TREATABILITY STUDIES ON RAW WATER FROM APONMU RESERVIOR IN ILARA -MOKIN, NIGERIA

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ABSTRACT

Adequate water supply is an important ingredient in human's development. In this study, samples of war water were collected from Aponmu reservoir at Elizade University, Ilara – Mokin , Ondo State, Nigeria at intervals of one week for six months. These water samples were subjected to laboratory studies (Column, pH adjustment, Jar and residual chlorine tests). Laboratory analysis of flocs formation during coagulation, iron and microbes removal of chlorination process, pH adjustment and residual chlorine after treatment of the samples were conducted using standard methods in a bench scale and executed at prototype phase. Iso-concentration curves were developed from column tests to ascertain settle-ability of the flocs during treatment. The study revealed that optimum doses of coagulant and chlorination were 80 mg/l, and 10 mg/l, respectively for effective removal of iron and residual chlorine concentration of 3 mg/l. Flocs removal was 65 % of the influent flocs in the coagulated raw water at a depth of 1.2 m and at a retention time of 60 minutes. Analysis of iso-concentration curves revealed that overall flocs removal was 89 % at 60 minutes. This indicated that for a retention period of an hour 350 mg/l of flocs would be removed from the coagulated raw water. Removal of iron from the coagulated water was between 90 and 95 % of initial iron concentration of 1.42 mg/l and removal of microbes was 99.1 % at retention time of 40 minutes. It was concluded that Aponmu reservoir can be used as water source with little modification of the current facilities, but further studies are required to ascertain effects of other factors (quality of raw water, rainfall intensity, time of concentration, discharge rate) on quality of water production.

Keywords: *suspended solid, iso-concentration curves, raw water, pH adjustment, potable water.*

INTRODUCTION

Pollutions of surface water have increased tremendously, because they have been found to be easy methods for discharging wastes. This waste treatment process is known for ineffective removal of nitrogenous compounds, heavy metals, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (Viessman and Hammer, 1993, Tebbutt, 1991, Metcalf and Eddy, 1991) due to dilution process. Solids in wastes can be in the form of settle-able, suspended as well as dissolved solids, organic, inorganic, non-volatile or volatile materials. The presence of solids in the wastes is due to human waste, agricultural activities, industrial processing of food and chemical substances. Effects of flocs on surface water treatment plants are well known as follows: increases amount of coagulant required, increases the number of microorganisms, reduces hydraulic retention time, supports anaerobic reaction which yields gases such as methane and hydrogen sulphide and reduces efficiency of surface water treatment plants (Martins and Martins, 1993). Studies on removal of solids from water and wastewater had been done by some researchers (De Clereq *et al.,* 2008). Methods for removing solids from water and wastewaters include: aeration, chlorination, pH adjustment, coagulation, flocculation, biological, filtration and sedimentation. Out of these methods chlorination, coagulation, flocculation, sedimentation and biological are the cheapest methods because of either low initial or operational costs. Removal of flocs from raw water of Aponmu reservoir at Elizade University has rarely been documented or mathematically described. Its column, pH adjustment, and residual chlorine tests and iso-concentration curves had not been presented. Literature explained more on column test (Figure 1). Studies of flocs and settled pattern of suspended solid of coagulated water from Aponmu reservoir at Elizade University as an effort to provide potable water and to improve water supply system are required. The main aim is of future utilization of the reservoir as surface water source for future water supply development. This study was geared toward treatability properties of flocs in coagulated raw water from Aponmu reservoir at Elizade University and its iso-concentration curves presentation to improve on adequate quality and quantity water supply in the University.

MATERIALS AND METHOD

Grabbed samples of raw water were collected from Aponmu reservoir at Elizade University, Ilara – Mokin at the aeration unit of the Water Treatment plant weekly (at selected hours of the day and selected day of the week) for six months. These water samples were subjected to laboratory studies (Column, pH adjustment, Jar and residual chlorine tests). Laboratory analysis of flocs formation during coagulation, iron and microbes removal of chlorination process, pH adjustment and residual chlorine after treatment of the samples were conducted using standard methods (APHA, 2012). Iso-concentration curves were developed from column tests to ascertain settle-ability of the flocs (type II settlement) during treatment. Column, pH adjustment, Jar and residual chlorine tests were conducted on raw water in a bench scale and executed at prototype phase at Elizade University, Ilara Mokin. Samples of raw water collected were subjected to Jar tests using alum as coagulant to determine the optimum dose of the coagulant (alum). Optimum dose of the alum determined was used to coagulate the raw water for further studies. Samples raw coagulated water collected were fed into a column (1500 mm long and 70 mm diameter column, Figure 2) through which column tests were conducted. Laboratory analysis of the flocs concentration, microbes, iron and residual chlorine concentration in the influent and effluent from the column were carried out as outlined in Standard Methods for Water and Wastewater Analysis (APHA, 2012, van Loosdrecht *et al.,* 2016). Averages and deviations of flocs removed at different depths and at different times were used for isoconcentration curves from which overall percentages of solid removed at different depths and at different retention periods were computed (Equation (1)). More on column tests are in Tay (1982) Tebbutt (1991), Metcalf and Eddy (1991), and Viessman and Hammer (1993), Ekama *et al. (*1997), Kinnear (2000), Parker *et al.* (2000) and van Loosdrecht *et al.(2016)*. Daily averages of the column test results were used to prepare iso-concentration curves. Analysis of these iso-concentration curves was based on:

$$P = \frac{\Delta h_1}{h_n}\left(\frac{P_1+P_2}{2}\right) + \frac{\Delta h_2}{h_n}\left(\frac{P_3+P_2}{2}\right) + \frac{\Delta h_3}{h_n}\left(\frac{P_3+P_4}{2}\right) + ----\frac{\Delta h_{n-1}}{h_n}\left(\frac{P_{n-1}+P_n}{2}\right) \quad (1)$$

where, P = percentage solids removed, P_n= iso-concentration curve of the same percentage removal, h_n = desired depth of the column (m),and Δh = change in the depth of the column (m). Jar tests were conducted for coagulation, pH adjustment, iron removal and residual chlorine concentration using standard methods (APHA, 2012, van Loosdrecht *et al.,* 2016). Performance of the systems was computed as follows:

$$P_f = 100\left(\frac{C_i - C_t}{C_i}\right) \quad (2)$$

where; P_f is the performance (%), C_i and C_t are initial and final concentrations (mg/l) respectively.

Analysis of Variance (ANOVA) and statistical analysis of all the results were conducted using standard statistical method. The efficiencies of the column test equipment were determined regularly (10, 20, 30, 40, 50 and 60 minutes) at different depths (0.2, 0.4, 0.6, 0.8, 1.0. 1.2 and 1.4 m) from the inlet, based on the ability to reduce flocs concentrations.

RESULTS AND DISCUSSION

The summary of the efficiencies at different retention times during the study is presented in Table 1. The mean of the efficacies was between 17.69 and 55.487 %, standard deviation of 0.898 to 1.048 and skewness of 0.418 to 1.033, which indicated flat distribution. A statistical analysis (ANOVA, Table 2) of the results shows that there is a significant difference between the solid settlement along the depth of the column in all the samples at 99.0 % confidence level and between solids removed at different treatment time of settlement in the column at 99.0 % confidence level. These results and the statistical analysis show that removal of flocs (solid settlement) from raw water is a function of time of settlement and depth of the column. Figure 3 presents results of coagulation test conducted during wet (Figure 3a) and (Figure 3b) dry seasons. The result revealed that optimum dose of the coagulant was between 60 mg/l and 100 mg/l of alum with 80 mg /l as the average for dry season and between 80 mg/l and 120 mg/l of alum with an average of 110 mg/l for wet season. Figure 4 presents results of iron removal test conducted during wet (Figure 4a) and (Figure 4b) dry seasons. These results revealed that optimum doses of calcium hypochlorite stock solution were between 8 mg/l and 16 mg/l of oxidant with 10 mg /l as the average. Figure 5 presents results of pH adjustment test conducted during wet (Figure 5a) and (Figure 5b) dry seasons. These results revealed that optimum doses of calcium hypochlorite stock solution were between 8 mg/l and 16 mg/l of oxidant with 10 mg /l as the average. Figure 6 presents results of residual chlorine test conducted during wet (Figure 6a) and (Figure 6b) dry seasons. The result revealed that optimum dose (target of 3.0 mg/l of residual chlorine concentration and effective removal of microbes) of calcium hypochlorite stock solution was between 8 mg/l and 16 mg/l of oxidant with 10 mg /l as the average. In order to establish relationships between the depth, time and flocs removed smooth iso-concentration curves (the maximum trajection of settling path for specific concentrations in a flocculent suspensions) for the flocs removed at various depths and at various times were done. Attempts were made to fit the flocs removed from raw water into iso-concentration curves of the best fit forced through intercept of zero. The iso-concentration curves describing the best fit for the flocs in coagulated water are as presented in Figure 7. The iso-concentration curves (Figure 7) have common characteristics as follows:

i. between the depth of 0.0 and 0.4 m the curves have the greatest slope,
ii. followed by the slope between 0.4 and 0.8 m
iii. with the slope between 1.0 and 1.2 m having the least slope.

Explanations of each of these slopes are as follows:

a) flocs of higher particle sizes were being formed between the depth 0.0 and 0.4 m (the effect of flocculation on the particles was much because of the greater slope curves),
b) maximum sizes of flocs were reached at the depth of 0.8 m
c) settlement of the maximum sizes of flocs occurred thereafter between 0.8 and 1.2 m.

All these activities led to removal of these solids from the effluent. Similarly, the description of the curves indicate that possible flocculation of flocs in coagulated water occurred between the influent stage and the depth less than 0.8 m after which the influence of flocculation on the flocs decreases with the depth of the column. In addition, these iso-concentration curves show that for an effective settlement (removal) of flocs in coagulated water, minimum depth of 0.8 m is required. Figure 8 presents colonies of the microbes before and after application of optimum chlorine dose. All initial colonies were completely removed after treatment (40 minutes), indicating that optimum dose was adequate.

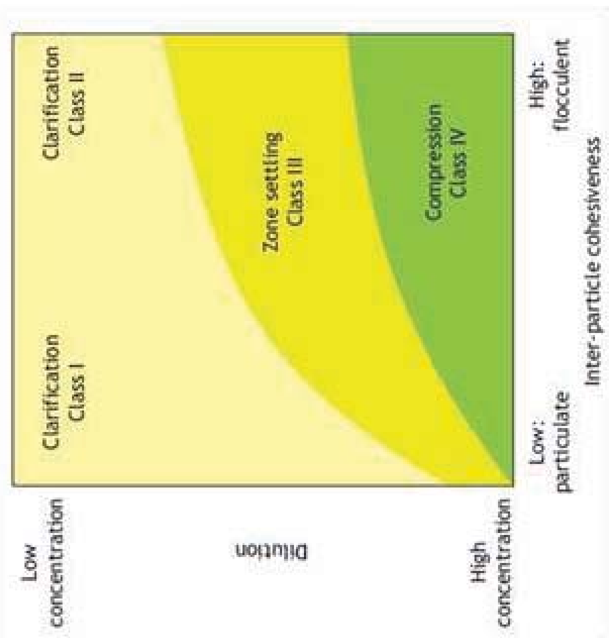


Figure 1a Settling regimes (Ekama *et al*., 1997).

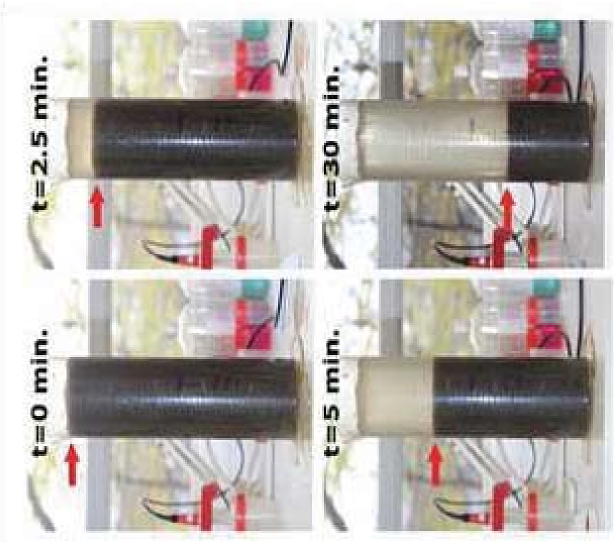


Figure 1c: Photograph of the batch settling column at different settling times, indicating the suspension-liquid interface (Ekama *et al*., 1997)

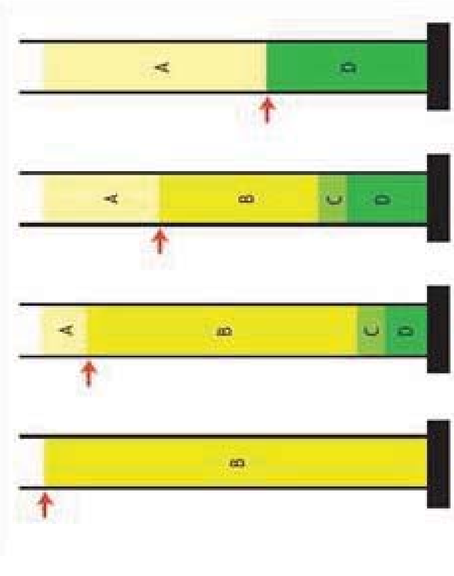


Figure 1b: Chronological process of a batch Settling test (Ekama *et al*., 1997)

Figure 2: Laboratory set of locally developed column test apparatus

Table 1: Efficiencies of the column test equipment at 0.8 m depth

Time (Minutes)	20	30	40	50	60	70
Solid Settlement A	16.7	24.9	32.4	40.4	48.4	54.5
Solid Settlement B	17.1	25.3	32.5	40.5	48.5	54.6
Solid Settlement C	18.8	27.08	34.58	42.38	50.38	56.48
Solid Settlement D	18.2	26.49	33.99	41.99	49.99	56.09
Solid Settlement E	16.5	24.7	32.2	40.2	48.7	54.8
Solid Settlement A	17.5	25.7	33.2	41.2	49.2	55.3
Solid Settlement B	16.9	25.15	32.65	40.65	48.65	54.86
Solid Settlement C	19.2	27.72	35.22	43.22	51.22	57.52
Solid Settlement D	17.2	25.32	32.82	40.82	48.62	54.82
Solid Settlement E	18.8	27.22	34.72	42.72	49.5	55.9
Mean	17.690	25.958	33.428	41.408	49.316	55.487
Standard Deviation	0.930	1.025	1.048	1.027	0.898	0.936
Skewness	0.418	0.527	0.533	0.562	1.020	1.033

Table 2: statistical analysis (ANOVA) of efficiencies of the column test

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*F-value*	*P-value*	*F crit*
Solid Settlement	55.456335	9	6.16	135.154	1.535×10^{-29}	2.095
Time	10201.685	5	2040.34	44753.06	5.816×10^{-82}	2.422
Error	2.051595	45	0.046			
Total	10259.193	59				

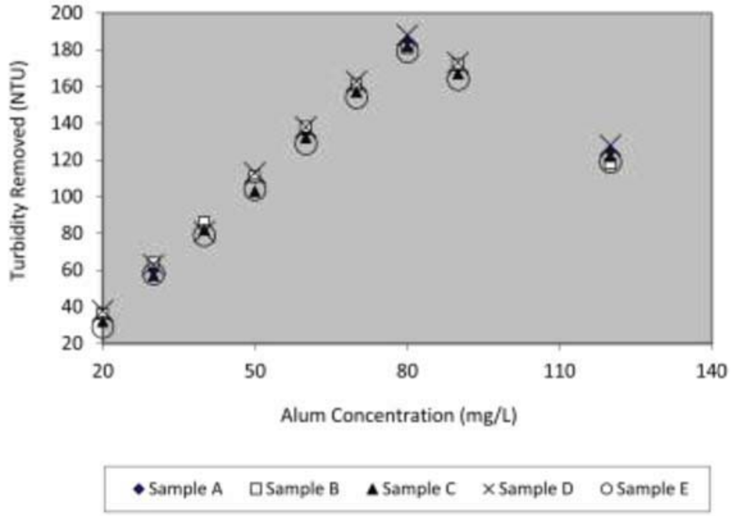


Figure 3a: Coagulation Tests on samples during wet season

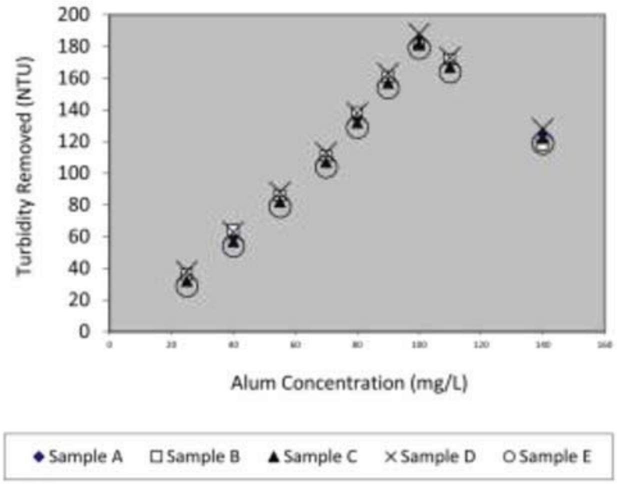


Figure A1: Jar Test for coagulation process in Dry Season

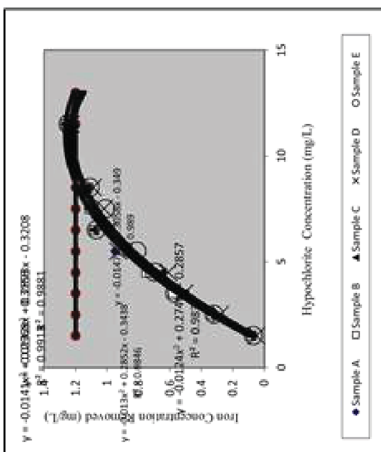


Figure 4a: Iron removal Tests on samples during wet season

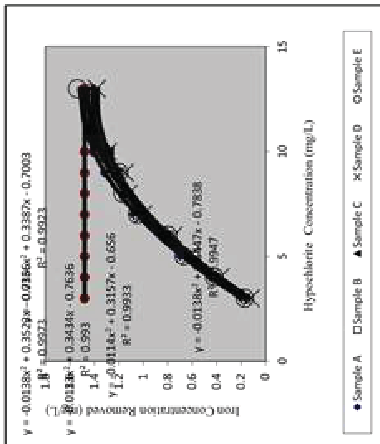


Figure 4b: Iron removal Tests on samples during dry season

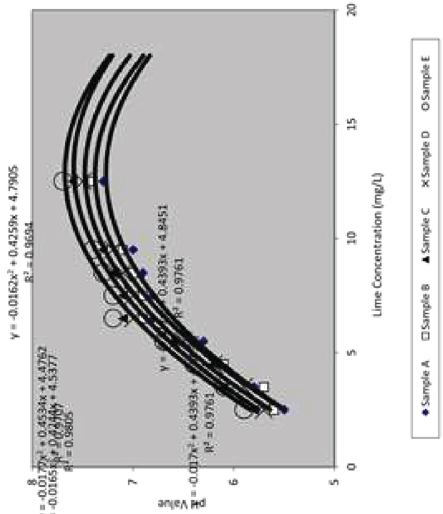


Figure 5a: pH adjustment Tests on samples during wet season

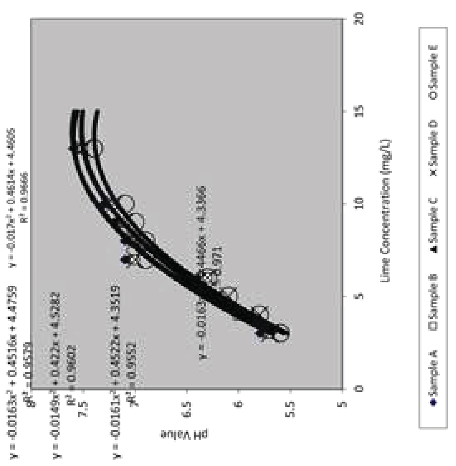


Figure 5b: pH adjustment Tests on samples during dry season

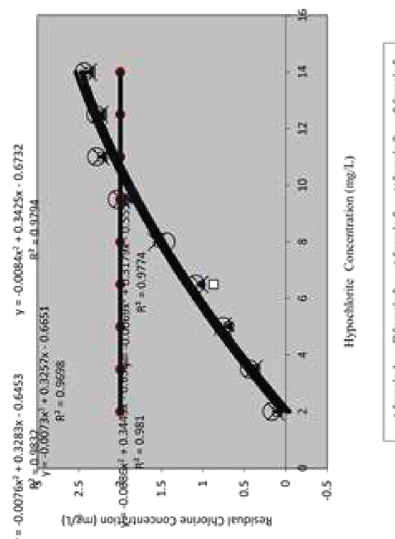


Figure 6a: Residual Chlorine tests on samples during wet season

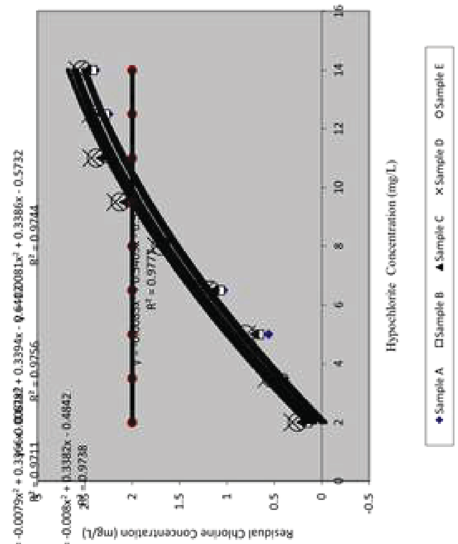


Figure 6b: Residual Chlorine tests on samples during dry season

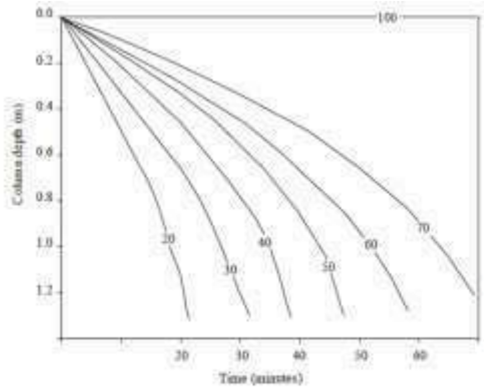


Figure 7a: Iso- concentration curves on samples during wet season (Sample A)

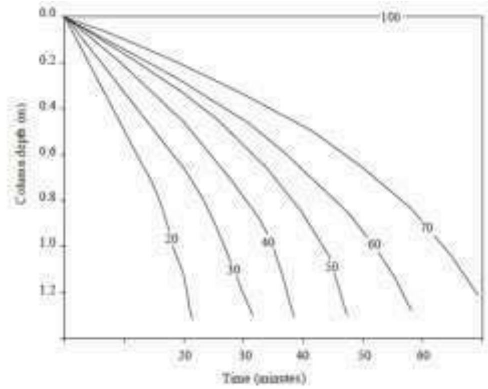


Figure 7b: Iso- concentration curves on samples *during wet season (sample B)*

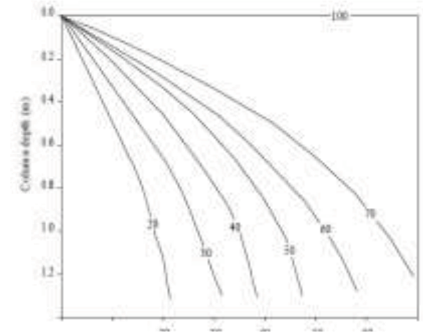


Figure 7d: Iso- concentration curves on samples during wet season (sample D)

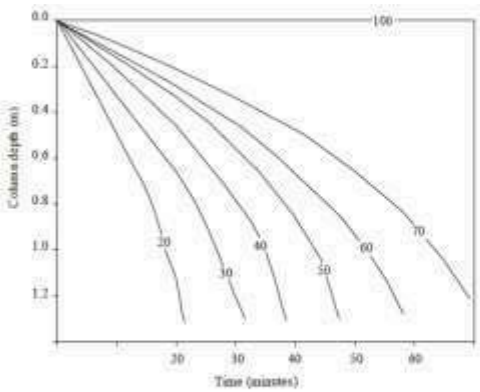


Figure 7c: Iso- concentration curves on samples during wet season (sample C)

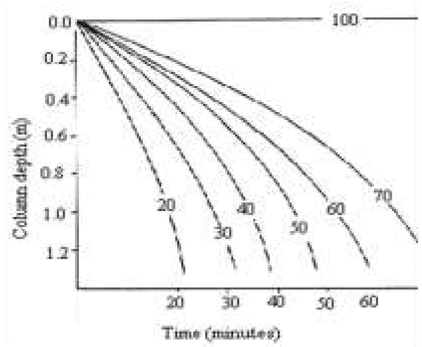


Figure 7e: Iso - concentration curves on samples during wet season (sample E)

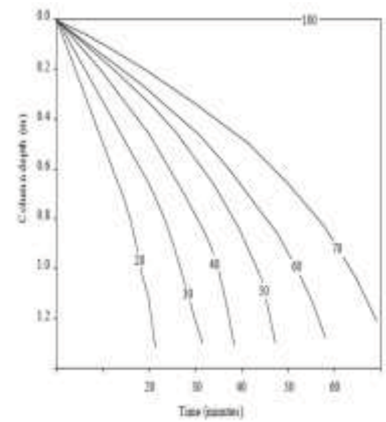


Figure 7f: Iso- concentration curves on samples during dry season (sample A)

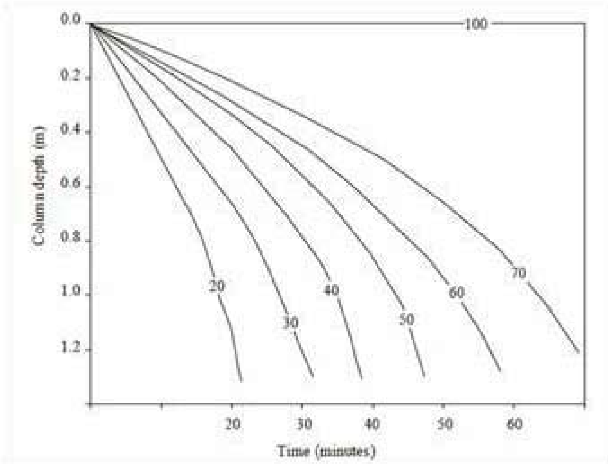
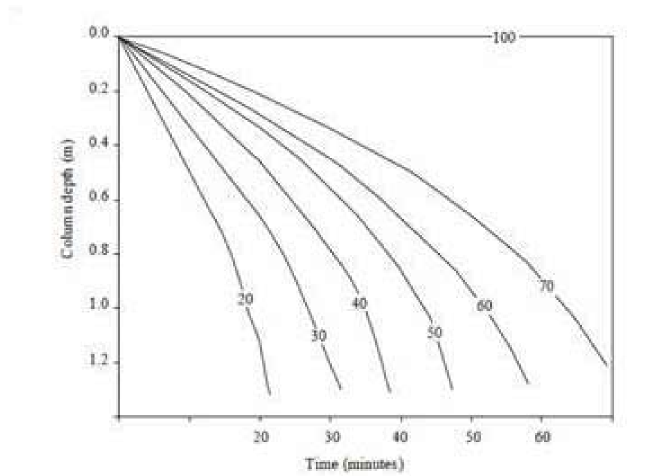


Figure 7g: Iso- concentration curves on samples during dry season (sample **B**)



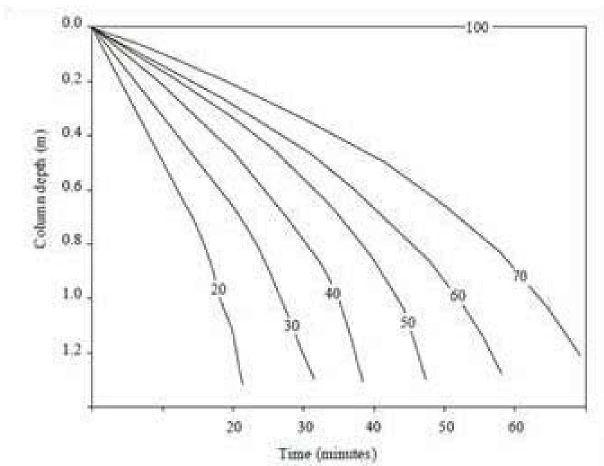


Figure 7i: Iso- concentration curves on samples during dry season (sample D)

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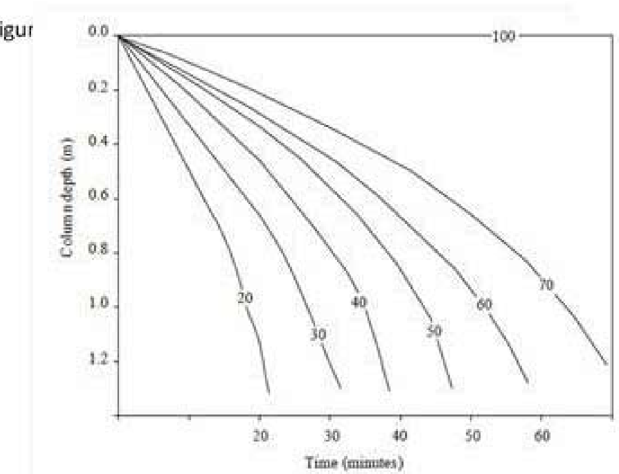
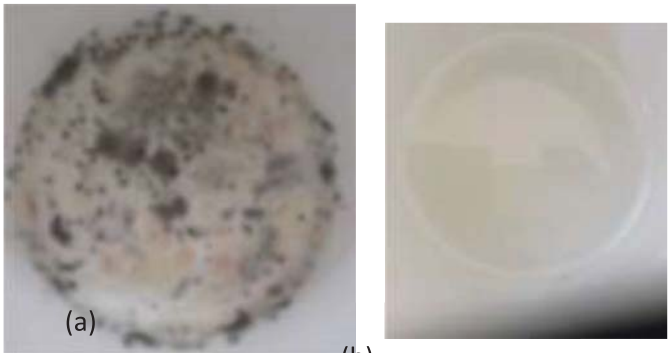


Figure 7j: Iso- concentration curves on samples during dry season (sample E)



(b)

Figure 8: Colonies of microbes in the water sample

(a) Colonies before treatment
(b) Colony after treatment

CONCLUSIONS

Based on the findings of the study conducted the following conclusions can be drawn about treatability property of raw water:

i. coagulation, iron removal, residual chlorine and settling properties of raw water form Aponmu river is similar to properties of surface obtained in literature, but different from settlement of wastewaters obtained from industrial processes,
ii. Desludging of settled solids would not be difficult and current depth of sedimentation tank at the treatment plant would help in removing solids and nature of the iso-concentration curves.

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