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Comparative Analysis of Arsenic Concentration in Tube Well and Deep Boring Water in Ratnanagar

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Abstract

Arsenic contamination in groundwater poses significant health risks. This study investigates arsenic levels in tube wells and deep boring water in Wards 1, 6, and 10 of Ratnanagar Municipality, Nepal, using UV-visible spectrophotometry. The results revealed varying arsenic concentrations, with tube wells in Ward 10 exhibiting higher levels compared to Wards 1 and 6. Deep boring water in Ward 6 showed the highest concentration among the studied ward. Although all the measured concentrations are below the national limit of 50 µg/L (50 parts per billion) adopted by Nepal, India, and Bangladesh, they still exceed the stricter safety limit of 10 µg/L (10 parts per billion) set by the World Health Organization (WHO) for drinking water. These findings highlight the importance of regular monitoring and taking precautions to reduce potential long-term health risks.

Keywords: *Arsenic, UV-visible spectrophotometry, groundwater, tube wells, deep boring water, Ratnanagar Municipality*

Introduction

Arsenic, As is a natural component of earth's crust and a metalloid which consist of both non-metal and metal properties. It is also recognized as a toxic heavy metal. Arsenic exhibits four oxidation states; 0(arsenic), +3(arsenite), -3(arsine) and +5(arsenate) due to its complex chemical properties (Issa et al.,2010). Arsenic forms a wide range of compounds categorized as organic and inorganic arsenic compounds. Through biomethylation process, various organisms like humans and shellfish produce organic arsenic which is considered as less toxic than inorganic arsenic. Arsanilic acid, arsenobetaine, methylarsonic are the common organic arsenic compounds. Inorganic arsenic exists in nature in trivalent form As (+3) and pentavalent form As(+5). The most common trivalent compounds are arsenic trioxide, arsenic trichloride and sodium arsenite while arsenates (eg: Calcium arsenate and lead arsenate), arsenic pentoxide and arsenic acid are pentavalent compounds. As we know, arsenic naturally exists in soil, water, atmosphere and numerous minerals like arsenopyrite, orpiment and realgar (Atsdr, 19970. Weathering of rocks, volcanic emission and breakdown of organic matter are natural sources of arsenic whereas anthropogenic includes smelting of non-ferrous metals, mining, burning of fossil fuel and use of arsenic-containing fertilizers. (Smedley & Kinniburgh, 2002). When arsenic comes in contact with the environment it cannot be easily damaged whereas in contact with oxygen or molecules and bacteria present in natural resources, it can attach or detach from different particles or can cause to change their form. One of the routes whereby arsenic gets into the human body is inhalation. The workers are exposed to arsenic fumes and dust from the industries of smelting, chemical manufacturing, arsenic-containing ore and glassmaking (Lu, 1990). Residents who live close to industrial sites or volcanoes may be exposed to arsenic in the air, which can cause breathing issues. Arsenic exposure in the air typically ranges from 0.4 to 30 ng/m3. The US Environmental Protection Agency (EPA) estimates daily human arsenic inhalation at 40-90 ng, while in unpolluted areas, it's around 50ng or less (Mitra et al., 2020). People can also be exposed to airborne arsenic who inhale smoke from burning arsenic-treated wood or tobacco and tobacco plants can absorb arsenic from the soil. Another route is ingestion. Food is a less significant source of arsenic exposure compared to contaminated groundwater. Seafood contains less toxic organic arsenic than fish, meat and poultry. Rice is of particular concern due to its widespread consumption. Studies show that food imported from Bangladesh had higher arsenic concentration compared to that grown in the UK and North America (Al Rmalli et al., 2005). Children can become exposed to arsenic by ingesting small amounts of contaminated soil or dust especially for small children, in houses constructed on or close to arsenic-contaminated sites. Water being a priceless natural resource and vital for life, it covers 71% of Earth's surface, with 97% saline and 3% freshwater (Sampat & Peterson, 2000). Surface water includes freshwater from lakes, ponds, rivers and streams as well as saltwater from oceans. Humans consume 80% of surface water, which supports both life and ecological systems. Surface water near industrial sites or natural arsenic deposits can be contaminated with arsenic, leading to health risks through ingestion (Piel et al., 2012). Rainwater is the purest form of soft and arsenic free water which is collected from rain or rooftops with minimal dissolved solids (0.005%) (Campisano et al., 2017). Sulfur and nitrogen oxides can pollute rainwater, causing acid rain in industrial regions, but it remains a drinking water source in tropical regions like Australia and Africa (Chubaka et al., 2018). Groundwater is water found beneath the Earth's surface which is stored in soil or rock formations and a crucial resource for drinking, agriculture and industry, accessed through wells and springs. Groundwater often contains high levels of natural arsenic, leading to health risks in humans. Arsenic enters groundwater through processes like geothermal release and leaching from sulfide bicarbonates, description from oxides and hydroxides and oxidation of arsenic-bearing sulfides, affecting millions of people globally who rely on wells and springs supplied by aquifers.

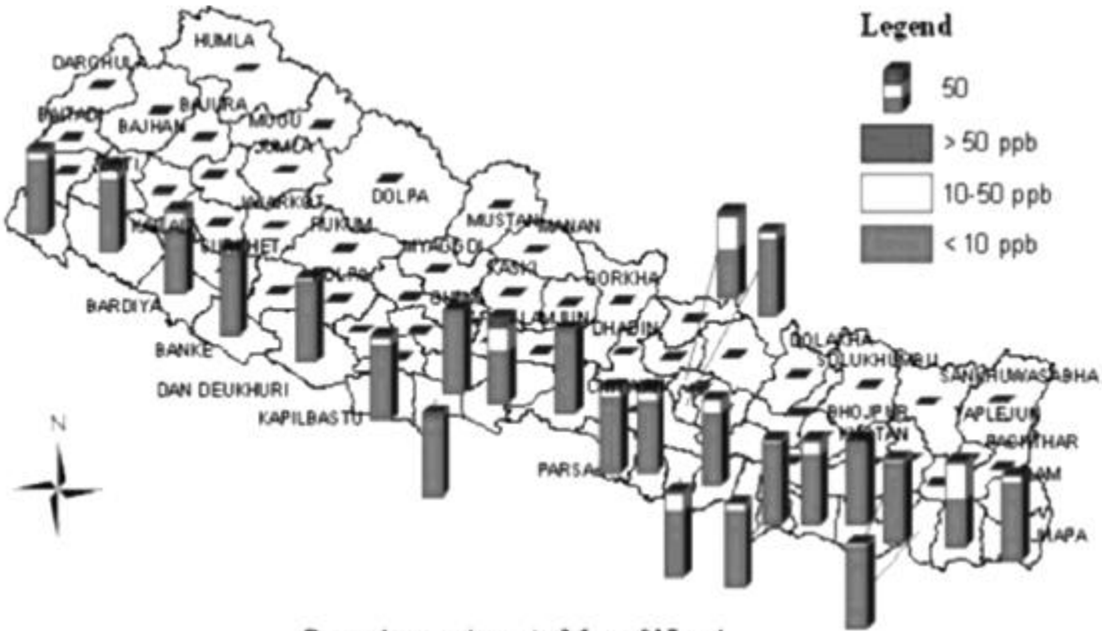
Every country has different acceptable levels of arsenic in drinking water based on local conditions. The WHO lowered the recommended level in drinking water from 50µg/L in 1963 to 10µg/L in 1992 due to cancer risk (WHO, 2002). Countries like Bangladesh, India, Nepal, Great Britain, Russia, Korea and Taiwan are 0.05mg/L whereas Japan, Germany, Australia and USA have set 0.01mg/L as their standard.

Agency/Country	**Maximum contamination level (mg/L)**
Nepal	0.05
India	0.05
Bangladesh	0.05

Germany	0.01
Canada	0.025
Japan	0.01
Australia	0.01
China	0.03
Great Britain	0.05
Russia	0.05
Korea	0.05
Tiawan	0.05
United States	0.01
WHO	0.01

Table 1. Arsenic acceptable level set by various regulatory agencies and countries (Shrestha et al., 2014).

In 1999, WHO discovered arsenic in groundwater in Nepal's Terai district. Various organizations and individuals studied the concentration of arsenic in groundwater samples from 25 districts of Nepal which is shown in figure (1). The southeastern and southwestern regions near the Indian border were found to have high arsenic contents, exceeding 50µg/L highlighting a critical issue in these areas and required urgent analysis, mitigation and removal of arsenic from groundwater.



Groundwater Arsenic Map of Nepal

Figure 1: Groundwater arsenic distribution map of Nepal, highlighting the percentage of arsenic contaminated samples across different districts of Nepal. (Shrestha et al., 2014).

The districts of Iiam, Jhapa, Morang, Udayapur, Mahottari, Parsa, Kathmandu, Lalitpur, Chitwan, Palpa, Dang, and Bardiya have low levels of arsenic, so arsenic pollution is not a big problem there (Figure 2)

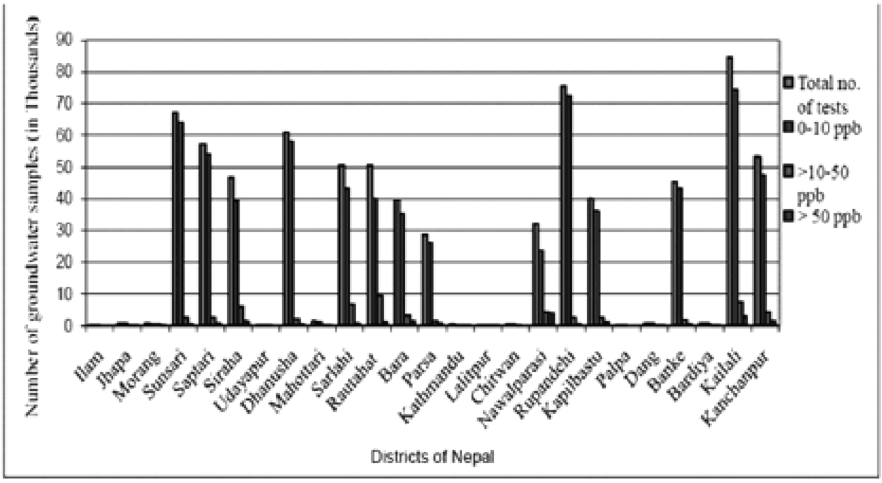


Figure 2: Total arsenic levels in groundwater samples from various districts in Nepal (Shrestha et al., 2014).

Districts like as Sunsari, Saptari, Nawalparasi, Siraha, Dhanusha, Rautahat, Bara, Rupandehi, Kapilvastu, Banke, Kailali and Kanchanpur reported arsenic levels ranging from 10–50 µg/L, with some exceeding 50 µg/L. Nawalparasi had the highest concentrations, while districts like Ilam, Palpa, and Chitwan had lower levels. Overall, 89.8% of samples had arsenic levels below 10 µg/L, 7.9% between 10–50 µg/L, and 2.3% above 50 µg/Land areas with higher concentrations require regular monitoring and improved strategies to address arsenic contamination and its health impacts. From the above data, Chitwan has a minimum concentration of arsenic. So, from this study, we found out water is yellow in colour which indicates the presence of arsenic. We collect the water samples from tube wells and deep bored in Ratnanagar municipality, Chitwan. It reacts with oxygen to form arsenic trioxide and pentoxide, and with metals to form arsenides. Arsenic is stable in dry form but tarnishes in humid air and emits a garlic-like odor when heated.

Arsenic is a naturally occurring substance and a p-block element with the symbol As, atomic number 33 having electronic configurations [Ar] 3d10 4s2 4p which is located in Group 15(V) of the periodic table. Arsenic can dissolve in water and occurs in four oxidation states: 0, +3, -3 and +5. Chemical reactions most commonly occur in the +3 and +5 oxidation states (WHO, 2001). Arsenic exists in three primary forms: grey, yellow, and black while grey being the most prevalent one. Yellow arsenic is the most toxic and turns into grey arsenic when exposed to light (Norman, 1997). It reacts with oxygen to form arsenic trioxide and pentoxide, and with metals to form arsenide. Arsenic is stable in dry form but tarnishes in humid air and emits a garlic-like odor when heated (National Research Council et al., 1977).

While speaking about the effects of arsenic, firstly we should be aware of arsenic poisoning and its consequences. Excessive intake or inhalation of arsenic can result in arsenic poisoning. Over 230 million people globally are currently impacted by arsenic toxicity. Those countries that are exposed to contaminated drinking water may contain high levels of arsenic and these countries include Bangladesh, Nepal, China, India, United States, Thailand, Mexico, etc. (Bhat et al., 2023). Acute and chronic poisoning are two major forms of arsenic poisoning. When a toxic substance is exposed for a short period of time, it causes acute poisoning, and their symptoms may appear within minutes to hours. Long-term low-level exposure to a toxic substance can cause chronic poisoning with symptoms appearing gradually, often taking weeks to years. Often acute and chronic poisoning shows similar or dissimilar effects on the human body. Acute arsenic ingestion commonly causes gastrointestinal symptoms like nausea, vomiting, abdominal discomfort, and diarrhea, leading to fluid loss and hypotension. These symptoms can last from a few days to longer and may include weight loss and dehydration. Chronic arsenic ingestion can damage the liver, causing toxic hepatitis raising liver enzyme levels and cirrhosis. Consuming arsenic overtime may result in portal hypertension near the liver without cirrhosis. Long-term exposure has been linked to an increased risk of liver cancer. Chronic arsenic exposure usually leads to skin lesions such as hyperpigmentation and hyperkeratosis often appears on the neck, chest, back, arms, eyelids, armpits, palms and soles. These skin lesions may appear at lower exposure levels than those that lead to other health problems like neuropathy or anemia, but they will gradually develop over time. Both acute and chronic arsenic exposure can affect cardiovascular systems. Chronic exposure does not appear to have a significant association with peripheral vascular disease, hypertension or cardiovascular disease. The severity of acute arsenic poisoning is dependent on the result in diffuse capillary leakage, cardiomyopathy and shock. Long-term exposure to arsenic can cause a variety of neurological symptoms including peripheral and autonomic neuropathy which is an early indicator of arsenic poisoning. Early symptoms include numbness, tingling or pain in the hands and feet, with more signs like muscle cramps, sweating, weakness and spontaneous pain may appear within 7-14 days and paralysis in severe poisoning. Arsenite and arsenate are the neurotoxic forms. Breathing in high amounts of arsenic can irritate the respiratory systems causing respiratory problems like airway irritation, pulmonary edema, bronchitis, pneumonia, nasal septum damage and chronic lung diseases in addition to digestive problems like vomiting, diarrhea and abdominal pain. Exposure to arsenic has been associated with decreased fertility, increased risk of miscarriage, birth abnormalities and development issues in children. It can cross the placenta with similar levels in the baby and mother. One case reported an infant's death shortly after birth due to high arsenic levels. In severe case of arsenic exposure, it can cause renal effects such as acute renal failure, acute tubular necrosis and kidney damage, leading to reduced kidney function, proteinuria, and chronic kidney disease. Arsenic is less toxic to the kidneys than arsine gas. Across the world, drinking water is heavily contaminated with inorganic arsenic, a known carcinogen. Chronic arsenic exposure causes strong association with cancers of bladder, lung, and skin while weaker with liver and kidney. Skin cancer risk in humans is associated with chronic exposure to inorganic arsenic, particularly through contaminated drinking water or certain workplace and arsenic-related skin cancer includes basal cell carcinoma, squamous cell carcinoma, and possibly melanoma. Exposure of inorganic arsenic can lead to a higher risk of developing lung cancer. Workers exposed to arsenic trioxide or pentavalent arsenical pesticides face a higher risk of lung cancer commonly from contaminated water, industrial processes, or food grown in contaminated soil. Prolonged ingestion of arsenic-containing drinking water is associated with an increased risk of bladder cancer which damages the cells. Long-term drinking water arsenic exposure raises the risk of liver cancer by altering gut microbes and damaging DNA. Kidney cancer, also known as renal cancer, is caused due to the high exposure of arsenic in drinking water and environmental contamination. The common type is renal cell carcinoma with symptoms of blood in the urine, back pain and weight loss (Hong et al., 2014).

To remove arsenic, regularly test water and soil and use treatments like reverse osmosis and avoid planting in contaminated areas. Implement strict regulations and enforce the use of personal protective equipment (PPE) for workers and regularly monitor workplace environments for arsenic exposure. Inform locals about the dangers of arsenic and safe measures to take, such as testing and treating water and promoting routine health examinations for those who may be at risk. Set rules for safe arsenic levels in water, soil, food, and air, and make sure to enforce these rules and address any violations quickly. Support research and provide funding to create better ways to detect and remove arsenic, on its health impacts and control methods. Clean up polluted sites using methods like washing soil, using natural processes to break down contaminants, and stabilizing the area. Using bottled water while traveling can be a wise move, particularly in places where the quality of the local water may be in doubt. Following environmental regulations when disposing of arsenic containing waste to prevent contamination and health risk. Use low-arsenic sources, such as treated surface water and rainwater, rather than high-arsenic groundwater to reduce arsenic exposure.

Rationale of the Study

Access to safe drinking water is essential for maintaining public health. Arsenic contamination in water is a serious environmental and health issue, especially in areas where groundwater sources like tubewells are widely used. In Nepal, particularly in the Terai region, arsenic contamination has been reported. However, there is limited research comparing arsenic levels in different water sources.

This study focuses on comparing the arsenic concentration in tubewell water and deep boring water, which are the main sources of drinking water in Ratnanagar, Chitwan. Arsenic is a harmful element that can cause severe health problems over time, such as cancer, heart diseases, and developmental disorders. Understanding the levels of arsenic in these water sources can help design better public health strategies and inform policy decisions.

Tubewell water directly draws from groundwater, which can have varying levels of arsenic depending on the geology of the area. On the other hand, deep boring water is often treated or sourced differently. Comparing these two water sources can reveal how effective water treatment systems are and how safe untreated groundwater is for consumption.

Ratnanagar wards 1, 6, and 10 in Chitwan are areas where both tubewell and deep boring water are commonly used. Identifying arsenic contamination in these areas can help evaluate local risks and guide solutions tailored to the community's needs. This study provides important baseline data on arsenic contamination in these water sources. Such data can assist local authorities and policymakers in creating targeted plans to improve water quality and protect public health.

Additionally, the study contributes to the scientific knowledge of arsenic distribution in Nepal's water sources. It fills a gap in the existing research and encourages further studies on water quality and its impact on health. By comparing arsenic levels in these two key water sources, the study highlights potential risks and emphasizes the need for regular monitoring and effective water management practices in the region.

Materials and Methods

Study Area

The study was conducted in Wards 1, 6, and 10 of Ratnanagar Municipality, Chitwan District, Nepal. Water samples were collected from tube wells and deep borings in these wards.

Sample Collection and Preparation

Water samples were collected in clean polyethylene bottles and filtered using Whatman filter paper. Samples were treated with potassium iodide (KI) and stannous chloride (SnCl2) to reduce arsenate to arsenite before analysis.

Analytical Method

The Molybdenum Blue Method was used to determine arsenic concentration. Ammonium molybdate and ascorbic acid reagents were added to the samples to form a blue-colored complex. Absorbance was measured at 880 nm using a UV-visible spectrophotometer. A calibration curve was constructed using standard arsenic solutions (10–50 µg/L).

Results

Tube Well Water

Arsenic concentrations in tube well water varied across the wards. Ward 10 exhibited the highest levels, with concentrations ranging from 11.36 to 24.95 µg/L. Wards 1 and 6 showed lower concentrations, ranging from 10.10 to 15.29 µg/L and 11.95 to 16.81 µg/L, respectively.

Deep Boring Water

Deep boring water in Ward 6 had the highest arsenic concentration (16.97 µg/L), followed by Ward 1 (16.51 µg/L) and Ward 10 (15.08 µg/L).

Discussion

The findings indicate that arsenic levels in tube well water are generally higher than in deep boring water, consistent with previous studies. The highest concentrations were observed in Ward 10 tube wells, likely due to localized geological factors. Although all concentrations were below the national permissible limit of 50 µg/L, prolonged exposure even at lower levels can pose health risks.

Conclusion and Recommendations

This study highlights the presence of arsenic in groundwater sources in Ratnanagar Municipality. While current levels are within safe limits, regular monitoring and public awareness campaigns are essential to prevent potential health impacts. The Molybdenum Blue Method proved to be a cost-effective and reliable technique for arsenic analysis. Future research should focus on long-term monitoring and the implementation of arsenic mitigation strategies, such as using alternative water sources or arsenic-removal technologies.

Table 2- Calibration curve for the determination of amount of arsenic

S.N.	Concentration(μg/L)	Absorbance
1	10	0.001
2	20	0.002
3	30	0.003
4	40	0.004
5	50	0.005

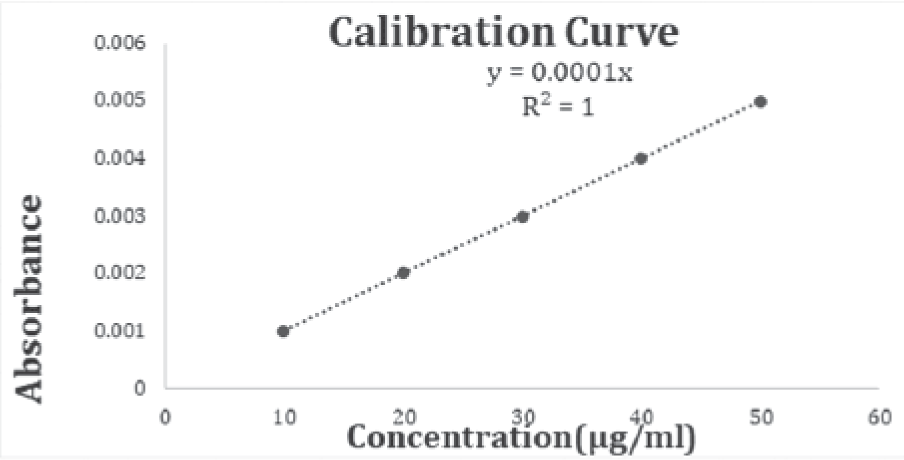


Figure 3. Calibration curve for arsenic analysis by UV-Visible spectrophotometric technique

Table 3. Concentration of arsenic in water (Tube wells) of Ward-1, Ratnanagar Municipality

S.N.	Water Sample	Absorbance	Concentration
1	W_1S_1	1.232	12.32
2	W_1S_2	1.246	12.46
3	W_1S_3	1.529	15.29
4	W_1S_4	1.478	14.78
5	W_1S_5	1.010	10.10
6	W_1S_6	1.048	10.48

7	W_1S_7	1.463	14.63
8	W_1S_8	1.342	13.42
9	W_1S_9	1.178	11.78
10	W_1S_{10}	1.180	11.80

Table 4. Concentration of arsenic in water (Tube wells) of Ward-6, Ratnanagar Municipality

S.N.	**Water Samples**	**Absorbance**	**Concentration**
1	W_6S_1	1.681	16.81
2	W_6S_2	1.345	13.45
3	W_6S_3	1.313	13.13
4	W_6S_4	1.401	14.01
5	W_6S_5	1.448	14.48
6	W_6S_6	1.430	14.30
7	W_6S_7	1.246	12.46
8	W_6S_8	1.656	16.56
9	W_6S_9	1.195	11.95
10	W_6S_{10}	1.661	16.61

Table 5. Concentration of arsenic in water (Tube wells) of Ward-10, Ratnanagar Municipality

S.N.	**Water Samples**	**Absorbance**	**Concentration**
1	$W_{10}S_1$	1.136	11.36
2	$W_{10}S_2$	1.263	12.63
3	$W_{10}S_3$	2.495	24.95
4	$W_{10}S_4$	1.158	11.58
5	$W_{10}S_5$	1.225	12.25
6	$W_{10}S_6$	1.324	13.24
7	$W_{10}S_7$	1.155	11.55
8	$W_{10}S_8$	2.198	21.98
9	$W_{10}S_9$	2.347	23.47
10	$W_{10}S_{10}$	1.237	12.37

Table 6. Concentration of arsenic in water (Deep boring) of Ward-(1,6,10), Ratnanagar Municipality

S.N.	Ward No	Water samples	Absorbance	Concentration
1	1	W_oS_1	1.651	16.51
2	6	W_oS_6	1.697	16.97
3	10	W_oS_{10}	1.508	15.08

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