# INVESTIGATION ON THE IMPURITIES OF SURFACE WATER AND ITS PURIFICATION FOR DRINKING PURPOSE BY A PROTOTYPE TREATMENT PLANT

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## ABSTRACT

In Bangladesh, underground water is abundantly available, but the underground water for drinking purposes is getting vulnerable due to excessive arsenic, dissolved iron, and other forms of contamination. Moreover, using a lot of underground water has become a problem in lowering the underground water table. In this perspective, consumption of surface water has been practiced in many places in Bangladesh. However, it is physically and bacteriologically polluted due to poor sanitation and hygiene practices. Hence, it needs proper treatment to make it potable. This study was conducted to design and develop purifying techniques to purify surface water collected from the Padma river in Faridpur city. A low-cost prototype water treatment plant, including a rapid sand filter, was designed. It was estimated that the total production cost per 26.4 liters is only one taka, which is very economical. The plant efficiently removed turbidity and other essential parameters such as iron, TDS, TSS, etc. The test results show that water quality is allowable with BD and WHO standard limit for pH, color, turbidity, TSS, TDS, hardness, DO, odor, chloride and manganese. This study would be helpful to build a large-scale surface water treatment plant in Faridpur city.

***Keywords:*** *Impurities, Prototype Treatment Plant, Rapid Sand Filter, Turbidity*

## 1. INTRODUCTION

Water is found in nature from two main sources ground water source and surface water source. Ground water has been pulled in our country by deep, shallow and handpump tube wells and also by ring wells. Oceans and seas are the main sources of water on earth, but this water is salty (Aziz, 1975, p. 1). The fresh liquid water sources on land surfaces and in the ground constitute only about 1% of the total water on earth. The main sources of water in Bangladesh are surface waters in rivers, reservoirs, lakes, canals and ponds and groundwater in shallow and deep aquifers. The rain water is alternative sources water and has good potential for water supply in Bangladesh (Zahid, 2015).

Bangladesh has one of the highest population densities in the world, with a population of 165 million living within 57,000 square miles. Of those 165 million people, More than 1.8 million people in Bangladesh lack access to an improved water source (Bangladesh, 2021). Water is associated with the spread of communicable diseases in essentially two ways. The first is the well-known direct ingestion of the infectious agent when drinking contaminated water and the second is due to a lack of sufficient water for personal hygiene purposes (Gibson & Singer, 1969, p. 2). About 80% of all illness and diseases can be attributed to inadequate water supply or sanitation. For example, in developing countries every year diarrheal disease kills 6 million children (Bangladesh, 2021). The World Health Organization says that every year more than 3.4 million people die because of water related diseases (Voanews, 2009)

There are 123 upazilas including 11 million affected people in whole or in part by a seasonal low water table. Moreover, extensive extraction of ground water enhances the risk of stability of underground strata. It is estimated that over 70 percent of tube wells in Bangladesh have iron concentration in excess of the 1 mg/L set by WHO as the maximum desirable level. Consuming excessive iron may create fatigue, weight loss, joint pain and eventually may affect liver, heart and lead to pancreatic damage and diabetes (Rebecca, 2012). Groundwater in Bangladesh contains a higher concentration of arsenic than surface water sources and the groundwater contains both forms of inorganic arsenic (AsIII and AsV), and AsIII is the predominant species. In 2003, a nationwide blanket survey was conducted by Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), covering 57,482 villages located in 271 upazilas, where it was reported that out of 4.95 million tube-wells for arsenic contamination, 1.44 million tubewells were contaminated. Arsenic is toxic substance to human health and toxicity depends on the amount of arsenic intake, which is classified into acute, sub-acute and chronic toxicity respectively. It is a silent killer (Ahmed et al., 2018).

However, ground water is not very scare to the rural people but they cannot use it always due to above mentioned problems. It is important to ensure the use of surface water instead of underground water to avert the impending risk as the underground water level is lowering at an alarming rate. The present source of water supply for Faridpur municipality is completely depends on groundwater. The groundwater of Faridpur municipality contains excessive dissolved iron. There are two iron removal plants having capacity of 200 m3/day. This treatment plant can produce 8,800 m3/day treated water for 6,760 residential connections and 308 commercial connections which is not sufficient to meet the present water demand. The piped water supply system can cover 40% of the total population, and 60% depends on shallow hand tube-wells and other own sources. As the groundwater quality of the area has deteriorated overtime, the municipality needs to explore utilization of surface water sources. Water from the Padma River may be a good source of surface water available for Faridpur municipality (Asian Development Bank, 2017).

### 1.1 Objectives of the Study

The specific objectives to conduct the research are as follows:

- To find out the impurities in surface water collected from Padma River.
- To build a prototype surface water treatment plant.
- To determine the effectiveness of prototype surface water treatment plant.
- To Supply safe drinking water at reasonable cost.

## 2. METHODOLOGY

A detailed literature survey on the relevant subject was carried out to understand better and represent the problem. The research framework involves the statement of the research's problems, creating an acceptable hypothesis, data collection, analysis of data, interpretation of the results, recommendations, etc. The study was carried out in several stages. In this study, descriptive and inferential methods were used. The type of data required will largely determine the most appropriate method to be used. This study was conducted step-by-step some major conceptual processes are shown in Figure 1.

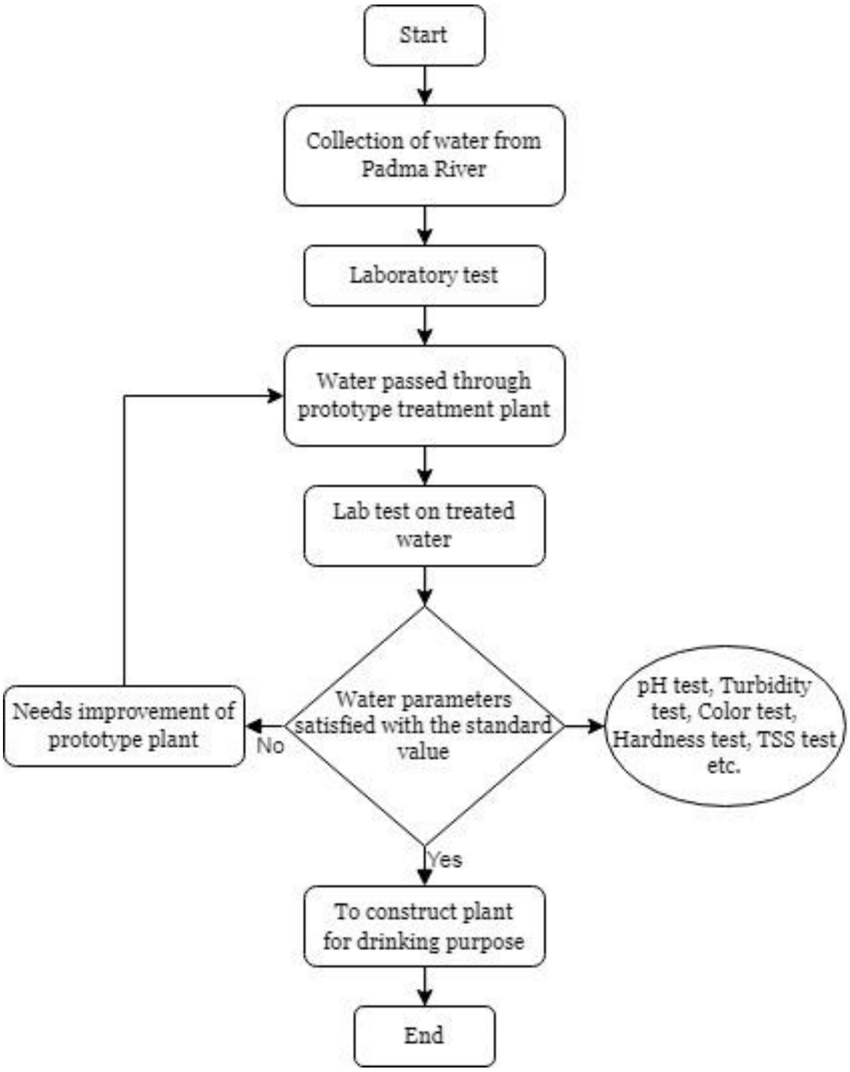


**Figure 1:** Methodology Flow Chart

An efficient surface water treatment plant was developed, which includes preliminary treatment, primary treatment, secondary treatment by RSF and tertiary treatment by chlorination.

## 2.1 Sampling and analytical Methods

The three surface water samples were collected from Padma River at dholar mor area (23°36'59"N, 89°52'10"E) at a depth of 10–15 cm with three 25-L plastic containers at a distance of about 10 meters from each other, which was sterilized and soaked overnight with distilled water to avoid any change in the characteristic of the water sample. Then the sample was placed in a box containing ice bags to reduce temperature and transported to the Environmental Laboratory of the Civil engineering department of Faridpur Engineering College for analysis of physicochemical parameters of the water sample. In situ analysis for pH, dissolved oxygen and TDS was taken by Hanna- HI98194 multiparameter water quality meter. Turbidity was measured with Turbidity Meter-Lutron TU-2016. Hardness and iron were measured using a professional-grade test kit. Chloride was measured using chloride test kit (Hanna-HI3815) by titration with mercuric nitrate. TSS was measured using a portable total suspended solids meter and manganese using a manganese test kit.

## 2.2 Plant Design and Components of Plant

Firstly, the plant’s frame structural design has been considered. For that purpose, some slotted angle was taken to build the frame of the plant. The frame's height, width, and length were 42 inches, 40 inches, and 83 inches, respectively. The plant components were a raw water storage tank equipped with a screen, cascade aerator, rapid mix unit, sedimentation tank, Rapid sand filter, disinfection chamber and distribution chamber. These components were connected to each other by 1.5-inch dia water pipe. Wooden stair, test tubes, silicon paste as a sealant, alum, electric board, 6 meters water pipes (1.5-inch dia), 12-meter water pipes (0.5-inch dia), two water pumps (12v) and seven cylindrical tanks (8 litre water bottles) were used to construct the plant. The vital part of the plant was the cascade aerator and rapid sand filter. A cascade aerator was used because the process of cascade aeration is based mainly on gravity and the aeration of this type have more efficiency due high surface for contact with atmosphere. The water is pumped to the top of the aerator and cascades over a series of trays. Air is naturally inducted into the water floc to accomplish iron oxidation and some reduction in dissolved gasses. The rapid sand filter has six layers. The filter ingredients were coarse aggregate (stone chips), coarse sand, charcoal and filter paper.

(a) (b) (c) (d) (e)

**Figure 2:** (a) Stone chips;(b) Coarse sand;(c) Charcoal;(d) Filter paper;(e) Rapid sand filter

## 2.3 Process Description

Raw water was first stored in a cylindrical storage tank to settle heavier particles like sand and clay. A separation screen has been provided at the inlet of the storage tank to prevent large particles from passing through. After the pre-treatment stage, the water was allowed to enter into primary treatment, where a cascade aerator aerates it. Then the water is subjected to a coagulation process in a rapid mix unit where alum was used as a coagulant. After that, the water was allowed to pass through the sedimentation process, which is basically in a settling tank and settling was allowed to occur. Suspended material may be particles, such as clay or silts, initially present in the source water. A layer of accumulated solids, called sludge, forms at the bottom of the tank, stored in a sludge storage tank. Then the water passed through the rapid sand filter to remove turbidity and color. After that, the water needs to be disinfected, or else it cannot be drunk. Chlorination was used for disinfection. The Prototype Plant can supply 72 liters/day. The percentage of chlorine in bleaching powder ranges from 20-35%. To disinfect water, the required value of chlorine per liter of water is 1 milligram. For regular domestic use, residual chlorine levels at the point where the consumer collects water should be between 0.2 and 0.5 mg/l (WHO, 1996). Bleaching powder was used at the rate of 5 milligrams per litre for disinfecting the water. Then the water was ready for drinking purposes and stored in a distribution chamber.

**Figure 3:** Prototype plant lay-out

## 2.4 Economic Analysis

Economic consideration is the major factor of any plant design. Here we considered only cost of the whole plant and off-course the maintenance cost of the plant.

### 2.4.1 Prototype Plant Design Cost

As for our design consideration, there used seven water bottles as cylindrical tanks, two water taps and other instruments.

**Table 1:** Prototype plant design cost

| Item | Cost (tk) |
|---|---|
| 7 Cylindrical tank @50 tk each | 350 |
| 2 Water tap @150 tk each | 300 |
| Piping | 150 |
| Wooden stair | 700 |
| Decoration cost | 120 |
| Total cost of prototype plant | 1670 |

Therefore,
total cost of the prototype plant was 1670 taka.

### 2.4.2 Maintenance Cost

The plant have one 12V 1Amp water pump and one 12V 1Amp motor, so total power consumption,

$$E = pt = VIt \tag{1}$$

= 12×1×24 Wh
= 0.288 KWh/day
= 2×0.288 KWh/day (1 pump and 1 motor)

One unit retail tariff rate in Bangladesh was 5.72 tk (Bpdb, 2020).

= 0.576×5.72 tk/day (1KWh =1 Unit)
= 3.29 tk/day

Bleaching Powder required = 72×5 mg = 360 mg/day
The required value of alum per litre is 20 mg. So,
Alum required = 20 mg×72 = 1440 mg/day
Cost for Alum and Bleaching powder
= 1 tk/day (Approximately)
Total maintenance cost = 4.29 tk/day

The plant can produce 72 litres/day. Therefore, the production cost per 17 litres of drinking water was only one taka.

### 2.4.3 Plant Design Cost

As per our design consideration, the plant required seven cylindrical tanks (200m$^3$), one rapid sand filter with a backwashing system and one chlorine dioxide generator. The cost of these instruments was considered according to Alibaba.com, which is the leading platform for global trade.

**Table 2:** Plant design cost

| Item | Cost (tk) |
|---|---|
| 7 Cylindrical tank @17,00,000 tk each | 1,19,00,000 |
| 1 Rapid sand filter with backwashing system | 85,00,000 |
| 1 Chlorine dioxide generator | 4,00,000 |
| Piping cost @10-15% of tank | 11,90,000 |
| Instrumentation cost@ 5% of tank cost | 5,95,000 |
| Labor and supervisory cost @20% of tank cost | 23,80,000 |
| Miscellaneous @5% of tank cost | 5,95,000 |
| Total plant design cost | 2,55,60,000 |

## 3. RESULTS AND DISCUSSION

Through our research methodology, we got the laboratory test results of physicochemical parameters before and after treatment by our innovated prototype water treatment plant. In this research, laboratory analysis for three samples were carried out to study the effectiveness of the prototype treatment plant. The water samples quality parameters (such as chloride, hardness, manganese, iron, odor, color, pH, TDS, TSS, turbidity, dissolved oxygen) before and after water treatment are presented in Table 3.

**Table 3:** Average value for physicochemical parameters of raw and treated water samples

| SL No | Water Quality Parameters | Unit | Bangladesh Drinking Water Quality Standards | WHO Drinking Water Quality Standrads | Before Treatment (Avg.) | After Treatment (Avg.) |
|---|---|---|---|---|---|---|
| 1 | Chloride | mg/l | 150-600 | 250 | 25.5 | 8.6 |
| 2 | Hardness | mg/l | 200-500 | 500 | 175.2 | 24.2 |
| 3 | Manganese (Mn) | mg/l | 0.1 | 0.1 | NIL | NIL |
| 4 | Iron (Fe) | mg/l | 0.3-1 | 0.3 | 0.55 | 0.11 |
| 5 | Odor | | NIL | NIL | NIL | NIL |
| 6 | Color | | NIL | NIL | Sandy- Brown | NIL |
| 7 | pH | | 6.5-8.5 | 6.5-8.5 | 7.49 | 7.25 |
| 8 | $BOD_5$ | mg/l | 0.20 | 0.16 | 7.83 | 0.14 |
| 9 | Total Dissolved Solid(TDS) | mg/l | 1000 | 600-1000 | 470.63 | 98.8 |
| 10 | Total Suspended Solid(TSS) | mg/l | 10 | No guideline | 327.35 | 7.22 |
| 11 | Turbidity | NTU | 10 | 5 | 201 | 1.20 |
| 12 | Dissolved Oxygen | mg/l | 6 | No guideline | 6.52 | 9.64 |

Higher turbidity and bacterial concentration present in river and pond water which is generally unsafe for rural community health. Prior to the water treatment, the average chloride of raw water was 25.5 mg/L. The chloride concentration was reduced from 25.5 mg/l to 8.6 mg/l by filtration, which was satisfactory. The average iron contamination of raw water was found in the range of 0.55 mg/l and after filtration, the iron concentration was far below the WHO and BD standards. In the filtered water, the average TDS value was found to be 98.8 mg/l. The maximum TSS value was relatively high (327.35 mg/l) before treatment and reduced to a range of 7.22 mg/l, which was low and within the permissible limit. There was a significant reduction in TSS level from 327.35 to 7.22 mg/l. The reduction of turbidity was very satisfactory and efficient. Removal of alkalinity of water also a major advantage. The pH value dropped to 7.25 from 7.49. There was a bad smell of water before the treatment

(a) (b)

**Figure 4:** (a) Raw water; (b) Treated water

which went away after the treatment. The color of the water also changed from sandy brown to colorless during the filtration process. The turbidity of water was entirely removed after the treatment process was completed and completely disinfected water was found. From the data in the Table 4 it can be said that this method can be used in surface water treatment plant. The plant's design was done in such a way so that it can do purification with low maintenance cost. From the economic evaluation, the cost of producing 17 litres of purified water was only one tk, which seems to be very economical though the installation cost was found to be two crore fifty five lakh sixty thousand taka which seems to be high.

## 4. CONCLUSION AND RECOMENDATIONS

Although the initial installation cost was high, the maintenance cost was very economical and can be used. According to BD standard value, proper disinfection has been achieved in post-treatment. Therefore, from the above fact, the whole treatment seems to be economical and highly efficient for water treatment containing high organic and inorganic components and gives nearly complete disinfection, which can be used for surface water treatment plant.
The following recommendations can be used for future study by reviewing the results and experience of the research work presented in this research.

- This study is targeted to fulfill the water demand of Faridpur municipality. It is only a small set up for a surface water treatment plant. A broad study can be done for further development of the plant.
- Proper storage of surface water is an essential part of the surface water treatment system. The design of a sustainable surface water treatment plant should be well studied, and the possibility of improvement of the design can be evaluated.

For day-to-day domestic work and drinking water purification, utilizing a vast amount of surface water can reduce the pressure on groundwater. Surface water utilization should be practiced in different regions of Bangladesh, where groundwater is treated as a primary water source.

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