Analysis of Recycled Water for Reuse

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Abstract-
Recycled water at a facility in Yola, Nigeria was studied for its suitability for irrigation. Biological and physiochemical analyses of the recycled water samples from four different points namely; A (inside pool; chlorinated), B (outlet 1; after chlorination), C (outlet 2; before receiving tank) and D (outlet 3; for irrigation) were carried out for four weeks. The physicochemical analysis include temperature, pH, turbidity, NO₃-, total dissolved solids (TDS), Cl -, heavy metals and alkalinity were studied. The pH values obtained varied between 6.9 and 8.1 and were within the acceptable values for irrigation water. The water samples obtained in week 4 had higher turbidity and TDS values as against samples obtained in weeks 1, 2, and 3. High NO₃- concentration was found in the water sample taken in weeks 1 and 2 compared to weeks 3 and 4 water samples. Meanwhile, Cl- concentrations were low in the water samples obtained in weeks 1 and 2 relative to concentrations in weeks 3 and 4 water samples. Metals detected from AAS were copper with 4 x 10⁻⁵ ppm in all the points (A, B, C and D). The concentrations of iron were 2.72 x 10⁻³, 5.54 x 10⁻³, 3.62 x 10⁻³ and 2.98 x 10⁻³ ppm in samples A, B, C and D, respectively. Fecal coliforms present were pathogenic coliforms and the Biochemical Oxygen Demand (BOD) analysis showed negative values due to presence of chlorine in the water samples. There are benefits of availability of recycled water for irrigation but care must be taken not to infect users with pathogenic coliforms which are hazardous to health.

Key words: E-coli, irrigation, recycled water, water hardness, water quality

1. Introduction

Water scarcity, climate change and increasing demand for water have placed considerable pressure on freshwater sources across the globe and have left about 1.1 billion people worldwide with unsafe drinking water. The problem is worsening by the contamination of the underground water [1]. Africa is among the continents with low availability of fresh water, as 47 % of the population in the sub-Saharan Africa lack adequate water supplies [1]. It was predicted that water withdrawal for industrial, domestic and livestock uses will increase by at least 50 % and this will impact irrigation water usage, which will have limited water withdrawal, thereby constraining food supplies [2]. In today’s society, recycling of community wastewater has become an essential part of water resources management.
Researchers in recent time have been looking for different means of conserving freshwater for industrial and domestic use and found purifying contaminated water and recycling of water as a viable means to partially supplementing fresh water supplies and substantially alleviate the worsening water problems [3]–[6]. Water recycling such as grey water reuse is also being focused on. Most available freshwater resources can be used for agricultural irrigation; demand for irrigation water has been predicted to rise due to increasing land use for agricultural purposes resulting from increase in the world population. Therefore, water resources availability is expected to reduce owing to change in climate and uneven rainfall distribution[7]. Thus, this work examined the quality of recycled water from a facility in Yola and its suitability for irrigation.

2. Methodology

2.1 Materials

The materials used in this study include pH probe, turbidity meter, conductivity meter were from Vernier software and technology Beaverton, Oregon, LB Broth Millier, eosin methylene blue agar (EMB), *Salmonella Shigella* agar (SS) were from Oxoid Basingstoke, Hampshire England. Biochemical oxygen demand (BOD) bottles, and 88 Adam analytical weighing balance. The following chemicals: Ethylenediaminetetraacetic acid (EDTA), calmagite, sulfuric acid, ammonium chloride, ethanol, sodium hydroxide and magnesium chloride were procured from Fisher Scientific UK or Sigma Aldrich. All chemical used were from reputable vendors.

2.2 Sample Collection

Water samples were collected from four different points A (inside pool; chlorinated), B (outlet 1; after chlorination), C (outlet 2; before receiving tank) and D (outlet 3; for irrigation) for four consecutive weeks from the month of October to November using calibrated bottles and BOD bottles.

2.3 Methods

A pH meter was used to measure the acidity and basicity of the water samples, while the water temperature was obtained using the temperature probe. Turbidity meter, conductivity meter, Nitrate Ion-Selective Electrode (ISE) sensor, and chloride ISE sensor were from Vernier Software and Technology were used to determine the turbidity, total dissolve solids (TDS), nitrate and chloride contents of the water samples, respectively data was collected using Logger Pro 3 software. Buck Scientific atomic absorption spectrophotometer (AAS) model 210 VGP was used to determine the concentrations of cadmium, copper, nickel, and iron present in the water samples. The BOD test was carried out using dilution method described by Hocking [8]. The initial and final values of DO1 and DO5 after 5 days were utilized to calculate the BOD of the water samples using the equation below:

\[
BOD = \frac{DO_1 - DO_5}{p}
\]  

[1]
Where DO1 = initial BOD of sample.
DO5 = final BOD of sample after 5 days.
P = volumetric fraction of sample used.
Most probable number (MPN), eosin methylene blue (EMB) and *Salmonella Shigella* (SS) microbial analysis methods were used to determine the presence of microbes in the water.

3. Result and discussions

3.1 Physicochemical Analysis

The results obtained from the physicochemical analysis were compared with the WHO standard for irrigation water. The results for chlorides are presented in Tables 1, while Figures 1 and 2 show the variation in pH, turbidity, total dissolved solids (TDS), alkalinity and nitrate.

3.1.1 pH and alkalinity

The pH initially increased with time but decreased by the fourth week. The pH values range between 6.9 and 8.1 and they varied with temperature. At temperature from 29 °C to 30 °C, the pH value was about 7 and at temperature of 25 °C, the pH value was about 8. This indicates that a low pH was experienced at high temperature and at low temperature there was high pH. Some of these pH range are within the acceptable pH for irrigation given by Ourimbah (5.5 – 7.5) [9], 6.5 – 8.4 [10], [11], 6.0-8.5 [12], 8.0 [13]. According to the author, pH less than 6.0 or greater than 8.5 could limit the effectiveness of pesticides. It is known that pH above 8.5 result from high concentrations of carbonate (CO$_3$)$^{2-}$ and bicarbonate (HCO$_3$)$^-$ [14]. High bicarbonate concentrates can cause scale build-up in drip or micro-spray used in irrigation systems [14].

Alkalinity was seen to decrease initially but increased in weeks 3 and 4 from samples A, B and C. Sample D showed a different trend, whereby an increase in alkalinity was seen for the four weeks of study. The highest alkalinity obtained was 190 mg/L and the lowest was 61 mg/L. The acceptable alkalinity (CaCO$_3$) range for irrigation water is 100 ppm maximum [15].

![Figure 1: pH and water alkalinity](image-url)
3.1.2 Turbidity

High turbidity values were obtained for all the water samples, which indicates that the water samples were not clear. However, cloudy water can be useful for irrigation. The results obtained showed the water samples obtained in week 4 to exhibit higher turbidity (Figure 1). The water turbidity generally increased with increase in time, but sample B, was higher in week 1, however, it increased in weeks 3 and 4. Sample C had the least turbidity, this could be due to the fact that there were gravels tin the channel through which the water flows into point D.

Figure 2: Turbidity and TDS variation with time

3.1.3 Total dissolved solids (TDS) and Nitrate concentrations

As seen in Figure 2, the TDS values of all the water samples were high. This means the water could contain some ions, which could be conductive. This may be due to fact that the source
of the water contains detergents and other organic wastes. Similar behavior was observed with all the samples. The lowest TDS values were recorded on the third week. This could be due to the rainfall which lowered the TDS concentrations. TDS values less than 1000 mg/L are classified as class 1 (excellent) for irrigation purpose [11], the values obtained in this study are higher than this range.

The nitrate concentration in the water samples was higher in sample D compared to the other samples. This could be due to the fact that the water sample was taken from a pond like area where nitrogen fixation can take place faster than in the other points A (chlorinated), B (flowing), and C (flowing). The nitrate concentrations are all in the acceptable range for irrigation water (5 ppm) [11], except for Sample D in the first two weeks of the study.

![Variation of nitrate with time](image)

**Figure 3: Variation of nitrate with time**

### 3.1.4 Chloride ions (Cl⁻)

Chloride is an essential nutrient to plants, but in small concentration. High concentration of chloride can have detrimental effect on plants. The concentration of chloride acceptable in the water for irrigation is between 350 and 2800 mg/l depending on the type of plant been irrigated [16]. The results obtained showed significant variation in the chloride concentrations. For the water sample taken in week 1, the Cl⁻ concentration level was slightly higher compared to week 2. This could be due to rainfall a day before the samples were collected. In weeks 3 and 4, Cl⁻ concentrations were however significantly higher because there was no rainfall during these periods; this indicates that rainfall has effect on the Cl⁻ concentrations in the water as it contributes substantially by diluting the volume of the reservoir. The Cl⁻ concentration was expected to be high in all the water samples because the water was pre-treated with chlorine to remove bacteria. However, the rainfall during weeks 1 and 2 reduced Cl⁻ concentrations.
Table 1. Results for Chloride in mg/l for the Different Experiment Points for Four weeks

| Samples\Time (wk) | 1    | 2    | 3    | 4    |
|------------------|------|------|------|------|
| A                | 93.1 | 43.6 | 3000 | 4304 |
| B                | 93.1 | 47.7 | 33657| 4207 |
| C                | 91.3 | 44.6 | 3373 | 4202 |
| D                | 69.4 | 57.2 | 3220 | 99   |

*There was rainfall a day before water sample was collected in weeks 1 and 2.

3.1.5 Heavy metals

In all the water samples, there was no trace of Cadmium and Nickel, but Copper was $4 \times 10^{-5}$ ppm in all the samples, while Iron concentration differ in the entire outlet. Sample A, had $2.72 \times 10^{-3}$ ppm, sample B, $5.54 \times 10^{-3}$ ppm, sample C, $3.6 \times 10^{-3}$ ppm and samples had $2.98 \times 10^{-3}$ ppm.

3.1.6 Biological tests

The BOD results for sample A and sample D were negative values compared to the control water sample, which was $3.0 \times 10^{-3}$ ppm. This indicates that oxygen present in the water was not adequate due to the addition of chlorine in the water during pre-treatment [17]. This resulted in less biological activities in the water sample.

In the most probable number (MPN) total coliform tests, presence of gases was observed in all the test tubes in both double and single feedings. The LB Broth Milier was used as the feeding medium in all the tests due to its sugar content. Sample D exhibited the highest amount gases as seen from the bubbles, followed by sample B, then sample C and sample A had the lowest gases due to the chlorination process, which was usually done in this water source. Bacteria were seen to be more in significant amount in the water by the MPN method.

Also, from the Eosin Methylene Blue Agar (EMB), the presence of E-coli was confirmed. Sample D contained the highest E-Coli, followed by Sample C, then sample B and lowest was in sample A (Figure 3).

Salmonella Shigella (SS) feeding was again used to check whether shigella and salmonella were present in the water samples. All the water samples studied, showed the presence of SS with sample C having the lowest SS followed by sample A and sample B. Sample D had the highest SS just as E-coli.
4. Conclusion

The physicochemical test (pH, coliforms, Cl⁻ and NO₃⁻ ions) values of the recycled water studied were within threshold limits for irrigation water. However, the users of this water needs to take precautions in order not to be infected by the pathogens detected in the water as they pose hazard to health. The BOD values obtained were negative as a result of the chlorination of the water during treatment. Rainfall during the sampling period contributed largely to variation in some physicochemical analysis especially the Cl⁻. The TDS values were high, and the pH values varied with turbidity and temperature. There is a need for the analysis of other compounds produced as a byproduct disinfection in recycled waters and further purify the water to make it useful for other purposes, as recycled water will most likely be the source of future, global renewable water.

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