An Investigation of the Padma River Water Quality Parameters near Rooppur Nuclear Power Plant: A case of study for Nuclear Power Plant grade water

Md. Nur Salam, Md.Farhan Hasan, Md. Akhlak Bin Aziz

Department of Nuclear Science and Engineering, Military Institute of Science and Technology,
Mirpur Cantonment, Dhaka,Bangladesh.

Abstract— Water samples collected from five different points near under construction Rooppur Nuclear Power Plant were tested in this work to assess the availability of nuclear grade water. The average value of pH was found to be 8.02, mean value of Electrical Conductivity (EC) was found 430 µS/cm, Total Dissolve Solid (TDS) 215 ppm, Salinity 0.8, total Alkalinity 79.6 ppm, total hardness 149 ppm and Chloride Content was found 16.87ppm. The Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) of water were founded to be 0.15 ppm, 31 ppm and 8.85 ppm respectively. Among the heavy metals the amount of Cr, Pb, As, Mn, Fe, Mn, Cd, Co, Ni were found to be 0.0041 ppm, 0.00602 ppm, 0.0088 ppm, 0.02 ppm, 0 ppm, 0.00099ppm, 0 ppm and 0.00182 ppm respectively by using atomic absorption spectrophotometer. The pH meter (HANNA Instrument HT 2002-0, S/N CO316002) was used to determine the pH. Total dissolved solids (TDS) and EC were determined by digital TDS meter and EC meter (HANNA -2003-02, S/N: CO1271A1) and to determine the chemical properties of the samples water various tests were done. Utilizing the contrAA® 800 G (HR-CS AAS) Atomic Absorption Spectrophotometer , detection of heavy metals is performed. In this study, we compare the water quality parameters of Padma River with Nuclear Power Plant grade water and the deviation of result of our samples from the standard value is assessed.

Index Terms— Investigation of Water quality, Padma River water, Rooppur Nuclear Power Plant, Quality measurement, reactor grade water.

———————————————— ◆ ————————————————

1 INTRODUCTION

In order to meet power demand, Bangladesh government is constructing going a nuclear power plant of 2400 MW (2×1200) in Rooppur, Pabna on the north bank of the River Padma. The reactor will need around 800 million gallons of water per day for cooling in the tertiary loop.[1-6] At elevated temperature of the reactor environment, corrosion of structural materials may increase if impurities are present. This means that the durability of many systems in nuclear power plants depends strongly on water quality. Since primary circuits and fuel cladding are in direct contact with water, it should be free from undesirable substances. Water Chemistry and corrosion problems are issues of special importance in the safe and reliable operation of nuclear power plants[6-9]. Hence, water parameters such as pH, Electrical Conductivity (EC), Hardness must be within recommended values.

2 Materials and Methods

The aim of the present study is to evaluate different water quality parameters (pH, EC, Hardness, TDS, salinity, alkalinity, BOD, COD, DO, Chloride, sulfate and heavy metals) of water collected from five selected points of Padma River near Rooppur Nuclear Power Plant Site.

2.1 Sample collection

In March 2017, twenty litres of water sample from five points namely PW-01, PW-02, PW-03, PW-04, PW-05 were four litres each, on the month of March 2017. The samples were stored in Environmental Science and Engineering Laboratory, Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy

Commission.

Figure-01: Sample Collection Area

2.2 Sample analysis

Water quality of the river was investigated and compared with standards. The pH was determined by digital pH meter (HANNA Instrument HT 2002-0, S/N CO316002). Total dissolved solids (TDS) and EC were determined by digital TDS meter and EC meter (HANNA -2003-02, S/N: CO1271A1) and the chemical properties of the samples water were determined by various chemical tests.

2.3 Determination of the different water parameters

2.3.1 pH

At first, calibration is required for pH meter. Selecting the pH mode and set the temperature control knob to 25°C, meter was calibrated at two points.250 ml of sample was taken in clean beaker of 400 ml and immersed the pH meter into it. By proper calculation the pH of the solution appears in the display.

2.3.2 EC, TDS, Salinity and Temperature

Firstly, electrode of conductivity meter was cleaned by distilled water. Around 250 ml sample was taken in 400 ml beaker and immersed the electrode and waited the counting signal. EC, TDS, Salinity and temperature readings were recorded.

2.3.3 Total Hardness (TH)

The solution of sample of 10 ml and solution of ammonia buffer of 1 ml were taken in a conical flask and 2-3 drops of Erithochrome black T (EBT) indicator was added intoit and then solution turned into wine red color. The content was then titrated with 0.01M EDTA solution till the color changing from wine red to blue, which indicates the ending point of the titration.

Calculation: TH (mg/L) = ml EDTA used×1000 / ml sample taken.

2.3.4 Total Alkalinity (TA)

In a conical flask, 20 ml sample was taken and 2-3 drops of phenolphthalein indicator were until a pink color appeared. The solution was then titrated with 0.02N sulfuric acid until the permanent pink color disappeared. This indicates the phenolphthalein alkalinity. Now 2-3 drops of methyl orange indicator was added to the solution in which phenolphthalein was just determined. The solution was then titrated with 0.02N sulfuric acid. The color changed from yellow to pink. Reappearance of

Criteria	Range for pH value(25°C)
Padma River water	7.06-8.27
Primary Water	4.2-10.5
Steam generator blowdown	9.00-10.00
Main feed water	8.5-10.5

pink color indicates TA.

Calculation: TA (as $CaCO_3$, mg/L) = (U+V)×N×1000×50 / ml sample taken

Where, U=Volume of H_2SO_4 used with phenolphthalein indicator; V= Volume of H_2SO_4 used with methyl orange indicator; (U+V) = Total vol. of H_2SO_4 used with both indicator; N=Normality of H_2SO_4; 1 g of equivalent acid= 1g of equivalent $CaCO_3$.

2.3.5 Chloride Content

In a conical flask, 20 ml sample was taken and 1 ml 5% K_2CrO_4 solution was added as an indicator. The solution was titrated with 0.02N $AgNO_3$ solution till permanent brick red color was appeared that is the indication of the end point.

Calculation: Chloride (mg/L)=(A-B)×N×35.5×1000/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^- =35.5g Cl^-

2.3.6 Sulfate

Sulfate ion precipitated in an acetic acid medium with barium chloride, so as to form barium sulfate crystal of uniform size. Light absorbance of barium sulfate

suspension is measured by UV-Visible Spectrophotometer and the sulfate concentration is determinated by comparison of the reading with a standard curve. In this method minimum detection limit is 1mg/L (ppm). Light with 420 nm is used to determinate sulfate. Padma River water was colorless and with minor turbidity so blank measurement was not necessary.

3   Result and Discussion

3.1 pH

The pH values of different points are shown in Table 1. The average pH value of water was 8.02. The highest value was observed at PW-05 and lowest at PW-03. The standard value of surface water ranges from 6.5-8.5 according to Environment Conservation Rules (ECR), 1997. The pH of the study area was very good and suitable for Nuclear Power Plant.

 Table-01: Comparison between the range of pH of the Padma river water and the pH range required for three different types of a third generation reactor based nuclear power plant.[10]

3.2 Electrical Conductivity (EC)

EC usually used for indicating the total concentration of ionized constituents of water. The standard value of electrical conductivity is 300μS/cm(De, 2007). [11-16]. The average value of EC was430 μS/cm.

Table-02: Comparison between the range of EC of the Padma river water and the EC range required for three different types of third generation reactor based nuclear power plan. [10]

Criteria	EC in μS/cm(25°C)
Padma River water	425-441
Primary Water	1-40
Steam generator blowdown	0-100
Main feed water	0-100

From the obtained values it is observed that in terms of electrical conductivity , the Padma river water requires chemical treatment to use in any of the three criteria of nuclear power plant grade water.

3.3   Total Dissolved Solids (TDS)

The values of TDS at different points are shown in Table-

01. The TDS was found in the range from 162ppm to 169ppm.The locations were found within permissible limit of 500 ppm for potable water. [11-16]

3.4   Total Hardness (TH)

The hardness of all collected water samples from five different points, namely, PW-01 to PW-05were found to be143 ppm, 151 ppm, 147 ppm, 150 ppm and

 153 ppm in Table-01. No significant change was observed in TH of the water samples.

3.5 Total Akalinity (TA)

The alkalinity of all collected water samples from five locations in winter were found to vary from 70 to 91.6ppm with an average value of 79.6ppm. The minimum alkalinity 70 ppmwas found at point PW-05 and maximum alkalinity 91.6 ppm was found at the point PW-03. A little significant change was observed in another four points in comparison with point PW-03.

Table-03: Water quality parameters of Padma River Water

Sample name	PW-01	PW-02	PW-03	PW-04	PW-05
pH	7.53	8.01	7.06	8.17	8.27
EC(μS/cm)	429	441	425	427	430
TDS(ppm)	212	220	212	213	215
Salinity (%)	0.8	0.9	0.7	0.8	0.8
Total Hardness (ppm)	143	151	147	150	153
Total Alkalinity (ppm)	76.67	75	91.6	85	70
Chloride (ppm)	10.6	17.75	17.75	14.2	24.85

3.6 Chloride

Chloride is an indication of salinity in water. Surface water with significant amount of chloride indicates increase number of marine life. From an environmental standpoint, chloride is basically a conservative parameter and may serve as an index of pollution occurring in

natural freshwater from primary sources such as industrial and municipal outlets. The value of chloride contents in Padma water were found in the range of 10.6 ppm to 24.85 ppm with an average value of 16.87 ppm.

Table-04: Comparison of Chloride concentration between Padma river water, primary water and steam generator blowdown water of third generation nuclear reactor. [10]

Criteria	Chloride concentration(ppm)
Padma River water	10.6-24.85
Primary Water	<0.15
Steam generator blowdown	0-1

3.7 Sulfate (SO$_4^{2-}$)

From the calibration curve for sulfate, the highest value is 19.8 ppm and the lowest value is 10 ppm. In an average value of sulfate was founded 15 ppm.

Table-05: Absorbance of standard sulfate solution for calibration curve

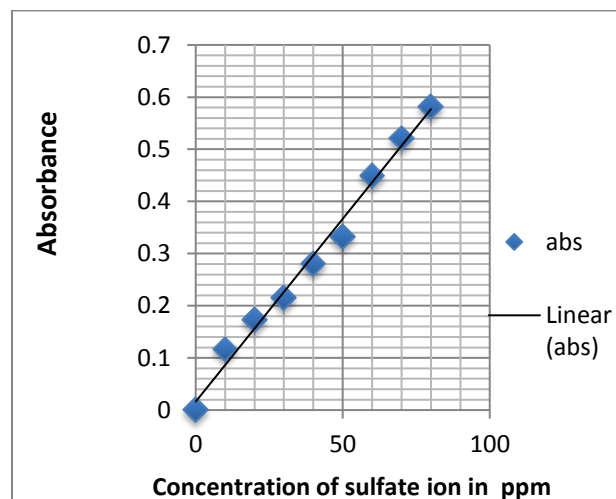| Wave length	Concentration (ppm)	Absorbance
420 nm	0.00	0.00
	5.00	0.095
	10.00	0.117
	15.00	0.129
	20.00	0.173
	25.00	0.186
	30.00	0.215
	35.00	0.252
	40.00	0.281
	45.00	0.332

Figure-02: Calibration curve for sulfate

3.8 Biochemical oxygen demand (BOD)

Biochemical oxygen demand (BOD) refers to the amount of dissolved oxygen required by the aerobic biological organisms for breaking down organic material present in a given water sample at certain temperature over a specific time period. The BOD of the Padma river water is shown in Table-02.In terms of BOD level, water with BOD level ranging from 1 ppm to 2 ppm is considered to be of very good quality. The BOD level of the Padma river water was founded to be 0.15 ppm which is optimum.

3.9 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) refers to the quantity of oxygen required in order to chemically oxidize the organic matter in a water sample to inorganic end products under specific conditions of oxidizing agent, temperature and time. The COD level of the Padma water is shown in Table-06.

3.10 Dissolved Oxygen (DO)

Dissolved Oxygen (DO) refers to the quantity of gaseous oxygen dissolved in a given volume of water at specific temperature. The DO level of the Padma river water is shown in Table-05.

Table-06: BOD, COD and DO levels of Padma River Water

Parameters	ppm
Biochemical Oxygen Demand, BOD	0.15
Chemical Oxygen Demand, COD	31.0
Dissolved Oxygen, DO	8.85

3.11 Heavy metal

Heavy metals are found in water collected from Padma River Near Rooppur Nuclear Power Plant. Although the percentages of Mn and Co are zero, the bottomless heavy metals appear as

Fe>As>Pb>Cr>Cd>Ni>Mn>Co

Generally, Iron is the most abundant and common element in the Earth's crust as well as the earth surface. This can be one of the reason for which iron was obtained in highest levels in water sample especially (Table 03). High concentration of iron was obtained in water samples. It is well known that the pyrite by oxidation can produce sulphate (Fe^{2+}) and then Fe^{2+} ion, is oxidized to Fe^{3+} by micro organisms such as *Thiobacillus ferrooxidans*.

Table-07: Amount of different heavy metals present in Padma River Water

Serial	Heavy metal	Quantity of the metal founded in water (ppm)
1	Chromium(Cr)	0.0041
2	Lead(Pb)	0.00602
3	Arsenic(As)	0.0088
4	Iron(Fe)	0.02
5	Manganese(Mn)	0
6	Cadmium(Cd)	0.00099
7	Cobalt(Co)	0
8	Nickel(Ni)	0.00182

4 Conclusion

This study was conducted to assess the physicochemical parameters of the Padma River water. All the physicochemical parameters of Padma River measured in this study was compared with the standard values of primary and secondary water of third generation PWR (Pressurized Water Reactor) nuclear reactor. It is recommended that Padma River water is suitable for secondary circuit except Electrical Conductivity (EC) to safe operation of Rooppur Nuclear Power Plant. Proper water treatment is required to standardize the quality of Padma River and it is possible to utilize as secondary circuit water.

References:

1. R. S. Lucy, M. E. Huda and S. M. D. Islam, Comparative Study on Physicochemical and Biological Parameters of Water among Fish Culture and Reconstructed Pond at Jahangirnagar University Campus, Bangladesh, 2016. J. Environ. Sci. & Natural Resources, 9(1): 1-7, 2016.

2. Abida, B. and Harikrishna. 2008. Study on the Quality of Water in Some Streams of CauveryRiver. E-Journal of Chemistry, 5 (2): 377-384.

3. Ahipathi, M. V. and Puttaiah, E. T. 2006. Ecological Characteristics of Vrishabhavathi River in Bangalore (India). Environmental Geology, 49: 1217-1222.

4. Ahmed, M. F. and Rahman, M. M. 2000. Water Supply and Sanitation. ITN-Bangladesh, Centre for Water Supply and Waste Management, BUET, Dhaka, Bangladesh.

5. Ahmad, M. K.; Islam, S; Rahman, S.; Haque, M. R. and Islam, M. M. 2010. Heavy Metals inWater, Sediment and Some Fishes of Buriganga River, Bangladesh. Int. J. Environ. Res., 4(2): 321-332.

6. Alam, M. J. B.; Islam, M. R., Muyen, Z.; Mamun, M. and Islam, S. 2007. Water Quality Parameters along Rivers. Int. J. Environ. Sci. Tech., 4 (1): 159-167.

7. Khan, H. R. 1999. Irrigation Water Pricing in Bangladesh. In: Proceedings of the expert group

meeting on water pricing. United Nations Water Resources Series no. 55, pp. 5566.

8. Razo, I.; Carrizales, L.; Castro, J.; Diaz, B. F.; and Moroy, M. 2004.Arsenic and Heavy Metal Pollution of Soil, Water and Sediments in a semi-arid Climate Mining area in Mexico. Water, air, Soil Poll., 152 (1-4): 129-152.

9. Davis, M.L. and Cornwell, D.A. 1998. Introduction to Environmental Engineering, third edition, McGraw Hill Book Company, pp 289-297

10. Qinghua Li, Guangfei Wang, Yao Pi, Bo Li and Xiaoli Yang. Study on Standards Applicable for Primary and Secondary Water Chemical Analysis in the Third-Genaration PWR, proceedings of the 20th Pacific Basin Nuclear conference 2017.

11. APHA. 1995. Standard Methods for the Examination of Water and Waste water, 19thedition, American Public Health Association Washington DC

12. Peavy, H.S.; Rowe, D.R and Technology, G. 1985. Environmental Engineering McGraw Hill Publishing Company Ltd, pp11-46

13. Sawyer, C.L.; McCarthy, P.L.; Parkin, G.F. 1994. Chemistry for Environmental Engineering Fourth edition, McGraw Hill Book Company, p545

14. Cuena, R.H. 1989. Irrigation System Design. Prentice Hall, Englewood Cliffs, NJ, USA. pp. 552.

15. Ayres, R.S. and Westcot, D.W. 1985. Water Quality for Agriculture. Irrigation and Drainage Paper No. 29. Food and Agriculture Organization of the United Nations. Rome. pp. 1-117.

16. J. Environ. Sci. & Natural Resources, 5(2) : 53 - 57, 2012.

IJSER