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EFFICIENCY OF COAGULATION-FLOCCULATION PROCESS IN THE TREATMENT OF ABATTOIR EFFLUENT

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Abstract. The use of coagulation-flocculation process as means of wastewater treatment is gradually becoming more popular. This research work is to evaluate the efficiency of coagulation-flocculation process in the treatment of abattoir effluent. Samples of abattoir effluent were collected from a slaughterhouse at Ede, Nigeria, and Alum was used in the coagulation-flocculation treatment of the effluent. The physico-chemical and bacteriological analyses of the untreated and treated effluent were carried out and these were used in determining the efficiency of the treatment process. The values obtained (from the physico-chemical and bacteriological analyses) were also compared with the effluent standard of Environmental Protection Agency (EPA). Coagulation-flocculation process is performed efficiently in reducing the contaminant level of Colour, TDS, Turbidity, Conductivity, TSS, Total Hardness, COD, Coliform, metals and other pollutants from the effluent.

Keywords: *Abattoir Effluent, Coagulation, Contaminants, Wastewater, Treatment.*

1. Introduction

Coagulation is the process by which particles become destabilized and begin to clump together; it is an essential component in water treatment operations [1]. Wastewaters often contain pollutants that are present in colloidal form. In such cases the colloidal suspension may contain organic materials, metal oxides, insoluble toxic compounds, stable emulsions and material producing turbidity. The primary purpose of the coagulation/flocculation process is the removal of turbidity from the water. The chemical and electrical means of water and waste water treatment can be achieved by using coagulation as the most important physico-chemical operation [2].

Management of wastewater from the red meat processing industry is an important issue. Due to the specific characteristics of wastewater, such as irregular discharge and considerable organic and biogenic loading, it can be difficult and costly to treat. The organic loading rate of wastewater from the red meat processing industry can be several times higher than the average domestic sewage. Also, it is well known that its high content of fat, oil and grease (FOG) is another issue that makes the treatment process much more difficult. A combination of a main and an aid coagulant has shown to be efficient and cost-effective in treating abattoir wastewater. Coagulant aids are capable of reducing the amount of chemicals required and the sludge produced [3].

It is important to note that preliminary settling time, alum dose, rapid and slow mixing times, addition of polyelectrolyte as coagulant aid and particle size distribution were found to be important operational parameters for effective treatment of abattoir wastewater. Alum generally provides good clarification, rapid settling sludge and permits the use of a simple method of recovery that ensures destruction of most sewage solids in the resulting sludge [4]. In the work of [5], after using three common coagulants (Aluminium Sulphate ($Al_2(SO_4)_3.18H_2O$), Poly-Aluminum Chloride (PAC), and Ferrous Sulphate ($FeSO4.7H_2O$)) with the wastewater from a slaughterhouse, it was concluded that coagulation is one of the effective methods to remove organic matter from slaughterhouse wastewater, the results of their work prove that the coagulation method is a fast and an effective method in a partial treatment of slaughterhouse pollution and could be an important step before biological methods. Coagulant like Sodium aluminate ($NaAlO_2$) has been used in wastewater treatment in the phosphorous removal process. While the other aluminium and iron salts act as acids consuming alkalinity, sodium aluminate acts as a base [6]. The electro-coagulation (EC) technology [7, 8] can also be used to treat abattoir wastewater for safe discharge. Under the operating conditions studied, the performance of the process was improved by lowering the initial solution pH and increasing the electrolysis time, current intensity, settling time and operating temperature. The removal efficiency of over 90% was achieved under optimum condition. The findings of their separate study show that electro-coagulation technique using Fe-Fe electrodes and/or Fe-Al electrodes is effective in abattoir wastewater treatment. The aim of this research work is to evaluate the efficiency of coagulation-flocculation process in the treatment of abattoir effluent.

2. Materials and methods

2.1 Materials and Equipment Required for the Study

The materials and equipment used in carrying out this research work include:

- Aluminium Sulphate (Alum)
- Flocculating Machine
- Jar Test Apparatus
- GPS
- Standard laboratory for physico-chemical and bacteriological analyses.

2.2 Methods

Preparation of alum (coagulant)

Aluminium Sulphate (alum) purchased from an outlet in Osogbo, Nigeria was used in preparing an alum solution in which 200g of alum was dissolved per 1000ml of distilled water.

Collection of effluent samples

Samples of abattoir effluent were taken from an abattoir at Ede, Nigeria (at coordinates 7^0 42’ 25” N and 4^0 23’ 38” E).

Jar test on the effluent sample

10ml of abattoir effluent was put in a cuvette and inserted into a Lovibond comparator, to determine the colour that matches with the wastewater sample. After the determination of initial colour, pH and temperature, 500ml of the wastewater sample was measured in three places (beakers) and the equivalent volume of Alum solution was measured with respect to the colour into each abattoir sample. The beakers were placed into the flocculating machine and the roller was allowed to mix the sample rigorously for five minutes and then the speed was reduced for another 15mins. The samples were left to settle and the abattoir samples were decanted to check for the final colour, pH and temperature.

Coagulation-Flocculation Process

A known volume of abattoir effluent was fed into the coagulation/flocculation bucket and the alum dose (determined from jar test) was added to $0.001m^3$ of the abattoir effluent in the flocculation bucket. The flocculation bucket was placed into the flocculating machine and the roller was allowed to mix the samples rigorously for five minutes; followed by 15 minutes of slow mixing. The sample was left to settle for one hour and later decanted.

Physico-Chemical and Bacteriological Analyses should be indented

Three samples each of the untreated and treated (coagulated) abattoir effluent were taken to the laboratory of Osun State Water Corporation, Ede, Nigeria for physico-chemical and bacteriological analyses. The parameters were determined in line with the standard methods of water and wastewater examination as prescribed by American Public Health Association [9].

3. Results and discussion

3.1 Jar Test

It was revealed from the jar test results that the mean coagulant dosage (Alum) required to treat 500ml of abattoir effluent is 150ml.

3.2 Physico-Chemical and Bacteriological Analyses of the Wastewater

The physico-chemical and bacteriological parameters of the untreated and treated wastewater samples are as shown in Table 1.

pH

The value for the pH of the abattoir effluent was 5.150±0.044, after coagulation, the value increased to 5.840±0.157. The coagulation brings about slight increase in the pH but the values obtained fall slightly off the limit (6 - 9) promulgated by the effluent standard of [10]. There was an improvement in the value after the treatment because the coagulant is an alkaline substance.

Turbidity

The value for the Turbidity of the abattoir effluent was 200.000±1.528 FTU, after coagulation, the value decreased to 180.000±2.291 FTU. The reduction in turbidity level could be traceable to the Silica content of the coagulant.

Table 1

Physico-Chemical and Bacteriological Analyses of the Treated and Untreated Abattoir Effluent

	N	Abattoir Effluent	Alum-Coagulated	Efficiency (%)
Colour (HU)	3	1500.000±1.732*	450.000±7.000	70.000
Appearance	3		Not Clear	
Taste & Odour	3		Objectionable	
Turbidity (FTU)	3	200.000 ±1.528	180.000±2.291	10.000
pH	3	5.150 ±0.044	5.840 ±0.157	-13.398
Conductivity (μS/cm)	3	1005.000±4.583	750.000±7.550	25.373
Temperature (^{0}C)	3	26.000±0.200	25.400±0.500	2.308
TSS (mg/l)	3	1.036 ± 0.004	1.000±0.020	3.475
TDS (mg/l)	3	850.000 ± 4.093	346.00±3.606	59.294
Dissolved Oxygen (mg/l)	3	0.130 ± 0.013	0.820±0.044	-530.769
Total Alkalinity (mg/l)	3	546.000 ± 3.606	428.000 ± 1.323	21.612
Total Hardness (mg/l)	3	546.000 ± 2.646	428.000±2.180	21.612
Calcium Hardness (mg/l)	3	160.000 ± 2.646	314.000±2.646	-96.25
Calcium ions (mg/l)	3	64.000 ± 1.732	125.600±0.721	-96.25
Magnesium Hardness (mg/l)	3	386.000 ± 5.568	114.000±2.180	70.466
Magnesium ions (mg/l)	3	96.500 ± 1.803	28.500±2.291	70.466
Chloride ions (mg/l)	3	131.000 ± 1.732	85.000±3.123	35.115
Iron (mg/l)	3	84.110 ± 0.840	4.213±0.015	94.991
Silica (mg/l)	3	61.192 ± 0.731	21.132±1.253	65.466
Nitrate Nitrogen (mg/l)	3	20.146 ± 1.076	2.500±0.046	87.591
Nitrite Nitrogen (mg/l)	3	7.132 ± 0.020	0.725±0.007	89.835
Copper (mg/l)	3	18.143 ± 0.061	1.046±0.004	94.235
Manganese (mg/l)	3	1.389 ± 0.025	0.841 ± 0.002	39.453
Aluminium (mg/l)	3	2.413 ± 0.011	0.928 ± 0.003	61.542
Fluoride (mg/l)	3	1.009 ± 0.019	0.516 ± 0.004	48.860
Sulphide (mg/l)	3	2.316 ± 0.010	1.044 ± 0.005	54.922
Chromium (mg/l)	3	0.917 ± 0.006	0.418±0.003	54.417
Sulphate (mg/l)	3	10.000 ± 0.132	7.000 ± 0.173	30.000
Zinc (mg/l)	3	0.841 ± 0.005	0.400 ± 0.017	52.438
Carbonate (mg/l)	3	546.000 ± 3.606	428.000 ± 1.323	21.612
Bicarbonate (mg/l)	3	1907.200 ± 0.755	1640.000 ± 1.323	14.010
Chlorine (mg/l)	3		NIL	
COD (mg/l)	3	460.000 ± 2.291	380.000 ± 5.568	17.391
BOD (mg/l)	3	0.050 ± 0.002	0.150±0.017	-2.000
Coliform (MPN/100ml)	3	204.000 ± 1.000	179.833 ± 0.764	12.092

*Each value represents the mean value ±standard deviation of three samples

Temperature

The value for the temperature of the abattoir effluent was 26.000±0.200^{0}C, after coagulation, the value decreased to 25.400±0.500^{0}C. The values obtained satisfy the limit 35^{0}C promulgated by the effluent standard of [10].

Colour

The value for the colour of the abattoir effluent was 1500.000±1.732 HU, after coagulation, the value decreased to 450.000±7.000 HU. The value obtained after the treatment satisfies the limit (550 HU) promulgated by the effluent standard of [10].

Conductivity

The value for the Conductivity of the abattoir effluent was 1005.000±4.583 µS/cm, after coagulation, the value decreased to 750.000±7.550 µS/cm respectively. The reduction in the Conductivity level could be traceable to reduction in TDS witnessed during coagulation since Conductivity is a function of TDS in a water/wastewater sample.

Total Suspended Solids (TSS)

The value for the TSS of the abattoir effluent was 1.036±0.004 mg/l, after coagulation, the value decreased to 1.000±0.020 mg/l. The values obtained satisfy the limit (30 mg/l) promulgated by the effluent standard of [10].

Total Dissolved Solids (TDS)

The value for the TDS of the abattoir effluent was 850.000±4.093 mg/l, after coagulation, the value decreased to 346.000±3.606 mg/l.

Alkalinity

The value for the Total Alkalinity of the abattoir effluent was 546.000±3.606 mg/l, after coagulation, the value decreased to 428.000±1.323 mg/l. The higher Alkalinity level of the wastewater after the treatment could be traceable to the carbonates formed in the process.

Hardness

The value for the Total Hardness of the abattoir effluent was 546.000±2.646 mg/l, after coagulation, the value decreased to 428.000±2.818 mg/l. The increase in hardness could be traceable to the richer content of Magnesium oxide in the coagulant.

Silica

The value for the Silica of the abattoir effluent was 61.192±0.731 mg/l, after coagulation, the value decreased to 21.132±1.253 mg/l.

Fluoride

The value for the Fluoride of the abattoir effluent was 1.009±0.019 mg/l, after coagulation, the value decreased to 0.516±0.004 mg/l. The values obtained satisfy the limit (15 mg/l) promulgated by the effluent standards of [10].

Sulphide

The value for the Sulphide of the abattoir effluent was 2.316±0.010 mg/l, after coagulation, the value decreased to 1.044±0.005 mg/l. The values obtained satisfy the limit (1.0 mg/l) promulgated by the effluent standards of [10].

Sulphate

The value for the Sulphate of the abattoir effluent was 10.000±0.132 mg/l, after coagulation, the value decreased to 7.000±0.173 mg/l.

Chloride

The value for the Chloride of the abattoir effluent was 131.000±1.732 mg/l, after coagulation, the value decreased to 85.000±3.123 mg/l.

Manganese

The value for the Manganese of the abattoir effluent was 1.389±0.025 mg/l, after coagulation, the value decreased to 0.841±0.002 mg/l. The values obtained satisfy the limit (10 mg/l) promulgated by the effluent standards of [10].

Zinc

The value for the Zinc of the abattoir effluent was 0.849±0.005 mg/l, after coagulation, the value decreased to 0.400±0.017 mg/l. The values obtained satisfy the limit 5 mg/l promulgated by the effluent standard of [10].

Aluminium

The value for the Aluminium of the abattoir effluent was 2.413±0.011 mg/l, after coagulation, the value decreased to 0.928±0.003 mg/l.

Chromium

The value for the Chromium of the abattoir effluent was 0.917±0.006 mg/l, after coagulation, the value decreased to 0.418±0.003 mg/l. The values obtained satisfy the limit 2 mg/l promulgated by the effluent standard of [10].

Copper

The value for the Copper of the abattoir effluent was 18.143±0.061 mg/l, after coagulation, the value decreased to 1.046±0.001 mg/l. The value obtained after the treatment satisfies the limit 3 mg/l promulgated by the effluent standard of [10].

Iron

The value for the Iron of the abattoir effluent was 84.110±0.840 mg/l, after coagulation, the value decreased to 4.213±0.015 mg/l. The value obtained after the treatment satisfies the limit 5 mg/l promulgated by the effluent standards of [10].

Nitrate

The value for the Nitrate of the abattoir effluent was 20.146±1.076 mg/l, after coagulation, the value decreased to 2.500±0.046 mg/l. The values obtained satisfy the limit 50 mg/l promulgated by the effluent standards of [10].

Dissolved Oxygen (DO)

The value for the DO of the abattoir effluent was 0.130±0.013 mg/l, after coagulation, the value increased to 0.820±0.044 mg/l.

Bio-Chemical Oxygen Demand (BOD)

The value for the BOD of the abattoir effluent was 0.050±0.002 mg/l, after coagulation, the value increased to 0.150±0.017 mg/l. The values obtained satisfy the limit 30 mg/l promulgated by the effluent standard of [10].

Chemical Oxygen Demand (COD)

The value for the COD of the abattoir effluent was 460.000±2.291 mg/l, after coagulation, the value decreased to 380.000±5.568 mg/l. The coagulation helps in removing the COD from the wastewater, but the COD value obtained could not satisfy the limit 100 mg/l promulgated by the effluent standard of [10].

Coliform

The value for the Coliform of the abattoir effluent was 204.000±1.000 MPN/100ml, after coagulation, the value decreased to 179.833±0.764 MPN/100ml. The presence of Coliform suggests the possible presence of pathogenic micro-organisms in the wastewater sample.

3.3 Efficiency of the treatment method

The efficiency (Ƞ) of the coagulation-flocculation process (as shown in Table 1) was determined from eq. 1:

$$\eta = \frac{(C1 - C2)\ X\ 100}{C1} \tag{1}$$

where Ƞ is the efficiency of the treatment unit,

C_1 is the parameter value before treatment, and

C_2 is the parameter value after treatment.

4. Conclusion

The treatment of abattoir effluent through coagulation-flocculation process has proved to be efficient in reducing the contaminant level of Colour, TDS, Iron, Copper, Aluminium, Chromium, Zinc, Silica, Fluoride, Nitrates, Nitrites, Sulphide and Magnesium Hardness in the effluent as the efficiency values range from 40% to 100%, but the process has a very weak efficiency in removing Turbidity, Conductivity, TSS, Total Alkalinity, Total Hardness, Chloride, Manganese, Sulphate, COD and Coliform from the effluent as the efficiency values range from 0% to 39%.

However, the removal efficiency is of negative value in terms of the DO, BOD and Calcium Hardness of the effluent. In respect of those pollutants for which the coagulation-flocculation process has a very weak or negative efficiency, the efficiency can be improved by combining the coagulation-flocculation process with the filtration process.

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