Design of a Surface Water Treatment Plant for Afe Babalola University, Ado-Ekiti (Abuad) Community

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ABSTRACT
Water treatment plant is collectively the industrial scale process that makes water more potable or useful by the use of some processes according to the tests and experiments carried out on the water. This project involves the use of surface water. Surface water could be regarded as all inland water permanently or intermittently occurring on the earth surface. The two sources of surface water used are ‘Elemi’ and ‘Ureje’ River. The objectives of this project is to find out the quality of water based on BOD, COD, DO, pH and other water quality parameters, to design a water treatment plant, to do a physical model of the water treatment plant and to provide information for engineers to execute the project. The processes involved in treating the water are; pretreatment, coagulation, flocculation, sedimentation, filtration and disinfection. The pretreatment stage includes include oxidizing agents for color or tastes and odors, activated carbon for tastes and odors, and aeration for iron or hydrogen sulphide gas. The coagulation stage involves adding certain chemicals, known as coagulants in a rapid mix, while flocculation is slow mix allowing the particles to form floc. In the sedimentation stage, floc particles that have been formed settles to the bottom of the tank as sludge. The filtration process removes particles that have not been removed during the sedimentation process. Lastly, the disinfection process involves the addition of chemicals like chlorine, ozone or chloroamines. Measurements for the each of the tanks containing these processes are given in the appendix. A physical model was done according to the measurements gotten. This design can be adopted by the institution to solve their water problem.

Keywords------ Microbial, BOD, COD

I. INTRODUCTION

According to M.G. Khublaryan (1988), surface waters could be regarded as including all inland waters permanently or intermittently occurring on the Earth surface. Surface water includes water obtained from dams, streams and rivers. It can be contrasted with groundwater and atmospheric water. It is replenished by precipitation and by recruitment from ground-water. It is lost through evaporation, seepage into the ground where it becomes ground-water, used by plants for transpiration, extracted by mankind for agriculture, living, industry etc. or discharged to the sea where it becomes saline. These sources may be more easily contaminated by animal and human wastes, and chemicals from runoff. Surface water may also be at risk of algal blooms.
Water Treatment is, collectively, the industrial scale process that makes water more acceptable for an end-use, which may be drinking, industry, or medicine. Water treatment is unlike small-scale water sterilization that campers and other people in wilderness areas practice. Water treatment should remove existing water contaminants or so reduce their concentration that their water becomes fit for its desired end-use, which may be safely returning used water to the environment. For most people, the term ‘water treatment’ refers to the treatment of polluted water, where the pollution could be from human waste or other sources of pollution.

Only a small, but specialized sector in the field of water technology is the design, construction and operation of water treatment plants. There are numerous papers and books where the various procedures of treatment steps, the different types of reactors, the process dynamics and reactions are described in detail. The purpose of treatment is the provision of safe drinking water. The following approach to the design, implementation and control of processes to effect or mediate quality transformations in water emphasizes physicochemical processes rather than operations.

Safe drinking water is water with microbial chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality.

1.1 Study Area

Afe Babalola University, Ado-Ekiti (ABUAD), a Federal Government-licensed Private University is a model which is unique in many ways. It is located on 130 hectares of land at an altitude of over 1500 feet above sea level which ipso facto provides cool and ideal climate of learning and sports activities. It is located in Ado-Ekiti along Ijan road, opposite The Federal Polytechnics. The study areas, Ureje River lies at longitudes 005°18’25.87”E and latitudes 07°36’ 23.82”N and longitudes and Elemi River lies at longitudes 005° 18.683’E and 07° 36.603’N. The area is underlain by Precambrian basement complex rocks. The continuous increase in population and the progressive infrastructural development within the campus daily emphasize the need for the development of a sustainable water supply. The University has spent fortunes in purchasing water to ensure that the daily demand for potable water on the campus is met. The rivers used for this research are the Elemi River and the Ureje River. The Elemi River comes from the town and flows through the school. The Ureje River comes from the mountainous sides which also flow through the school. The Ureje River lies at longitudes 7°37’67.40”E and latitude 5°18’65.30”N at an elevation of 451m.
1.2 Aim and Objective

The aim of this study is to design a water treatment plant for ABUAD which will be safe and adequate. The specific objectives are:

1. To determine water quality based on BOD, COD, DO, TSS, pH and other water parameters
2. To design water treatment plant for ABUAD community
3. To do the physical model of the water treatment plant.
4. Provision of information for Engineers to execute this project

1.3 Water Demand Projection/ Requirement

According to the World Health Organization (WHO), stated that a minimum of 65 liters per capita per day should be assured to take care of basic hygiene needs and basic food hygiene.

Presently, the population of students is 2000 and the population of staffs is 5000 (source: Registry office at ABUAD). Therefore, the total population is 7000.

II. METHODOLOGY

This discusses further about the water quality assessment methods used to achieve the result of this study.
2.1 Laboratory Tests

Tests were conducted in laboratory and the following parameters were involved which are Hardness, Taste and Odor, Color, Turbidity, pH, BOD, COD and NH$_3$-N. BOD and COD were tested directly on arrival in the laboratory. However, curing must be done as soon as possible. If possible, to plan conservation strategies simultaneously tests conducted BOD. This is to avoid changes in the content, while accelerating the process of testing parameters. All steps are done with careful plan.

2.1.1 Turbidity

Turn on the turbidity meter. Standardize the meter using the 0.02 NTU Reference Standards. If possible, allow samples to come to room temperature before analysis. In cold weather, it may be necessary to move the turbidity meter indoors to measure sample turbidity. Mix sample to thoroughly disperse the solids. Wait until air bubbles disappear before dispensing sample into a cuvette. Gently agitate the sample to re-suspend any heavier particles without introducing air bubbles. Fill a clean, indexed sample cuvette to within approximately ½” (12 mm) of the top with a sample aliquot directly from the churn splitter or from a sample bottle. Place the cap on the cuvette and carefully clean any condensation from the outside of the cuvette with a lint free wiper such as Kim wipes. (Condensation may be prevented by coating the outside of the cuvette with a small amount of silicon oil). Place the sample cuvette into the well, align with the locator pin on the optical well, and take the NTU reading directly from the display. Select the appropriate display range for best resolution. Read the turbidity within 3-5 seconds.
2.1.2 pH
The pH was gotten using a probe and a meter. The probe and meter is calibrated according to the manufacturer’s directions. Use of two buffers (pH 7 and 10) for calibration is recommended. The water sample can be collected in any glass or plastic container. Collect enough water samples so that you can submerge the tip of the probe. Rinse the probe with sample water before placing it in the sample. Place the probe in the sample and wait for the meter to equilibrate. If the meter needs to be manually adjusted to correct for temperature – you’ll know it does if it has an extra temperature knob – adjust it to the temperature of the sample before allowing it to equilibrate. The meter will have come to equilibrium when the signal becomes steady. If it is taking a long time to equilibrate, you may try gently stirring the probe. However, do not agitate the sample since this may cause changes in the pH. Read the pH directly from the meter according to the manufacturer’s directions.

![Plate 2.2: Ph metre and the probe](image)

2.1.3 Taste and Odor
For getting the taste of the water sample, the water sample is poured into a beaker. The water sample is then warmed to 23°C. After this, use the front and back of your tongue to the sample and immediately spit out.
Using the threshold method, two water samples are poured into a conical flask. The first water sample is a clean source of water /odor free while the second water sample is the one we are trying to test or the water sample that has odor. The water is then warmed to a room temperature of 23°C. Dilute the odor free water sample with the water sample that has odor. After it has been diluted it is stirred and measured. The diluted water sample is then titrated with the suspected water sample. After this has been done, you will observe by using your nose to smell.

<table>
<thead>
<tr>
<th>CODE</th>
<th>DESCRIPTION/ OBSERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aromatic or spicy eg odor of camphor, lavender, cloves or lemon</td>
</tr>
<tr>
<td>AC</td>
<td>Cucumber or synura</td>
</tr>
<tr>
<td>B</td>
<td>Balsamic eg flowery</td>
</tr>
</tbody>
</table>

2.1.4 Dissolved Oxygen
The test for determining the amount of oxygen present in a sample of water is to expose the water sample for 4 hours at a temperature of 27°C with 10% acid solution of potassium permanganate. The quantity of oxygen absorbed can be calculated.

2.1.5 Hardness
The water sample is poured into a conical flask and boiled. Next add 1.0ml of ammonia buffer to the water sample. Then add 3 drops of eriochrome indicator. The water sample is titrated with a standard EDTA (Ethylene Diamine Tra-acetic Acid) solution. The color of the indicator changes from wine red to blue.
Table 2.2: Analysis of Hardness result

<table>
<thead>
<tr>
<th>Hardness mg/lit as CaCO₃</th>
<th>Type of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-75</td>
<td>Soft Water</td>
</tr>
<tr>
<td>75-150</td>
<td>Moderately hard water</td>
</tr>
<tr>
<td>150-300</td>
<td>Hard water</td>
</tr>
<tr>
<td>Above 300</td>
<td>Very hard water</td>
</tr>
</tbody>
</table>

2.1.6 Biochemical Oxygen Demand

BOD is tested in 5 days period and placed in incubator with a temperature of 20±1°C to determine rates of oxygen uptake. Dissolved oxygen is measured initially and after incubation, and the BOD is calculated from the difference between initial and final DO by using DO meter. Because the initial DO is determined shortly after the dilution is made, all oxygen uptake occurring after the measurement is included in the BOD measurement (Martone, 1976). The apparatus used in this testing are air incubator or water bath and BOD bottle with 350mL volume while BOD nutrient used as a reagent which consists of phosphate buffer solution, magnesium sulfate, calcium chloride, ferric chloride, sulphuric acid, sodium hyroxide and sodium sulphite solution.

2.1.7 Chemical Oxygen Demand

Before conducting COD testing, a blank samples need to be prepared as a control sample to ensure that no unneeded organic material added to the samole to be measured. COD reagent was added into the specified volume of distilled water to prepare a blank sample while distilled water can be replaced with water sample in order to prepare the measuring sample. Both blank and water samples was heated by a temperature of 180°C with a period of 2 hours duration. After that, COD concentration was measured by DR5000 and the oxygen demand in the blank sample is subtracted from the COD for blank sample to ensure accurate measurement of organic matter.

2.1.8 Ammoniacal Nitrogen

NH3-N is created as one of the intermediate compounds during metabolism and when combined with organic nitrogen, they had been recognized as the pollution indicators (Weiner et. al, 2003). Same as COD testing, a blank sample was prepared in order to control the concentration of NH3-N value. Several reagents such as Polyvinyl Alcohol, Mineral Stabilizer and Nessler Reagent were added into distilled water and samples and the concentration was determined by data recorded from DR5000.

2.1.9 Total Suspended Solids

A volume of 50 mL sample is used to determine concentration of suspended solid from each sampling stations. Each sample is weighted as initial weight before it can be filtered by filter paper. The filtration apparatus was set up with filter paper and vacuum to suck the samples and the paper was transferred to aluminum weighing dish before it can be placed into oven with 104±1°C within 1 hour. Once it is achieved at room temperature, the paper was weighted to determine the final weight. The final reading is subtracted with initial weight then divided by the volume of samples used in order to determine the concentration of total suspended solids.

2.2 Adopted Surface Water Treatment

The purpose of chemical treatment is to remove any undesirable contaminants and produce water that is safe and acceptable to consumers. Undesirable impurities can be removed, using conventional treatment, including Pretreatment, Coagulation, Flocculation, Sedimentation, and Filtration.
III. RESULTS

3.1 pH

Table 3.1: Laboratory data based on pH for Elemi River and Ureje river

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value for Elemi River</td>
<td>7.61</td>
<td>7.66</td>
<td>7.81</td>
<td>8.22</td>
<td>7.66</td>
<td>7.64</td>
</tr>
<tr>
<td>pH value for Ureje River</td>
<td>7.43</td>
<td>7.56</td>
<td>7.63</td>
<td>7.76</td>
<td>7.83</td>
<td>8.38</td>
</tr>
</tbody>
</table>
3.2 Dissolved Oxygen

Table 3.2: Laboratory data based on Dissolved Oxygen for Elemi River and Ureje River

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>DO for Elemi River (%)</th>
<th>DO for Ureje River (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.5</td>
<td>96</td>
<td>93</td>
</tr>
<tr>
<td>25.6</td>
<td>98</td>
<td>41</td>
</tr>
<tr>
<td>25.7</td>
<td>95</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 3.2: The graph DO values versus temperature for Elemi River and Ureje River
3.3 Biochemical Oxygen Demand

Table 3.3: Laboratory data based on BOD for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A(mg/l)</td>
<td>21.60</td>
<td>21.62</td>
<td>21.63</td>
</tr>
<tr>
<td>Sample B(mg/l)</td>
<td>27.60</td>
<td>27.62</td>
<td>27.61</td>
</tr>
</tbody>
</table>

![Graph of BOD values for Elemi and Ureje River](image)

Figure 3.3: The graph of the BOD values for Elemi and Ureje River

3.4 Chemical Oxygen Demand

Table 3.4: Laboratory data based on BOD for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A(mg/l)</td>
<td>30.2</td>
<td>32.5</td>
<td>29.0</td>
</tr>
<tr>
<td>Sample B(mg/l)</td>
<td>35.0</td>
<td>34.2</td>
<td>36.9</td>
</tr>
</tbody>
</table>
3.5 Ammoniacal Nitrogen

Table 3.5: Laboratory data based on Ammoniacal Nitrogen for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th></th>
<th>Sample A (mg/l)</th>
<th>Sample B (mg/l)</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>0.20</td>
<td>0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Sample B</td>
<td>0.50</td>
<td>0.30</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Figure 3.4: The graph of the COD values for Elemi and Ureje River

Figure 3.5: The graph of the Ammoniacal Nitrogen values for Elemi and Ureje River
3.6 Total Suspended Solids

TSS is an indicator of water pollution. High TSS value causes the water to become turbid and polluted. After conducting the laboratory test on the water sample, the result gotten for the TSS is given in Table 4.8.

Table 3.6: Laboratory Data based on Total Suspended Solid for Elemi River and Ureje River

<table>
<thead>
<tr>
<th>Water Sample</th>
<th>Volume of sample used (ml)</th>
<th>Initial weight of solid (g)</th>
<th>Final weight of solid (g)</th>
<th>Suspended solid (g)</th>
<th>Concentration of suspended solid (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>50</td>
<td>3.49</td>
<td>1.13</td>
<td>2.36</td>
<td>4.72</td>
</tr>
<tr>
<td>Sample B</td>
<td>50</td>
<td>3.31</td>
<td>1.09</td>
<td>2.22</td>
<td>4.44</td>
</tr>
</tbody>
</table>

3.7 Turbidity

The result gotten from testing the water sample using a turbidity meter is in Table 4.6. Using a standard solution of 664NTU.

Table 3.7: Laboratory Data based on Turbidity for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th>Cell 1</th>
<th>Cell 2</th>
<th>Cell 3</th>
<th>Cell 4</th>
<th>Cell 5</th>
<th>Cell 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elemi River</td>
<td>2.54</td>
<td>1.18</td>
<td>1.08</td>
<td>1.31</td>
<td>1.60</td>
</tr>
<tr>
<td>Ureje River</td>
<td>2.40</td>
<td>1.01</td>
<td>2.60</td>
<td>2.47</td>
<td>2.20</td>
</tr>
</tbody>
</table>

Figure 3.6: The graph of the Turbidity values for Elemi and Ureje River

3.8 Taste and Odor

Table 3.8: Laboratory data based on Taste and Odour for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th>Water Sample</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>AC</td>
<td>Cucumber or Synura</td>
</tr>
<tr>
<td>Sample B</td>
<td>B</td>
<td>Balsamic eg Flowery</td>
</tr>
</tbody>
</table>
3.9 Hardness

Table 3.9: Laboratory data based on Hardness for Elemi River (Sample A) and Ureje River (Sample B)

<table>
<thead>
<tr>
<th>Water Sample</th>
<th>Type of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>Soft water</td>
</tr>
<tr>
<td>Sample B</td>
<td>Soft water</td>
</tr>
</tbody>
</table>

3.10 Design Specification for the Tanks

Population = 15570
Average Demand = 65 litres/day
Factor for getting the maximum daily demand = 1.5

Design Capacity \( (Q) = 15570 \times \frac{65}{1000} + 1.5 \)

\[ Q = \frac{1518.075}{24} \]
\[ Q = 63.25 \text{m}^3/\text{hr} \]

Because, the second sample gotten from Ureje River is turbid, it may be subjected to plain sedimentation. Two sedimentation tanks should be built. The second tank serves only as a reserve for when the first tank is out of operation, then each of the sedimentation tank has to be designed to take full design flow (63.25m \(^3\)/hr). Provide 2 tanks of 31.63m \(^3\)/hr capacity each. This gives saving in construction cost. With one of these tanks out of operation for cleaning, the other tank has to be overloaded for the duration of the cleaning operation.

Assume surface overflow rate or surface loading of 1.2m/hr. The sizing of the tank for design capacity of 63.25m \(^3\)/hr would be as follows:

\[ Surface\ Loading\ Rate = \frac{Q}{BL} \]

\( BL = \frac{Q}{Surface\ Loading\ Rate} \)
\( BL = 53m^2 \)

Assume 2 units,
\( L = 15m \) and \( B = 3.5 \)

The measurement for the length and breadth is applicable to all the tanks.

Velocity of flow = \( Q/BH \)
Assume effective depth of 4m

Velocity of flow = \( 63.25/(3.5 \times 4) \)
= 4.5m/hr

The pipe’s diameter is 0.3m wide

IV. CONCLUSION

From the results gotten from the experiments carried out, in which my second objective is to design a water treatment plant for ABUAD community. The water treatment plant includes the reservoir tank, the screening tank, the coagulation tank, the flocculation tank, the sedimentation tank, the filtration tank, the disinfection tank and the storage tank.

A physical model is also constructed to show how the water treatment plant should look like, according to the third objective as shown in Plate 4.1.
Design measurements are given for the tanks which is important information for an Engineer to execute the project in the fourth objective.

V. RECOMMENDATION

A few recommendations were made on the basis of experiments carried out and some of the results presented in the report.

There is a need to put the surface water available into use, since the following treatment process has already been stated when the ground water source existing in ABUAD is not yielding enough.

The ultimate goal of designing a water treatment plant is to make it functional while avoiding factors that put them out of use. Such factors may include maintenance, foreign technology without appropriate adaptation and lack of resources (human, material and financial).

The following water quality parameters should be routinely monitored;

- Turbidity
- Dissolved Oxygen
- pH
- Hardness
- Biochemical Oxygen Demand(BOD)
- Chemical Oxygen Demand(COD)
- Total Suspended Solids(TSS)

Another recommendation is that, the school should adopt this design provided if the two sources of
water tested in this work are used. This will tackle the problem of water in the school since ground water does not yield much. The execution of the work should be given to well experience engineers.

**REFERENCE**


