10.1016/j.jenvman.2018.12.034

Meharg, A.A. and Zhao, F. (2012). *Arsenic & rice*. Springer

Mridha, D., Gorain, P. C., Joardar, M., Das, A., Majumder, S., De, A., Chowdhury, N., Lama, U., Pal, R., & Roychowdhury, T. (2022). Rice grain arsenic and nutritional content during post harvesting to cooking: A review on arsenic bioavailability and bioaccessibility in humans. *Food Research International*, 154, 111042. https://doi.org/10.1016/j.foodres.2022.111042

National Food Authority (2020). https://www.officialgazette.gov.ph/section/briefing-room/department-of-agriculture/national-food-authority-department-of-agriculture/

National Research Council (2001). *Arsenic in drinking water: 2001 update.* National Academy Press.

National Bureau of Agricultural Commodity and Food Standards Ministry of Agriculture and Cooperatives (2010). Thai agricultural standard 9000 part 4 – 2010, Organic agriculture part 4: Organic rice. https://www.acfs.go.th/standard/download/eng/ORGANIC_RICE_part4.pdf

Nguyen, H. P. A., Cu, Y. H., Watchalayann, P., & Soonthornchaikul, N. (2020). Assessing inorganic arsenic in rice and its health risk to consumers in Ho Chi Minh City, Vietnam. *Journal of Health Research*, *35*(5), 402–414. https://doi.org/10.1108/jhr-09-2019-0221

Nuvolone, D., Stoppa, G., Petri, D., & Voller, F. (2023). Long-term exposure to low-level arsenic in drinking water is associated with cause-specific mortality and hospitalization in the Mt. Amiata area (Tuscany, Italy). *BMC Public Health*, *23*(1). https://doi.org/10.1186/s12889-022-14818-x

Nunes, L. S., Li, G., Chen, W., Meharg, A. A., O'Connor, P. J., & Zhu, Y. (2022). Embedded Health Risk from Arsenic in Globally Traded Rice. *Environmental Science & Technology*, *56*(10), 6415–6425. https://doi.org/10.1021/acs.est.1c08238

Rahmanian, N. Ali, S.H., Homayoonfard, M., Ali, N., Rehan, M., Sadef, Y., & Nizami, A. (2015). Analysis of physiochemical parameters to evaluate the drinking water quality in the state of Perak, Malaysia. *Journal of Chemistry*. https://doi.org/10.1155/2015/716125

Ramly, N., Mahir, H. M. A., Azmi, W. N. F. W., Hashim, Z., Hashim, J. H., & Shaharudin, R. (2023). Arsenic in drinking water, hair, and prevalence of arsenicosis in Perak, Malaysia. *Frontiers in Public Health*, *11*. https://doi.org/10.3389/fpubh.2023.998511

Rettner, R. (2013). *Arsenic in rice not a risk over short term, FDA Finds*. http://www.livescience.com/39474-arsenic-rice-fda.html

Rokonuzzaman, M., Li, W. C., Man, Y. B., Tsang, Y. F., & Ye, Z. (2022). Arsenic accumulation in rice: sources, human health impact and probable mitigation approaches. *Rice Science/Rice Science*, *29*(4), 309–327. https://doi.org/10.1016/j.rsci.2022.02.002

See, D. (2020). *NFA assures sufficient rice supply for Baguio, Benguet*. http://www.baguio.gov.ph/content/nfa-assures-sufficient-rice-supply-baguio-benguet

Sharma, A.K., Tjell, J.C., Sloth, J.J. & Holm, P.E. (2014). Review of arsenic contamination, exposure through water and food and low cost mitigation options for rural areas. *Applied Geochemistry*, *41*, 11-33. https://doi.org/10.1016/j.apgeochem.2013.11.012

Shraim, A. (2017). Rice is a potential dietary source of not only arsenic but also other toxic elements like lead and chromium. *Arabian Journal of Chemistry*, *10*, S3434–S3443. https://doi.org/10.1016/j.arabjc.2014.02.004

Signes-Pastor, A. J., Carey, M., & Meharg, A. A. (2016). Inorganic arsenic in rice-based products for infants and young children. *Food Chemistry*, *191*, 128–134. https://doi.org/10.1016/j.foodchem.2014.11.078

Sobel, M. H., Sanchez, T. R., Jones, M. R., Kaufman, J. D., Francesconi, K. A., Blaha, M. J., Vaidya, D., Shimbo, D., Gossler, W., Gamble, M. V., Genkinger, J. M., & Navas-Acien, A. (2020). Rice Intake, Arsenic Exposure, and Subclinical Cardiovascular Disease Among US Adults in MESA. *Journal of the American Heart Association*, *9*(4). https://doi.org/10.1161/jaha.119.015658

Soe, A. M. M., Mu, A. A., & Toyoda, K. (2023). Arsenic and heavy metal contents in white rice samples from rainfed paddy fields in Yangon division, Myanmar—Natural background levels? *PloS One*, *18*(3), e0283420. https://doi.org/10.1371/journal.pone.0283420

States, J.C., Barchowsky, A., Cartwright, I.L., Reichard, J.F., Futscher, B.W. & Lantz, R.C. (2011). Arsenic toxicology: Translating between experimental models and human pathology. *Environmental Health Perspective*. https://doi.org/10.1289/ehp.1103441

Su, L. J., Chiang, T., & O'Connor, S. N. (2023). Arsenic in brown rice: do the benefits outweigh the risks? *Frontiers in Nutrition*, *10*. https://doi.org/10.3389/fnut.2023.1209574

United Nations Food and Agricultural Organization/World Health Organization (UN FAO/WHO) (2011). *Safety evaluation of certain contaminants in food*. Prepared by the sixty-fourth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). FAO Food and Nutrition Paper.

Uppal, J. S., Zheng, Q., & Le, X. C. (2019). Arsenic in drinking water—recent examples and updates from Southeast Asia. *Current Opinion in Environmental Science & Health*, *7*, 126–135. https://doi.org/10.1016/j.coesh.2019.01.004

US Food and Drug Administration (2016). *Arsenic in rice and rice products risk assessment report*. https://www.fda.gov/files/food/published/Arsenic-in-Rice-and-Rice-Products-Risk-Assessment-Report-PDF.pdf

US Food and Drug Administration (FDA) (2014). *Arsenic in rice and rice products*. http://www.fda.gov/food/foodborneillnesscontaminants/metals/ucm319870.htm

Watson, C., & Gustave, W. (2022). Prevalence of arsenic contamination in rice and the potential health risks to the Bahamian population—A preliminary study. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.1011785

World Health Organization International Agency for Research on Cancer (IARC) (2004). Some drinking-water disinfectants and contaminants, including arsenic. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, *84*, 1–19.

World Health Organization (WHO) (2019). *Drinking water*. https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Health Organization (WHO) (2018). *Arsenic.* https://www.who.int/news-room/fact-sheets/detail/arsenic

WHO (2014). *Environmental health criteria, No. 224: Arsenic and arsenic compounds.* http://www.who.int/ipcs/publications/ehc/ehc_224/en/

Yim, S. R., Park, G. Y., Lee, K. W., Chung, M. S., & Shim, S. M. (2017). Determination of total arsenic content and arsenic speciation in different types of rice. *Food Science and Biotechnology/Food Science and Biotechnology*, *26*(1), 293–298. https://doi.org/10.1007/s10068-017-0039-9