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Effect of Iron–Based Coagulants in Municipality Operation A Case Study of Kwara State Water Corporation

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Abstract
Coagulants can be added to the water either as a solution which is much the commonest way or in powder or shiny form. As treatment is a continuous process, dosing must also proceed in continuous and controlled fashion. Iron –based coagulants are not as widely used as Aluminum –based coagulants in drinking water treatment as the presence of iron in drinking water poses possible risks to human as well as technical, Economical, social and their environmental impacts. Aluminium sulphate are classified as inorganic coagulant while Moringa oleifera is an example of organic coagulants.
Keywords: inorganic and organic coagulants, Drinking water ,Aluminium and iron based coagulants, flocs, Turbidity, and treatment plant

1. INTRODUCTION

Sulphate of alumina AL2(SO4)3.18H20) is also known as aluminium sulphate or (incorrectly) as alum . It is a very commonly used coagulant and can be bought in various forms aluminoferric in blocks) granulated kibbled (in lumps) or liquid in blocks) granulated kibbled (in lumps) or liquid in blocks) forms, where 50kg of this salt contains the equivalent of 7.65kg of aluminium oxide, it can theoretically react to produce 11.7kg of floc (smerthurst. G .1979).

Its alumina (AL2O3) content and is graded and priced as 14-15%, 16%or 17-18% see physic o-chemical analysis of aluminium based and that of iron based sulphate coagulants in table 1A and 1B .

IRON SALTS: Certain iron salts can be used as coagulants and when available normally cheaper, produce heavier flocs and operate over a wide range than sulphate of alumina.

However, they normally required to be used with lime and are a little more difficult to control in connection with the following problems might be listed.

(a) Special materials may have to be used to line up the containers.
(b) Iron salts tend to cake in humid locations.
(c) Iron salts are dirty to handle , causing staining
(d) Sludge is more difficult to dispose of without giving complaint.
(e) Lime must generally be added, usually in advances.
(f) While often inferior to aluminium based coagulant in end results bigger flocs or chamber may be required as well as promoting rusting and oxidation of the metal component of our facilities.

In this study, the evaluation of different Coagulant and substitute capable of replacing aluminium based coagulants for water treatment in kwara state water works was conducted. The different alternative coagulants available were evaluated according to the literature to commercial suppliers and their possible use in water treatment. Alternative treatments and options in the clarification process are also studied.

All zonal Biochemist/ Engineers were contacted to discuss their experiences and their perception related to the use of alternative coagulants iron based coagulant i.e technical, economical, social as well as environmental impacts have been identified and when possible evaluated.

1.1 COAGULANTS USED TO TREAT DRINKING WATER

Analyzing different experiment conducted using Coagulation Flocculation process allowed identifying potential products that may be used as coagulants for water treatment some of which are widely available (aluminium and iron based coagulants) while others are experimental coagulants. According to the literature, the performance of each coagulant fluctuates according to the type of water being treated.

1.2 AlUMINIUM -BASED COAGULANTS

Compared to others, the use of aluminium- base Coagulants is not restricted by by the availability of their prime components. The natural bauxite resources are abundant and the production of sulphuric acid is common. Aluminium salts are produced from dissolution of purified (or non- purified) aluminiunm tri hydrate with sulphuric acid followed by a filtration. The cost of these coagulants generally varies with volume produced and the distance between the production site and water treatment plant. A health based guideline for the presence of alumina in drinking water has not been established (FPSDW) however, water treatment plants using aluminium –base Coagulants should optimize their operations to reduce residual aluminium levels in treated water as a precautionary measures operational guidelines of less than 0.1ppm of total aluminium for conventional treatment plants and less than 0.2ppm of total aluminium for other types of treatment system are recommended (FPSDW2011).

Aluminium based coagulant is the most widely used coagulant chemical (AWWA and ASCE1990). The U .S.E.P.A (1990) requires drinking water utilities to conduct jar tests using aluminium based coagulant to establish their total organic carbon removal by. Enhanced Coagulants are those that maximize aluminium and produce low turbidities and particle counts.

(Edward and Tobiason1999). Aluminium based coagulation is the most popular reference in water treatment.

1.3 IRON –BASED CONGULANTS

(Feso4.7H20) contains 29% of Fe203, it is supplied in small lumps or as light green or brown crystals /lumps it is meant to be used on alkaline bicarbonate waters and should be accompanied by sufficient lime or caustic soda to raise the PH 8.5 - 10. It is not widely used on domestic supplies but is encouraged in industrial softening plants and in the treatment of waste water. It cannot be used on soft colored or turbid waters where ions formation occurs at a PH of about 6, as the ferric hydroxide form from the reaction of ferrous hydroxide only in the presence of lime at high PH values. The reactions are:

Ca(HC03)2+Feso4_ Fe(oH)2+CaSo4+2C02

2Fe(oH)2+o+H20_ 2Fe(oH)2 which is the floc.

It is hygroscopic and tends to clog in dry – feeding equipment and should therefore be added as solution (Smethurst G. 1979).

1.4 ENVIRONMENTAL IMPACTS

The substitution of aluminium –based coagulants may have environmental impacts depending on the sludge disposal mode used in the different drinking water plants. Most sludge clarification processes is released at periodic intervals in the sewers in order to facilitate the waste water treatments. Therefore Coagulants change may not affect significantly the efficiency of a chemical coagulant containing coloured iron oxide (red oxide – based coagulants may be difficult on the other hand the the use of natural organic coagulants would facilitate sludge disposal and valorization for agricultural activities. They will also reduce the volume of the sludge produced from the perspective of sustainable development of our industrial society, the impacts of chemical use for drinking water treatment have to be analyzed and evaluated. The long term resource availability will limit the use of non –renewable chemicals and energy must be minimized when producing service water.

Furthermore, all alternative coagulations will need to be carefully studied and implemented especially in small municipalities where staff formation will be necessary.

In all cases treatment modification must not affect water quality and the potential consequences caused by micro bial contaninmination are such that its control must always be of paramount importance and must never be compromised (WHO1998).

The implementation of enhanced coagulation which maximize pathogen removals, produces low turbidities and minimizes residual alumina.(Edward and Tobiasson 1999) in canada.

2.0 JAR TESTING

Jar testing is a method of stimulating a full scale water treatment process, providing system operators(Chemist or Engineer) a reasonable idea of the way a treatment Chemical behave and operate with a particular type of raw /fresh water. Because it mimics full scale operation system operators can use jar testing to help determine which treatment chemical will work best with their system raw water.

Jar testing entails adjusting the amount of treatment chemicals and the sequence in which they are added to samples of raw /fresh water held in jars or beakers. The sample is then stirred so that the formation development and settlement of floc can be watched just as it would be in the full scale treatment plant.

Floc forms when treatment chemicals react with materials in the raw water and clump together.

The operator then performs a series of tests to compare the effect of different amounts of flocculation agents at different PH values to determine (The right size of floc depends upon the system is filter dimensions and other considerations).Jar testing is done so as to save money and one of the common problems in water treatment is overfeeding or overdosing especially with coagulants. This may not hurt the quality of water, but it can cost a lot of money one of the easiest things an operator can do for optimization of the plant is jar testing and jar testing is a must when looking at the best available technologies.

2.1 JAR TESTING PROCEDURES

The following jar test procedure uses alum (aluminium sulphate) a chemical for coagulation/flocculation I n water treatment and a typical six –gang jar tester.

The results of this procedure can help optimize the performance of the plant.
(1) First using a 1000 milliliter (mL) graduated cylinder, add 1,000mL of raw water to each of the jar test beakers we record Temperature, pH, Turbidity, alkalinity, TDS of the raw Water before jar testing
Please see table 2&3 for an example of such readings before and after jar testing
(2) Next preparation of stock solution by dissolving 10.0grams of aluminiusulphate into 1000ml distilled water ,, each 1.0ml of this stock solution will equal 10mg/l or ppm when added to 1,000ml of water to be tested.
(3) After dosing each beaker turn on the stirrers. This part of the procedure should reflect the actual conditions of the plant as much as possible meaning if the plant has a static mixer following chemical addition, followed by 30 minutes in a flocculator, then 1.5 hours of settling time before the filters then the test also should have these steps.

The jar test would be performed as follows:

Operate the stirrers at a high RPM for 1minutes to stimulate the static mixer . Then reduce the speed of the stirrers to match the conditions in the flocculator and allow them to operate for 9 minutes.
Observe the floc formation periodically during the 9 minutes. At the end of the 9 minutes turn off the stirrers and allow settling most of the settling will be complete after one hour. Sample are taken from be about 10ml are taken from each beakers and PH, Turbidity, Conductivity ,TDS and alkalinity readings are done to pick the best dosage or flocculants with the best supernatant water along with heavier floc and right dosage formation.
See Table 4 showing the result of the readings Pask, David (1993).

2.2 FREQUENCY OF JAR TESTING
Jar testing should be done seasonally (temperate) Monthly, weekly, daily, or whenever a chemical is being changed or new pumps rapid mix motors , new floc motors , new feeders are installed.

There is no set requirement for how often jar testing should be conducted but more it's done the better the plant will operate optimization is the key to running the plant more efficiently.

Look at the table 5 to see the summary of coagulant distributed to the major water works across kwara state using the flocculants or dosage result obtained from the jar testing during the raining and dry season for the year 2012.

See table6 to see the flocculants or dosage and coagulant bags/day for the same year.

2.3 RESULT AND DISCUSSION
Looking at table 1A and 1B showing physico –chemical analysis of Aluminium based coagulant and that of iron based coagulant. It is observed that most of the parameters in the Aluminium based coagulant fall within the (AWWA) American water work association specification which indicate that the coagulant is good as water treatment chemicals on the other hand the iron based coagulant physico-chemical analysis results shows that the iron and Zinc content are out of the standard or AWWA specification.

These parameters analyzed for are on the higher concentration and this inform us that the coagulant do not pass (AWWA) standard and as such it is recommended as bad water treatment chemicals that enhance continuous oxidation of the treatment facilities consequently rusting and total collapse of the whole system.

It also has an advance health effect on the consumer as well as know that the consumption of higher iron content in food or water result in the formation of Goiter in human being from medical point of view.

See table 6:The most probable flocculants for both raining and dry season allocation is 30ppm except for Offa old and new which are 20 and 15ppm as well as New and Old Sobi @ 50ppm and30ppm for raining and dry season allocation respectively, also 25ppm for Asa head work during the dry season while the capacity utilization chart for the eight water works are shown on table 5 with the highest number of bags of coagulant allocated to Asadam water work during the dry and raining season respectively and the least allocation to Offa and Agba dam water works.

3.0 CONCLUSION AND RECOMMENDATION
It is recommended that a position paper on the use of aluminium based coagulant rather than the iron based coagulant should be written to the federal and state ministry of water resources as well as water boards/water corporation across the nation that they should desist from using coagulant that are iron based since the disadvantages are more than the advantages which include dirty to handle formation of heavy sludge rusting of the facilities and destruction of pipes, in this regard the most popular iron salts used to treat drinking water are ferric chloride and ferric sulphate. According to the AWWA(1990) both ferric chloride and ferric sulphate are corrosive compounds and attacks metals rapidly so much that ductile iron storage tanks clarifier and through are readily attacked by this compound as well as as dosage equipments so using ferric chloride or ferric sulphate as a coagulant in drinking water treatment may exhibit higher operational costs than using aluminium sulphate, also many metal impurities may be present in ferric salts due to their production process, as compare to aluminium sulphate which is made from purified bauxite.

TABLE 1A

PHYSICO –CHEMICAL ANALYSIS OF COAGULANT

NAME OF PRODUCT: COAGULANT
TYPE OF PRODUCT: ALUMINIUM BASED
BATCH ES NO: 246
MANUFACTURE DATE: 2012
EXPIRY DATE : 2019

PHYSICO- CHEMICAL ANALYSIS OF ALUMINIUM BASED COAGULANT.

S/N	PARAMETERS	ANALYTICAL RESULT	AWWA LIMIT.
1	COLOUR	WHITE	PURE OR OFFWHITE
2	TEXTURE	CRYSTALINES	LUMPS OR CYRSTALINE
3	SOLUBILITY	VERY SOLUBLE	READILY SOLUBLE
4	PH	3.5	≥3.5
5	INSOLUBLE IMPURITY	0.02	≤0.05ppm
6	%ALUMINA	17%	17-18%
7	IRON OXIDE	0.01ppm	0.03ppm
8	COPPER OXIDE	0.0051ppm	0.01ppm
9	ZINC OXIDE	0.0274ppm	0.1ppm
10	CHROMIUM OXIDE	0.042	0.05ppm

COMMENT:All the parameters are within the AWWA specification hence the coagulant is recommended as good water treatment chemicals.

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TABLE1B

PHYSICO –CHEMICAL ANALYSIS OF COAGULANT

NAME OF PRODUCT: COAGULANT
TYPE OF PRODUCT: IRON BASED
BATCH ES NO: 542
MANUFACTURE DATE: 2011
EXPIRY DATE : 2013

PHYSICO- CHEMICAL ANALYSIS OF IRON BASED COAGULANT.

S/N	PARAMETERS	ANALYTICAL RESULT	AWWA LIMIT.
1	COLOUR	BROWNISH	BROWNISH
2	TEXTURE	LUMPS	LUMPS OR CYRSTALINE
3	SOLUBILITY	SOLUBLE	READILY SOLUBLE
4	PH	4.36	≥3.5
5	INSOLUBLE IMPURITY	0.079	≤0.05ppm
6	%ALUMINA	15%	17-18%
7	IRON OXIDE	0.57ppm	0.03ppm
8	COPPER OXIDE	0.0051ppm	0.01ppm
9	ZINC OXIDE	0.0274ppm	0.1ppm
10	CHROMIUM	0.0604ppm	0.05ppm

COMMENT: the iron content is on the high side hence the coagulant do not pass the AWWA specification.
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TABLE:2

RESULT OF INSITU ANALYSIS OF RAW WATER FROM MAJOR WATER WORKS ACROSS KWARA STATE WATER CORPORATION BEFORE THE JAR TESTING.

WATER WORKS	TEMPERATURE	CONDUCTIVITY	PH	TURBIDITY	ALIKALINITY	TDS
ASA DAM	25.30	45.10	7.50	31.50	130	72.55
AGBA DAM	26.30	145	7.68	32	135	70
SOBI -DAM	29.50	161	7.40	35	120	80.5
OFFA DAM	24.40	63	6.82	25	125	31
OMU ARAN DAM	30.0	187	6.9	30	110	93.5

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TABLE: 3

RESULT OF INSITU ANALYSIS OF TREATED WATER FROM MAJOR WATER WORKS ACROSS KWARA STATE WATER CORPORATION A AFTER JAR TESTING.

WATER WORKS	TEMPERATURE	CONDUCTIVITY	PH	TURBIDITY	ALIKALINITY	TDS
ASA DAM	25.30	78	7.0	1.00	200	39
AGBA DAM	27.50	136	7.2	0.5	70	68
SOBI -DAM	24.0	215	7.1	2.1	125	96
OFFA DAM	28.0	80	7.0	2.0	110	40
OMU ARAN DAM	39.30	118	7.0	1.5	255	59

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TABLE: 4

S/N	JAR No	Ml OF ALUM STOCK ADDED	Mg/L DOSAGE.
1a	1	1.0	10.0
2a	2	1.5	15
3a	3	2.0	20
4a	4	2.5	25
5a	5	3.0	30
6a	6	3.5	35
7a	7	4.0	40
8a	8	4.5	45
9a	9	5.0	50
10a	10	5.5	55
11a	11	6.0	60
12a	12	6.5	65

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TABLE: 5
MAJOR WATER WORKS CAPACITY UTILIZATION CHART

S/N	WATER WORKS	TREATMENT CAPACITY	HOURS OF OPERATION	RAINING SEASON ALLOCATION	DRY SEASON ALLOCATION.
1	ASADAM	117,600	24	2116.8BAGS	1764BAGS
2	AGBADAM OLD	6,000	24	120 BAGS	72BAGS
3	AGBADAM NEW	3,000	24	72BAGS	54BAGS
4	SOBIDAMNEW	3,000	24	90BAGS	54BAGS
5	SOBIDAMOLD	3,000	24	90BAGS	54BAGS90BAGS
6	OFFADAMNEW	7,716	24	138 BAGS	909BAGS
7	OFFADAM OLD	6,000	24	72BAGS	54BAGS
8	OMUARAN	6,000	24	108BAGS	72BAGS

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TABLE: 6

	WATER WORKS	DOSAGE OR FLOCCULANT FOR RAINING	DOSAGEOR FLOCCULANT FOR DRY.	ALUMBAGS/DAY FOR RAINING SEASON	ALUMBAG/DAY FOR DRY SEASON.
1	OFFA OLD	20ppm	15ppm	2.4	1.8
2	OFFA NEW	30ppm	20ppm	4.6	3.0
3	AGBA NEW	30ppm	20ppm	4.0	2.4
4	AGB A OLD	40ppm	30ppm	2.4	1.8
5	SOBI NEW	50ppm	30ppm	3.0	1.8
6	SOBI OLD	50ppm	30ppm	3.0	1.8
7	OMU ARAN	30ppm	20ppm	3.6	3.0
8	ASADAM	30ppm	25ppm	70.56	58.8

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FIGURE1
FLOCCULATOR FOR JAR TEST.