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An Analysis of Water Characteristics of Shiddhirganj 210MW Steam Power Plant, Sirajganj 225MW Combined Cycle Power Plants and Rooppur 2400MW Nuclear Power Plant in Bangladesh: A Comparative Study of Power Plant Grade Water

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ABSTRACT
Water quality has long been an important part of the operation of nuclear and thermal power plants. Water is used as a working and cooling fluid in power plants. The quality of source water to be used in the power plants after treatment should conform to the prescribed values of Physico-Chemical properties like pH, EC, TDS, Alkalinity, Hardness, presence of Chloride content, Silica, and Heavy metals as recommended by technical guidelines. To analyze the water characteristics, water samples were collected from various sources. Two river water samples and a groundwater sample (marked as PP1, PP2, and NPP site) were tested to determine the water properties. The Physico-chemical properties of the water samples were determined using various analytical tests. Heavy metals were also investigated using the Atomic Absorption Spectrophotometric (AAS) process. The Physico-chemical properties of investigated samples were so good as to the recommended values of the World Health Organization (WHO), United States of Public Health (USPH), and Bangladesh Environmental Department. But the values were very far from the recommended values for thermal power plants operation. So, it needs to treat to use in the boilers. Gravitation, Carbon filtration, Ion exchange method, and Reverse Osmosis (RO) are good ways to treat the water before use in power plants. The Padma River water is better than the other two samples when the Physico-chemical characteristics of the sample waters were analyzed to the prescribed levels for the boiler water of a thermal power plant and the secondary water circuit of a third-generation nuclear PWR reactor. The aim of this work is to explore the difference between the source water quality parameters values and those of the recommended values of technical guidelines. To minimize the water treatment cost, a new site for the installation of a power plant project in Bangladesh can be advocated depending on the availability of good quality water.
Keywords: Water Quality, Thermal Power plant, Nuclear Power Plant, Analysis of Water.

1 INTRODUCTION
In Bangladesh, 133 power plants are installed around the country. The present power generation capacity per capita in the country is 300 kWh. To ensure proper energy, two nuclear power plants of capacity (2×1200MW) are in the process of installation and extensive civil work is going on [1-2]. Water quality has long been an important factor in the operation of thermal and nuclear power plants [3-4]. A Proper water chemistry program is essential for the safe operation of power plants. It guarantees consistency with the design's assumptions and intents regarding the key plant structures, systems, and components. Sufficient information/data on water characteristics of the thermal power plants (Shiddhirganj 210 MW and Sirajganj 135 MW northwest Power Generation Company Bangladesh Limited (NWPGCBL) are not available in Bangladesh. This work has been undertaken to analyze the water characteristics in

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conventional type thermal and under construction Rooppur Nuclear Power Plants (RNPP). For the safe and reliable operation of thermal and nuclear power plants, difficulties with corrosion and the chemistry of water coolant play an important role [5-7] and the water regime for commercial water-cooled components must be improved to have the recommended value of water quality parameters, such as turbidity, pH, Electrical Conductivity (EC), Total Hardness (TH) and presence of Heavy metals proved to be satisfactory. [8-9].

2 MATERIAL AND METHOD

2.1 Sample Collection

The sample was collected from different source waters. To analyze the water characteristics two river waters and a groundwater sample were analyzed to study the water characteristics. The water sample was collected from the river of Shitalakkha near Shiddhirganj 210 MW steam turbine power station (marked as PP1) and was analyzed in their laboratory. The groundwater sample Sirajganj 225MW combined cycle power plant near Jamuna River (marked as PP2) at Sirajganj District was analyzed by the NWPGCBL lab. Another surface water sample was collected from the Padma River near the under-construction Roopppur Nuclear Power Plant (NPP) site at Rooppur, Pabna, Bangladesh, and analyzed in Environmental Engineering Laboratory, MIST, Dhaka.

2.2 Sample Analysis

The quality of Water of various source water was analyzed and compared with the standard values of boiler waters of conventional type thermal power plants and secondary circuit of VVER-1200, PWR Reactor. A digital pH meter (HANNA Instrument HT 2002-0, S/N CO316002) was used to calculate the pH, Digital TDS and EC meters (HANNA -2003-02, S/N: CO1271A1) were used to measure total dissolved solids (TDS) and electrical conductivity (EC), respectively. Heavy metals were estimated by the AAS process and the chemical properties of the samples of waters were determined by various analytical methods [10-12].

3 WATER QUALITY PARAMETERS

3.3.1 pH

The pH meter first needs to be calibrated, setting the temperature control knob to 25°C when choosing the pH mode. The pH meter was calibrated twice. A clean 400 ml beaker was used to hold the 250 ml of the sample while the pH meter was submerged within. The pH of the solution is calculated correctly and displayed [13–14]. PH, which is defined as the negative logarithm of the hydrogen-ion concentration, is the most common way to express the hydrogen-ion concentration.

$$pH= -\log_{10}[H+]$$

3.3.2 Electrical Conductivity (EC), Total Dissolve Solids (TDS), Salinity and Temperature

First, distilled water was used to clean the electrode on the conductivity meter. The electrode was inserted into a 400 ml beaker containing a 250 ml sample, and the beaker was then filled with water while signal counting was performed. Using a pH and EC meter, measurements of EC, TDS, salinity, and temperature were taken.

3.3.4 Atomic Absorption Spectrophotometer (AAS)

Atomic absorption by using the absorption of optical radiation (light) by free atoms in the gaseous or liquid form, spectrometry is a spectro-analytical method for the qualitative and quantitative determination of chemical elements as shown in Figure 1. The method makes use of absorption spectrometry to evaluate the analysis concentration in a sample. The Beer-Lambert Law is used to identify the relationship between the observed absorbance and, consequently, the analyte concentration when standards with known analytical content are not available. In fact, by absorbing a certain amount of energy, the electrons of the atoms in the atomizer are frequently moved to higher orbitals (exciting state) for a brief amount of time (nanoseconds) (radiation of a given wavelength). This level of energy, or wavelength, is only available during a certain electron transfer in a specific element. Since each wavelength typically corresponds to only one element, the length of an optical system is only a few picometers (pm), giving the method its elemental selectivity. A detector is used to monitor the radiation flux with and without a sample inside the atomizer, and Beer is then used to translate the difference between the two readings (the absorbance) to analyte concentration or mass. Lambert Law [15-17].

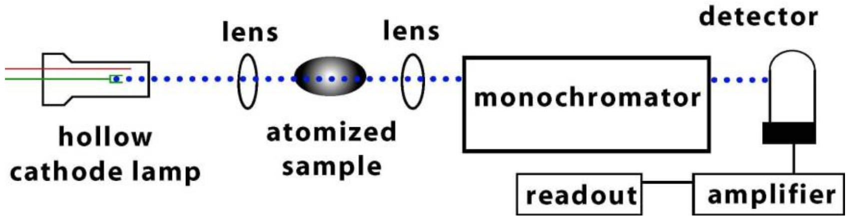

Figure 1: Schematic diagram of atomic absorption experiment (adapted) [17].

3.4 Analytical Techniques

3.4.1 Total Hardness (TH)

In a conical flask, 10 ml of the sample solution and 1 ml of the ammonia buffer solution were added, followed by 2-3 drops of the Erithochrome black-T (EBT) indicator, which caused the solution to turn wine red. The volume was then determined by titration with 0.01 M EDTA solution until the wine-red hue changed to blue, indicating the point at which the titration was complete.

TH (mg/L) = ml EDTA used x 1000 / ml sample obtained is the formula.

3.4.2 Total Alkalinity (TA)

20 ml of the sample was taken, and then 2-3 drops of the phenolphthalein indicator were added, titrated, and added until a pink hue was seen. The permanent pink tint was then eliminated by titrating the solution with 0.02N sulfuric acid. This shows the alkalinity of phenolphthalein. The solution in which phenolphthalein had just been identified was now mixed with a couple of drops of methyl orange indicator. Sulfuric acid 0.02N was then added to the solution and titrated. Pink replaced the previous yellow shade. The pink color is back, which denotes TA.

TA (as CaCO3, mg/L) is calculated using the following formula:

(U+V) N100050 / ml sample collected

where;

U=Volume of H_2SO4 used with phenolphthalein indicator

V=Volume of H2SO4 used with methyl orange indicator

(U+V) = Total vol. of H_2SO_4 used with both indicators

N=Normality of H_2SO_4; 1 g of equivalent acid = 1g of equivalent $CaCO_3$

3.4.3 Chloride Content

A 20 ml sample was collected in a conical flask, and 1 ml of a 5% K2CrO4 solution was placed as an indicator. The solution was titrated with 0.02N AgNO3 solution until a permanent brick red color emerged, which is the indicator of the endpoint.

Formula: Chloride (mg/L) = (A-B) N-35.51000/ml sample taken

Where;

A= Volume of $AgNO_3$ used for Sample Titration

B= Volume of $AgNO_3$ used for Blank Titration

1 g eq. of $AgNO_3$ = 1 g eq. Cl^- = 35.5 g Cl

4 RESULT AND DISCUSSION

4.1 Experimental Result of the Water Sources

We present all the experimental observations obtained in the present analysis are presented in tabular form, respective to the individual sample used in the current experiments. The water qualities of the source waters and the recommended values of boiler water of thermal power plant and secondary circuit of VVER-1200 PWR reactor [18-20] are shown in Table 1. The deviations in the result are briefly discussed below.

Table 1: Raw water quality parameter of PP1, PP2 & NPP Site with the standard.

No.	Parameter	Unit	PP1 (River Water)	PP2 (Ground water)	Standard value of DM water	NPP site	Standard Value PWR Secondary Circuit
1	pH		7.34	6.51	9.0-9.5	7.53	4.5-10
2	Electrical Conductivity (EC) at 25ºC	μS/cm	681	433	≤ 1.5	429	00
3	TDS	ppm	312	404	00	212	00
4	Chloride	ppm	11	7	< 0.1	10.6	< 0.1
5	Total Hardness	ppm	3.6	248	00	143	00
6	Total Alkalinity	ppm	5.1	10	00	0.03	00
7	Silica (SiO_2)	ppm	28.8	10	≤ 0.03	15	----

4.2 Discussion on Experimental Result

Water quality metrics from the source waters, including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chloride Content, Total Hardness (TH), Alkalinity, Silica, and Heavy Metals, were carefully measured both before and after the treatment. Then, we selected the ideal circumstances for the best source of water to be used in the production of electricity.

4.2.1 pH Analysis

A sample's pH value of any liquids indicates whether it is acidic or basic. Demineralized (DM) and purified water should have a pH of 7, which is neutral. Water has a pH between 7 and >7, falls between 7, and is acidic. Bangladesh's specified pH range for drinking water quality is 6.5 to 8.5. The pH level will be lower the more hydrogen ions are contained in the solution. Like this, a solution's pH value will increase the more hydroxyl ions are present in the solution. The standard range of pH of boiler water in the thermal power plant is from 9.0-9.5 and in the Nuclear VVER PWR reactor, the value is from 4.5-10. The pH values of the different power plants are graphically presented in Figure 2 along with the recommended values. are shown in Table 1. Water had an average pH of 8.02. Surface water has a standard value that falls between 6.5 and 8.5. The study area's pH was excellent and suited for both thermal and nuclear power facilities. The secondary circuit's suggested value is 4.5–10. [21-23].

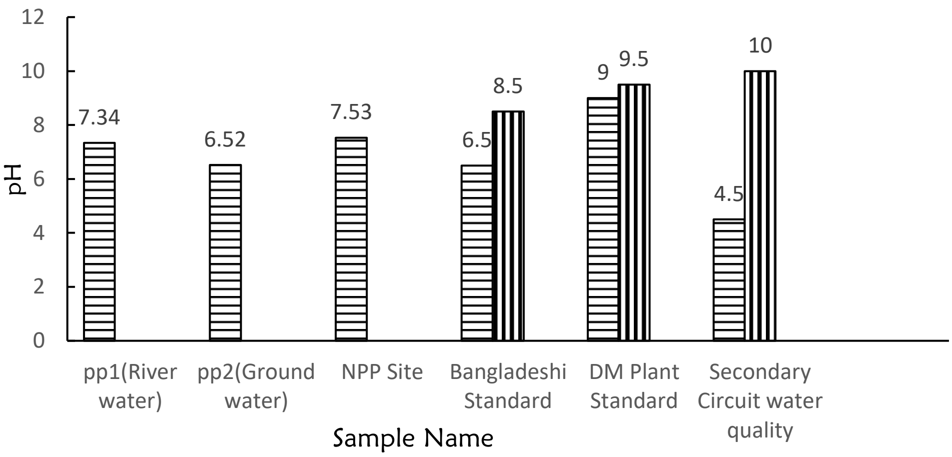

Figure 2: Analysis of pH quality gap between raw water and DM water.

4.2.2 Electrical Conductivity

Pure water is a poor conductor of electricity. Electrical conductivity depends on the concentration of dissolved salt in water. It can be dissolved most of the salts are soluble in water. The acceptable level of conductivity in drinking water recommended by the United States Public Health (USPH) is 300 micro-Siemens/cm. The presence of different salts in the water body and OH^- and H^+ ions enhance Conductivity**.** The comparison of EC among the source water of thermal power plants and the quality of NPP water has shown in Table 1 and Figure 3 with standard values [24-25].

From the gained values it is executed that in terms of electrical conductivity of the source waters required chemical treatment to use in the power plant grade water. Ion exchange method is used to remove ions, present in the water body and produce DM water. The EC of DM water must be zero.

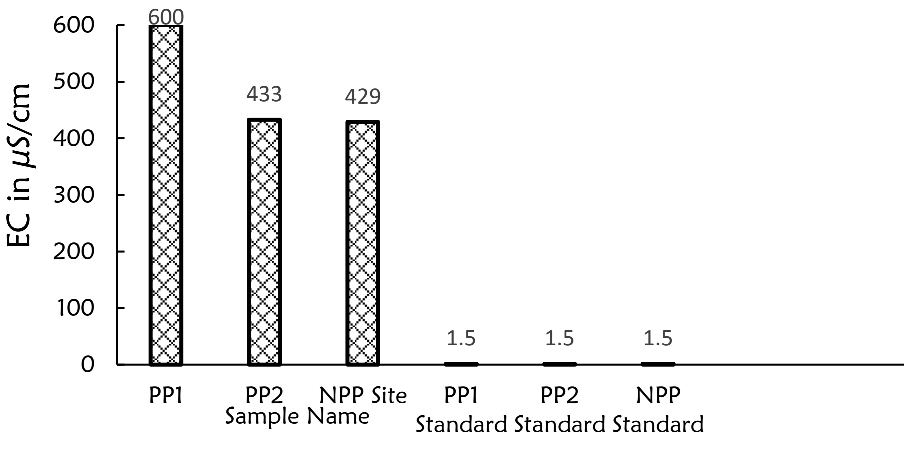

Figure 3: Analysis EC gap between raw water and DM water

4.2.3. Total Dissolved Solids (TDS)

The inorganic salts and trace amounts of organic materials found in water bodies are explained by Total Dissolved Solids (TDS). The primary components are typically Hydrogen, Carbonate Sulfate, Chloride, and Nitrate anions, as well as Calcium, Magnesium, Sodium, and Potassium cations and anions. Particles that are completely dissolved are not charged. In a solution, it might be in a colloidal form. Table 1 displays the TDS values for several samples. The World Health Organization (WHO), United States Public Health (USPH), and Bangladesh all have standard TDS standards for drinking water quality that is 1000, 500, and 500 ppm respectively as shown in Figure 4 [26-27].

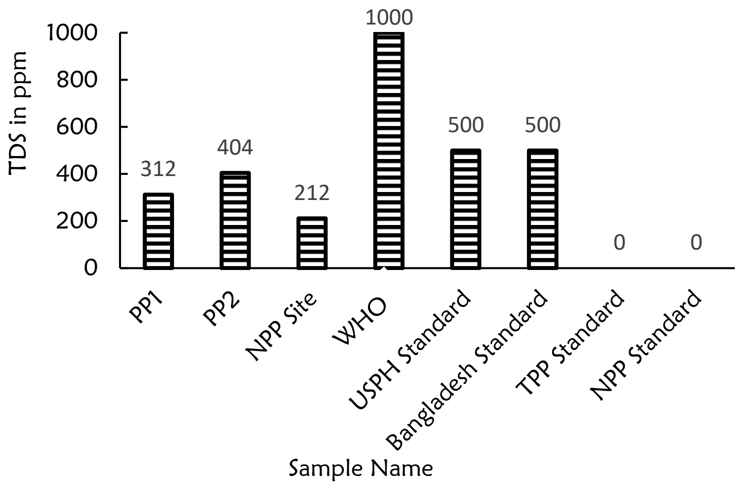

Figure 4: Analysis of TDS gap between raw water and DM water.

The TDS values of three source glasses of water were found in the range of 212 ppm to 404 ppm. The permissible limit of TDS is 500 ppm for potable water. For DM water TDS must be zero. Otherwise, the ions will make corrosion and will produce damage to the power plant instruments. These ions are removed from the water body by using ion exchange methods.

4.2.4 Chloride Content

Chloride is a sign of water's salinity. Significantly chloride-rich surface water suggests a greater diversity of marine life. Chloride is a conservative characteristic from an environmental aspect and can be used as an indicator of contamination coming from primary sources like industrial and municipal outputs in natural waters. The value of chloride contents in PP1, PP2, and NPP sites 11, 7, and 10.6 ppm respectively as shown in Figure 5 where the recommended values of chloride content in DM water is < 0.1 ppm.

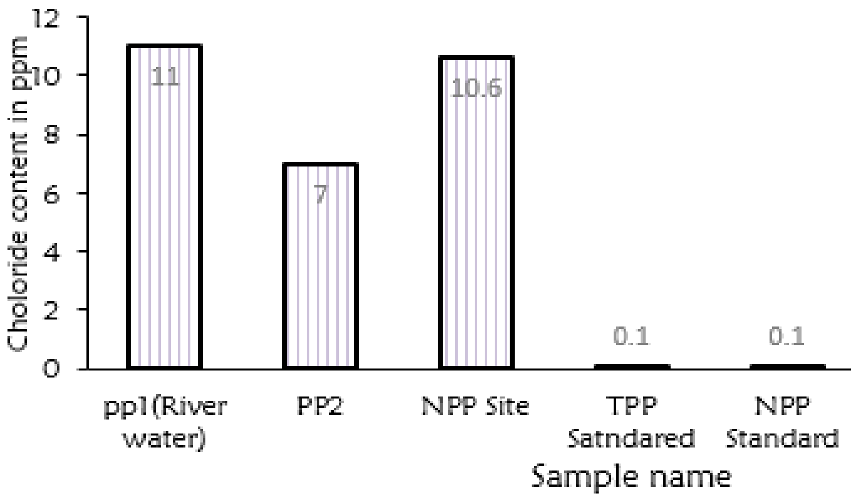

Figure 5: Analysis of Chloride content between raw water and DM water.

4.2.5 Total Hardness (TH)

$CaCO_3$ in ppm has been computed as the samples' hardness. Divalent metallic cations, of which Ca & Mg are the most prevalent in PP2 water, are the cause of hardness. The lowest value of TH was found at 3.6 ppm in PP1 and the highest level at 248 in PP2. So, the result shows that the PP1 sample is the best quality according to the parameter. The DM plant refers the TH to 00 ppm for power generation. The Standard values of Total Hardness of drinking water quality in Bangladesh, the World Health Organization (WHO), and the United States Public Health (USPH) are 250, 500, and 500 ppm, respectively [27-28]. However, certain ranges can be delineated, and these are shown in Table 2.

Table 2: Total Hardness range and the quality of water

Total Hardness (TH) range in ppm	Description
0-40	Soft
40-100	Moderately Hard
100-300	Hard
300-500	Very Hard
500-Up	Extremely Hard

4.2.6 Alkalinity

A water sample is titrated with a standard acid to a predetermined pH to determine alkalinity, which is then recorded as P, M, or T alkalinity. P alkalinity is titrated to pH 8.3, M alkalinity to pH 4.6, and T alkalinity to pH 4.5 using phenolphthalein, methyl orange indicator, and total alkalinity indicator, respectively. The T-Alkalinity were found in the sample of PP, PP2, and NPP sites were 5.1, 10, and 0.03, respectively. The recommended values of DM plant water are 00 ppm. According to other parameters, it is saying that the source water quality is good to use after simple treatment.

4.2.7 Silica (SiO_2)

After silica enters the boiler water, the usual corrosive action increase in boiler instruments and decreases the lifetime of boiler instruments. To decrease the boiler water silica to acceptable levels and then to effect of the condition caused by the silica contamination must be proved recommended limit. The Silica found in the source water sample of PP1, PP2, and the NPP site were 28.8, 10, and 15 ppm respectively as shown in Figure 6 where the DM plant and the secondary circuit require relatively zero. Reverse Osmosis, Carbon filtration, and Gravitation are good ways to remove Silica from the water body [29-30].

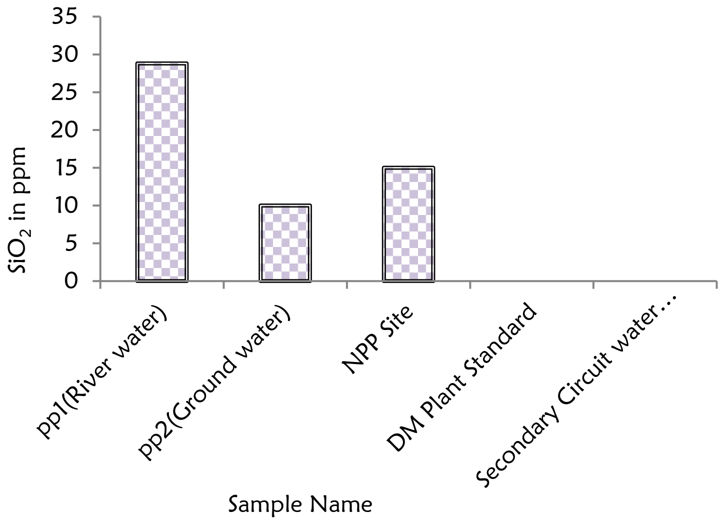

Figure 6: Analysis of the quality of SiO_2 between raw water and DM water with standard

4.2.8 Heavy Metal

Heavy metals are most of the important parameters for boiler water it makes corrosion with the power plant components and damage to the power plant accessories. So, it is very important to control the heavy metal in boiler water as well as the secondary circuit of NPP. After analysis, the heavy metals found in water collected from the source water appear in increasing order given below,

$$Co < Mn < Ni < Cd < Cr < Pb < As < Fe$$

Iron is typically the element that is most prevalent and abundant in both the Earth's crust and its surface. This can be one of the reasons why iron was obtained at the highest levels in water samples especially. A high concentration of iron was observed in water samples. It is well known that the Fe presence in the water body is in terms of Fe^{2+} and Fe^{3+} ions. To reduce corrosion and make the longevity of power plant boiler instruments, the concentration of heavy metals in DM water must be proved satisfactory [31-32]. The existence of heavy metals in DM water and boiler water must be zero.

5 CONCLUSIONS

The aim of this research work was to detect the Physico-chemical characteristics of Padma River water at the NPP site, Shitalakkha River water, and NWPGCL groundwater near the Jamuna River. The quality of source waters to be used in the power plants after treatment should conform to the prescribed values of Physico-Chemical properties like pH, EC, TDS, Alkalinity, presence of Chloride content, Silica, and Heavy metals as recommended by technical guidelines.

The Padma River water was found better than the other two samples after analyzing and comparing the Physico-chemical parameters of samples waters with the recommended values of the secondary water circuit of a third-generation nuclear PWR reactor. Padma River water is suggested for secondary circuits for the safe operation of the Rooppur Nuclear Power Plant, except for the value of Electrical Conductivity (EC). To standardize the quality of Padma River water, proper water treatment is required, and then Padma River water can be used as secondary circuit water. Gravitation, Reverse Osmosis (RO), Carbon filtration, and Ion exchange method are good ways to treat the raw waters used in thermal power plants.

The mission in the incoming days will be to raise the coolant heat, enhance the heat flux, and extend the burnup extension time in the reactor core. Corrosion, corrosion product accumulation, and deposition can be liable to an increased risk of fuel failure. More resistant cladding alloys should be used, or the water chemistry should be improved, avoid cladding failures in new conditions in thermal and nuclear power Plants. To comprehend the corrosion product behavior process and construct a grand pattern of the Physico-chemical system in reactor circuits, more study and research is required.

The difference between the source waters quality parameters values and those of the values of technical guidelines, the Physico-Chemical properties should be as small as possible for the minimization of the water treatment cost. Depending on the availability of good quality water new site for the installation of a power plant project in Bangladesh can be advocated.

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