

SETTLING PHYSIOGNOMIES OF COAGULATED RAW WATER

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ABSTRACT

This study examined the settling pattern of chemically coagulated and electrocoagulated raw water in a settling column. The collection depth of sample as well as the time in settling column were key factors in this study. Samples used were obtained from the Opa dam, Obafemi Awolowo University Ile-Ife, Nigeria. The optimum alum dosage was determined by carrying out jar test on six 500 litres samples using 10% stock solution of alum. Measured volume of the stock solution was added to each of the samples and each was stirred for 2 minutes and left to settle for 30 minutes before determining the transmittance of the samples. The settling column analysis for chemical coagulation was carried out in three experimental runs on 13.5 litres samples into which the optimum alum dose (8g/L) had been added. Also, settling column analysis for electrocoagulation was carried out in three experimental runs on the same volume of samples as for the chemical coagulation. Results showed that for a given sampling depth in the settling column, the percentage removal of flocs as compared to the initial flocs concentration improved with time. It was also found out that for a given time, the percentage of flocs increased (90%) with depth indicating a decreasing percentage removal with depth (32 cm). The results obtained for electrocoagulation showed that at a particular depth and time, the percentage flocs removal is more than the corresponding results obtained for chemical coagulation at the same depth and time. Concluding results showed that electrocoagulation is more efficient than chemical coagulation.

Keywords: Settling, Electrocoagulation, Chemical coagulation, Opa dam

INTRODUCTION

Water is the common name given to the liquid state of the hydrogen-oxygen compound H₂O. The ancient philosophers regarded water as a basic element typifying all liquid substances. Scientists did not discard that view until the latter half of the 18th century (Ahmad et al., 2016). In 1781 the British chemist Henry Cavendish synthesized water by detonating a mixture of hydrogen and air. However, the results of his experiments were not clearly interpreted until two years later, when the French chemist Antoine Laurent Lavoisier proved that water was not an element but a compound of oxygen and hydrogen.

Water is unusual in that it is a liquid under normal conditions, water relationships between other analogous hydrides of oxygen's column in the periodic table suggest it should be a gas, as is Hydrogen Sulphide. If the periodic table is examined, it will be noted that the elements surrounding oxygen are nitrogen, fluorine, phosphorus, sulphur and chlorine. All of these elements combine with hydrogen to produce gases at normal temperature and pressure. The reason that oxygen forms a liquid is that it is more electronegative; oxygen pulls on electrons much more strongly than hydrogen, leaving a net positive charge on the hydrogen side of the molecule, and a net negative charge on the oxygen side. The electrical attraction 'pulls' separate molecules closer together and raises the boiling point. This attraction is known as hydrogen bonding (Freitas and Oliveira, (2015).

The nature of the water source commonly determines the planning, design and operation of the collection, purification, transmission and the distribution of water works (Hammer and Hammer, 2000). The two major sources of water are surface water and subsurface water.

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation and sub-surface seepage. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water considered a recreational usage.

According to American Water Works Association (Holt *et al.*, 2002), the main function of water treatment is to provide a continuous supply of safe, good-tasting, and cold drinking water that is free of contaminant that can cause diseases or be toxic to a consumer. The main objective of water treatment is to provide a potable supply one that is chemically and microbiologically safe for human consumption (Hammer and Hammer, 2000). For domestic uses, treated water must be free from apparent turbidity, colour, odour and objectionable taste.

Water purification is the removal of contaminants from raw water to produce drinking water that is pure enough for human consumption or for industrial use. Substances that are removed during the process include parasites (such as Giardia or Cryptosporidium), bacteria, algae, viruses, fungi, minerals (including toxic metals such as Lead, Copper etc.), and man-made chemical pollutants. Other contaminants are suspended solids, colour, tastes and odours, trace organic compounds and hardness (Ndi *et al.*, 2015).

One very important process of surface water purification is coagulation. The purpose of coagulation is to destabilize suspended contaminants in water such that the particles contract and agglomerate, forming flocs that drop out of solution by sedimentation. Destabilization of colloids, particularly hydrophobic colloids is accomplished by the addition of a coagulant which will lower the energy barrier and allow the particles to agglomerate (Holt *et al.*, 2002; Wang, *et al.*, 2015).

Sedimentation, or clarification, is the process of letting suspended material settles by gravity. Suspended material may be particles, such as clay or silts, originally present in the source water. More commonly, suspended material or floc is created from material in the water and the chemical used in coagulation or in other treatment processes, such as lime softening. The terms sedimentation and clarification are commonly used interchangeably with regard to preparation of potable water. Although there are some subtle

differences in the connotations of the two words, they both convey the idea of physically separating solid material from water (Ramavandi, 2015).

Several factors affect the separation of settleable solids from water. The most common of the factors are particle size, water temperature and currents.

Depending upon the characteristics and concentrations of suspended materials, sedimentation can be classified into four types: Discrete (Type I), Flocculating particles (Type II), Zone settling (Type III) and Compression settling (Type IV).

MATERIALS AND METHODS

Materials used in this study includes the water sample, distilled water and alum salt. Since this study involves the analysis of settling characteristics of chemically coagulated and electrocoagulated raw water, the water sample that was used was not pre-treated or partially treated. However, some known amount of bentonite was added to the water that was used so as to enable it to have uniform characteristics that will aid uniform comparison between the chemical coagulation and the electrocoagulation.

Two series of experiments were performed, the first one involving the determination of alum dosage for the coagulation of water using jar test and the other one involving the analysis of the settling characteristics of raw water that has been pre-coagulated with both alum and electric current by carrying out an experiment for Total Suspended Solids (TSS) determination.

An mrc spectrophotometer was used to determine the transmittance of samples from the jar test. In order to obtain a desired result, the spectrophotometer is expected to be set to a wavelength of 530 nm for all readings.

Measurement of turbidity was done by measuring transmittance using spectrophotometer. Transmittance is the ability of a material to let radiation pass completely through it, measured as the ratio of incident radiation to transmitted radiation.

Alum stock solution

In preparing the alum stock solution (for the determination of optimum alum dosage), some quantity of alum salt was used. The total amount that was used was dependent on the volume of water that was coagulated and analysed. However, a 10% stock solution of alum was prepared by dissolving 100 g of powdered alum salt in 100 ml of distilled water and it was then filled up to 1L volume. 10 % stock solution was used instead of the normal 1% because it was observed after some trials that more volume of the 1 % stock solution was needed for the jar test.

Settling column

A model settling column made of Plexiglas, 9 cm in diameter was used for the settling characteristics analysis. The model settling column consists of four holes of 8 mm diameter drilled at 32cm intervals for collection of water samples. Attached to the lower part of the settling column is a plastic pipe to serve as sludge zone for the column. Copper pipes of 7.5 mm diameter were used as sampling pipes with the settling column. Four copper pipes (of say 4 cm long) were required to fit into the holes drilled in the settling column.

13.5 L of raw water was prepared by thoroughly mixing an appropriate dosage of alum with the water. The sample was then poured into the well balanced settling column apparatus and a 50ml volume of the water was collected to determine the initial suspended solids concentration as $Co(mg/L)$. Samples were then taken from each of the four ports, at intervals of 15 minutes, 30 minutes, 60 minutes, 90 minutes, and 120 minutes

for the determination of the final suspended solids concentration. The final suspended concentration was then expressed as a percentage of the original concentration.

Optimum alum dosage determination (Jar test)

The optimum alum dosage for coagulation was determined by carrying out the jar test experiment. Series of containers of at least 1 L capacity were used for the jar test. Initially, the spectrophotometer was first calibrated using distilled water whose transmittance was 100% and the wavelength value was set to 530 nm. Six samples of 500 ml volume raw water were prepared in six different jars. Different volumes of the 10% stock solution of alum (5ml, 10ml, 20ml, 30ml, 40ml and 50 ml) were added to the 500 ml water samples in those jars. The water samples were then stirred rapidly for 2 minutes using the electric stirrer to ensure complete dispersion of the coagulant and to aid flocs formation. After the mixing, the samples were allowed to settle for 20minutes, and little volume of each of the samples was taken for measurement of transmittance. The optimum dosage of the coagulant was determined by plotting the transmittance against alum dosages and the maximum point of inflection represent the optimum dosage.

Electrocoagulation

Electrocoagulation was carried out by passing current to water through two electrodes so that an electrolytic reaction can occur between the electrodes and the solids present in the water. The current was passed through the electrodes comprising Aluminium as anode and Stainless steel as cathode. Each 3.6 L of water was coagulated electrolytically within a period of 7 minutes. 14.4 L (3.6 L x 4) of water was prepared and it was coagulated for 28 minutes (7minutes for each 3.6 L) out of which 13.5 L was used for settling column analysis. At the end of the period for coagulation, the coagulated water was mixed together before passing it on to settling column for analysis.

RESULTS AND DISCUSSION

The results obtained during this study are represented using tables and graphs.

Jar test result

The experiment was performed in three trials and the results of those experiments are represented graphically. In order to determine the optimum alum dose, a plot of transmittance against alum dose was prepared and the graph are as shown in Figure 1, 2 and 3 for three trials respectively.

From each of the plots, it can be observed that maximum point of inflection occur at 40 ml of alum dosage, therefore, the optimum alum dose is 40 ml of 10% alum stock solution in 500 ml of water which is equivalent to 80 ml/L. Since 10% of the stock solution contains 100 g in 1000 ml of water, therefore, the amount in gram of the optimum dose is 8g/L.

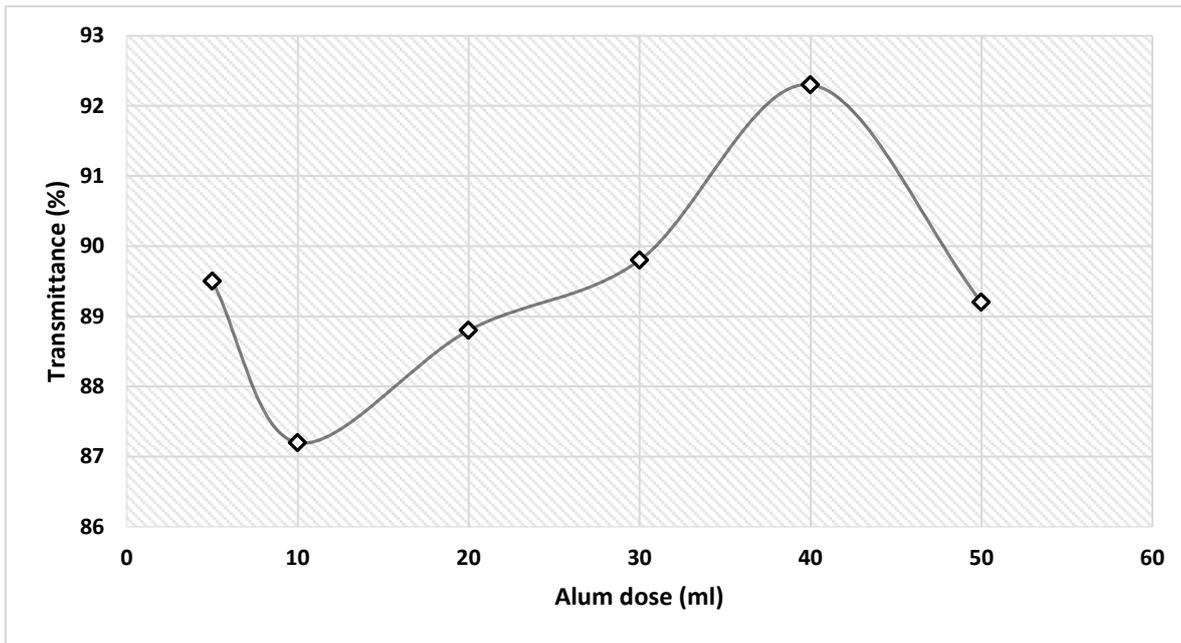


Figure 1: Transmittance against Alum dose (Experiment 1)

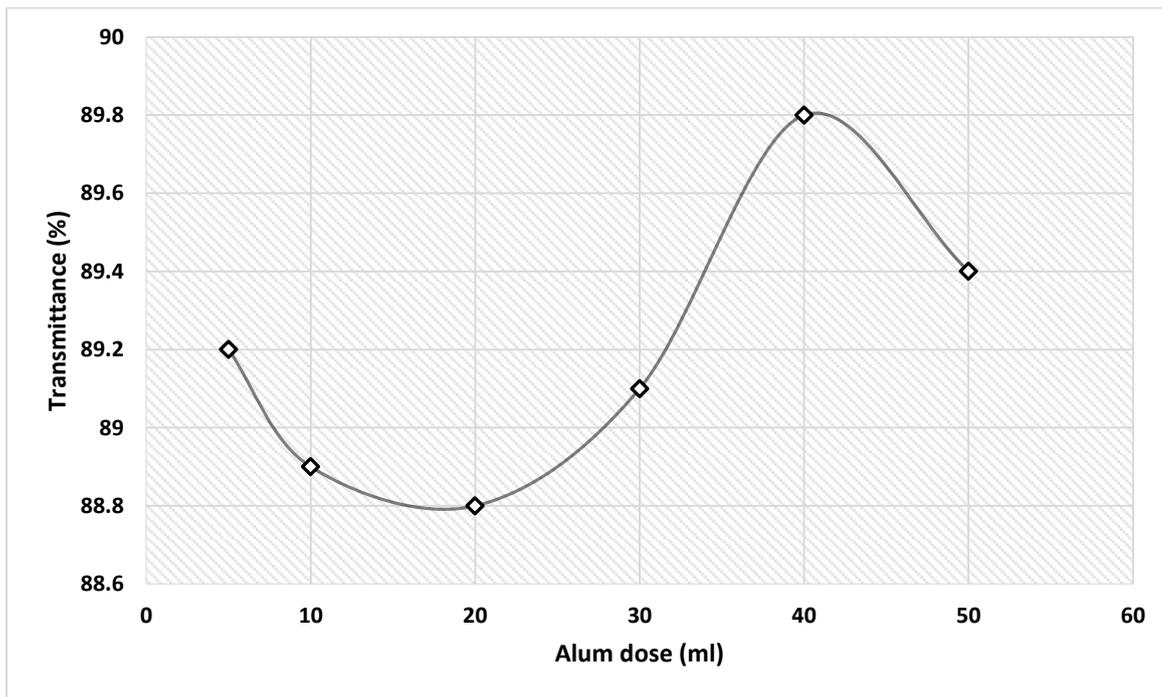


Figure 2: Transmittance against Alum dose (Experiment 2)

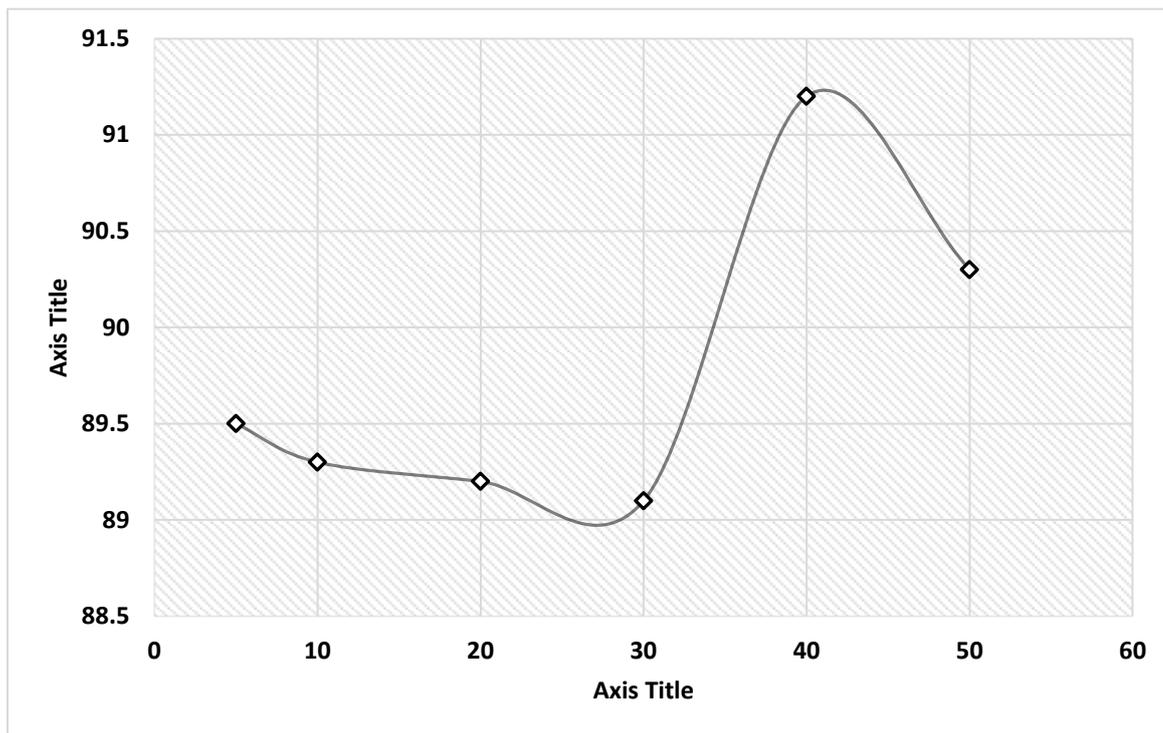


Figure 3: Transmittance against Alum dose (Experiment 3)

Settling column result

For the chemical coagulation test, the percentage solids removed at each of the ports for selected intervals of time are presented in Table 1, 2 and 3 for each of the three trials that were carried out.

For the electrocoagulation experiment, the percentage solids removed at each of the ports for selected intervals of time are presented in Table 4, 5 and 6 for each of the three trials that were carried out.

Table 1: Percentage solids removed at various ports (Experiment 1)

% Solids Removed					
Time (min)	Ports	1	2	3	4
0		0	0	0	0
15		77.8	71.1	48.9	28.9
30		84.4	77.8	71.1	68.9
60		91.1	82.2	77.8	73.3
90		93.3	88.9	82.2	77.8
120		95.6	93.3	88.9	84.4

Table 2: Percentage solids removed at various ports (Experiment 2)

% Solids Removed					
Time (min)	Ports				
		1	2	3	4
0		0	0	0	0
15		65.9	56.1	34.1	9.8
30		73.2	65.9	58.5	53.7
60		82.9	75.6	68.3	63.4
90		90.2	85.4	78.0	70.7
120		95.1	90.2	85.4	80.5

Table 3: Percentage solids removed at various ports (Experiment 3)

% Solids Removed					
Time (min)	Ports				
		1	2	3	4
0		0	0	0	0
15		69.4	63.3	42.9	22.4
30		79.6	73.5	69.4	67.3
60		87.8	81.6	75.5	73.5
90		91.8	87.8	83.7	79.6
120		95.9	91.8	89.8	87.8

Table 4: Percentage solids removed at various ports (Experiment 1 - Electrocoagulation)

% Solids Removed					
Time (min)	Ports				
		1	2	3	4
0		0	0	0	0
15		60.9	41.3	26.1	15.2
30		87.0	76.1	67.4	63.0
60		89.1	87.0	80.4	76.1
90		95.7	91.3	89.1	87.0
120		97.8	95.7	95.7	93.5

Table 5: Percentage solids removed at various ports (Experiment 2 - Electrocoagulation)

%Solids Removed					
Time (min)	Ports				
		1	2	3	4
0		0	0	0	0
15		66.7	41.7	35.4	22.9
30		85.4	75.0	62.5	56.3
60		87.5	85.4	81.3	77.1
90		93.8	91.7	87.5	85.4
120		97.9	95.8	91.7	89.6

Table 6: Percentage solids removed at various ports (Experiment 3 - Electrocoagulation)

%Solids Removed					
Time (min)	Ports	1	2	3	4
	0		0	0	0
15		68.8	45.8	37.5	18.8
30		87.5	72.9	64.6	58.3
60		89.6	87.5	77.1	75.0
90		93.8	93.8	89.6	83.3
120		97.9	97.9	93.8	91.7

Discussion

The settling pattern of the coagulated raw water was observed to be a flocculent settling pattern (Type II settling) which could not be analysed by the Stoke's equation. Flocculating suspensions could not be generalized in the same manner as discrete particle suspensions. The Stokes equation could not be used because the flocculating particles were continually changing in size, shape and size, they decrease in density because of entrained density. Teh *et al.* (2016) stated that the particles grow in size, they decrease in density because of entrained water but they usually settle faster.

From Table 1 and 3, selecting Port 4 as the reference port, it was observed that 80% removal of flocs occurred at an average detention time of 105 minutes whereas 90% removal occurred at 120 minutes but at port 3. Generally, it can be observed that for a given depth of the settling column, percentage removal of flocs increases with time.

However, from observation based on variation of percentage removal of flocs with depth, it can be seen (for example in Table 2) that at 90 minutes detention time for depths 32 cm, 62 cm, 92 cm and 122 cm; about 90%, 85%, 78% and 70% flocs were removed respectively. The same trend can be observed for Table 1 and 3. This analysis implies that percentage removal for any given detention time decreases with depth.

It should be noted that the velocity becomes greater at greater depth. This common characteristic of flocculating suspensions reflects the increase in particle size and subsequent increase in settling velocity because of continued collision and aggregation with other particles.

Considering Table 4 for the electrocoagulation, it can be observed that 80% flocs removal occurred at an average detention time of 70 minutes and 90% removal occurred at 105 minutes both at port 4. The same trend occurs in Table 5 and 6.

This implies that, In general, percentage flocs removal is more efficient in electrocoagulation than in chemical coagulation.

Therefore, the efficiency removal of flocs where type II sedimentation is taking place is governed by: Concentration of particles, Type and size of particles, Hydraulic detention time and, Depth of sedimentation basin.

Conclusion

Based on the results and discussions, the following conclusions can be made:

1. The settling pattern for chemically coagulated raw water from Opa dam of the Obafemi Awolowo University waterworks is a flocculent settling pattern (Type II settling).
2. The percentage removal of flocs for a given depth of the sedimentation tank increases with time.
3. Percentage removal for any given time in the sedimentation tank decreases with depth.

4. Velocity of flocs becomes greater at greater depth of the sedimentation tank.
5. Sedimentation is more efficient in electrocoagulation than in chemical coagulation.

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