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RESEARCH PAPER

Physical-chemical quality analysis of Serayu River water, Banjarnegara, Indonesia in different seasons

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Abstract. This article discusses the analysis of the physico-chemical parameters of water in the Serayu River, Banjarnegara, Indonesia during the dry and rainy seasons. The parameters to be measured are heavy metals, alkalinity, pH, temperature, TDS, TSS, and corrosivity. The sampling location is at the mouth of the Serayu River, where Serayu River water is one of the Mrica Reservoir water sources used for hydroelectric power plants. (PLTA). When the samples were taken in the rainy and dry season in 2018. The results showed that in the rainy season, the surface water pH of the Serayu River estuary was 6.61; the TDS was 178 mg/l; the TSS was 62 mg/l; the BOD was 6.66 mg/l; the COD was 33.31 mg/l; and the nitrate was 4.03 mg/l. Meanwhile, in the dry season, the pH was 8.15; the TDS wa 121 mg/l; the TSS was 55 mg/l; the BOD was 6.35 mg/l; the COD was 31.77 mg/l, and the nitrate was 3.08 mg/l. All physical and chemical parameters meet the quality standards required in Indonesian Government Regulation No. 82 of 2001 concerning Management of Water Quality and Class III Water Pollution Control. The surface water of the Serayu River estuary is weak corrosive which means it is safe for hydropower activities. In general, in the rainy season the chemical physics parameters of the Serayu River estuary water level are higher than the rainy season.

Keywords: Serayu River; physico-chemical parameters; dry season; rainy season

1. Introduction

Water is one of the most important natural heritages for humanity. Initially, water was used to meet primary needs such as drinking, washing, bathing, and cooking. The development of industry and urbanization encouraged the use of water for other purposes such as irrigation, fish production, industrial refrigeration, electricity generation, aquaculture, and clean water sources. The river is often used to dispose of household, industrial and agricultural waste (Ravindra & Kaushik, 2003). Solid waste thrown into the river is produced from household and restaurant activities in the form of meat, fish, cooked food scraps, moldy bread, bone scraps,

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cakes, expired meals, dairy products, fruit and vegetables (Callaghan, 2012). When the food waste is put into the river, there will be decay and it will produce a foul odor that ultimately pollutes the water. The amount of food waste generated from household activities is relatively high with amounts exceeding 60% and others are recyclable waste, such as plastic, paper, glass, and metal. Increased human activity puts greater pressure on aquatic ecosystems which results in changes in their characteristics.

Serayu River crosses Wonosobo Regency before entering the downstream waters of the Mrica Reservoir. Sungai Serayu estuary accepts organic and inorganic pollutants from different sources. The river receives wastewater discharges of various types of human activities such as municipal waste disposal that is not treated as a source of pollutants, washing clothes, bathing and disposal of sewage along the river bank. Upstream to the north of the Serayu River there are steep slopes in Wonosobo regency, which are considered as critical environmental areas for erosion (Priyambada et al., 2008).

Quality river water is needed by every living organism. Water quality is determined by physical, chemical and microbiological parameters (Villa-achupallas et al., 2018). Natural heritage such as rivers, seas and oceans have been exploited and contaminated. It is important to systematically monitor river water quality in relation to various human activities during the rainy and dry seasons. Physical-chemical parameters are used to detect the effects of surface water pollution. In addition, Mrica reservoir water is used for hydropower activities, so it is necessary to know the characteristics of water corrosivity so that it does not affect hydropower equipment such as turbines.

Factors causing degradation in water quality need to be evaluated to take appropriate steps before the situation becomes worst and out of control. Pollution is the creation of waste by human activities and the inability of nature to absorb it. Monitoring water quality in the rainy and dry seasons is important for environmental protection, managing waterways, identifying pollution and public education. Monitoring consists of making observations and taking measurement that are analyzed and reported to provide information and knowledge about water quality.

2. Literature review

Water characteristics are very important to know before they are used for drinking, domestic, agriculture or industry. Water must be tested with different physico-chemical parameters. The selection of test parameters depends on the designation of the water and the extent to which we need quality and purity. Water contains various types of impurities that are floating, dissolved, suspended and microbiological as well as bacteriological. Some physical tests must be carried out to test their physical appearance such as temperature, color, odor, pH, turbidity, TDS etc., while chemical tests must be carried out including Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), dissolved oxygen, alkalinity, and other parameters. The parameters of metals, heavy metals, and organic pesticide residues are tested if we need higher quality and purer water.

2.1. Biological Oxygen Demand and Chemical Oxygen Demand

BOD is a measure of pollutants of organic matter in water. In general, BOD has mg/L units. BOD is the amount of dissolved oxygen needed for biochemical decomposition of organic compounds and oxidation of certain inorganic substances, whereas COD is another measure of contamination of organic matter in water (mg/L) (Patil et al., 2012). COD is the amount of dissolved oxygen needed to cause chemical oxidation of organic matter in water. Both BOD and COD are the main indicators of environmental health. Determination of COD levels generally uses spectrophotometric methods and uses chemicals such as mercury. Until now, simple, fast, and accurate COD testing procedures have not yet been developed (Geerdink et al., 2017). The accumulation of BOD and COD from pollutant sources will cause pollutant burden on the river's ability to recover, thereby reducing the capacity of pollution load (Sara et al., 2018).

2.2. pH and Temperature

The amount of pH determines the water corrosivity. A low pH value has high corrosivity. The increase in pH is influenced by a decrease in the level of photosynthetic activity, assimilation of carbon dioxide and bicarbonate. Water temperature functions to control the rate of all chemical reactions, and affects the growth, reproduction, and immunity of fish. Drastic temperature changes can be fatal to fish. According to Ly & Giao, (2018) Rivers in Vietnam have pH values in the dry and rainy seasons ranging from 6.9 to 7.1, which show very small seasonal and spatial fluctuations over an eight-year period.

2.3. Carbon Dioxide and Alkalinity

Carbon dioxide is the final product of organic carbon degradation in waters and its variation is often a measure of clean ecosystem metabolism. CO_2 is also the most important greenhouse gas on Earth which causes an increase in air temperature. Alkalinity consists of carbonates (CO_3^{2-}) and bicarbonate (HCO_3^-), Alkalinity acts as a pH buffer. Alkalinity, pH, and hardness affect water toxicity (Patil et al., 2012).

3. Methodology

Surface water quality sampling locations are at the mouth of the Serayu River with coordinates 7 23'26.16" SL and 109 41'2.92" EL as shown in Figure 1. Sampling time was in the rainy season and the dry season in 2018. Surface water samples were put into a 1 liter volume polyethylene bottle. The parameters of temperature and pH were measured in situ using the Water Quality Checker brand Horiba U-50 series (according to SNI 06-2413-1991). For the purpose of testing other physico-chemical parameters, preservation was carried out by storing at ± 4^{0}C using a cooling box. This procedure follows the standard methods (Arnold et al., 1985) and SNI 06-2412-1991 about this method is used as a guide in taking field water samples for water quality testing. Surface water quality analysis methods refer to standard methods (Arnold et al., 1985). Total Suspended Solid (TSS) was tested using gravimetric method. A total of 50 ml of water sample was then filtered using filter paper of known weight. Filter paper was heated using an oven (Memmert) at 105^{0}C, then weighed to a constant weight. The difference in initial and final weight is calculated as the TSS value. Total Dissolved Solid (TDS) was measured using Horiba U-50 series Water Quality Checker. The chloride content of the water sample was determined using the argentometric method by titrating the water sample using silver nitrate solution of 0.02 M and potassium chromate as an indicator. Alkalinity was determined by titrating standard acid solutions using indicators such as phenolphthalein and methyl orange. The sulfate content in water samples was determined using a nephelometer. Metal ions were detected by photometry Atomic Absorption Spectrophotometry (AAS) brand Buck Scientific VGP 210.

Figure 1. The location of surface water quality sampling is at the mouth of the Serayu River with coordinates 7 23’26,16” SL and 109 41’2,92” EL

4. Results

Water quality parameters tested refer to Indonesian Government Regulation No. 82 of 2001 concerning Management of Water Quality and Water Pollution Control. The type of parameters (chemistry and physics) taken are Class III, which is the water whose designation is for the cultivation of freshwater fish, animal husbandry, water for irrigating crops, and or other designation that requires the same water quality as these uses. Surface water quality (functioning as an inlet of the Mrica Reservoir) is associated with corrosivity, changes in water pH, changes in particle transport, changes in turbidity or suspended solids, changes in metal content, and changes in pollutants (International Hydropower Association et al., 2000). Water resources testing is expected to be able to maintain a sustainable environment. More or less pollutants are not only determined by the hydrological cycle, but also physical-chemical processes. The results of testing the physical and chemical parameters of the Serayu River estuary surface water in 2018 are shown in Table 1.

Based on the data in Table 1, the quality of physical and chemical parameters of the Serayu River estuary water is explained as follows:

a. pH

In natural waters, the pH scale ranges from 0 to 14. The pH value of 7 is neutral; pH less than 7 is acidic and greater than 7 is alkaline. The main component that regulates pH in natural waters is carbonate, which consists of CO_2, H_2CO_3 and HCO_3 (Arnold et al., 1985). Based on the results of tests in 2018, both in the rainy season and the dry season, the pH parameters in the surface water of the Serayu River estuary ranged from 6.61 to 8.15. The pH value required in Indonesian Government Regulation No. 82 of 2001 concerning water quality management and class III water pollution control is 6-9. Based on the pH value, the Serayu River estuary surface water meets the required quality standards. pH is related to the ability of life of some aquatic organisms that can withstand the conditions of that pH. Based on the pH range values according to the Environmental Protection Agency (EPA), the life of aquatic organisms is 6.5 to 8.5. Most aquatic biota are sensitive to pH changes and like pH values of around 7 to 8.5 (Keizer et al., 2001).

Table 1. The results of testing the physical and chemical parameters of the Serayu River estuary surface water in 2018, both in dry and rainy seasons.

No	Parameters	Units	Rainy season	Dry season
I. PHYSICS				
1	Temperature	°C	25,0	26,5
2	Dissolved Residue	mg/l	178	121
3	Suspended Residue	mg/l	62	55
II. ANORGANIC CHEMICAL				
1	pH	-	6,61	8,15
2	BOD	mg/l	6,66	6,35
3	COD	mg/l	33,31	31,77
4	DO	mg/l	7,01	7,26
5	Total Phosphate as P	mg/l	0,006	0,011
6	NO_3 as N	mg/l	4,03	3,08
7	Ammonia (NH_3-N)	mg/l	0,115	0,091
8	Arsenic (As)	mg/l	<0,25	<0,25
9	Cobalt (Co)	mg/l	<0,05	<0,05
10	Barium (Ba)	mg/l	<0,50	<0,50
11	Boron (B)	mg/l	-	-
12	Selenium (Se)	mg/l	<0,50	<0,50
13	Cadmium (Cd)	mg/l	< 0,001	< 0,001
14	Chrome (Cr), (VI)	mg/l	<0,004	<0,004
15	Copper (Cu)	mg/l	<0,005	<0,005
16	Iron (Fe)	mg/l	< 0,05	< 0,05
17	Lead (Pb)	mg/l	<0,008	<0,008
18	Manganese (Mn)	mg/l	<0,03	<0,03
19	Mercury (Hg)	mg/l	-	-
20	Zinc (Zn)	mg/l	<0,005	<0,005
21	Chloride (Cl)	mg/l	1,04	0,99
22	Cyanide (CN)	mg/l	0,00	0,00
23	Fluoride (F)	mg/l	0,00	0,00
24	Nitrite as N	mg/l	0,58	0,06
25	Sulfate (SO_4^{2-})	mg/l	0,51	0,51
26	Sulfur as H_2S	mg/l	0,00	0,00

b. Dissolved Residue

Water with a high Dissolved Solid (TDS) residue shows a higher ion concentration, and can trigger adverse physicochemical reactions. Kataria et al. (1996) reported that an increase in the value of TDS indicates pollution by foreign sources. The high amount of dissolved, suspended, and total solids affects the quality of running water and is not suitable for irrigation and drinking water. Table 1 shows that TDS in the rainy season was 178 mg/l and in dry season was 121 mg/l. This value is much smaller than the TDS quality standard of 1000 mg / l.

c. Suspended Residues

Suspended solids (TSS) is one of the parameters tested. This parameter causes the level of turbidity of the water to increase and block sunlight from entering the waters, thereby disrupting chemical, physical and biological processes on the surface of the waters. TSS usually consists of fine clay, plankton, organic compounds, inorganic compounds or other microorganisms. Particle sizes range from 10 nm to 0.1 nm. TSS levels in 2018 are in the range of 62 mg/l to 55 mg/l. The TSS quality standard required by Indonesian Government Regulation No. 82/2001 is 400 mg/l. This means that TSS levels still meet the required quality standards so that they can be used for the cultivation of freshwater fish, livestock, irrigating crops, and/or other designations that require the same water quality as these uses. TSS levels in the rainy season are higher than the dry season.

d. BOD and COD

BOD parameter is one indicator of water pollution. BOD is used as an indicator of organic pollutants that can be decomposed by bacteria under anaerobic conditions**.** Based on table 1 it appears that the BOD concentration ranged from 6.66 mg/l (in rainy season) to 6.35 mg/l (in dry season). According to applicable regulations, the maximum BOD level required is 6 mg/l. Other pollutant parameter was in the form of COD (Chemical Oxygen Demand) value. The results of COD testing in 2018 ranged from 33.31 mg/l (in rainy season) to 31.77 mg/l (in dry season). The maximum COD content of the required class III surface water is 50 mg/l. So based on COD parameters, the Serayu River estuary water in 2018 meets the required quality standards. In the rainy season, BOD and COD levels are higher than the dry season, possibly due to erosion of agricultural land, plantations, and domestic waste containing organic matter.

e. Nutrients

The content of aquatic nutrients includes nitrogen compounds (nitrates, nitrites, ammonia, organic nitrogen) and phosphorus. In the rainy season, nitrate level was 4.03 mg/l and in the dry season it was 3.08 mg/l. The required quality standard for nitrate level is 20 mg/l. So the Serayu River estuary water seen from the nitrate parameter meets the quality standard, meaning that the waters can be used for the cultivation of freshwater fish, livestock, water to irrigate plants, and or other purposes that require the same water quality as these uses. Nitrate levels in the rainy season are higher than in the dry season. The increase in nitrate levels is most likely derived from agricultural and domestic wastes around the Serayu River flow. In agricultural waste, the main source is an increase in the use of nitrogen-based fertilizers upstream, followed by runoff from plantations and livestock waste such as leftovers. *Run off is likely to be a secondary source of nitrogen pollution in surface water, especially after the first and second runoff* (James, 1990). Nitrate content has the potential to result from the degradation of organic matter that is available in the water by microorganisms (Naseema et al., 2013).

f. Iron (Fe)

Iron (Fe) levels in the Serayu River estuary water <0.05 mg/l, both in the rainy season and in the dry season. Maximum sulfate levels are not required in Indonesian Government Regulation No. 82 of 2001. High iron content may come from runoff from plantations and agriculture.

g. Metal

Metal parameters such as Arsenic (As), Cobalt (Co), Barium (Ba), Boron (B), Selenium (Se), Cadmium (Cd), Chromium (Cr) (VI), Copper (Cu), Lead (Pb) , Manganese (Mn), Mercury (Hg), and Zinc (Zn) in all stations are below the required quality standards. The quality of the Serayu River estuary water can be used for the cultivation of freshwater fish, animal husbandry, water for irrigating crops, and/or other purposes that require the same quality of water for these uses.

h. Sulphate

Sulphate levels in the rainy and dry season are 0.51 mg/l. Maximum sulphate content is not required in Indonesian Government Regulation No. 82 of 2001. The main source of sulphate comes from run off waters from agricultural lands might have contributed to overall sulphate content in the river water

i. Corrosivity of the Serayu River estuary water

Chemical parameters that affect the water corrosivity to the construction of concrete foundations are pH, aggressive CO_2, ammonium (NH_4^+), magnesium (Mg^{+2}), and sulphate (SO_4^{2-}). Based on the five chemical parameters, pH is a parameter that must be considered in determining the water corrosivity. Corrosion starts to form at a pH of water less than 4.0, so the lower the pH of the water the faster the corrosion forms. In addition, other biological parameters that can trigger corrosion are one type of plankton, Euglena sp, where the mucus can trigger corrosion. Based on planton monitoring results, no Euglena sp. is fond. Water is categorized as weak corrosive if aggressive CO_2 is in the range of 15-30 mg/l. The results of testing the level of corrosive water in the Serayu River estuary are shown in Table 2.

Table 2. Results of the measurement of the corrosive parameters of the Serayu River estuary water in 2018

Season	pH	TDS (mg/l)	HCO_3^- (mg/l)	Free CO_2 (mg/l)	aggressive CO_2 (mg/l)	NH_4^+ (mg/l)	Corrosivity
Rainy	6.60	178	97.6	21.87	20.97	0.09	Weak
Dry	8.15	121	128.1	17.04	16.14	0.12	Weak

Based on water quality testing, chemical parameters that affect water corrosivity such as pH, aggressive CO_2, ammonium (NH_4^+) have values that can indicate that water has weak corrosive properties. Parameters of pH, ammonium ions, and magnesium ions that cause corrosion according to APHA for the water in the Serayu River estuary water do not exceed the quality standard, only some values of aggressive CO_2 are below the range of 15-30 mg/l so that the water is corrosive weak. The emergence of aggressive CO_2 comes from the decomposition of organic matter that is measured as a BOD value.

5. Conclusion

In the rainy season, the surface water pH of the Serayu River estuary is 6.61; the TDS is 178 mg/l; the TSS is 62 mg/l; the BOD is 6.66 mg/l; the COD is 33.31 mg/l; and the nitrate is 4.03

mg/l. In the dry season, the pH is 8.15; the TDS is 121 mg/l; the TSS is 55 mg/l; the BOD is 6.35 mg/l; the COD is 31.77 mg/l, and the nitrate is 3.08 mg/l. All physical and chemical parameters meet the quality standards required in Indonesian Government Regulation No. 82 of 2001 concerning Management of Water Quality and Class III Water Pollution Control. The surface water of the Serayu River estuary is weak corrosive which means it is safe for hydropower activities. In general, in the rainy season the chemical physics parameters of the Serayu River estuary water level are higher than the rainy season.

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