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Current Status and Technologies for Treating Groundwater Arsenic Pollution in Bangladesh

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방글라데시 지하수 내 비소 오염 현황 및 처리기술

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Abstract

Arsenic (As) contamination in groundwater is one of the main problems in Bangladesh. As toxicity causes serious human health problems such as edema, skin cancer, bladder cancer, lung cancer, hyperkeratosis, premature birth, and black foot disease. As contamination in groundwater mainly originates from the geological characteristics of the area due to the influence of anthropogenic activities. Since most of the people in Bangladesh rely on tube well for drinking water, it is necessary to investigate the current status of As pollution and identify the treatment technologies that can be used to provide arsenic-free drinking water in water-scarce areas. A total of 92 papers were reviewed in this study to present a complete overview of the recent status of groundwater As contamination in Bangladesh and different low-cost remediation technologies. A method for evaluating the relative feasibility of different treatment technologies was also utilized to determine the most appropriate technologies for groundwater As treatment in Bangladesh. The districts with the highest groundwater As contamination include Brahamanbariya, Tangail, Barisal, Pabna, Patuakhali, Kurigram, Magura, and Faridpur, with concentrations exceeding 0.05 mg/L. Only six districts had relatively low groundwater arsenic concentrations (0.01 mg/L), including Kushtia, Khagrachari, Jessore, Dinajpur, Meherpur, and Munshiganj. There were a number of technologies used for treating As in water, but aerated electrocoagulation, Mg-Fe-based hydrotalcite-like compound, and electro-chemical As remediation (ECAR) reactor were found to be the most feasible treatment methods for As. Overall, the investment, operational, and maintenance costs, availability of materials, and expertise requirements should be considered when selecting the most appropriate treatment method for As in water.

Key words : Arsenic, Bangladesh, groundwater, water treatment

요 약

지하수의 비소(As) 오염은 방글라데시의 주요 문제 중 하나이다. 독성은 부종, 피부암, 방광암, 폐암, 각화 과다증, 조산, 흑사병과 같은 심각한 건강 문제를 야기한다. 지하수의 오염은 주로 인위적 활동의 영향을 받는 지역의 지질학적 특성에서 발생된다. 방글라데시 국민의 대부분이 지하수에 식수를 의존하고 있기에 비소 오염 현황을 조사하고 물이 부족한 지역에 안전한 식수를 제공하기 위하여 비소 처리를 위한 수처리 기술이 필요하다. 따라서 본 연구는 92개의 논문을 기반으로 방글라데시의 지하수 As 오염 관련 최근 현황과 다양한 저비용 정화 기술에 대한 트렌드를 조사하였다. 방글라데시에서 지하수 비소 오염이 가장 높은 지역은 Brahamanbariya, Tangail, Barisal, Pabna, Patuakhali 및 Kurigram등 총 4곳이며,

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Magura 및 Faridpur 등의 지역에서는 비소 농도가 0.05mg/L를 초과한다. WHO 표준 가이드라인 값(<0.01 mg/L)을 만족하는 지역은 Kushtia, Khagrachari, Jessore, Dinajpur, Meherpur 및 Munshiganj 등 총 6곳으로 나타났다. 수중에서 As를 처리하는 기술이 다양하다. 시간-비용효율적인 처리 방법은 Mg-Fe계 Hydrotalcite와 유사 화합물, electro-chemical As remediation (ECAR) reactor, aerated electrocoagulation 등이 적용되고 있다. 전반적으로 예산, 운영 및 유지 관리 비용, 재료의 가용성 및 전문 지식 요구 사항 등을 고려하여 수질 내 비소를 처리해야 한다.

핵심용어 : 비소, 방글라데시, 지하수, 수처리

1. Introduction

Arsenic (As) is found in fluid media. It mainly exists in the oxidation states, such as Arsenite and, Arsenate, as a factor of natural phenomenon or anthropogenic-mediated factors. As was first detected in Bangladesh's groundwater in the year 1993 (Dhar et al., 2021). As toxicity has no recognized feasible treatment; however, lowering the As concentrations in the water remains crucial in preventing its adverse effects on human health. The groundwater in Bangladesh contains natural As, with concentrations mostly surpassing 0.01 mg/L. As is a naturally occurring crystalline metalloid (Chakraborty et al., 2015). It is a toxic substance that can cause physiological disorders including edema, skin cancer, bladder cancer, lung cancer, hyperkeratosis, premature birth, and black foot disease. As toxicity poses a global challenge since a large population relies on groundwater for drinking purposes. The United States of America, the European Union (EU), and the World Health Organization (WHO) set 0.01mg/L as the limit of As concentration in drinking water (Jiang et al., 2012). As is found in natural water in the inorganic forms of arsenite (trivalent As) and arsenate (pentavalent As). These substances are considered toxic since they can be deposited in body tissues and fluids. Before tube wells, people in Bangladesh mainly relied on surface water resources, such as rivers, canals, lakes, and hand-made reservoirs like ponds and wells (Kabir et al., 2021). According to the World Health Organization (WHO), the elevated levels of As contamination in groundwater poses great risks to human health. A number of countries, including Argentina, Chile, China, India, Mexico, and the United States of America, also reported high amounts of inorganic As in groundwater. Human exposure to As are usually derived from the consumption of contaminated drinking water, crops irrigated with polluted water, and food cooked with contaminated water. Bangladesh is a developing country that mostly relies on groundwater for potable uses and thus, this study was conducted to determine the current status of groundwater As pollution in the country. Various treatment technologies were also compiled to identify the most feasible techniques that can be employed to reduce the risks of As-contaminated water in Bangladesh.

2. Materials and Methods

2.1 Study Area

Bangladesh is located in the eastern part of the South Asian sub-continent. It is surrounded by the Indian states of West Bengal and Meghalaya. In the east, it is bounded by the state of Rakhine (Myanmar). It has a total land area of 147,620 km^2 and a population of approximately 160,000,000 (Bangladesh Bureau of Statistics, 2011). The majority of the regions belong to low-lying areas which are usually subjected devastating floods. Surface water and groundwater are the two major water resources in Bangladesh (Chakraborty et al., 2010). It has eight major administrative units, referred to as divisions, namely Dhaka, Barisal, Comilla, Maymansing, Khulna, Rajshahi, Rangpur, and Sylhet. These divisions are subdivided into 64 districts with 495 sub-districts and 12 city corporations. In the south, the country is bordered by the Bay of Bengal, and some of the parts are large mangrove forests known as (Chowdhury et al., 2017). The climate of the country is humid and warm with pre-monsoon, monsoon, and post-monsoon seasons. The average temperature is 26 °C, but the temperature may fluctuate from 15 °C to 34 °C throughout the year. Annual rainfall depth varies from 1194 mm to 3454 mm (Hossain et al., 2020). In general, it experiences frequent heavy precipitation and cyclones. it has split into three geotectonic regions including Northwest Stable Shelf, Center Foredeep Basin, and East Folded Flank. Geomorphologically, groundwater can be found in four major areas: tableland, deltaic coastal area, flood plain, and hill tract (Chakraborty et al., 2010).

In this study, a collection of scientific publications was utilized to assess the degree of groundwater As contamination in Bangladesh. Using a standard engine search using the keywords "groundwater" and "arsenic," publications from 1960 to the query date (April 1, 2022) were retrieved. The search results were filtered to only include publications classified as articles published by authors from Bangladesh. The data from the 42 scientific articles retrieved from the query were summarized

Fig 1. Areas in Bangladesh covered by the review

to assess the current status of groundwater As pollution in Bangladesh. Moreover, various treatment technologies for the removal of As in water were compiled to assess their feasibility of application in Bangladesh. The areas covered by the review were shown in Figure 1 and the characteristics of each area were summarized in Table 1.

2.2 Evaluation of the Feasibility of Various Treatment Processes

A method for determining the relative feasibility of various As treatment processes were utilized to systematically select the most feasible option for treating As in the groundwater of Bangladesh. Using the removal efficiency and treatment cost as the evaluation criteria, the items were categorized as highly feasible (high), moderately feasible (moderate), and not feasible (low). The data collected from scientific publications were standardized using Equation 1 and the items were rated according to their feasibility of application in Bangladesh.

$$E = \left(\frac{H-L}{n}\right) \quad (1)$$

Where: E = increment or range
n = 3, to represent the number of categories
H = highest observed value
L = lowest observed value

Table 1. Characteristics of the study areas

Site no.	Location	Population*	Geological formation**
1	Khulna	1,476,090	Deltaic deposits
2	Comilla	5,387,288	Alluvial deposit
3	Manikgang	1,392,867	Alluvial deposit
4	Naraynganj	1,572,386	Marsh clay and peat a and Alluvial deposits
5	Kushtia	2,366,811	Deltaic deposits
6	Faridpur	472,366	Marsh clay and peat and Deltaic deposits
7	Shatkhira	113,322	Deltaic deposits
8	Dhaka	21,741,090	Madhupur clay and Alluvial deposits
9	Rangpur	2,881,086	Barind Clay
10	Noakhali	3,108,083	Deltaic and Alluvial deposits
11	Jessore	201,796	Marsh clay and peat, and Deltaic deposits
12	Magura	918,419	Marsh clay and peat, and Deltaic deposits
13	Sylhet	554,535	Marsh and peat, Alluvial fan,Alluvial,Tertiary and quaternary
14	Kurigram	2,069,273	Alluvial fan and Alluvial deposit
15	Madaripur	1,165,952	Deltaic and Alluvial deposits
16	Munshiganj	1,445,660	Alluvial deposit
17	Khagrachori	47,278	Tertiary and quaternary
18	Chadpur	159,021	Deltaic deposits
19	Brahamanbariya	2,840,498	Marsh clay and peat and Alluvial
20	Pabna	144,442	Marsh clay and peat and Alluvial
21	Barishal	355,967	Deltaic deposits
22	patuakhali	316,462	Deltaic deposits
23	Netrokona	2,229,642	Marsh and peat
24	Sherpur	332,825	Marsh and peat , Alluvial fan
25	Meherpur	655,392	Deltaic deposits
26	Cox's bazar	1,773,709	Beach and dune sand
27	Bogra	400,983	Alluvial deposits
28	Tangail	3,605,083	Madhupur clay
29	Pirojpur	1,113,257	Deltaic deposits
30	Dinajpur	2,990,128	Barind clay

* Population data from the Bangladesh Bureau of Statistics (BBS)
** Geological information from Hossain et al., 2020

3. Results and Discussion

3.1 As levels in different areas of Bangladesh

The groundwater deposits of Bangladesh are connected to the main geomorphological features, such as Branch let hills, Pleistocene highlands, and Holocene plains (Harvey et al., 2005). The mean As concentrations in different districts of Bangladesh were shown in Figure 2. Natural processes (i.e. dissolution of As-containing bedrock minerals), anthropogenic activities (i.e. percolation of water from mines and agricultural chemicals), and geomorphological components (i.e. Holocene sediment deposits are the main sources of As in the groundwater) are considered as the potential sources of As in Bangladesh. Among the 30 districts included in the study, eight districts, including Brahamanbariya, Tangail, Barisal, Pabna, Patuakhali, Kurigram, Magura, and Faridpur have As concentrations greater than guideline values for drinking water in Bangladesh (0.05 mg/L). Approximately 26% of the investigated districts were found to have groundwater As concentrations ranging from >0.05 to 0.16 mg/L. As illustrated in Figure 2, only the districts of Kushtia, Khagrachari, Jessore, Dinajpur, Meherpur, and Munshiganj have As concentrations of between WHO guideline 0.01 mg/L, indicating that the groundwater from these areas are safe for consumption. The low arsenic concentration in these districts can be attributed to the low liquefaction rates of As-containing minerals and low anthropogenic activities.

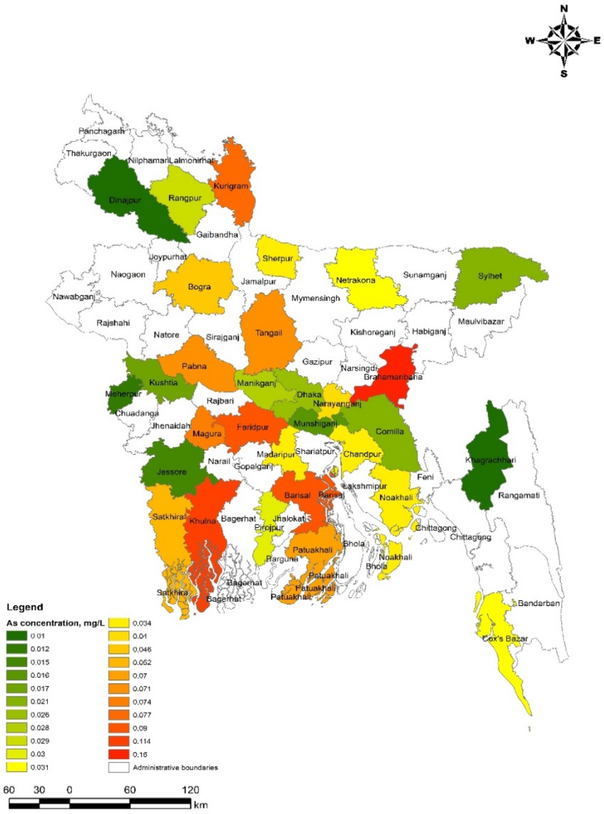

Fig 2. As concentrations in different areas of Bangladesh

3.2 Groundwater As concentrations in different countries

Environmental management techniques and regulations differ among countries. The groundwater As concentrations reported in different countries were summarized in Table 2. Currently, US Environmental Protection Agency (USEPA) and the World Health Organization jointly set the limit of safe arsenic concentration in water to 0.01 mg/L. Among the examined scientific publications, the highest concentration of As (0.757 mg/L) was found in the Republic of Korea (Hanam Area, South Gyeongsang). This high concentration of As was attributed to the high desorption rates under low pH conditions and high anthropogenic activities (Ahn et al., 2012). From the compilation of studies conducted in South Korea, the lowest As concentration, amounting to 0.024 mg/L, was found in Geumsan. In the USA, studies revealed that some cases of cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate can be linked to chronic As exposure. Due to the potential harmful effects of As, the USEPA set the arsenic threshold in drinking water to 0.01 mg/L in order to prevent or minimize the harmful effects of chronic As exposure in humans (Hoover et al., 2017). Moreover, in the USA, elevated groundwater As concentration can be attributed to the influence of industrialization, anthropogenic activities, and geothermal processes (Gonzalez-Horta et al., 2015). The highest As concentration (0.11 mg/L) was found in Florida, whereas the lowest was recorded in South California (0.026 mg/L). The current EU drinking water limit for arsenic is also set at 0.01mg/L. According to the investigation, nearly 98 percent of the samples obtained by the European Food Safety Authority revealed arsenic levels that were below this limit (Meharg et al., 2008). In the European region, it was recognized that As pollution in groundwater was due to the geogenic and hydrothermal systems, which mainly dominate bedrock and volcanic sediments (Medunic et al., 2020). In the United Kingdom, the highest As concentration was found in Cornwall (0.023 mg/L), whereas in Germany, the highest As concentration was found in Neiderfrauendorf (0.187 mg/L). The Australian suitable drinking water restriction has been also set to 0.01mg/L. The Guidelines went through a series of revisions to ensure the appropriate limit of As in the guidelines for safe drinking water (Hrudey, 2019). In Australia, the high As concentration was attributed to the geogenic processes of volcanic eruption, pedogenesis, and forest fire, which presented ancient sedimentary materials. On other hand, low concentrations of As was caused by the absence of desorption processes like pyrite oxidation and the ascendant of pH (Medunic et al., 2020). The Japanese Water Supply Law and Ordinance presently restricts the allowable As concentration in drinking water to less than 0.01 mg/L (Sawada et al., 2013). In the case of Japan, As concentration is relatively controlled as shown by the low As concentrations (0.004 mg/L to 0.038 mg/L). The main factors resulting to low As concentrations were the low anthropogenic activities, auspicious geological characteristics, and developed groundwater guidelines (Hossain et al., 2016). China was considered one of the countries with a high rate of As contamination and they set their drinking standard As concentration value of 0.05mg/L.This can be attributed to the hydrolysis of Fe (Hydroxides) and high alkaline environments (He et al., 2020). In the case of Bangladesh, As pollution continues to be a major issue due to the influence of industrial activities and high rates of pesticide use. Soil erosion from tablelands generally transports heavily As contaminated soils. As can leach from the soils and reach the groundwater table, thus polluting the groundwater (Please change to (Harvey et al., 2005). The British Geological Survey (BGS) reported that the groundwater in Bangladesh is highly contaminated with As. Due to the extreme levels of As in the groundwater, the WHO approved the As limit of 0.05 mg/L for drinking water in Bangladesh. The highest As concentration was observed in Brahamanbaria (0.16 mg/L), whereas the lowest value (0.011mg/L) was recorded in Dinajpur. In comparison

Table 2. Groundwater As concentrations in different countries

Country	Drinking-Water Standard Limit As (mg/L)	As concentration (mg/L)	Reference
South Korea	0.01	0.024	Ahn et al., 2012
		0.026	Kim et al., 2021
		0.036	Mani et al., 2021
		0.757	Kim et al., 2020
USA	0.01	0.11	Missimer et al., 2018
		0.026	Haugen et al., 2021
		0.042	Zheng et al., 2013
		0.041	Hoover et al.,2017
UK	0.01	0.015	Polya et al., 2017
		0.023	Middlenton et al., 2016
		0.011	Crabbe et al., 2017
		0.016	Olszewska et al., 2017
Germany	0.01	0.012	Maier et al., 2017
		0.187	Feistel et al., 2016
		0.042	Houbenet al., 2019
		0.051	Glodowskaet al., 2020
Australia	0.01	0.30	Medunić et al., 2020
		0.013	Hose et al., 2016
		0.051	Hartland et al., 2015
		0.0023	Prommer et al., 2018
Japan	〈 0.01	0.004	Hossain et al., 2016
		0.001	Thuyet et al., 2016
		0.011	Hossain et al., 2016
		0.034	Wang et al., 2021
China	0.05	0.038	He et al., 2020
		0.021	Zhou et al., 2017
		0.029	Wei et al., 2021
		0.003	Zhang et al., 2020
Bangladesh	0.05	0.16	Ganguli et al., 2021
		0.011	Howladar et al., 2018
		0.091	Saha et al., 2020
		0.071	Uddin et al., 2018
		0.074	Rahman et al., 2021

with other countries, Bangladesh exhibited relatively higher concentrations of As in groundwater, indicating that groundwater As pollution in Bangladesh remains a serious problem. Furthermore, elevated levels of As in Bangladesh highlighted the need for improving the current environmental management schemes in Bangladesh. This can be achieved by formulating guidelines derived from other countries with known effective As management policies.

3.3 Remediation processes involved in various technologies for treating As in water

The major remediation processes involved in the removal of As in water oxidation, coagulation, precipitation, filtration, adsorption, membrane, bio-remediation, and ion exchange. Some of the existing technologies present a combination of several As remediation technologies. Oxidation includes changing trivalent As to pentavalent As. Oxidation induces the formation of Oxy-anions to simplify other processes involved in various remediation technologies. After oxidation, As can be removed through the adsorption, precipitation, and filtration processes (i.e., Modified Solar Oxidation, Activated laterite). This technology is being used in USA, India, and China (Bissen & Frimmel, 2003; Barnaby et al., 2017; He et al., 2016; Majumder et al., 2013). The processes of coagulation, precipitation, and filtration in removing As in water is commonly used in Mexico (Guzman et al., 2019; Thakur & Mandal, 2017). In this process, arsenite will be converted to arsenate, then metal coagulants will be added to induce precipitation of particles, and finally, the remaining solid particles can be removed through the filtration process. Metal salts, such as aluminum salts and ferric salts, are commonly used in the coagulation phase. In the filtration stage, the water will be directed through a column of MnO media, which adsorbs and catalyzes the oxidation of the iron and manganese (Sancha et al., 2006). Aluminum electrodes, atomization, and spraying with ferric chloride can also be used in these types of remediation technologies (Thakur and Mondal, 2017; Chen et al., 2015). Adsorption technologies are very common and widely used globally. The adsorption process is based on the oxidation of arsenite to arsenate. The As-contaminated water is allowed to pass through adsorptive media wherein negative As(V) ions can adsorb to the positively-charged media (Mohan & Pittman, 2007). Chitosan goethite bio-nano composite (CGB), activated alumina metal oxide, and Mg-Fe-based hydrotalcite-like compounds can also be used in the treatment processes involving adsorption (He et al., 2016; Visoottiviseth & Ahmed, 2008). These technologies are commonly used in China, Argentina, Bangladesh, and Vietnam (He et al., 2016; Kato et al., 2013; Bundschuh et al., 2011). Membrane technologies involve the use of artificial membranes that incorporate billions of microscopic pores that manipulate the motion of molecules (Figoli et al., 2016). This technology was used in Southeast Asian countries like Singapore, Thailand, and Vietnam (Hoinkis et al., 2019). Bioremediation resembled biological techniques like phytoremediation, wherein renewable plant biomass is used for adsorption and bio-filtration. In this process, the As can be removed by a chemical-degrading bacteria. By adjusting the iron and As ratio, sand filtration columns can also be used to treat As in water. The utilization of green alga (*Chlorella Vulgaris*) is an example of a bioremediation treatment (Pokhrel & Viraraghavan, 2009). Ion exchange involves a physio-chemical process that requires the oxidation of arsenite to arsenate. In this process, As contaminated water is forced through a column full of strong base anion alternate resin. However, in this process, pH remains uncontrolled and may vary from 6.5 to 9 (U.S Environmental Protection Agencies, 2015). Activated laterite and zero-water pitcher filters were among the technologies that are based on the principle of ion exchange. USA and Argentina are among the countries that utilize this technology (Mondal et al., 2017; Barnaby et al., 2017; Bundschuh et al., 2011).

3.4 Comparison of treatment performance and cost in different remediation technologies

Groundwater is a vital supply of drinking water, especially in areas with very scarce surface water sources; however, most of the groundwater reserves are also contaminated by harmful chemicals as a result of anthropogenic disturbance (Faroque and south, 2022). Some policies for improving ground water quality or minimizing As contamination include proper disposal of wastes containing harmful chemicals, minimizing the use of products infused with toxic substances, ensuring proper storage of chemicals and wastes, development of a pollution prevention plan, conducting household hazardous waste collection, and formulation of legislations and programs for improving groundwater quality (Human Rights Watch, 2016; MIT, 2009; Machingura & Lally 2017; United Nations, 2020). The performance of different As treatment technologies, in terms of removal efficiency and treatment cost, were summarized in Table 3. The As removal efficiency of different treatment technologies ranged from 82% to 99%. Most of the identified treatment technologies exhibited As removal efficiencies > 90%. Specifically, 12 out of the 17 technologies presented high removal efficiency, whereas four technologies were evaluated to have moderate As removal capabilities. Moreover, among the listed treatment technologies, the treatment process using ferric chloride exhibited the lowest removal efficiency (82%). The treatment cost variations among the different treatment technologies ranged from 0.098 to 299 (USD/m^3). Most of the technologies for removing As in water were found to cost approximately 1 USD/m^3. Among the identified technologies Mg-Fe-based hydrotalcite-like compound (MF-HT), Modified Solar Oxidation and Removal of As (SORAS), ferric chloride, household ceramic filter, activated laterite, and Sono arsenic filter were found to be the cheaper alternatives for As removal in water. Despite the high As removal performance, zero-waste pitcher, carbon composite electrode, and Chitosan goethite bio-nano composite (CGB) had relatively higher treatment costs (2.32 to 299 USD/m^3). The evaluation based on the removal efficiency and treatment cost revealed that the most feasible options for treating As in groundwater are aerated electrocoagulation, Mg-Fe-based hydrotalcite-like compound, and electro-chemical As remediation (ECAR) reactor. These treatment technologies were found to have high As removal efficiency in the water while incurring minimal costs for treating the contaminated water. The cost of treatment may also change over time due to inflation or other economic variables that can cause adjustment to the operating or materials cost. It is therefore necessary to conduct a more updated inventory of the costs incurred by the advanced treatment technologies for removing As in water.

Table 3. As removal efficiency and treatment cost of the remediation technologies

Treatment technology/component	Process	As removal efficiency, %	Treatment cost, USD/ m^3	References
Aerated electrocoagulation	Coagulation	98	0.098	Goren et al., 2021
Iron oxide-coated sand filter process	Filtration	91	2	Callegari et al., 2018
zero-water pitcher filter	Filtration	97	299	Barnaby et al., 2017
A two-bucket system with ferric sulfate (FS) and poly ferric sulfate (PFS)	Coagulation, filtration	95	0.46	Cui et al., 2015
Mg-Fe-based hydrotalcite-like compound	Adsorption, Ion Exchange	98	0.1	Kumasaka et al., 2013
Carbon composite electrode	Capacitive deionization	98	2.32	Lee et al., 2016
ECAR Reactor	Electro-coagulation, precipitation, filtration	99	1.11	Amrose et al., 2014
Modified Solar Oxidation and Removal of As	Oxidation, coagulation, precipitation, filtration	95	0.1	Bundschuh et al., 2011
Atomization spray with ferric chloride	Coagulation, precipitation, filtration	82	0.1	Chen et al., 2015
Household ceramic filter	Filtration	< 93	0.23	Hasan et al., 2012
Activated laterite	Adsorption, oxidation	< 98	0.36	Mondal et al., 2017
Activated alumina metal oxide as an adsorbent	Adsorption	> 90	1.76	Visoottiviseth and Ahmed, 2008
Sono arsenic filter	Filtration	93	0.36	Shafiquzzaman et al., 2009
Chitosan goethite bio-nanocomposite (CGB)	Adsorption, oxidation	98	15.35	He et al., 2016
Mg-Fe-based hydrotalcite-like compound	Adsorption, ion Exchange	97	0.1	Kato et al., 2013
ARUBA (Arsenic Removal Using Bottom Ash)	Adsorption	98	0.76	Mathieu et al., 2010
Aluminum electrode	Coagulation, precipitation, filtration	98	0.37	Thakur and Mondal, 2017

Note: High Moderate Low

4. Conclusion

Bangladesh has been considered one of the countries most affected by As pollution in groundwater. Out of 30 districts investigated in Bangladesh, 80% of the districts have groundwater As concentrations exceeding 0.01mg/L. Specifically, Brahamanbariya, Tangail, Barishal, Pabna, Patuakhali, Kurigram, Magura, and Faridpur districts exhibited groundwater As concentrations greater than 0.05 mg/L. Only six districts, including Kushtia, Khagrachari, Jessore, Dinajpur, Meherpur, and Munshiganj meet the WHO water quality standard value (<0.01 mg/L). The comparison of As concentration in different countries revealed that the highest concentration of As was found in the Republic of Korea (0.757 mg/L) which was attributed to the high desorption process under low pH conditions and the high anthropogenic activities in the area. There are currently several technologies used to treat As in groundwater; however, considering the treatment efficiency and cost of treatment, aerated electrocoagulation, Mg-Fe-based hydrotalcite-like compound, and ECAR reactor were found to be the most recommended options for groundwater As removal. Overall, the investment, operational, and maintenance costs, availability of materials, and expertise requirements should be considered when selecting the most appropriate treatment method for As pollution water in Bangladesh. Improving the environmental policies for groundwater protection is also recommended to preserve one of the country's major sources of potable water. Groundwater has been referred to as an exceptional hidden resource.

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