# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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**Proposal of Proper Technology for the Arsenic Level Control in the water.**

**Area - Kushtia, Bangladesh**

**Master's Thesis**

**Prague 2019**

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# Declaration

I, Arafath Jahan, hereby declare that this thesis entitled Proposal of proper technology for the Arsenic level control in the water - area Kushtia, ward Pourasava, Bangladesh is Author (2019) work, otherwise referenced or acknowledged.

In Prague,………….. ……………………

Arafath Jahan

# Acknowledgement

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# Abstract

Bangladesh is known as a land of rivers and its own resources of water. But unfortunately, it faces a big challenge to provide safe drinking water. Most of the population collect their drinking water from their own area water supply which is a source of underground water. In the area of Kushtia, 90% of population collect water from Kushtia Municipal water supply. Kushtia Municipal has a total of 26 pump stations to supply the water to the population and from each pump station, they cover almost 2000 households. But unfortunately, they don't have a specific filtration system for Arsenic pollution. Latest estimates suggest 43,000 people in Bangladesh die each year from arsenic-related diseases.

Our case study is focused on that Arsenic problem in the area named Kushtia, ward Pourasava, Bangladesh. Therefore, the research focused on analyzing samples and the technology collected from the Pourosava water pump station. From the result obtained and based on the technology, we designed a water treatment unit to better the technology and purify the water from Arsenic to a certain level.



**Key words:** Bangladesh, Kushtia, Pourosava, Kushtia Municipal, Underground Water, Pump Station, Arsenic, Filtration, Water purification technology.

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# Abbreviations

| | |
|---|---|
| **As** | Arsenic |
| **BMDL** | Benchmark Dose (Lower Confidence Limit) |
| **BFD** | Black Foot Disease |
| **BWDB** | Bangladesh Water Development Board |
| **°C** | degrees Celsius |
| **Fe** | Iron |
| **GDP** | Gross Domestic Product |
| **g/cm3** | mass in grams divided by volume in cubic centimetres |
| **JECFA** | Joint Expert Committee for Food Additives |
| **JHPN** | Journal of Health, Population and Nutrition |
| **$km^2$** | Square kilometer |
| **km** | kilometer |
| **K** | Kelvin |
| **mg/kg** | milligram of medication per kilogram |
| **mg/m3** | milligrams per cubic meter |
| **mg/l** | milligrams per liter |
| **NGOs** | Non-Governmental Organisation |

| | |
|---|---|
| **PVD** | Peripheral Vascular Disease |
| **PTWI** | Provisional Tolerable Weekly Intake |
| **Ppb** | Parts per billion |
| **sq km** | square kilometer |
| **UNICEF** | United Nations International Children's Emergency Fund |
| **UNDP** | United Nations Development Programme |
| **VB group** | VB group in the periodic table |
| **WHO** | World Health Organization |
| **WPP** | Water Purification Plant |
| **µg** | micrograms |
| **µg/m3** | micrograms (one-millionth of a gram) per cubic meter |
| **µg/l** | micrograms per liter |
| **$** | United States Dollar |
| **Ωm** | omega meter |

# 1 Introduction and Literature review

Arsenic (As) is a naturally occurring, metalloid component of the Earth's crust. Minuscule quantities of arsenic occur in all rock, air, water, and soil. A metalloid is a substance that is not a metal but shares many qualities with metals (Mike Paddock, 2018).

Arsenic can be found in seawater (2-4 ppb), and in rivers (0.5-2 ppb). Half of the arsenic present is bound to particles. In some marine organisms, such as algae and shrimp, arsenic can be found in organic compounds. The legal limit for arsenic in water applied by the World Health Organization (WHO) is 10 µg/l (Lenntech,2018).

The contamination of groundwater by arsenic in Bangladesh is the largest poisoning of a population in history. More than 20 million people are thought to be at risk of drinking water contaminated by arsenic in Bangladesh. Arsenic occurs naturally in groundwater supplies throughout parts of Bangladesh, India, and Nepal. It was first identified as a problem in Bangladesh in 1987, and concentration levels in some places exceed 50 milligrams per liter (mg/l) – way beyond the maximum level recommended by the World Health Organization of 10 µg/l. Each year, an estimated 43,000 people die from arsenic poisoning in the country (The Guardian,2006)

## 1.1 General information about Bangladesh

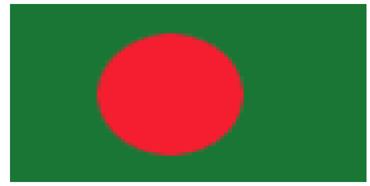


Figure 1: Flag o Bangladesh

Image source- Google

Bangladesh, an independent country since 1971, named officially People's Republic of Bangladesh. The country is situated in southern Asia in the Ganges River (Padma) delta on the Bay of Bengal. Bangladesh is bordered by India in west, north, and east and has a short border with Myanmar (Burma) in the southeast. The state occupies an area of 143,998 $km^2$, compared it is slightly larger than Greece (131.957 $km^2$) or slightly smaller than the U.S. state of Iowa. It is one of the world's most densely populated countries. Bangladesh has a population of more than 164 million people (in 2017). Most of its population are followers of Islam (about 88%). Capital and largest city are Dhaka. Spoken language is Bangla (or Bengali by 98%) (Nations Online Project, 1998-2019).

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures, and humidity. There are three distinct seasons in Bangladesh a hot, humid summer from March to June a cool, rainy monsoon season from June to October and a cool, dry winter from October to March. In general, maximum summer temperatures range between 30°C and 40°C. April is the warmest month in most parts of the country. January is the coldest month when the average temperature for most of the country is about 10°C (Climate of the World, 1999-2019).

Bangladesh is renowned for its beautiful geomorphic features, including the massive rivers flowing throughout the country. Within the borders of Bangladesh lie the bottom reaches of the Himalayan Ranges' water sources, which serve as the primary sources for rivers that flow through such countries as China, Bhutan, and India and eventually passing into the Bay of Bengal in Bangladesh. The Bangladesh Rivers also drive various economic activities such as agriculture, waterway communication, and energy source among others.

Since these rivers play a significant role in economic growth. There are 10 major rivers in Bangladesh (Benjamin Elisha Sawe, 2017, worldatlas).

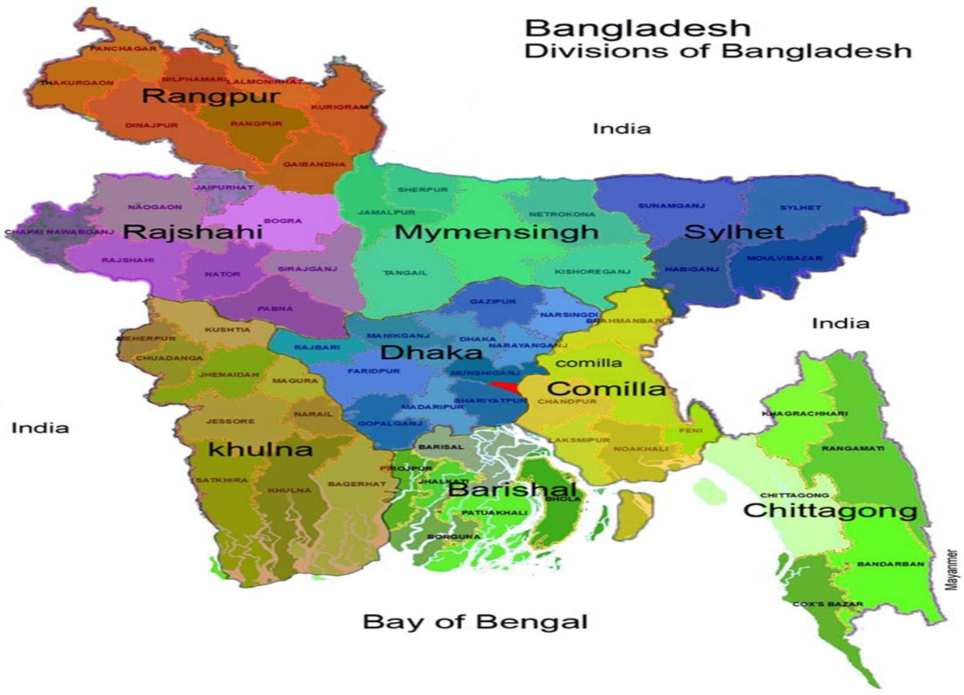



Figure 2: Map of Bangladesh

Image source – Google

### 1.1.1 Geology & Geological timescale of Bangladesh

Geological evolution of Bangladesh is basically related to the uplift of the Himalayan Mountains and outbuilding of deltaic landmass by major river systems originating in the uplifted Himalayas. This geology is mostly characterized by the rapid subsidence and filling of a basin in which a huge thickness of deltaic sediments was deposited as a mega-delta out built and progressed towards the south. The delta building is continuing into the present

Bay of Bengal and a broad fluvial front of the Ganges-Brahmaputra-Meghna river system gradually follows it from behind. Only the eastern part of Bangladesh has been uplifted into hilly landform incorporating itself into the frontal belt of the indo-burman range lying to the east. All the above has been the result of the Indian plate colliding with the Asian plate as explained by the universally accepted theory of plate tectonics. Bangladesh occupies the delta plain of the Ganges (Padma) and the Brahmaputra (Jamuna) rivers. The country's geological history is covered by several kilometers of 2-million-year-old sediments (Sonia Nazneen, academia.edu)

### 1.1.2 Geological Time Scale

The geologic time scale provides a system of chronologic measurement relating stratigraphy to time that is used by geologists, paleontologists and other earth scientists to describe the timing and relationships between events that have occurred during the history of the Earth. The geological time scale divides the total time span of earth's 4.6 billion years of existence into units and sub-units based on rock records. It basically includes four eras, such as,

01. Precambrian Era

02. Paleozoic Era

03. Mesozoic Era

04. Cenozoic Era

**Geological Evolution (numbers are in millions of years before the present)**

| Eon | Era | Period | | Epoch | | Age | | Geological Evolution |
|---|---|---|---|---|---|---|---|---|
| PHANEROZOIC | CENOZOIC | Quaternary | | Recent or Holocene | 0.1 | Age of Mammals | | Appearance of modern man. River systems built out the backbone of the present Bengal Delta. Upliftment of the St Martin's Island and subsidence of the deltaic area are continuing. Monsoon season dominates the region. |
| | | | | Pleistocene | 2 | | Rise of the Himalayas | Global Ice Age. No evidence of glacial deposits in Bangladesh. Terraces like Barind and Madhupur tracts were formed. |
| | | Tertiary | Neogene | Pliocene | 5 | | | Characterised by global cooling climate and present Bengal Delta started to take shape. Subsidence of the Surma Basin continued. Siwalik river was closed during Late Pliocene. |
| | | | | Miocene | 24 | | Transitional Bengal Delta | Monsoon season started during Upper Miocene. Reservoirs of the natural gas deposits were formed. |
| | | | Paleogene | Oligocene | 37 | | | Chittagong Hill Tracts started to form as a Neogene accretionary prism. while Surma Basin began to subside. |
| | | | | Eocene | 58 | | | Tethys sea was closed during Upper Eocene Most of Bangladesh was under sea. |
| | | | | Paleocene | 66 | | | |
| | MESOZOIC | Cretaceous | | | 144 | Age of Dinosaurs | | Proto Bengal Delta together with Bay of Bengal started to develop in Late Cretaceous. |
| | | Jurassic | | | 208 | | | Volcanic rocks of Rajmahal Trap are found at Jamalganj, Shibganj and Bogra Graben areas. Indian Ocean started to form in Late Jurassic. |
| | | Triassic | | | 245 | | | No rock is recorded. |
| | PALEOZOIC | Permian | | | 286 | Age of Invertebrates | | Commercial coal deposits were formed in northwestern Bangladesh. Tethys sea was formed in Permo-Carbonifreous time. |
| | | Carboniferous | Pennsylvanian | | 320 | | | Paleozoic interior sag basins were formed. Boulder beds at the base of Gondwanaland Group. |
| | | | Mississippian | | 360 | | | Epeirogenic (upward and downward) movements occurred. Glacial condition prevailed in the Gondwanaland. |
| | | Devonian | | | 408 | | | No rocks of these periods are found in Bangladesh |
| | | Silurian | | | 438 | | | |
| | | Ordovician | | | 505 | | | |
| | | Cambrian | | | 570 | | | |
| PRECAMBRIAN | | Proterozoic Eon | | | 2500 | Precambrian comprises about 85% of the Geological Time | | Precambrian crystalline (igneous and metamorphic) rocks are found at a shallow depth of about 150 to 300m in the northwestern part of Bangladesh in Dinajpur and Rangpur districts |
| | | Archean Eon | | | 4600 | | | |
| | | No Record | | | | Origin of Earth | | |

Fig 3: The Geological evolution of Bangladesh is shown by time scale

Image source – Banglapedia

**In Geological Time Scale**

| ERA | PERIOD | | EPOCH | GROUP | FORMATION |
|---|---|---|---|---|---|
| CENOZOIC | QUATERNARY | | Holocene<br>Pleistocene<br>Pliocene<br>Late Miocene<br>Middle Miocene<br>Lower Miocene<br>Oligocene<br>Late Eocene<br>Middle Eocene<br>Early Eocene<br>Lower –Cretaceous<br>Late Jurassic<br>Late Permian<br>Early Permian | | Alluvium |
| | | | | | Madhupur Clay<br>St. Martin's<br>Limestone |
| | TERTIARY | NEOGENE | | | Dihing |
| | | | | | Dupitila-Claystone<br>Dupitila-Sandstone |
| | | PALIOGENE | | Tipam | Girujan Clay<br>Tipam Sand Stone |
| | | | | Surma | |
| | | | | Barail | Renji?<br>Jenum? |
| | | | | Jaintia | Kopili Shale<br>Sylhet Limestone<br>Tura Sandstone |
| MESOZOIC | CRETACEOUS<br>JURASSIC | | | Rajmahal | Sibganj<br>Rajmahal |
| PALEOZOIC | PERMIAN | | | Gondwana | Raniganj |
| PRECAMBRIAN | | | | | |

Fig 4: Geological time scale of Bangladesh

Image source- F. H. Khan

Geological formations are groupings of rock with similar characteristics. In geology, the term refers specifically to geological strata, while laypeople may refer informally to outcroppings of rock or interesting geological features as geological formations, even though this is not technically correct. Many geological formations are made from sedimentary rock, although other types of rock can also be found in a formation. The type of rock can be important, as it may provide information about the conditions in which the rock formed, and the geologic history of an area. Multiple deposits of limestone formations, for example, indicate that an area was once covered in an ocean, while a layer of volcanic flow would suggest that there was volcanic activity in the region at some point in history.

**Geological Group Formation of Bangladesh**-

Firstly: "Alluvium, Stream deposits" Delta plan deposit, FLood plain deposits.

Secondly: “Pleistocene terrace” (Madhupur clay)

Thirdly: “Pleistocene, Dupi Tila formation”

Fourthly: “Pleistocene Tipan sand stone formation” Girujan clay formation

Fifthly: “Miocene, Surma group”.

Sixthly: Paleogene (Sylhet lime stone, Renji formation).

Seventh: Lower Miocene – Pleistocene

The science of Geology is significant in locating water supplies, mineral resources, understanding the development of life on earth, developing predictive models for earthquake, volcano and tsunami activity and adding fundamental knowledge to the field of earth and planetary science (Sonia Nazneen, academia.edu).

### 1.1.3 Important facts about Bangladesh

The GDP of Bangladesh is $195.1 billion. Over half of the residents of Bangladesh are in the farming industry. Bangladesh is unusual in that it has six different seasons. In addition to summer, autumn, winter, and spring, it also has rainy and cool seasons. In terms of size, Bangladesh is only about one-tenth the size of Alas. The Bay of Bengal is the largest bay in the entire world. country in Asia. The capital, Dhaka, is the largest city in Bangladesh. Three percent of the world’s tea comes from Bangladesh. The industry also employs about four million people. There are approximately 700 rivers flowing throughout the country. There are approximately 3,000 people per square mile, making this country one of the most densely populated on earth (Nationfacts.net, 2018).

### 1.1.4 Groundwater Aquifers in Bangladesh-

Generally, four major physiographic units exist at the surface of Bangladesh. These are, (a) Tertiary sediments in the northern and eastern hills; (b) Pleistocene Terraces in the Madhupur and Barind Tracts; (c) Recent (Holocene) floodplains of the Ganges, the Brahmaputra and the Meghna rivers and (d) the Delta covering the rest of the country. Most of the present land surface of the country covered by the Holocene flood plains deposited by the GBM river systems. The tropical monsoon climate together with favorable geological and hydrogeologic conditions indicates high potential storage of groundwater in the country. The unconsolidated near surface Pleistocene to Recent fluvial and estuarine sediments underlying most of Bangladesh generally form prolific aquifers. The floodplains of the major rivers and the active/inactive delta plain of the GBM Delta Complex occupy 82 percent of the country. From the available subsurface geological information, it appears that most of the good aquifers occur between 30 to 130 m depth. These sediments are cyclic deposits of mostly medium to fine sand, silt and clay. The individual layers cannot be traced for long distances, horizontally or vertically. On a regional basis, three aquifers have been identified and named by BWDB-UNDP (1982). These are,

**The Upper (Shallow) or the Composite Aquifer**

Below the surface clay and silt unit, less than few to several hundred meters thick very fine to fine sand, in places inter bedded or mixed with medium sand of very thin layers are commonly encountered. The thickness of this zone ranges from a few meters in the northwest to maximum of 60m in the south. Over most of the country it represents the upper water-bearing zone (BWDB-UNDP, 1982).

**The Main Aquifer**

The main water-bearing zone occurs at depths ranging from less than 5m in the northwest to more than 75m in the south and most of the country. It is either semi confined or leaky or consists of stratified interconnected, unconfined water bearing formations. This aquifer comprises medium and coarse-grained sandy sediments, in places inter-bedded with gravel. These sediments occur to depths of about 140m below ground surface. Presently, groundwater is drawn predominantly from these strata (BWDB-UNDP, 1982).

**The Deeper Aquifer**

The deeper water-bearing unit is separated from the overlying main aquifer by one or more clay layers of varied thickness. Deep aquifers generally include those aquifers whose waters have no access vertically upward and downward but flow very slowly along the dips and slopes of the aquifers. The depths of the deep aquifers in Bangladesh containing usable water range from 190 to 960 m on the Dinajpur platform and 250 to 1500 m in the basin and mainly include the sediments of the Gondwana, Jaintia, Surma and Tipam groups and parts of the Dupi Tila Sandstone Formation (Khan, 1991). This water bearing-zone comprises medium to coarse sand in places inter-bedded with fine sand, silt and clay. At present the water-bearing formation deeper than 150-200 m are being exploited on limited basis in the coastal zone to cater to the need of municipal water supply and in the rural areas for drinking purpose. Large scale extraction has not been encouraged due to possibility of seawater intrusion or leakage of saline or arsenic contaminated water from the upper aquifer. Considering age, except the hilly regions, aquifers can be divided into following two categories for floodplains, delta and terrace areas (BWDB-UNDP, 1982).

**The Pleistocene Aquifers**

The major terrace areas considered being of Pleistocene age of highly oxidized sediments including the Madhupur Tract in greater Dhaka, Tangail and Mymensingh districts and the Barind Tract in greater Rajshahi and Bogra districts. The PlioPleistocene aquifers of the Dupi Tila Formation lie beneath the Pleistocene Madhupur Clay Formation. This aquifer is composed of light grey to yellowish brown, medium to coarse sand with pebble beds and dated as about or more than 20,000 years old (Aggarwal et al., 2000).

All of the water for Dhaka city is withdrawn from this aquifer and the water is as yet arsenic safe.This aquifer is confined to semi-confined in nature. The reddish-brown mottled deposits underlain by lower Pleistocene Dupi Tila Formation are more compacted and weathered and generally have a higher content of clay and silt than the recent Holocene alluvial deposits. The Dupi Tila forms the main aquifer beneath the terrace areas. Madhupur clay has been buried by younger sediments only on the margins where it lies beneath floodplain deposits (BWDB-UNDP, 1982).

With the existing deep tube well records in and around Manikganj district, two alluvial aquifer systems named Madhupur aquifer and Jamuna aquifer are classified (Davies, 1994). The older Madhupur aquifer occurs within Dupi Tila Formation sediments that underlie the Madhupur Pleistocene terraces. The younger Jamuna aquifer system occurs within grey non-indurated alluvial sediments of the Dhamrai Formation that infill the Jamuna, Brahmaputra and Ganges river valleys. The Jamuna aquifer system occurs within non-indurated grey alluvial sands and gravels at the Late Quaternary Dhamrai Formation. The Lower Dhamrai Formation is fining upward succession of coarse sand and gravels deposited by strongly flowing braided rivers and were deposited between 20,000- and 48,000-year BP. The upper Dhamrai Formation with coarse to medium sands of maximum 7000-year BP age were also deposited as a series of upward fining units, from smaller braided and meandering rivers. Monsur (1990) dated the Dupi Tila Formation as being more than 900,000-year-old. The Dupi Tila sandstone forms the saturated zone on the Dinajpur shield and platform. This Dupi Tila Sandstone Formation extends all over Bangladesh probably excepting the western two third of the delta. The total thickness of the aquifers measures more than 300 m (BWDB-UNDP, 1982).

**The Holocene Aquifers**

Other than the terrace areas, the remaining part of the Bengal Basin consists predominantly of Holocene alluvial and deltaic sediments. The age of Holocene aquifers ranges from 100 to more than 3,000-years (Aggarwal et al., 2000).

In the land above tidal inundation, these deposits are composed primarily of silt and sand of appreciable thickness extending to depth of more than hundred meters. In the lower delta, they are principally silt, clay and peat. These sediments contain high water content and are generally loosely compacted and usually grey in color. Holocene and Pleistocene alluvium form the principal aquifers in the country. The Recent alluvium deposits are of varying characteristics classified from piedmont deposits near the foot of the mountains to inter-stream alluvium including deposits in the interior, merging with swamp and deltaic deposits approaching the southern shoreline. Stratified deposits of sand, silt and clay constitute the subsurface formations. The character of the deposits varies remarkably vertically. Coarse and medium sand with gravel are found mainly in the northern border areas of greater Rangpur and Dinajpur districts. The sediments of coastal areas and northwestern part of Rajshahi district are predominantly silt, clay and fine sand with occasional coarse sand. The deeper aquifer consisting of fine to medium sand vertically extends 180 to more than 250 m depths from the surface and is separated by 10 to 50 m thick clay layer from the overlying aquifer and is promising for groundwater exploration in Chittagong coastal plain aquifer (Zahid et al,2004).

Rainwater is the principal source of groundwater recharge in Bangladesh. Floodwater, which overflows the river and stream banks, also infiltrates into the groundwater. Water from permanent water bodies (rivers, canals, wetlands, ponds, irrigated fields etc.) that lie above the water table also percolates to the groundwater. In the Pleistocene terraces, the recharge occurs through the incised antecedent drainage channels that cut through near-surface clays into the underlying sands. The greatest scope of recharge is within the coarse-grained sediments and the least is within the fine-grained sediments like clay. The regional hydraulic gradient is low, reflecting the low topographic gradient. The groundwater flows generally from north to south. Most of the flow probably takes place through the in-filled incised channels under the major rivers (Anwar Zahid and Syed Reaz Uddin Ahmed,2006).

## 1.2 Arsenic pollution and impact in Bangladesh

The severity of arsenic problem varies from one region to another because of the geological and geomorphological nature of the areas as well as the shallow aquifers (150m) (Mukherjee &Bhattacharya, 2001).

The worst affected aquifers are alluvial deposits beneath the recent flood plains (Ganges, Tista, Meghna & Brahmaputra). Older sediments beneath the Barind and Madhupur tracts and the eastern hills and their adjoining piedmontplains are not significantly affected by arsenic. The Ganges flood plains show the greatest spatial variability (Hossain, 2006).

In Bangladesh tube-wells generally tap into the shallow aquifer (start from 10 to 110m below the surface), which is the source of the current arsenic problem. Arsenic distribution in groundwater is not only controlled by depth but rather to a major extent by subsurface geology, that is, age and grain size of sediments,which reveals that distribution of arsenic in the wells is largely dependent on the facies characteristics of the alluvial deposits (Ahmeda

et al,2004).

So, there are extreme local variations, within the broad regional distribution pattern of occurrences of arsenic enriched groundwater in Bangladesh. More than 100 million people worldwide have been estimated to be chronically exposed to arsenic from drinking water containing high arsenic levels. The situation is devastating in Bangladesh which is easily reflected through the number of affected people. Among the country's 7-11 million hands pumped tube-wells, approximately half have been estimated to supply groundwater with an arsenic concentration more than 50 microgram/l, which is the maximum level of arsenic allowed in drinking water. People in Bangladesh become terror-stricken when they come to know that underground water in parts of the country is strained by deadly arsenic. The permissible level of arsenic in water is 50 ppb (parts per billion) according to experts. But according to the Bangladesh Atomic Energy Commission, the level of arsenic is between 150 and 200 ppb in tube-well water in the districts boarding West Bengal. It is estimated that nearly 80 million people of the country are affected by arsenic and one in ten has the probability of developing cancer from the poisoning. In Bangladesh, arsenic contamination in groundwater was first detected in the year 1993. According to the data provided by UNICEF in 2008, there are approximately 8.6 million tube-wells in Bangladesh. Of these, 4.75 million tube wells (55%) have been tested for arsenic among which 3.3 million (39%) were marked green indicating that the groundwater is safe; while 1.4 million (16%) were marked red indicating that they are unsafe to use as sources of drinking water due to the high arsenic level. Recent findings show that about 20 million people in Bangladesh are using tube-wells contaminated with arsenic over the permissible level (>50 ppb). The overall situation indicates that Bangladesh is in the highest risk of an epidemic of arsenic poisoning and arsenic-related diseases. Arsenic-affected people suffer from enormous social stigma here as people consider it as a contagious disease or a curse. It is a matter of great pride that nowadays the awareness about arsenic poisoning has improved significantly in recent years. Many international organizations such as WHO, UNICEF and national NGOs are working on this issue (Oman Med J,2011).

### 1.2.1 Contamination of Arsenic in Groundwater in Bangladesh

The contamination of groundwater by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed. This paper describes the history of the discovery of arsenic in drinking water in Bangladesh and recommends intervention strategies. Tube-wells were installed to provide ‘‘pure water’’ to prevent morbidity and mortality from gastrointestinal disease. The water from the millions of tube-wells that were installed was not tested for arsenic contamination. Studies in other countries where the population has had long-term exposure to arsenic in groundwater indicate that 1 in 10 people who drink water containing 500 mg of arsenic per liter may ultimately die from cancers caused by arsenic, including lung, bladder and skin cancers. The rapid allocation of funding and prompt expansion of current interventions to address this contamination should be facilitated. The fundamental intervention is the identification and provision of arsenic-free drinking water. Arsenic is rapidly excreted in the urine, and for early or mild cases, no specific treatment is required. Community education and participation are essential to ensure that interventions are successful; these should be coupled with follow-up monitoring to confirm that exposure has ended. Taken together with the discovery of arsenic in groundwater in other countries, the experience in Bangladesh shows that groundwater sources throughout the world that are used for drinking water should be tested for arsenic. The magnitude of arsenic poisoning in Bangladesh Population of Bangladesh: 125 million. The total population in regions where some wells are known to be contaminated: 35–77 million. **The maximum concentration of arsenic permitted in drinking-water according to WHO recommendations 0.01 mg/l (10 µg/l) maximum concentration allowed in Bangladesh 0.05 mg/l (50 µg/l) (like many countries worldwide).** Number of tube-wells sampled by the British Geological Survey (1998): 2022

– Proportion of wells with arsenic concentrations >50 mg/l: 35%

– Proportion of wells with arsenic concentrations >300 mg/l: 8.4% (Bulletin of the World Health Organization, 2000).

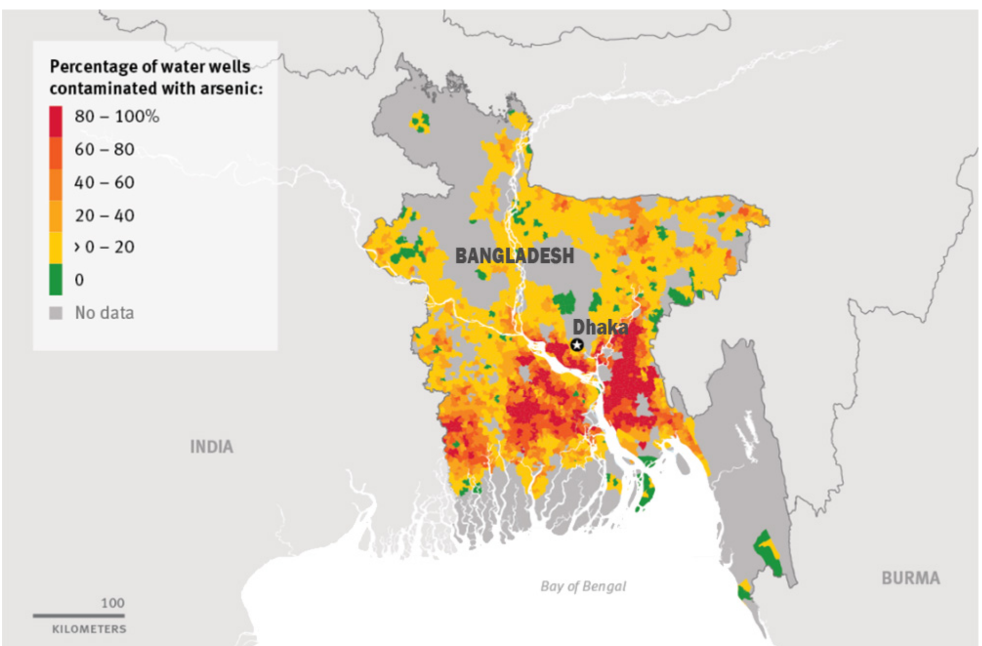



Figure 5: Map of Bangladesh with Arsenic contains Area

Image source – Undark.org (Bangladesh-arsenic-poisoning-drinking-water)

## 1.2.2. Causes of arsenic in groundwater of Bangladesh

Arsenic input into the ecosystem can be divided into two categories: natural and anthropogenic emissions. The actual causes of high arsenic concentration in the groundwater of Bangladesh have not been clearly pinpointed. Several factors have been assumed to have caused the substantial input of arsenic in the aquatic environment of Bangladesh. These are (a) wooden poles treated with arsenic-based compounds supporting electric wires, (b) uses of chemical fertilizers, pesticides, insecticides and herbicides containing arsenics, (c) tube-well filters coated with arsenic compound, (d) release of untreated effluent from facilities and (e) arsenic accumulated (enriched) in sediments by geological processes (BGS/DPHE, 1999).

The acceptable cause of widespread arsenic contamination in the groundwater of the Bengal Delta Plain (BDP) in Bangladesh is geological. Arsenic in the groundwater is N. Nahar / Water Policy 11 (2009) 362–378 367 released primarily from the sediments deposited during the Holocene period (BGS/DPHE, 1999).

However, scientists are not unanimous regarding the causes of the arsenic problem in Bangladesh. Among the few hypothesis initially proposed to explain the possible mechanism of arsenic release, most scientists have converged to two hypothesis: (a) the pyrite oxidation hypothesis—oxidation of arsenic mineral “arsenopyrite” (FeAsS) or arsenic rich “pyrite” ($FeS_2$) resulting in release of arsenic into groundwater and (b) the oxy-hydroxide reduction hypothesis—reduction of arsenic rich iron-oxide-hydroxides leaching the arsenic which remains in the adsorbed state on its surface. The third hypothesis is that it is Aman-made problem based on anthropogenic causes (Nurun Nahar,2009).

Drinking water has been the focus of attention since the early 1990’s when widespread contamination of groundwater by Arsenic (As) was discovered in shallow aquifers of Bangladesh (BGS-DPHE 2001).

### 1.2.2 Why is arsenic present in water?

Arsenic compounds are abundant in the earth's crust. Particles are released during mining and spread throughout the environment. Arsenic from weathered rocks and soils dissolves in groundwater. Arsenic concentrations in groundwater are particularly high in areas with geothermal activity. In aquatic ecosystems inorganic arsenic derived from rocks such as arsenic trioxide ($As_2O_3$), orpiment ($As_2S_3$), arsenopyrite (AsFeS), ($As_4S_4$) is most prevalent. Arsenic is applied in different shapes and forms and can enter water bodies as such. Large quantities of arsenic that are released from volcanic activity and from microorganisms are relatively small compared to the quantities released from for example fossil fuel combustion. Metallic arsenic is processed in lead or copper alloys, to increase hardness. The extremely toxic arsenic gas $ASH_3$ plays an important role in microchip production. Copper arsenate ($Cu_3(AsO_4)_2.4H_2O$) is applied as a pesticide in viticulture, but its use is currently prohibited in many countries. Paxite ($CuAs_2$) is an insecticide and fungicide. Other arsenic compounds are applied as a wood preservative, in glass processing, in chemical industries, or in semiconductor technique together with gallium and indium. Dutch painters applied arsenic as a yellow pigment. In the First World War arsenic was applied in chemical weapons. In the Vietnam War dimethyl arsenic acid was applied for the destruction of rice cultures. Although arsenic is applied less and less, it is still present in the environment in considerable quantities. For example, near abandoned mines soil quantities of arsenic may still be up to 30 g/kg. Arsenic was and is applied for medical purposes. In water from safe sources it probably aids curing asthma, hematological illnesses, dermatosis and psychosis. In the 19th century watery solutions of potassium arsenide (Fowler solution) were applied to treat chronic bronchial asthma and other diseases. At the beginning of the 20th century other arsenic compounds were applied to treat syphilis. Arsenic may assist in curing sleeping sickness and leukemia. Arsenic compounds may enter the body less specifically through food intake. This encompasses 90% of the total arsenic intake, mainly from fish products. Through fish grind in cattle feed arsenic may enter meat, and through contaminated soils it may enter plant products. In mushrooms near formed arsenic melting plants concentrations up to 50 mg/kg dry matter were found (Lenntech, 1998-2019).

### 1.2.3 How Does Arsenic Get into the Groundwater?

The conditions that favor arsenic dissolution (becoming dissolved in the water) and mobilization (movement with the groundwater to your tap) depend on the circumstances. One thing that is certain is that it takes more than just high arsenic concentrations in the soil or rocks of a region. The soil in Bangladesh is much lower in arsenic than soils in many areas that do not share the problem of high arsenic in groundwater, so what is the difference? Well, for one thing, the arsenic needs to be in a soluble form to end up in drinking water. Of the many known forms of arsenic, only a few are frequently detected in water. If the arsenic is not soluble, it will precipitate and remain in the solid phase of the groundwater system as part of the soil. If there is a binding site on the soil surface that is available, and the arsenic is in a form that binds strongly, it will also leave the water phase and attach to the soil. As the pH is raised, the compounds will tend to become more and more negatively charged as the arsenic and arsenious acid lose H+ groups. So, the charge of these arsenic compounds depends on the pH. As the pH goes up, the charge on the arsenic compounds becomes more negative and they should be better at binding to positively charged sites on the soil surface. The trouble is, the soil binding sites are also affected by the pH. As the pH goes up and the water becomes more basic, OH- groups from the water also associate with the adsorption or ion exchange sites on the soil, neutralizing them. Once they have been neutralized, they are not attractive to the arsenic compounds. The solubility of metals in water is also affected by pH, so if you get to a pH that dissolves the mineral phase, that will result in the release of anything bound to it. So instead of decreasing in concentration, the arsenic concentration in high pH water can go up! So, to sum up, we have seen three ways that arsenic can get in to water. In situations where the pH is high, arsenic may be released from surface binding sites that lose their positive charge. When organic carbon is present in the groundwater, it can feed bacteria that release arsenic either by (a) directly reducing As(V) to As(III), which is more soluble, or (b) by reducing the element at the binding site which releases the arsenic that was attached there (for example, Fe(III) is converted to Fe(II) which dissolves in the water, freeing the arsenic). Finally, arsenic trapped in sulfide minerals can be released when the minerals are exposed to oxygen. This can happen when the water level drops and the minerals are exposed to air (University of Maine/ National Sciences Foundation).

## 1.3 About Arsenic

Arsenic is a naturally occurring element that is widely distributed in the Earth's crust. It is found in water, air, food, and soil. There are two general forms of arsenic: Organic and Inorganic. Arsenic is found just about everywhere. It can leach into groundwater through rocks and soil, and is used in pesticides, wood preservatives, and tobacco. It is also released into the environment by volcanoes and mining processes (NIEHS,2019).

People are exposed to elevated levels of inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food and smoking tobacco. Long-term exposure to inorganic arsenic, mainly through drinking-water and food, can lead to chronic arsenic poisoning. Skin lesions and skin cancer are the most characteristic effects. Arsenic is naturally present at high levels in the groundwater of several countries. Arsenic is highly toxic in its inorganic form. Contaminated water used for drinking, food preparation and irrigation of food crops pose the greatest threat to public health from arsenic. Long-term exposure to arsenic from drinking water and food can cause cancer and skin lesions. It has also been associated with cardiovascular disease and diabetes. In utero and early childhood, exposure has been linked to negative impacts on cognitive development and increased deaths in young adults. Arsenic contamination of groundwater is widespread and there are several regions where arsenic contamination of drinking-water is significant. It is now recognized that at least 140 million people in 50 countries have been drinking water containing arsenic at levels above the WHO provisional guideline value of 10 µg/l (WHO,2018).

### 1.3.1 WHO response

Arsenic is one of WHO's 10 chemicals of major public health concern. WHO's work to reduce arsenic exposure includes setting guideline values, reviewing evidence, and providing risk management recommendations. WHO publishes a guideline value for arsenic in its guidelines for drinking-water quality. The Guidelines are intended for use as the basis for regulation and standard setting worldwide. The current recommended a limit of arsenic in drinking water is 10 µg/l, although this guideline value is designated as provisional because of practical difficulties in removing arsenic from drinking water. The provisional guideline value of 10 µg/l was previously supported by a JECFA provisional tolerable weekly intake (PTWI) of 15 µg/kg of body weight, assuming an allocation of 20% to drinking-water. However, JECFA recently re-evaluated arsenic and concluded that the existing PTWI was very close to the lower confidence limit on the benchmark dose for a 0.5% response (BMDL0.5) calculated from epidemiological studies (specifically for an increased risk of lung cancer) and was therefore no longer appropriate. The PTWI was therefore withdrawn (FAO/WHO, 2011).

JECFA concluded that for certain regions of the world where concentrations of inorganic arsenic in drinking-water exceed 50–100 µg/l, some epidemiological studies provide evidence of adverse effects. There are other areas where arsenic concentrations in water are elevated (e.g. above the WHO guideline value of 10 µg/l), but are less than 50 µg/l. In these circumstances, there is a possibility that adverse effects could occur as a result of exposure to inorganic arsenic from water and food, but these would be at a low incidence that would be difficult to detect in epidemiological studies. Every effort should, therefore, be made to keep concentrations as low as reasonably possible and below the guideline value when resources are available. However, millions of people around the world are exposed to arsenic at concentrations much higher than the guideline value (100 µg/l or greater), and therefore the public health priority should be to reduce exposure for these people. Where it is difficult to achieve the guideline value, Member States may set higher limits or interim values as part of an overall strategy to progressively reduce risks, while considering local circumstances, available resources, and risks from low arsenic sources that are contaminated microbiologically. The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene monitors progress towards global targets on drinking water. Under the new 2030 Agenda for Sustainable Development, the indicator of "safely managed drinking water services" calls for tracking the population accessing drinking water which is free of fecal contamination and priority chemical contaminants, including arsenic. **The maximum permissible level of arsenic in drinking-water recommended by the World Health Organization (WHO) is 10 µg/l and, in Bangladesh, it has been adjusted to 50 µg/l by the local authorities (WH0,2018).**

### 1.3.2 Basic information of Arsenic

Name: Arsenic

Symbol: As

Atomic Number: 33

Atomic Mass: 74.9216 amu

Melting Point: 817.0 °C (1090.15 K, 1502.6 °F)

Boiling Point: 613.0 °C (886.15 K, 1135.4 °F)

Number of Protons/Electrons: 33

Number of Neutrons: 42

Classification: Metalloid

Crystal Structure: Rhombohedral

Density @ 293 K: 5.72 g/cm3

Color: Gray

**Atomic Structure**

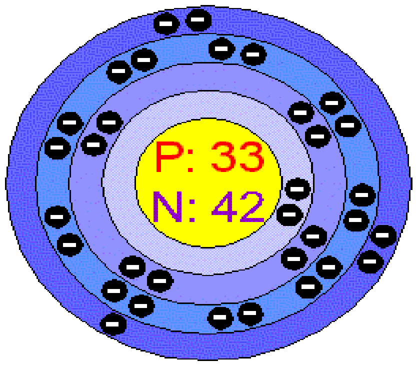



Figure 6: Atomic Structure

Image Source – Periodic table Arsenic

Number of Energy Levels: 4

First Energy Level: 2

Second Energy Level: 8

Third Energy Level: 18

Fourth Energy Level: 5

### 1.3.3 Chemistry and Geochemistry of arsenic

Arsenic, atomic number 33, belongs to the VB group in the periodic table. Arsenic is a metalloid, and it occurs in various oxidation states (-III, 0, +III and +V) in nature. In natural water, arsenic is mostly found in inorganic forms as tri-valent arsenate arsenic (III) and pentavalent arsenate arsenic (V). The concentration of arsenic in the earth's crust normally ranges from 1.5 - 5 mg/kg. The arsenic concentration in soil naturally ranges from

0.1 to 40 mg/kg, and the average concentration range from 5 to 6 mg/kg. Arsenic contaminates groundwater and surface water through processes such as erosion, dissolution, and weathering (Md. Fayej Ahmad,2012).

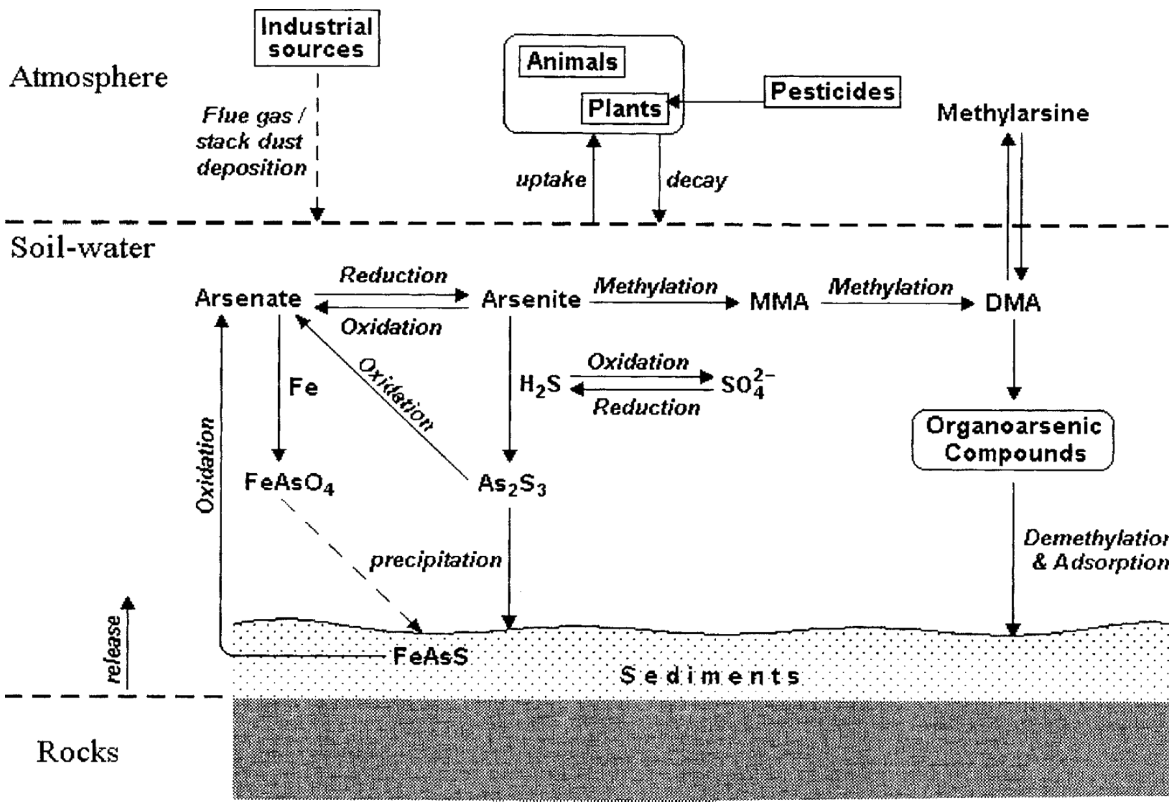



Figure 7: Arsenic cycle in the environment source

Image Source- Google

## 1.3.4 Natural distribution of arsenic

Arsenic is the 20th richest element in the earth crust and the 14th in sea water. Arsenic is an extraordinary crystal element comprising about five hundred thousandths of 1% (0,00005%) of the earth crust. The arsenic concentration in igneous and sedimentary rock is 2 mg/kg with different types of rocks containing different concentrations. Ranges from 0.5 – 2.5 mg/kg and higher concentrations were found in argillaceous sediments and phosphorites. Arsenic has been found to reduce marine sediment and may also co-precipitate with iron-hydroxides and sulfides in sedimentary rock. Table 2 shows arsenic concentrations in some natural geochemical materials (Mandal and Suzuki, 2002).

| Type of deposits | Arsenic mineral | Average arsenic concentrati on (mg/kg) | Location |
|---|---|---|---|
| Enargite-bearing copper–zinc–lead deposits | Enargite | 1000 (0.1%) | United States, Argentina, Chile, Peru, Mexico, Republic of the Philippines, Spain, Yugoslavia, USSR |
| Arsenical pyritic copper deposits | Arsenopyrite, tennantite | 40,000 (4%) | United States, Sweden, Federal Republic of Germany, Japan,Bangladesh France, USSR |
| Native silver and nickel–cobalt arsenide bearing deposits | Smaltite, domeykite, safflorite, rammelsbergite,co baltite,niccolite, loellingite, arsenopyroe, | 25,000 (2.5%) | Canada, Norway, Germany, Democratic Republic, Czechoslovakia |
| Arsenical gold deposits | Arsenopyrite, loellingite | <5000 (0.5%) | Unites States, Brazil, Canada, Republic of South Africa, Australia, USSR |
| Arsenic sulfide and arsenic sulfide gold deposits | Realgar, orpiment | 2000 (0.2%) | United States, People's Republic of China |
| Arsenical tin deposits | Arsenopyrite | 2000 (0.2%) | United States, Bolivia, Australia, Indonesia, Malaysia, Republic |

Table 1. Arsenic deposits in the world (Gomez-Caminero et al., 2001).

| Location | Arsenic source | Concentration (µg/l) |
|---|---|---|
| South-West Finland | Well waters; natural origin | 17–980 |
| New Jersey, USA | Well waters | 1 (median) 1160 (maximum) |
| Western USA | Geochemical environments | 48,000 (maximum) |
| South-west USA | Alluvial aquifers | 16–62 |
| Bangladesh | Well waters | 10 -1000 |
| Lagunera region, northern Mexico | Well waters | 8–624 |
| Shanxi, PR China | Well waters | 0.03–1.41 |
| Calcutta, India | Near pesticide production plant | <50–23,080 |

Table 2. Concentrations of arsenic in groundwater of the arsenic-affected countries (Mandal and Suzuki, 2002).

## 1.4 Effects of arsenic on human health

Long-term exposure to arsenic in drinking-water is causally related to increased risks of cancer in the skin, lungs, bladder, and kidney, as well as other skin changes such as hyperkeratosis and pigmentation changes. These effects have been demonstrated in many studies using different study designs. Exposure-response relationships and high risks have been observed for each of these end-points. The effects have been most thoroughly studied in Taiwan but there is considerable evidence from studies on populations in other countries as well. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported to be associated with ingestion of drinking-water at concentrations 50 µg arsenic/liter. Occupational exposure to arsenic, primarily by inhalation, is causally associated with lung cancer. Exposure-response relationships and high risks have been observed. Increased risks have been observed at cumulative exposure levels ≥ 0.75 (mg/l) × year (e.g. 15 years of exposure to a workroom air concentration of 50 µg/l). Tobacco smoking has been investigated in two of the three main smelter cohorts and was not found to be the cause of the increased lung cancer risk attributed to arsenic. However, it was found to be interactive with arsenic in increasing the lung cancer risk. Even with some negative findings, the overall weight of evidence indicates that arsenic can cause clastogenic damage in different cell types with different end-points in exposed individuals and in cancer patients. For point mutations, the results are largely negative. (Environmental Health Criteria 224 EHC, Green Facts, 2004)

### 1.4.1 Other health problems can arsenic cause

Soluble inorganic arsenic is acutely toxic, and ingestion of large doses leads to gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions, and eventually death. In survivors, bone marrow depression, hemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy may be observed. Chronic arsenic exposure in Taiwan has been shown to cause Blackfoot disease (BFD), a severe form of peripheral vascular disease (PVD) which leads to gangrenous changes. This disease has not been documented in other parts of the world, and the findings in Taiwan may depend upon other contributing factors. However, there is good evidence from studies in several countries that arsenic exposure causes other forms of PVD. Conclusions on the causality of the relationship between arsenic exposure and other health effects are less clear-cut. The evidence is strongest for hypertension and cardiovascular disease, suggestive for diabetes and reproductive effects and weak for cerebrovascular disease, long-term neurological effects, and cancer at sites other than lung, bladder, kidney, and skin. (Environmental Health Criteria 224 EHC, Green Facts, 2004)

### 1.4.2 Facts about arsenic poisoning

Arsenic is a natural metalloid chemical that may be present in groundwater. Ingestion only poses health problems if a dangerous amount of arsenic enters the body. Then, it can lead to cancer, liver disease, coma, and death. Treatment involves bowel irrigation, medication, and chelation therapy. It is rare to find dangerous amounts of arsenic in the natural environment. Areas with dangerous arsenic levels are usually well-known and provisions exist to prevent and handle the risk of poisoning. Anyone who suspects there may be high arsenic levels in their local environment should contact their local authorities for more information. (Mike Paddock, 2018, Medical News Today)

Figure 8: Arsenic Poison

Image Source - Google

### 1.4.3 Symptoms

The symptoms of arsenic poisoning can be acute, or severe and immediate, or chronic, where damage to health is experienced over a longer period. This will often depend on the method of exposure. A person who has swallowed arsenic may show signs and symptoms within 30 minutes. These may include drowsiness, headaches, confusion, severe diarrhea. If arsenic has been inhaled, or a less concentrated amount has been ingested, symptoms may take longer to develop. As the arsenic poisoning progresses, the patient may start experiencing convulsions, and their fingernail pigmentation may change. A metallic taste in the mouth and garlicky breath, excess saliva, problems swallowing, blood in the urine, cramping muscles, hair loss, stomach cramps, convulsions, excessive sweating, vomiting, diarrhea. Arsenic poisoning typically affects the skin, liver, lungs, and kidneys. In the final stage, symptoms include seizures and shock. This could lead to a coma or death. (Mike Paddock**,** 2018, Medical News Today).

### 1.4.4 Arsenic in the workplace

If proper safety measures are not taken, workers in certain industries may face a higher risk of toxicity. These industries include glass production, smelting, wood treatment, the production and use of some pesticides. The method through which arsenic enters the human body in these industries depends on the way the arsenic is being used. There may be traces of arsenic in some foods, such as meat, poultry, and fish. Normally, poultry contains the highest level of arsenic, due to antibiotics in the chicken feed. Rice has also been found to potentially contain higher levels of arsenic than water (Mike Paddock, 2018, Medical News Today).

### 1.4.5 Diagnosis

Pathological testing can confirm an instance of arsenic poisoning. In areas and occupations with a risk of arsenic poisoning, it is important to monitor the levels of arsenic in the people at risk. This can be assessed through blood, hair, urine, and fingernail samples. Urine tests should be carried out within 1 to 2 days of the initial exposure for an accurate measure of when the poisoning occurred. These tests can also be used to help diagnose cases of apparent arsenic poisoning. Tests on hair and fingernails can determine the level of arsenic exposure over a period of up to 12 months. These tests can give an accurate indication of arsenic exposure levels, but they do not show what effects they may have on the person's health (Mike Paddock, 2018, Medical News Today).

### 1.4.6 Treatment

The treatment depends on the type and stage of arsenic poisoning. Some methods remove arsenic from the human body before it causes any damage. Others repair or minimize the damage that has already occurred. Treatment methods include: removing clothes that could be contaminated with arsenic thoroughly washing and rinsing affected skin, blood transfusions taking heart medication in cases where the heart starts failing using mineral supplements that lower the risk of potentially fatal heart rhythm problems observing kidney function. Bowel irrigation is another option. A special solution is passed through the gastrointestinal tract, flushing out the contents. The irrigation removes traces of arsenic and prevents it from being absorbed into the gut. Chelation therapy may also be used. This treatment uses certain chemicals, including dimercaptosuccinic acid and dimercaprol, to isolate the arsenic from the blood proteins (Mike Paddock, 2018, Medical News Today).

### 1.4.7 Prevention

Arsenic removal systems in homes, if the levels of arsenic in an area are confirmed as unsafe, systems can be purchased for the home to treat drinking water and reduce the arsenic levels. This is a short-term solution until the arsenic contamination can be dealt with at the source. Testing nearby water sources for traces of arsenic, chemically examining the water can help to identify poisonous sources of arsenic. Taking care when harvesting rainwater: In areas of high rainfall, arsenic poisoning can be prevented by ensuring the process of the collection does not put the water at risk of infection or cause the water to become a breeding ground for mosquitos. Considering the depth of wells the deeper the well, the less arsenic its water is likely to have (Mike Paddock, 2018, Medical News Today).

## 1.5 Arsenic problem in the world

Over the past two or three decades, the occurrence of high concentrations of arsenic in drinking water has been recognized as a major public health concern in several parts of the world. There have been a few review works covering the arsenic-contamination scenario around the world. With the discovery of newer sites in the recent past, the arsenic-contamination scenario around the world, especially in Asian countries, has changed considerably. Before 2000, there were five major incidents of arsenic contamination in groundwater in Asian countries: Bangladesh, West Bengal, India, and sites in China. Between 2000 and 2005, arsenic-related groundwater problems have emerged in different Asian countries, including new sites in China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, DPR Korea, and Pakistan. There are reports of arsenic contamination from Kurdistan province of Western Iran and Viet Nam where several million people may have a considerable risk of chronic arsenic poisoning (Amitava Mukherjee, 2006, JHPN).

### 1.5.1 Example of some countries Arsenic Condition

Czech Republic – People living near a plant that burns coal containing 900-1.500 mg/kg arsenic was linked to the poisoning reported in this country, previously part of Czechoslovakia.

Ghana - Concentrations of arsenic in groundwater from two regions in Ghana—the Obuasi area in the Ashanti region and the Bolgatanga area of the Upper East region varied from less than 1 to 64 µg/l [As (III) range 6 - 30 µg/l] and less than 1 to 141 µg/l [As (III) range <1-9 µg/l] respectively. Sulfide minerals, such as arsenopyrite and pyrite, were found in the Biriman basement rocks of both the areas and these were the major sources of arsenic. The lowest concentrations were observed in shallowest groundwaters and increased at greater depths. High As (III) content in some groundwater samples was attributed to the leaching of soils containing kaolinite, muscovite, and laterites overlying saprolite.

Germany- Exposure to arsenic-containing pesticides and contaminated wine was claimed to be the causative factor in the large number of cases of liver-cirrhosis among German vintners in the 1940s and 1950s. Eleven of 27 Moselle vintners autopsied between 1950 and 1956 had lung cancers, and three had hepatic angiosarcomas. Of 180 vinedressers and cellarmen with symptoms of chronic arsenic poisoning, about 25% had evidence of vascular disorders of the extremities (Amitava Mukherjee, 2006, JHPN)

# 2. Aim of the Thesis

The goal of the research was to provide the theoretical foundation to improve the technology used by Kushtia Municipal, in the area of Kushtia, in the Ward Paurosava. The research was focused on a proposal for a basic water purification unit system which reduces Arsenic pollution in the underground water of specific local conditions and compares it with Bangladesh standard .05mg/l and international WHO standards .01 mg/l.

## 2.1 Main Objective

The main objective of this case study was to propose the design of a basic water purification unit technology to mitigate arsenic pollution in the ward Paurosava water pump station.

## 2.2 Specific Objective

The first specific objective was to analyze and evaluate the actual treated water, other water test reports and find the difference between the arsenic levels. From all the reports we found arsenic presence in the water more than **0.1 mg/l** in most of the cases where Bangladesh standard is **0.05mg/l**, which is much lower than what we found from our reports.

The second specific objective was to, from the help of the first specific objective propose an advanced water purification unit to reduce arsenic water pollution load with consideration of specific local condition.

# 3. Methodology

Sequential steps of our methodology started with

- First collected the underground water sample report from different pump station and then select our area.

- The second step of our methodology is the observation and testing the sampling water from the selected pump station where the primary data already obtained.

- The third step was an analysis of primary data based on scientific researches, my own knowledge, and international emission standards.

- The final step was proposing a designing of water purification unit based on the previous findings.

**WHO's provisional guideline value for arsenic in drinking water - 0.01 mg/l and for Bangladesh standard is 0.05 mg/l**

## 3.1 About the study area Kushtia

The study area (Municipal area of Khustia district) is located in the southwestern part of Bangladesh. Kushtia Municipality was established in 1969. Kushtia District (Khulna division) area 1621,15 sq km, located in between 23°42' and 24°12' north latitudes and in between 88°42' and 89°22' east longitudes. Water bodies Main rivers: Padma, Garai, Mathabhanga, Kumar. Annual Average Temperature: Maximum 37.8ºC and lowest 11.2ºC; annual rainfall 1467 mm. It is famous for Kuthibari of Rabindranath Tagore at Shilaidaha, the tomb of Lalon Shah. Population in Kushtia Sadar – 4,23,818.


Figure 9:  Kushtia in Bangladesh Map

Image Source – Google

### 3.1.1 Geology and Hydrogeology of the Study Area

Based on the subsurface lithology, water level, and water quality information, three types of aquifers are present in the study area.  (a)  Composite aquifer:  This aquifer exists within 50m below ground level (bgl).  It consists of very fine to fine sand occasionally interbedded with silt and clay. The thickness of such shallow, unconfined aquifer varies from 2 - 6 m.  Dug wells and hand pumped wells are generally used to withdraw water from these aquifers, (b) Main aquifer: This aquifer exists between approximately 50 - 150 m bgl and consists of medium to coarse sand with occasional fine sand and silt.  The aquifer thickness varies from 20 to 80 m. Thin beds of clay occur infrequently within this aquifer. (c)  Deep aquifer:  This aquifer occurs at or more than about 200 m bgl.  It generally consists of fine to medium sands and is mostly confined to semi-confined in nature. This aquifer is exploited mainly in the coastal zone.  The thickness of this fresh aquifer is variable. The concentration of arsenic ranges in the study area from 0.01 mg/l to 1.30 mg/l during the wet season and 0.01 mg/l to 1.08 mg/l during the dry season in shallow tube wells. In deep tube well it ranges from 0.015 to 0.035 mg/l in the wet season and 0.01 to 0.03 mg/l in the dry season. Ground water of the study area has higher proportion of iron. Although highest concentration of arsenic does not always correlate with highest concentration of iron, arsenic generally increases with the increase of iron concentration in the study area. Iron may be deposited as siderite onto the surface of sediments. With the increase of arsenic, calcium also increases (but few exceptions). Magnesium content tends to be higher in the wet season of the study area where arsenic concentration is high and relatively positive correlation with arsenic concentration is recognized. In the dry season the correlation of arsenic concentration with magnesium is negative. With the increase of arsenic, sodium also increases (but few exceptions). The correlation of arsenic concentration with potassium is negative. In both seasons arsenic concentration is high, where less potassium concentration is found. (International Journal of Earth Sciences and Engineering,2011).

The aquifers of Kushtia District, Bangladesh, are unconsolidated, alluvial in nature, and developed from Holocene floodplain and Pleistocene deposits. High As (6.04-590.7 μg/l) groundwater occurs mainly in shallow aquifers. The Ca-HCO3 type groundwater is distinguished by circum-neutral pH, medium-high EC, high HCO3-, and low content of NO3-, SO42-, K+, and Cl-. The reductive suspension of MnOOH increases the dissolved As loads and redox responsive elements such as SO42- and pyrite oxidation act as the main mechanisms for As release in groundwater. As is mobilized by anaerobic leakage from the brown-clay and gray-sand into the sediment. Infiltration from irrigation return and surface wash water are the potential factors that remobilize As. The weak loading of Fe suggests that the release of Fe and As is decoupled in sedimentary aquifers of Kushtia District (US National Library of Medicine National Institutes of Health2018).

### 3.1.2 Status of Water Supply System

No. of Water Connection : 6,978

Length of Pipe Line : 109.5 km.

No. of Overhead Tank : 04

No. of Iron Treatment Plant : 03

Water production capacity : 10.300 cubic-meter/day

Water demand : 9.500 cubic-meter/day

No. of staff in Water Section : 28

No. of production Tube-well : 14

No. of Street Hydrant : 40

No. of Hand Pump : 3,200

Piped water supply Coverage : 46% Municipal Citizen

## 3.2 Specification of problem

According to WHO Arsenic-contaminated drinking-water is a public health emergency for Bangladesh. Arsenic exposure in Bangladesh is widespread and involves thousands of wells. Estimates indicate that at least 100 000 cases of skin lesions caused by arsenic have occurred and there may be many more. Sustained drinking of water containing 0.05 mg/l of arsenic may result in 1 in 10 people dying from arsenic-related cancers. (WHO,2000)

From the below reports, we can see that between this 12-water pump station there are 2 water pump station no.6 and 7 contain the highest level of Arsenic in the water which is **0.096** and **0.197 mg/l**.

As my study area, I choose no 6 which is Pourasava water pump station which contains the 2nd highest rate of arsenic between all the pump station. Compared with the Bangladesh standard of arsenic in the water is 0.05 mg/l and WHO standards are 0.01 mg/l we can see how much higher level of arsenic present in the water in the area of my study.

Also, another reason behind to choose this pump station because this is the area where I live in Bangladesh and the area population always use this water for their daily needs.

According to the geological survey also in the study area Kushtia arsenic present **higher than 0.05 mg/l** which is Bangladesh standard.

After seen the reports it’s understandable that our study area is highly contaminated by arsenic and there is no technology present as a solution of this problem.

## Water test report from different water pump station

Government of the People's Republic of Bangladesh
Office of the Senior Chemist
Department of Public Health Engineering (DPHE)
Zonal Laboratory, Jhenaidah.
*Phone : 0451-61416, Email :wqmsc_jhenaidahzonallab@yahoo.com*

**Water Quality Test Report**

District : **Kushtia**, Pourashava : **Kushtia Pourashava.**
Water Quality Monitoring and Surveillance, Phase- 01(one), Month: August/2017.
Source of Sample : Production Tube-well.

| SL No. | Pump ID | Sample Type | Ward | Sample Location/Description | GPS Reading | | Arsenic (mg/L) LOQ:0.0007, BDS:0.05 | Iron (mg/L) LOQ:0.09, BDS:0.3-1 | Manganese (mg/L) LOQ:0.04, BDS:0.1 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Latitude | Longitude | | | | |
| 01. | Old Pump (AIRP-2) | Ground Water | 04 | DC court AIRP | 23°54'08'' | 89°07'18'' | 0.033 | 1.86 | 0.82 | |
| 02. | New Pump | Ground Water | 04 | DC court AIRP | 23°54'08'' | 89°07'18'' | 0.066 | 4.27 | 0.56 | |
| 03. | CWD | Ground Water | 04 | DC court AIRP | 23°54'08'' | 89°07'18'' | 0.023 | 0.004 | 0.04 | |
| 04. | Over Head Tank | Ground Water | 04 | DC court AIRP | 23°54'08'' | 89°07'18'' | 0.022 | 0.04 | 0.02 | |
| 05. | Pump of AIRP-1 compound | Ground Water | 01 | Thanapara | 23°54'42'' | 89°07'22'' | 0.067 | 1.49 | 0.44 | |
| 06. | Pourasava Pump | Ground Water | 01 | Thanapara | 23°54'42'' | 89°07'22'' | 0.096 | 2.11 | 0.86 | |
| 07. | Pump of Rainwith more | Ground Water | 01 | Thanapara | 23°54'42" | 89°07'22'' | 0.197 | 17.47 | 0.50 | |
| 08. | Over Head Tank | Ground Water | 01 | Thanapara | 23°54'42" | 89°07'22'' | 0.036 | 0.05 | 0.02 | |
| 09. | CWD | Ground Water | 01 | Thanapara | 23°54'42" | 89°07'22'' | 0.039 | 0.09 | 0.04 | |
| 10. | Kutipara pump | Ground Water | 03 | Kutipara | 23°54'37'' | 89°07'02'' | 0.034 | 1.05 | 0.89 | |
| 11. | Amlapara pump | Ground Water | 03 | Amlapara | 23°54'24'' | 89°08'18'' | 0.028 | 2.47 | 0.67 | |
| 12. | Rajarhat pump | Ground Water | 09 | Rajarhat | 23°54'14'' | 89°08'19'' | 0.027 | 0.73, | 1.56 | |

Page-01

Table 3 – Water test report for different water pump station

Image source – Author

**Percentage of Groundwater Surveyed in 1998 by British Geological Survey with Arsenic Levels above 0.05 mg/l**

| District | Percentage of Groundwater Surveyed | District | Percentage of Groundwater Surveyed |
|---|---|---|---|
| Bagerhat | 66 | Madaripur | 93 |
| Barisal | 63 | Magura | 19 |
| Brahmanbaria | 38 | Manikganj | 15 |
| Chandpur | 96 | Meherpur | 60 |
| Chittagong | 20 | Moulvibazar | 12 |
| Chuadanga | 44 | Munshiganj | 83 |
| Comilla | 65 | Narail | 43 |
| Cox's Bazar | 3 | Narayanganj | 24 |
| Dhaka | 37 | Nawabganj | 4 |
| Faridpur | 66 | Noakhali | 75 |
| Feni | 39 | Pabna | 17 |
| Gopalganj | 94 | Pirojpur | 24 |
| Jessore | 51 | Rajbari | 24 |
| Jhalakati | 14 | Rajshahi | 6 |
| Jhenaidah | 26 | Satkhira | 73 |
| Khulna | 32 | Shariatpur | 80 |
| Kushtia | 28 | Syllhet | 19 |
| Lakshmipur | 68 | | |

## 3.2.1 About Study Ward Pourosava, Kushtia

Pourasav is one of the wards under Kushtia Municipal and there is one water pump station situated for this ward. From this pump station, it supplies water more than in 2000 households. This water pump station is the only way to get water for this ward population for their needs. In the household, they used this water for drinking, cooking, washing, etc. And this ward water is highly contaminated by Arsenic (see table 3) which is unsafe and dangerous for the human body.


Figure 10: Map of study ward Paurosava

Image source: Kushtia Municipal

Shallow aquifer located in the upper part of the Gorai River catchment (mainly Kushtia district area). Kushtia Sadar The Ganges, the Gorai, Mathabhanga, Kaligonga and Kumar are the main rivers flowing through the district. The average maximum and minimum temperatures are 37.8 °C and 11.2 °C, respectively with an average annual rainfall of 1,898 mm. Geoelectrical layers are identified within the depth of 105 m, namely thin topsoil (8.0–97.6 Ωm, 0.5–3.6 m), conductive clay-silt-sand layer (8.6–27.5 Ωm, 1.3–49.4 m), medium resistive fine grained aquifer (25.8–45.0 Ωm, 10.1–30.4 m), and high-resistive coarse grained water-bearing aquifer (35.0–64.9 Ωm, 30.0–76.9 m). The shallow aquifer (third layer) is found to occur at a depth ranging between 1.7 and 51 m, whereas the deeper aquifer (fourth layer) is found to occur within the depth between 14 and 52 m, both saturated with water.The groundwater resistivity and formation resistivity factor in the study area is found to vary from 15 to 30 Ωm and 1.93 to 2.68, respectively. The narrow low-protective layer has made the shallow aquifer highly vulnerable to surface contaminant in the study area ward (M. Nozibul Haque, Mumnunul Keramat & Shamsuddin Shahid,2014).

### 3.2.2 Water test reports from my water samples

Government of the People's Republic of Bangladesh
Office of the Chief Chemist
Department of Public Health Engineering
Central Lab, 38-39, Mohakhali C/A, Dhaka-1212
Phone: 88-02-9881927, Fax: 88-02-9882003, Email: wqmsc_central_lab@yahoo.com

Lab Memo: 1326/ CC, DPHE, CL, Dhaka. Date: 14-01-2019

**Physical /Chemical/ Bacteriological Analysis of Water Sample**

| | |
|---|---|
| Sample ID: CEN2019010051 | Sample Receiving date: 02-01-2019 |
| Ref. Memo No: AJ/2019/Nill & Dated: 02-01-2019 | Sample Source: Tube Well |
| Sent by:Arafat Jahan ,Student , Czech University of Life Sciences, Prague. | Dist:Kushtia, Upa: |
| Care Taker: Arafat Jahan | Union:, Vill.:Lorence lane, Thanapara |
| Sample Collection date: | Date of Testing: 02/01/2019-10/01/2019 |

**LABORATORY TEST RESULTS:**

| Sl.# | Water quality parameters | Bangladesh Standard | Concentration present | Unit | Analysis Method | LOQ |
|---|---|---|---|---|---|---|
| 1 | Arsenic (As) | 0.05 | 0.107 | mg/L | AAS | 0.001 |
| 2 | Calcium (Ca) | 75 | 237 | mg/L | AAS | 0.17 |
| 3 | Chemical Oxygen Demand (COD) | 4.0 | 4 | mg/L | CRM | - |
| 4 | Iron (Fe) | 0.3-1 | 11.71 | mg/L | AAS | 0.05 |
| 5 | Magnesium (Mg) | 30-35 | 19 | mg/L | AAS | 0.05 |
| 6 | Manganese (Mn) | 0.1 | 0.11 | mg/L | AAS | 0.03 |
| 7 | Total Dissolved Solid (TDS) | 1000 | 345 | mg/L | Multimeter | - |
| 8 | Turbidity | 10 | 119 | NTU | Turbidity Meter | - |
| 9 | Carbonate (CO3) | - | 2.59 | mg/L | Titrimetic | - |

Comments: Sample was collected & Supplied by client.
N.B: AAS- Atomic Absorption Spectrophotometer, CRM-Closed Reflex Methods, LOQ - Limit of Quantitation.

| Test Performed by: | Signature | Countersigned/Approved by: | Signature |
|---|---|---|---|
| 1.) Name: Md. Saiful Alam Khosru | | 1.) Name: Md. Biplab Hossain | |

Table 4– Water test report from my own samples

Image source- Author

| | | | | | |
|---|---|---|---|---|---|
| Ing. Lukáš Praus | 2/7/2019 | ICP-MS (Agilent 7700x) | | | |
| | | | | | |
| | element | concentration | unit | analysis technique | LOQ |
| | As | 0.241 | mg/L | ICP-MS | 0.00004 |
| | Ca | 108 | | ICP-MS | 0.023 |
| | Fe | 12.6 | | ICP-MS | 0.0066 |
| | Mg | 27.3 | | ICP-MS | 0.0014 |
| | Mn | 0.265 | | ICP-MS | 0.00051 |

Table 5: Water test report from CULS Prague lab

Image source: Author

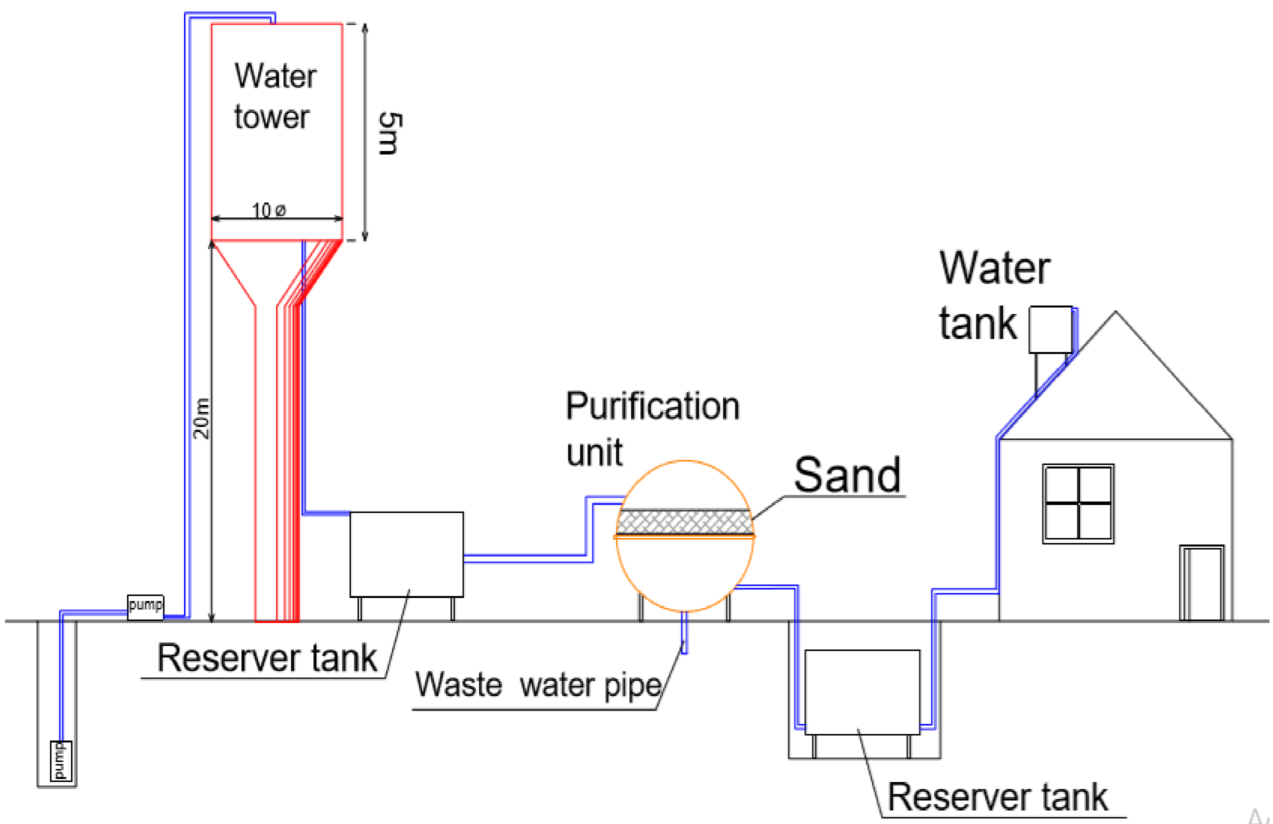
This water was collected from my own house where the water supply came from my chosen study pump station. This water sample was tested in the central laboratory, Dhaka. From this report (see table 4), we saw that the rate of arsenic in the water is .107 which is more than 2 times higher than the Bangladesh standard of .05mg/l.

The 2nd report (see table 5) we received from Czech University of Life Sciences Prague laboratory. I bought the water from Bangladesh and tested it here. From that report we can see the arsenic presence in the water is .241 mg/l - much higher than the previous report which was collected from the same water sample. In the 2nd report the level is arsenic is 4th times higher than the permissible standard.

Such levels are highly dangerous for the human body and especially for women, since it causes a high rate of stillbirths in Bangladesh. Unfortunately, the presence of arsenic in the human body cannot be diagnosed quickly. It takes a lot of time - at least 6 months to 1 year - to show the symptoms in the human body. So affected persons often do not experience symptoms of arsenic poisoning until it is too late.

Our case study pump station and the other pump stations do not have any purification system for arsenic or microbial elements (see schema 1). They have only water deferrization tank which is able to clean 30% of iron from the water only.

## 3.3 Water Supply technology in Pourosava Ward used




Schema 1- Technology used by the Pourasava water pump station

Image source- Author

The height of this water tower is approximately 20m and it's possible to use the 314$m^3$ amount of water from this tower. As we can see from schema 1 there is no proper technology, they used to mitigate the level of arsenic into the water. They used only the water deferrization or purification unit to mitigate the iron level by the using of the sand and this sand is inside the deferrization /purification unit. And in the next step, they reserved the water and supply the water to consumers without disinfection unit. There is another problem they face in that they need a constant supply of electricity to supply the water which is impossible according to the current situation in Bangladesh. Every day there are 5 to 6 hours without electricity available, which is a common problem in Bangladesh.

**Step 1**

Figure 11: The untreated water from the underground wells is supply to reservoir by the set of centrifugal pumps.

Image Source: Author (2018)

**Step 2**

Figure 12: The main water tower (reservoir) of untreated water (water is supply from the local water wells)

Image Source: Author (2018)

**Step 3**

Figure 13: Water deferrization unit of water purification plant (WPP)

Image Source: Author (2018)

**Step 4**

Figure 14: Sand filter tank

Image source: Author (2018)

**Step 5**

Figure 15: The residues from the sand filter tank (deferrization units) are drain out from the WPP

Image Source: Author (2018)

**Step 6**

Figure 16:  After deferrization water safety tank

Image Source: Author (2018)

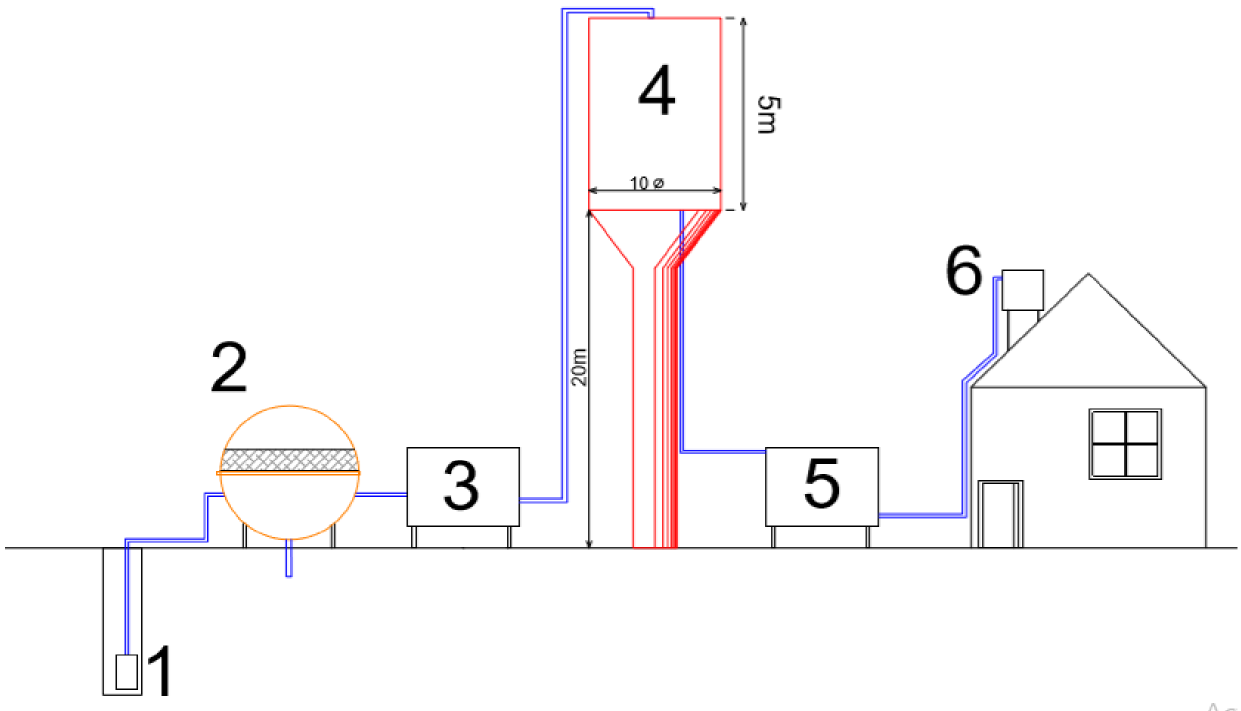
# 4. Result

After we analyzed our collected data and the system which is used by the Pourasava water pump station I have been proposing three solutions to mitigate the level of arsenic in the water. The technologies that we could use to improve water purification efficiency are described below. Resources and water quality are crucial to human health and children's development. If the water sources were contaminated and polluted, many lives could be endangered. In addition, care must be taken to ensure access to water resources for the poorest people, especially favela areas, which suffer from a major lack of access to safe drinking water.

As we can see from our own tested report (see Table 4) the arsenic level in our study pump station is too high **0.107 mg/l** in the water **(twice higher** than the Bangladesh standard, **ten times higher** than the WHO standard) and they don’t have any proper purification system to mitigate the arsenic level.

Our proposals for this problem solution are the three possible technologies which we can use to mitigate the arsenic level in the water through our propose technologies. Our proposed technologies combined with the current technology. Our new technologies to mitigate the arsenic level in the water described below.

## 4.1 Proposal of new technologies to mitigate the arsenic level into the water




Schema 2: Our Proposed new Technology

Image source: Author

In our Proposed technology we add three optional new technologies to mitigate the arsenic level in the water and we changed the operating system slightly to integrate the new technology.

In our proposed new technology point 1 is the water pump. This pump collected water from the underground wells.

Then the collected water went to the point 2 what is the same sand filter tank to purify the water from Iron by Kushtia Municipa.

Point 3$^{rd}$ is the addition of our new technology that mainly we are going to use to mitigate the arsenic level and purify the water from another harmful element.

We proposed three technologies

a) Ferrate

b) Ion Exchange

c) Reverse osmosis.

We can choose between these three technologies which will be more efficient according to Bangladesh climate and economic conditions.

After going through the point 3 water directly goes to the point 4 where is the water tower(reservoir) is. There the purifying water is stored.

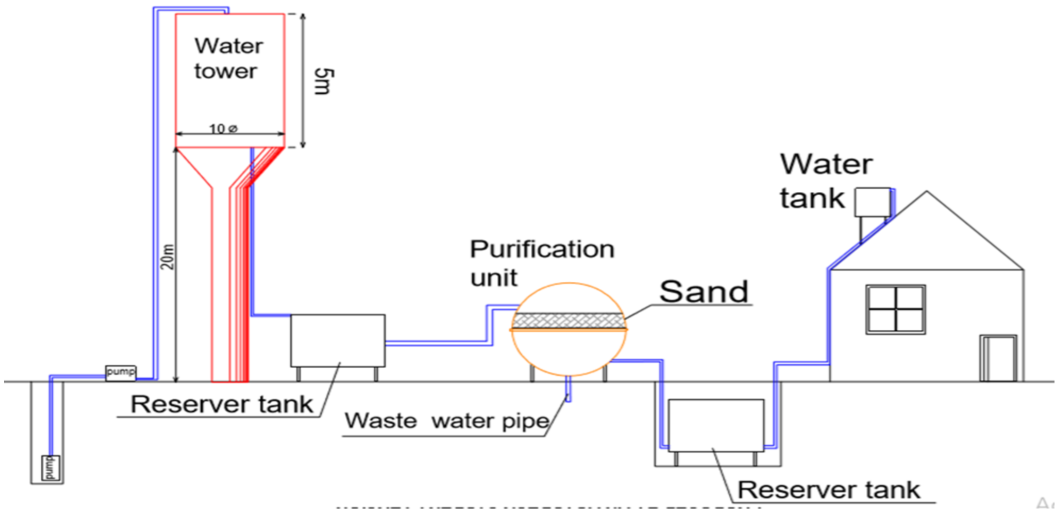
When the water needs to supply to the consumers then it will go through the point 5$^{th}$ where we add the disinfection unit (chlorination). Chlorination is the process of adding chlorine to drinking water to disinfect it and kill germs. With respect to the fact that water in reservoir could to be stored several days, the above-mentioned chlorination is essential step to keep water in the high quality.

After water goes through the point 5. The water is safe and could be supply to the consumers.

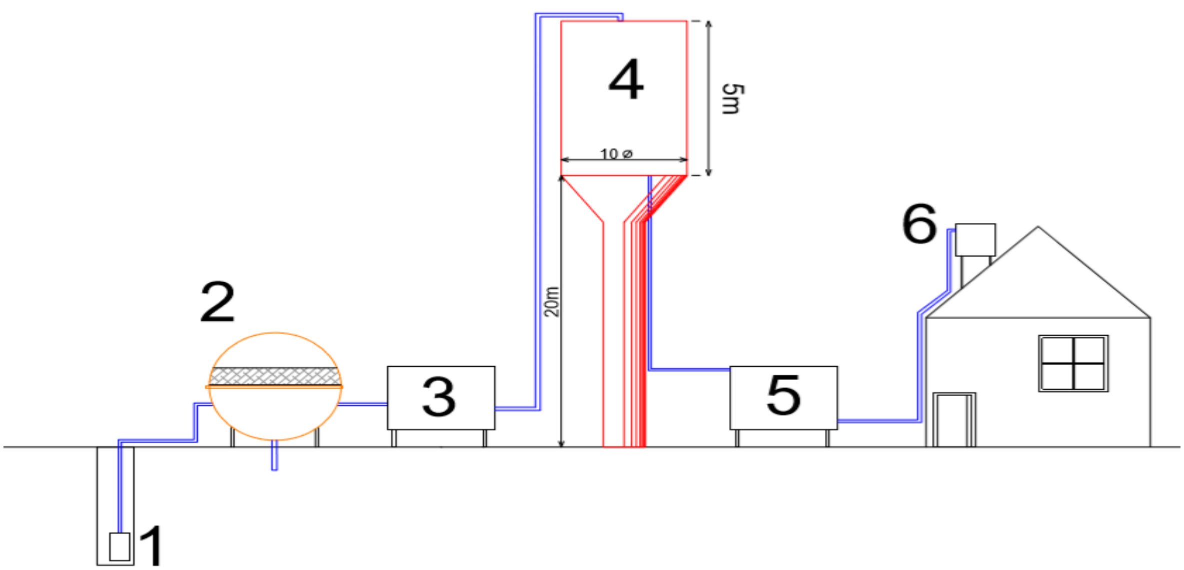
### 4.1.1 Difference between the present technology and the proposed technology

After analyzed the both technologies below we can see that in the present technology there is no technology used to mitigate the arsenic level which is **0.107mg/l**. There are many disadvantages in the present system 1$^{st}$ there is no technology present to mitigate this high level of arsenic also if there is no electricity available (which his quite common in Bangladesh) then there is no supply of water possible.

2$^{nd}$ there is no disinfection unit present to remove the bacteria from water which can easily grow because of stored the water for few days before supplying it to the consumers.




Present technology




New technology

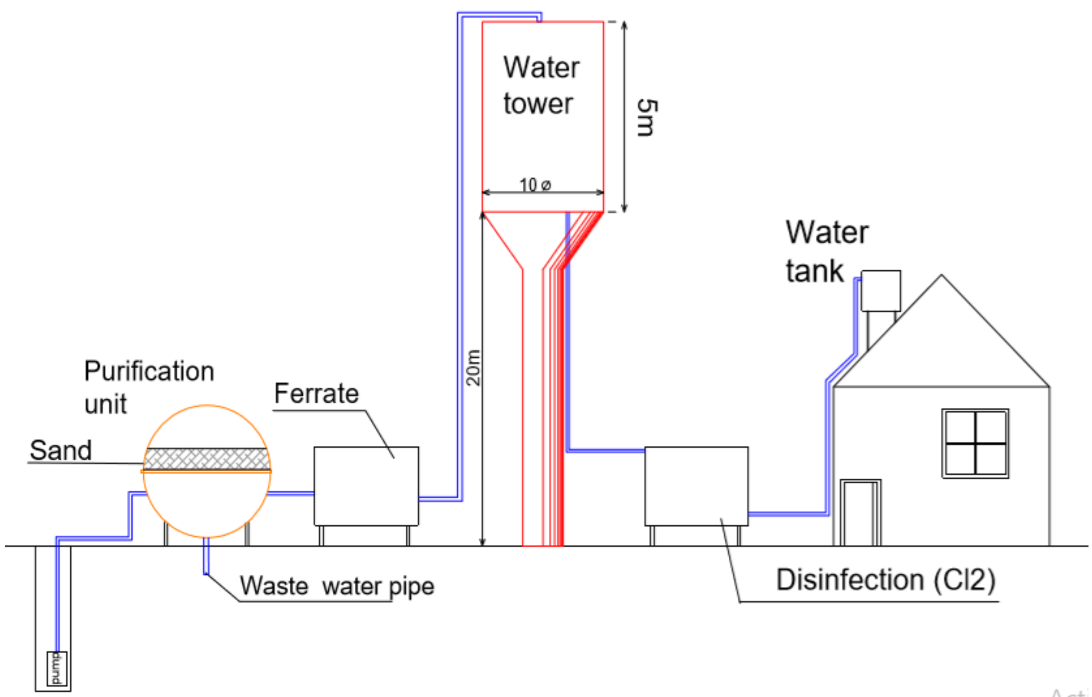
Figure 17: Present VS New technology scheme diagram

Image source: Author (2019)

As we described above about how the new technology work and all the function that is present in these technologies that mentioned advantage of these technologies. Also, from the above figure 15 we can see the main difference between these two technologies are the purification technology no 3 and the no 5 the disinfection unit which were added to the system to mitigate the arsenic level and supply safe water to the consumers.

## 4.2 Ferrate Technology

Ferrates are iron molecules in which iron is in a higher oxidation state than VI. This technology is suitable for the removal of heavy metals, pharmaceuticals, inorganic and organic contaminants, pesticides, disinfectants and lotion in water and is therefore not only ideal for removing substances after application of pesticides and fertilizers in fields that are subsequently washed away in rivers, but also in other issues with polluted water. These substances must be removed from the water for reasons for drinking water safety. (Ferrate Treatment Technologies 2017)




Schema 3: Our proposed technology with Ferrate technology

Image source: Author (2019)

Ferrates are iron molecules in which iron is in a higher oxidation state than VI. They do not produce any by-products, are environmentally friendly and are able to cure very heavily infested water. It is also one of the cheapest and most effective water purification options.

In a single dose, ferrate can act as a coagulum, oxidant, and disinfectant at the same time. They are stronger than other oxidants, such as ozone or sulfur dioxide. It can also replace coagulants such as ferric chloride. It can also overcome disinfectants such as UV, hydrogen peroxide and chlorine. Removal of organisms can be much greater than with chlorine. (Ferrate Treatment Technologies 2017)

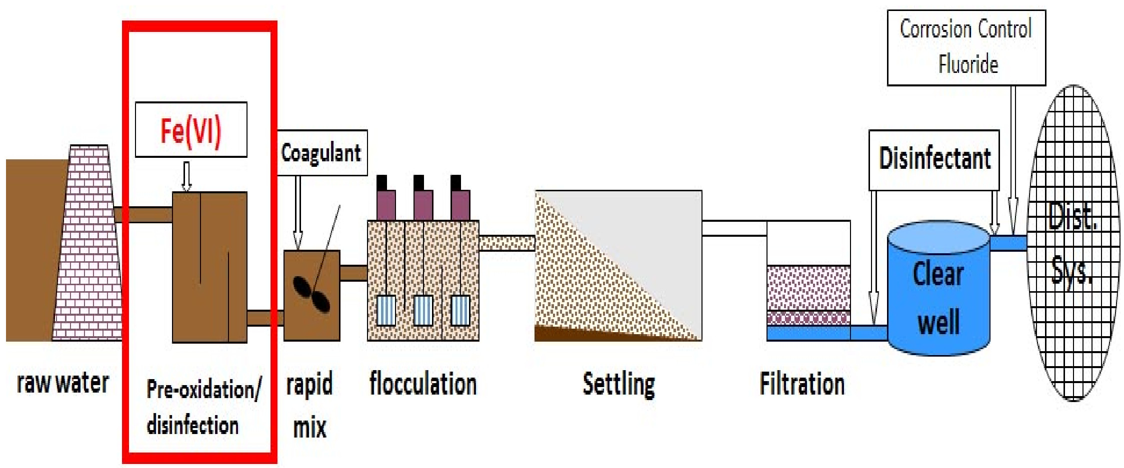



Figure18: Schema of Ferrate

Image source: Google

Ferrate is a potent, fast-acting, low-dose formulation that produces products such as ferric hydroxide, iron, and other non-toxic and environmentally friendly compounds. Based on proficiency tests, ferrate has been found to treat water, antibiotics, hormones, pesticides, and other personal care products that end up in sewage and go through urban wastewater treatment plants. Ferrates offers an economic and ecological alternative to conventional water and wastewater treatment technologies. Ferrate synthesis uses commodity chemicals that are already found in most wastewater and wastewater treatment plants. This system uses less real estate and uses less energy. (Ferrate Treatment Technologies 2017)

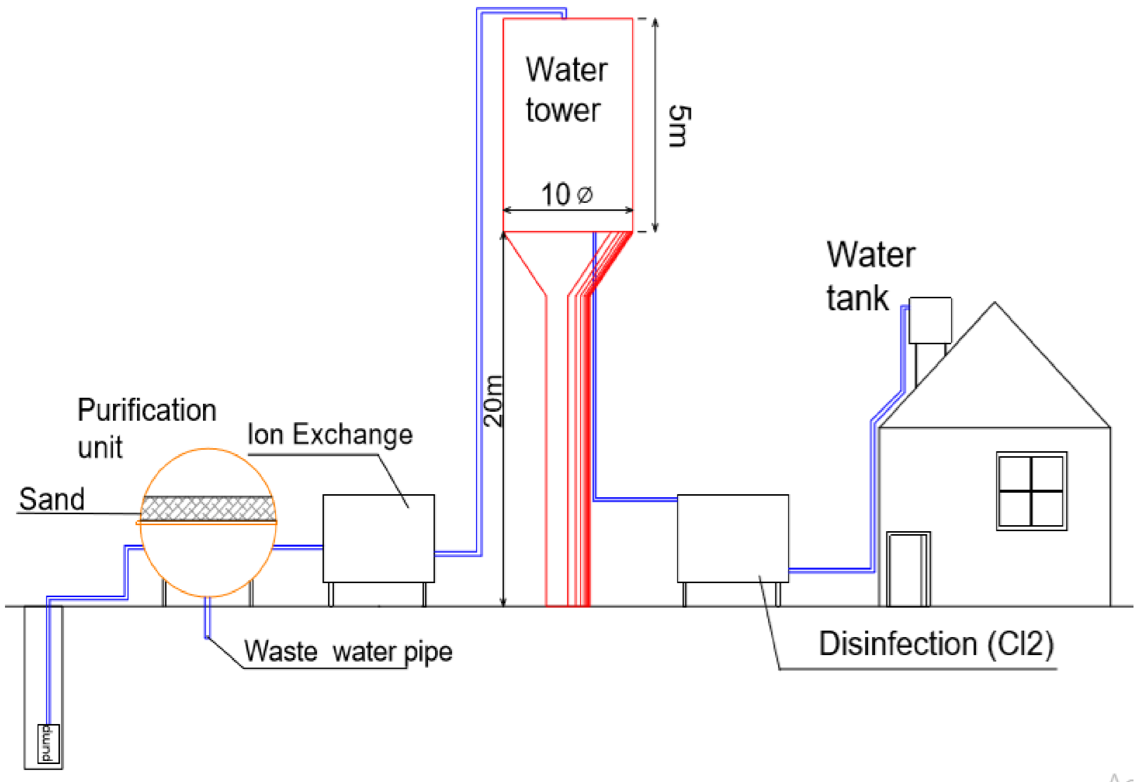
**This method reduce arsenic in range 82 to 96%.**

Figure 19: Ferrate Treatments technology

Image source- Google

## 4.3 Ion Exchange technology

Ion exchange is the exchange of ions with ionized species in water with ion exchangers, ie H+, and OH- ions. The process is reversible and can be regenerated by washing with excess ions. The principle of this technology is as follows. Water flows through the bed of ion exchange resins where the ions in solution migrate into the beads. Here, depending on the relative densities of the changes, they compete for exchange sites. The resins are 1 mm thick porous particles made of highly crosslinked, high ion exchange sites with high ion exchange rates. (Elga veolia 2019)




Schema 4: Our proposed technology with Ion Exchange

Image source: Author (2019)

Deionization beads are cationic or anionic and exchange either H+ ions for cations, which may be Na+, Ca 2+, or OH-ions for anions, which may be Cl-, NO 3-. The hydrogen ion from the cation exchanger is combined with the hydroxyl ion exchanger to form clear water. (Elga veolia 2019)

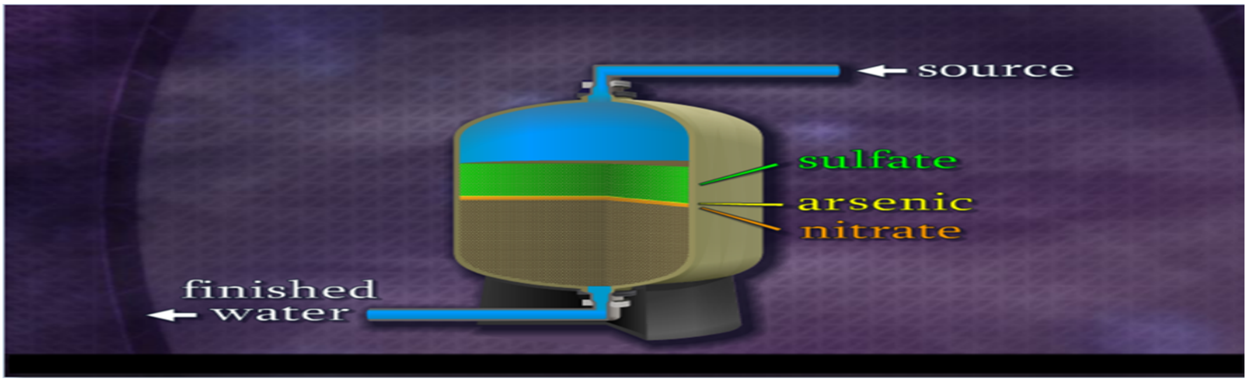


Figure 20: Ion exchange

Image Source: EPA 2015

The ion exchange resin beds are available as containers and are commonly used for some time before replacement. This occurs when cations and anions have replaced most of the active sites H+ and OH-. Once depleted, they can be regenerated by washing with excess desirable ions using strong acids and bases. This reverses the process and removes unwanted cations and anions. This process requires the use of chemicals. (Elga veolia 2019)

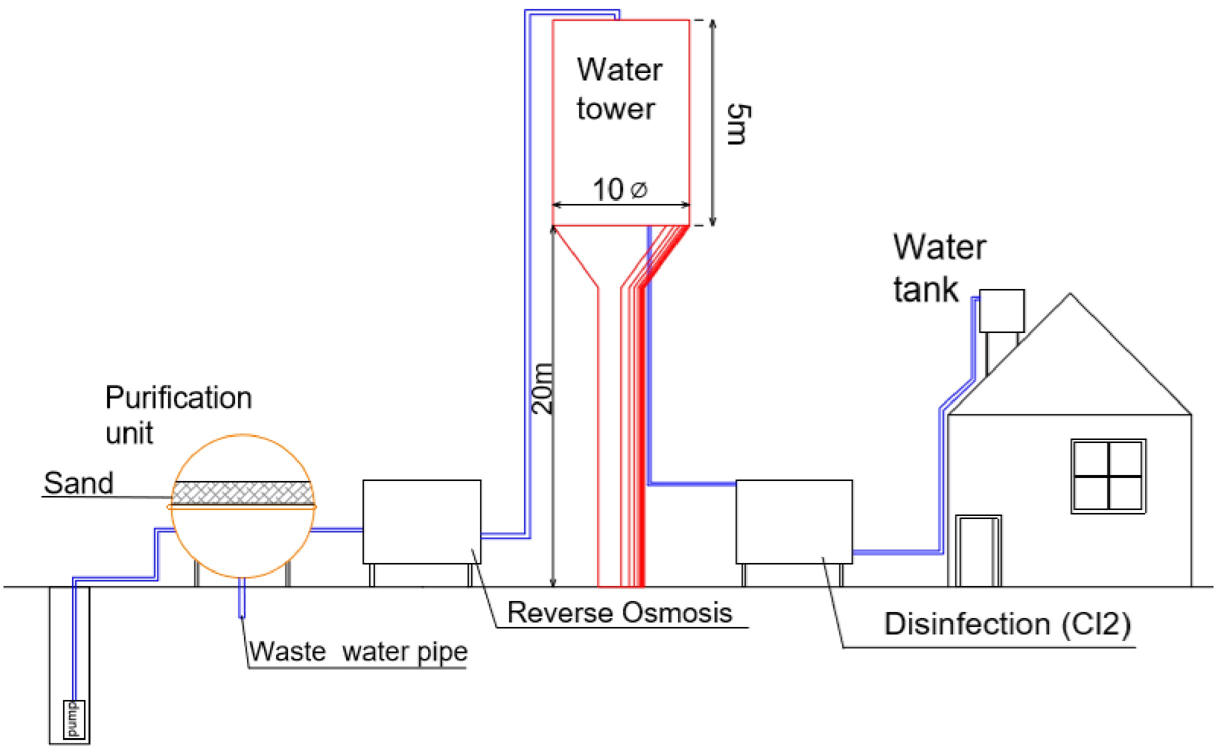
Figure 21: Ion Exchange Technology

Image source: Google

**This method reduce arsenic in range 90 to 96%.**

## 4.4 Reverse Osmosis technology

This technique is an effective way to remove impurities from water using a semipermeable membrane. It is a process in which water flows through a membrane under pressure. **This method removes up to 99 % of impurities.** (Elga veolia 2019)




Schema 5: Our proposed technology with Reverse Osmosis

Image source: Author (2019)

During reverse osmosis, the feed water is pumped around the inlet side of the reverse osmosis membrane under pressure – this is 4 to 16 bar. Normally 15-30 % of the feed water passes through the membrane as permeate and leaves the membrane as a concentrate that contains most of the salts, inorganic substances and other particles. (Elga veolia 2019)

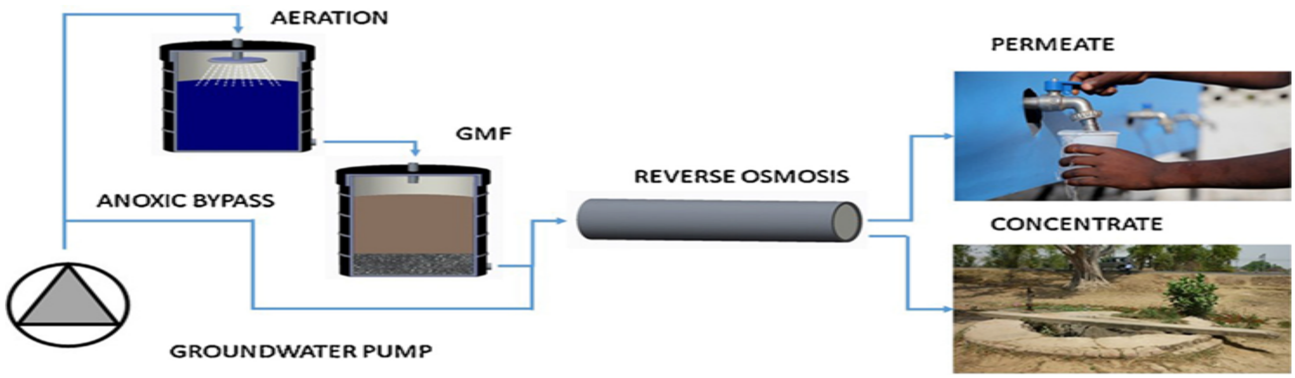



Figure 22: Schema of reverse osmosis

Image source: Schmidt et al. 2016

Reverse osmosis is a typical thin film polyamide and is stable over a wide pH range. However, it may be damaged by oxidizing agents such as chlorine. Before using this method, it is necessary to clean the water from all possible oxidizing agents. Reverse osmosis is used to remove contaminants from water and water pollution that is less than 1 nm in diameter. More than 90 % of the ionic impurities, most organic impurities and almost all particles, bacteria and bio-molecules are removed from the filtrate or water permeate. This technology is suitable for removing inorganic compounds, microorganisms and bacteria, organic compounds and particles from water. (Elga veolia 2019)

Figure23: Reverse Osmosis Technology

Image source: Blending Technologies 2016

# 5.Discussion

In Bangladesh, safe drinking water is not available for most of the population. Thousands of people die from arsenic poisoning every year in Bangladesh. Most of the population depends on their area water pump station for the supply of water for their needs. From our reports we can see that the arsenic present in the water is more than 0.1mg/l in most of the water pump station, where Bangladesh standard is 0.05mg/l and WHO standard is 0.01mg/l.

Arsenic is a slow poison which works slow but effectively in our body and that is the reason why people do not understand the effects of arsenic. And, there is no formal education or awareness about arsenic in Bangladesh so that people can understand the effect of arsenic and how dangerous it for our body. People living in contaminated areas, per capita, the daily average intake of arsenic was estimated to be 45.7% was from drinking arsenic-contaminated water and 54% through food. The exposure through vegetables and grains becomes more complicated when the food is cooked or processed with arsenic-contaminated water.

The Government of Bangladesh was alerted to the ailments caused by arsenic as early as 1993, and physicians at the Dhaka Community Hospital (DCH) saw many victims in 1996. 1st project done by the government was Unicef-Supported Arsenic Mitigation Programme, 1984. After the arsenic crisis noticed by government many projects done such as Environment Consciousness Education Arsenic and Waterborne Disease -Free Water A PILOT PROJECT, for teachers and children (Schools),2000.

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Development of the SONO Filtration System, 2001.

THE DCH DUGWELL DEMONSTRATION (PILOT) PROJECT April 2002.

Caretakers of government water points, as well as government officials and staff of nongovernmental organizations (NGOs) and the analysis of approximately 125,000 government water points installed between 2006 and 2012 (constituting approximately 85 percent of government water points installed during this period).

Despite government reports stating that the government should do a better job of targeting arsenic mitigation options in areas where they are most needed, it inexplicably fails to do so. Human Rights Watch wrote to the government to ask the reason for this approach, but no reply had been received at time of publication (Atish Saha/Human Rights Watch,2016)

Recently in 2018 Youth Mappers at AUW Bangladesh did project called Mapping Arsenic Contamination supported by USAID in the area of Barayadala, Sitakunda which has been recently found out to be a highly affected arsenic area ( Paromita Basak,2018).

As mentioned previously there is no such technology or project done or exist by Government that can help to mitigate the arsenic. Our study area Kushtia area is different than the other areas there is also no such technology exist to fight against the arsenic poison. In our study area Kushtia from there each pump station they supplied water for more than 2 thousand houses so almost for 5 thousand people each day. But there is no specific technology used to mitigate the arsenic level in the water (see schema 1). The water consumption for each house is approximately 50 liter per day. The water pump station with water purification unit is able produce about 100 $m^3$ per day. Area Kushtia very often suffers from power outages. With respect to the fact that real capacity of reservoir is about 314 $m^3$ the water in reservoir is able supply households, in case of blackout, for duration of three days.

By analyzing the current treated water and the other water test report, the arsenic level is found. Based on those results and analyzed the system, with the help of a specialist, we proposed an alternative solution to the current water treatment for Pourasava water pump station, with a design of water purification unit to improve the quality of the produced water and make it safe to drink for the consumers.

After the analysis the water test reports and compared to the existing technology, we upgrade the system (see schema 3,4,5) and add the technologies with it to mitigate the arsenic and other microbial elements. As shown in schema 3,4,5 we reverse the system a little bit. With our solution at first, we pump the water from underground than it directly goes the existed purification unit after that we add technology their ferrate/ ion exchange/ reverse osmoses then we hold the water in the water tower. In the water tank, we can hold the water for a few days. And when we want to supply the water, the water comes directly from the water tower then goes through the chlorination unit which helps to remove the bacteria from the water. We need this chlorination cation unit because when the water is stored for a few days, bacteria might begin to grow in the water supply. With the help of a chlorination unit, bacteria or any kind of harmful microbial elements are removed from the water. Then we can finally supply the safe water to the household for the consumers.

Importantly, our system will also work when there is no electricity available. This is highly significant for us because in Bangladesh there are almost 4 to 5 hours each day when there is no electricity available.

# 6.Conclusion

The result of the study has proposed a suitable design of the auxiliary water purification unit for the main water supply station in the city of Kushtia, in the ward of Pourasava. The study was conducted in different stages, starting with samples and data collections. The primary data got from the analyses on the data collected from Kushtia Municipal. The secondary data collected from my own household collected water test report and other different water test reports.

The evaluation of the analysis of the system used by the Kushtia municipal to provide the water for the consumer's results highlighted the critical points which are there is no external system to purify the water from highly contaminated arsenic. Therefore, based on that information, we designed an auxiliary water purification unit which would improve the output of the main treatment center.

The implementation of the new design of the auxiliary water purification unit with modern technologies should be recommended to the Kushtia municipal. By the implementation of the new proposed design, the quality of the water produced is not only improved but it also it provides the continuous supply of water to the consumers. The new system can supply the water when there is no electricity available because of the high altitude of the water tower.

Between all three proposed technologies the reverse osmosis can caught up to 99% of impurities but it is expensive technology which is difficult to implement in country like Bangladesh, where is low economy. The Ferrate technology would be the first choice with the respect of the Bangladesh climate and economical condition. These days it is the most popular technology in the world. Ion Exchange could be also suitable technology through the fact that design and implementation is relatively simple and cheap.

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# 8 The Appendix

## 8.1 The water test report from other water pump stations

(02)

| SL No. | Pump ID | Sample Type | Ward | Sample Location/Description | GPS Reading Latitude | GPS Reading Longitude | Arsenic (mg/L) LOQ:0.0007, BDS:0.05 | Iron (mg/L) LOQ:0.09, BDS:0.3-1 | Manganese (mg/L) LOQ:0.04, BDS:0.1 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 13. | Dinomoni Pump | Ground Water | 08 | Dinomoni | 23°54′14″ | 89°08′29″ | 0.024 | 0.69 | 0.69 | |
| 14. | Mohini Mill Pump | Ground Water | 10 | Mohini Mill | 23°54′02″ | 89°08′49″ | 0.034 | 1.11 | 0.71 | |
| 15. | North Side Pump (AIRP-3) | Ground Water | 12 | Harishankerpur | 23°53′34″ | 89°08′51″ | 0.014 | 0.68 | 0.97 | |
| 16. | South Side Pump (AIRP-3) | Ground Water | 12 | Harishankerpur | 23°53′34″ | 89°08′51″ | 0.019 | 0.87 | 1.96 | |
| 17. | Over Head Tank | Ground Water | 12 | Harishankerpur | 23°53′34″ | 89°08′51″ | 0.012 | 0.34 | 0.08 | |
| 18. | Surzasena club (New Pump) | Ground Water | 09 | Aruapara | 23°53′59″ | 89°08′19″ | 0.039 | 1.83 | 0.80 | |
| 19. | Surzasena club (Old Pump) | Ground Water | 09 | Aruapara | 23°53′59″ | 89°08′19″ | 0.037 | 1.16 | 1.03 | |
| 20. | Kalisankerpur Pump | Ground Water | 07 | Kalisankerpur | 23°53′46″ | 89°07′58″ | 0.027 | 1.15 | 0.63 | |
| 21. | New Pump | Ground Water | 06 | Housing-B, New | 23°53′32″ | 89°07′51″ | 0.013 | 1.24 | 0.65 | |
| 22. | Old Pump | Ground Water | 06 | Housing-A, Old | 23°53′31″ | 89°07′51″ | 0.018 | 1.46 | 0.77 | |
| 23. | Housing-C Pump | Ground Water | 06 | Housing-C | 23°53′31″ | 89°07′51″ | 0.020 | 8.74 | 0.39 | |
| 24. | Bus Terminal Pump | Ground Water | 05 | Bus Terminal | 23°53′33″ | 89°06′57″ | 0.030 | 2.85 | 0.37 | |
| 25. | Udibari Pump | Ground Water | 15 | Udibari Govt. Primary School | 23°54′20″ | 89°06′41″ | 0.030 | 1.10 | 0.22 | |
| 26. | Shisu park Pump | Ground Water | 04 | Kamrul Islam Siddiq Shisu park | 23°54′19″ | 89°07′49″ | 0.019 | 0.54 | 1.02 | |

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Sample Analyzer
DPHE, Zonal Laboratory, Jhenaidah.

06/09/17
Md. Moniruzzaman
Sample Analyzer
DPHE, Zonal Laboratory, Jhenaidah.

06/09/17
Md. Nazrul Islam
Junior Chemist (C.Ch.)
DPHE, Zonal Laboratory, Jhenaidah.

Water Test Report 1

Repot source: Kushtia Municipal

## 8.2 Water test report different houses collected water

Government of the People's Republic of Bangladesh
Office of the Senior Chemist
Department of Public Health Engineering (DPHE)
Zonal Laboratory, Jhenaidah.
Phone : 0451-61416, Email :wqmsc_jhenaidahzonallab@yahoo.com

**Water Quality Test Reports**

District : **Kushtia**, Pourashava : **Kushtia Pourashava.**
Water Quality Monitoring and Surveillance, Phase- 01(one), Month: August/2017.

| SL No. | Source of Sample | Ward | Sample Location/Description | GPS Reading | | pH | Fecal Coliform (FC) cfu/100ml | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | Latitude | Longitude | | | |
| 01. | Household Tap | 01 | Sirajul Islam (Raton), thanapara | 23°54′41″ | 89°07′22″ | 7.7 | 0 | |
| 02. | Street Hydrant | 02 | Near Kuti para Pump | 23°54′40″ | 89°07′43″ | 7.7 | 0 | |
| 03. | Household Tap | 12 | Sodanando Biswas, 32-Nuruddin Sarak | 23°53′34″ | 89°08′51″ | 7.5 | 0 | |
| 04. | Household Tap | 06 | Haider Ali, Housing - B,247 | 23°53′31″ | 89°07′49″ | 7.1 | 0 | |
| 05. | Household Tap | 05 | Jashoda Bala, Floor-1, Adarshapara | 23°53′34″ | 89°06′58″ | 7.1 | 0 | |
| 06. | Household Tap | 04 | Jalal Shekh, Beside Shisu park, H-009 | 23°54′20″ | 89°07′49″ | 7.2 | 0 | |
| 07. | Household Tap | 15 | Enamul Haq Chistia, Beside Udibari Pump | 23°54′20″ | 89°06′41″ | 7.3 | 0 | |

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DPHE, Zonal Laboratory, Jhenaidah.

06.09.17
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DPHE, Zonal Laboratory, Jhenaidah.

06/09/17.
Md. Nazrul Islam
Junior Chemist (C.Ch.)
DPHE, Zonal Laboratory, Jhenaidah.

Water Test Report 2

Report source: Kushtia Municipal

## 8.3 Water test report collected from Department of Public Health Engineering

**Government of the People's Republic of Bangladesh**
**Office of the Chief Chemist**
**Department of Public Health Engineering**
**Central Lab, 38-39, Mohakhali C/A, Dhaka-1212**
Phone: 88-02-9881927, Fax: 88-02-9882003 , Email: wqmsc_central_lab@yahoo.com

Lab Memo: 1345/ CC, DPHE, CL, Dhaka. Date: 21-01-2019

**Physical /Chemical/ Bacteriological Analysis of Water Sample**

| | |
|---|---|
| Sample ID: CEN2019010058 | Sample Receiving date: 06-01-2019 |
| Ref. Memo No: EM/UAEL/2019/02 & Dated: 06-01-2019 | Sample Source: Ground Water |
| Sent by:Salma Akhtari ,Proprietor , Miah Environmental Monitoring Centre. | Dist:Brahmanbaria, Upa:Ashuganj |
| Care Taker: Miah Environmental Monitoring Centre | Union:, Vill.: |
| Sample Collection date: 05-01-2019 | Date of Testing: 06/01/2019-14/01/2019 |

**LABORATORY TEST RESULTS:**

| Sl.# | Water quality parameters | Bangladesh Standard | Concentration present | Unit | Analysis Method | LOQ |
|---|---|---|---|---|---|---|
| 1 | Alkalinity | - | 105 | mg/L | Titrimetic | - |
| 2 | Arsenic (As) | 0.05 | 0.012 | mg/L | AAS | 0.001 |
| 3 | Chloride | 150-600 | 120 | mg/L | Titrimetic | - |
| 4 | Coliform (Faecal) | 0 | 0 | N/100ml | MFM | - |
| 5 | Coliform (Total) | 0 | 0 | N/100ml | MFM | - |
| 6 | Colour | 15 | 0.95 | Hazen | UVS | - |
| 7 | Hardness | 200-500 | 100 | mg/L | Titrimetic | - |
| 8 | Iron (Fe) | 0.3-1 | 0.19 | mg/L | AAS | 0.05 |
| 9 | Manganese (Mn) | 0.1 | 0.06 | mg/L | AAS | 0.03 |
| 10 | pH | 6.5-8.5 | 6.5 | - | pH Meter | - |
| 11 | Total Dissolved Solid (TDS) | 1000 | 256 | mg/L | Multimeter | - |
| 12 | Turbidity | 10 | 4.0 | NTU | Turbidity Meter | - |

Comments: Sample was collected & Supplied by client.
N.B: AAS- Atomic Absorption Spectrophotometer, UVS- UV-Visible Spectrophotometer, MFM= Membrane Filtration Method, LOQ - Limit of Quantitation.

| Test Performed by: | Signature | Countersigned/Approved by: | Signature |
|---|---|---|---|
| 1.) Name: Md. Saiful Alam Khosru<br>Designation: Sample Analyzer | 21.01.19 | 1.) Name: Md. Biplab Hossain<br>Designation: Chief Chemist | 21/01/2019<br>Md. Biplab Hossain<br>Chief Chemist<br>Department of Public Health Engineering<br>Central Laboratory Mohakhali, Dhaka. |
| 2.) Name: Taslima Akhter<br>Designation: Sample Analyzer | 21.01.19<br>Sample Analyzer<br>DPHE, Central Laboratory<br>Mohakhali, Dhaka. | 2.) Name:<br>Designation: | |

Page 1 of 1

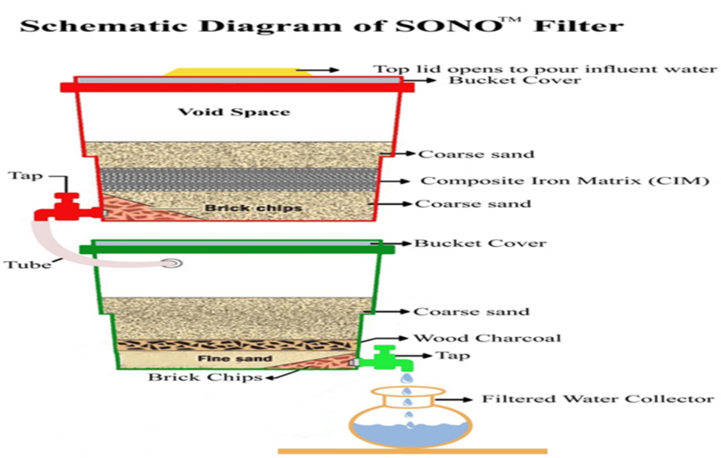
Water test Report 3

Report Source: DPHB

## 8.4 The technology could be used in the household to mitigate the arsenic level in the water

### Sono Filter

Invented in 2006, the Sono arsenic filter is a simple device that uses a “composite iron matrix” that can be manufactured locally from cast iron turnings, along with readily available river sand, wood charcoal, wet brick chips and two buckets. The top bucket is filled with locally available coarse river sand and a composite iron matrix. The sand filters coarse particles and controls the flow of the water, while the iron removes inorganic arsenic. The water then flows into a second bucket where it again filters through coarse river sand, then through wood charcoal to remove other contaminants, and finally through fine river sand and wet brick chips to remove fine particles and stabilize water flow. The filter’s humble housing in a stack of two buckets belies its power to change lives: It can remove 98 percent of the arsenic in water, as well as other organic, bacterial and mineral impurities. Tested by the US National Academy of Engineering in 2006, the Sono filter meets WHO and Bangladesh standards.




**Sono filter Schematic diagram( Smithsonian, 2011)**

## 8.5 Arsenic poisioning effect photos on Human body