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Effectiveness of using cement kiln dust as a coagulant in wastewater treatment

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Abstract: The constituents in wastewater are removed by physical, chemical and biological methods. Coagulation and floccula- tion is one of the chemical processes used in water and wastewater treatment for the removal of colloids and very fine suspended solids. In the conventional treatment process, chemicals and naturals coagulants are mostly used. Disposal of cement kiln dust produced from cement manufacturing is found to be a big problem. Many literature studies have revealed the application of cement kiln dust as a coagulant in industrial effluent treatment. The study shows cement kiln dust can alter levels of effluent characteristics like pH, BOD, COD, TDS, TSS. The objective of the project is to study the effectiveness of cement kiln dust in treating domestic wastewater through the coagulation-flocculation process.

Keywords: cement kiln dust, Scanning Electron Microscopy, Energy Dispersive X Ray Diffraction, coagulation,flocculation

1. INTRODUCTION

Coagulation is a physicochemical process used inthe removal of fine suspended particles in water and wastewater treatment systems. The removal efficiency of the effluents depends on the optimum dosage of co- agulant to be used. Common coagulants used in wa- ter and wastewater treatment are alum, ferric sulphate, ferric chloride etc. The effectiveness of the coagulant depends on suitable alkalinity conditions. Cement kiln dust, also known as waste cement dust is a by-product of the manufacture of Portland cement. The kiln dust is generated during the calcination process which takesplace in the kiln. The dust gets collected using air pol- lution control devices such as bag house filter, electro- static precipitator etc. The cement kiln dust consists of quicklime (CaO) as a major component. Hence the dustcan be used as a substitute for lime in the stabilization of wastewater. This is possible due to the high neutral- izing potential of cement kiln dust and fine particle dis- tribution. Cement kiln dust can be used in municipal wastewater treatment as a coagulant due to high $CaCO_3$content. Calcium carbonate acts as a ballasting agent in coagulation of organic particles. It can react with wastewater effluent to form large floc particles and helpsin settling easier.

LITERATURE REVIEW

Abdel Ghany and Wahab (2013) studied the effect of using cement kiln dust as a filter media for removing different metals from synthetic raw water. For the opti- mization of removal efficiency, different flow techniques were applied. The study revealed that removal effi- ciency was improved when the pH of the dust had been raised. Galagali et al. (2015) have investigated the fea- sibility of using cement kiln dust for maximum removal of COD from municipal wastewater, through bench- scale tests.Mahmoud et al. (2018) studied the efficacy of biochar and cement kiln dust as alternate low-cost ad- sorbents for removing organic and inorganic pollutants from textile wastewater. Tests were conducted to study the properties, which enhance the adsorption activity and help in the removal of pollutants. Siddique (2014) studied on "Utilization of industrial by-products" and it states that cement kiln dust has similar composition to that of ordinary Portland cement.Adaska et al. (2008) presented on "Beneficial uses of cement kiln dust". Study showed that the dusts collected from dry kilns are finer than the wet or semi dry kilns. Mostafa (2011) presented on "Effect of cement kiln dust addition on ac-tivated sludge process without primary settling for reuse applications". The study shows that it is possible to remove 80-90%of suspended solids, 70-80% of BOD_5, 80-90% of bacteria with the help of chemical precipita-tion.Abdel Ghany and Wahab (2013) have studied the optimization of cement kiln dust usage for removing different metals from synthetic raw water.

OBJECTIVES

The following are the objectives of the project.

- Determine the characteristics of cement kiln dust taken as a coagulant.
- Carry out the coagulation process with cement kiln dust as coagulant with different dosages.
- Estimate the optimum dosage of cement kiln dust at which coagulation takes place effectively.
- Analyze the range within which the maximum re- moval efficiency of the wastewater characteristics takes place.

2. METHODOLOGY

The following steps were carried out in this project

- Sampling of the cement kiln dust (Figure 1.) was done and tested for its composition and adsorption property using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy.
- The wastewater sample was collected and its efflu-ent characteristics such as pH, COD, BOD, TDS and TSS were determined using standard methods.
- Standard bench scale (jar test) (Figure 6) apparatus was used to carry out the coagulation and sedimentation of cement kiln dust in domestic wastewater treatment.
- The removal efficiencies of the effluent character- istics, corresponding to various dosages were de- termined.
- From the removal efficiencies, optimum dosage of cement kiln dust for the effectiveness of cement kiln dust as coagulant was determined.

TESTS PERFORMED

The chemical characteristics of cement kiln dust were determined using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy.

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Figure 1: Cement kiln dust

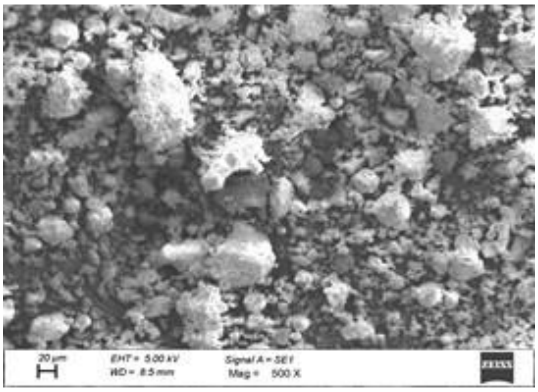


Figure 2: Scanning Electron Microscopy image of Cement Kiln Dust sample 1

Scanning Electron Microscopy

Scanning electron microscopy helps in obtaining in- formation on the surface topography and composition of the sample.

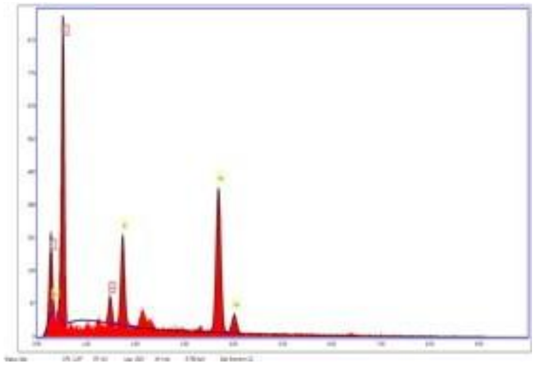
The textural and morphological structure of the ce- ment kiln dust samples were observed from the SEM photographs. Refer figure 2.

It was observed that cement kiln dust has fine parti- cle size and structure which is porous. The textural and morphological structure revealed that the cement kiln dust can have good sorption activity and can act as a good coagulant.

Energy Dispersive X-ray Spectroscopy

This analytic technique is done for the elemental analysis or chemical characterization of the sample. The analysis was done on the cement kiln dust and the ele- mental composition was thus determined as shown in Figure 3.

From the results obtained, it was found that the ce- ment kiln dust samples have Ca and O content as major components as shown in Table 1 and Table 2. Hence the cement kiln dust samples may be suitable to be used as coagulant.



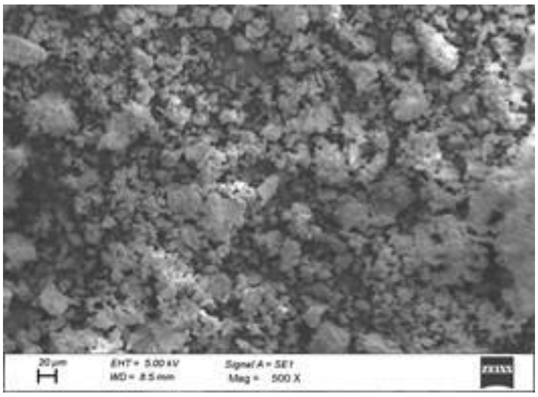


Figure 3: Scanning Electron Microscopy image of Cement Kiln Dust sample 2

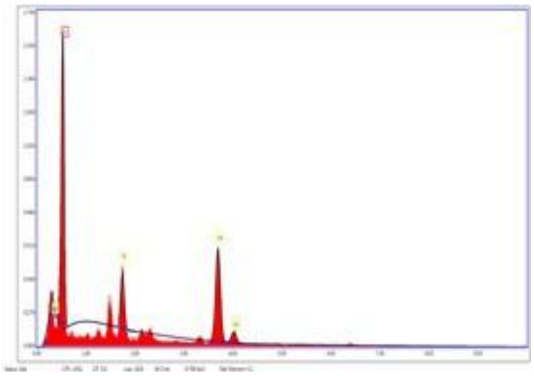


Figure 4: Energy dispersive X-ray spectroscopy image of Ce-ment Kiln Dust sample 1

Table 1: Elemental composition of CKD sample 1

Element	Weight %	Atomic %	Error %
O	65.58	81.59	9.76
Si	6.19	4.39	7.69
Ca	28.23	14.02	3.8

Table 2: Elemental composition of CKD sample 2

Element	Weight %	Atomic \%	Error %
C	11.12	17.73	12.15
O	52.93	63.35	10.48
Al	1.89	1.34	13.1
Si	6.37	4.35	6.71
Ca	27.69	13.23	3.77

Figure 5: Energy dispersive X-ray spectroscopy image of Ce- ment Kiln Dust sample 2

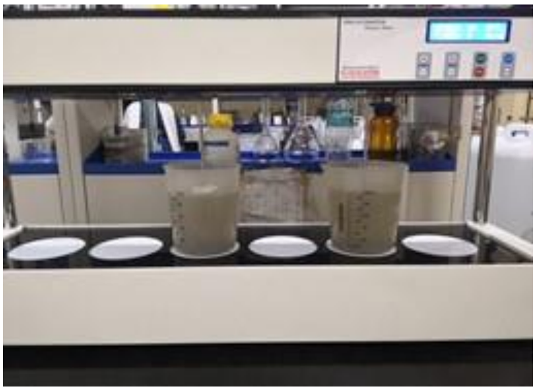


Figure 6: Bench Scale Apparatus (Jar Test)

Raw wastewater (Domestic)

Tests were conducted to determine some of the efflu- ent characteristics of the raw wastewater sample. Sam- ple of raw domestic wastewater was collected from the treatment plant of PSG College of Technology Hostel, Peelamedu, Coimbatore. The following influent charac-teristics of wastewater were considered for this study.

- pH
- Biological Oxygen Demand
- Chemical Oxygen demand
- Total Suspended Solids
- Total Dissolved Solids

3. RESULTS AND DISCUSSIONS

Influent characteristics

Before carrying out the coagulation process, the in- fluent characteristics of wastewater were tested by usingstandard methods. Results shown in Table 3.

Table 3: Influent characteristics of wastewater

Influent characteristics	Value
pH	6.89
Biological Oxygen Demand	620 mg/l
Chemical Oxygen Demand	759 mg/l
Total Suspended Solids	250 mg/l
Total Dissolved Solids	1333 l

Table 4: Effluent characteristics of wastewater corresponding to dosage of CKD (trial 1)

Dosage of cement kiln dust (g/l)	Effluent characteristics				
	pH	**BOD (mg/l)**	**COD (mg/l)**	**TSS (mg/l)**	**TDS (mg/l)**
0	6.98	620	759	250	1333
1	7.05	524	625	247	**1067**
1.5	7.09	340	435	233	1150
2	7.10	250	375	240	1227
2.5	7.10	300	539	235	1129
3	7.23	**233**	**340**	**217**	1117
3.5	**7.30**	300	547	234	1133

Trial 1

The cement kiln dust was added at the rate of 0.5g/l, starting from 1 g/l till 3.5 g/l. The effluent character- istics were tested after the addition of each dose and carrying out of coagulation-flocculation process. Results are shown in Table 4.

The removal efficiencies of the effluent characteristics for trial 1 were as illustrated. As shown in Table 5.

From the tests conducted

Table 6: Effluent characteristics of wastewater corresponding to dosage of CKD (trial 2)

Dosage of cement kiln dust (g/l)	Effluent characteristics				
	pH	**BOD (mg/l)**	**COD (mg/l)**	**TSS (mg/l)**	**TDS (mg/l)**
0	6.70	306	622	288	1688
1	7.01	250	543	250	1354
1.5	7.12	233	435	233	1227
2	7.20	158	321	217	1129
2.5	7.28	**117**	**220**	**207**	**1067**
3	7.33	133	340	235	1133
3.5	**7.40**	156	375	247	1260

Table 7: Removal efficiencies of effluent characteristics cor-responding to dosage of CKD (trial 2)

Dosage(g/l)	**Removal efficiency (%)**			
	BOD	**COD**	**TSS**	**TDS**
1	18.30	12.70	13.19	19.79
1.5	23.86	30.06	19.10	**27.31**
2	48.37	48.39	24.65	33.12
2.5	**61.76**	**64.63**	**28.13**	**36.79**
3	56.54	45.34	18.40	32.88
3.5	49.02	39.91	14.24	25.35

- The cement kiln dust was able to remove 62.42%of BOD and 55.20% of COD at a dosage of 3.0 g/l
- The suspended solids had its maximum removal ef-ficiency at a dosage of 3.0 g/l
  Trial 2
- The value of pH increased slightly on the addition of cement kiln dust, and also maintains within therange.

Table 5: Removal efficiencies of effluent characteristics cor-responding to dosage of CKD (trial 1)

Dosage (g/l)	**Removal efficiency (%)**			
	BOD	**COD**	**TSS**	**TDS**
1	15.48	17.65	1.20	13.73
1.5	45.16	42.69	6.80	**19.95**
2	59.67	50.55	4.00	7.95
2.5	51.61	29.04	6.00	15.30
3	**62.42**	**55.20**	**13.20**	16.20
3.5	51.61	27.93	6.40	15.00

The effluent characteristics with respect to same dosage as trial 1 was as shown in the Table 6. The removal efficiencies of the effluent characteristics for trial 2 were shown in Table 7.

- The value of pH increased slightly on the addition of cement kiln dust, and also maintains within therange.
- The cement kiln dust was able to remove 61.76% of BOD and 64.63% of COD at a dosage of 2.5 g/l
- The suspended solids had its maximum removal ef- ficiency at a dosage of 2.5 g/l

Trial 3

In trial 3, the cement kiln dust was added at the rate of 0.2g/l, starting from 2.4 g/l till 3.2 g/.The effluent char-acteristics were tested after the addition of each dose

Table 8: Effluent characteristics of wastewater corresponding to dosage of CKD (trial 3)

Dosage of ement kiln dust (g/l)	**Effluent characteristics**				
	pH	**BOD (mg/l)**	**COD (mg/l)**	**TSS (mg/l)**	**TDS (mg/l)**
0	6.90	592	652	380	1550
2.4	7.09	267	380	336	1332
2.6	7.10	267	372	326	1325
2.8	**7.10**	**247**	**350**	**317**	**1282**
3.0	7.11	250	368	329	1297
3.2	7.11	270	390	340	1329

Table 9: Removal efficiencies of effluent characteristics cor-responding to dosage of CKD (trial 3)

Dosage(g/l)	**Removal efficiency (%)**			
	BOD	**COD**	**TSS**	**TDS**
2.4	54.90	41.72	11.58	14.06
2.6	54.90	42.94	14.21	14.52
2.8	**58.28**	**46.32**	**16.58**	**17.29**
3.0	57.78	43.56	13.42	16.32
3.2	54.39	40.18	10.53	14.26

and carrying out of the coagulation-flocculation pro-cess. The results were shown in Table 8.

The removal efficiencies of the effluent characteristics for trial 3 were as shown in Table 9. From the tests conducted

- The value of pH increased slightly on the addition of cement kiln dust, and also maintains within therange.
- The cement kiln dust was able to remove 58.28% of BOD and 46.32% of COD at the dosage of 2.8

Figure 7: Water after coagulation-flocculation process

Figure 8: Dried flocs after coagulation-flocculation process

Table 10: Standards for sewage discharge (as per Central Pol-lution Control Board)

Effluent characteristic	**Discharge of effluents on land for irrigation as per CPCB standards**	**Values corresponding to optimum dosage**		
		Trial 1 at 2.5g/l	**Trial 2 at 3g/l**	**Trial 3 at 2.8g/l**
pH	5.5-9	7.30	7.40	7.10
TSS(mg/l)	200-450	217	235	317
BOD(mg/l)	100-350	233	133	247
COD(mg/l)	250-450	340	340	350

g/l

- The suspended solids had its maximum removal ef- ficiency at the dosage of 2.8 g/l. Refer Figure 7.
- Floc formed are dried and as shown in Figure 8.
- With reference to the CPCB standards for dis- charge of effluents, it was identified that the sewage treated by cement kiln dust coagulation can be dis-charged into the land for irrigation.

4. CONCLUSION

- For the wastewater taken into study, the maximum removal efficiency of the effluent characteristics takes place when the dosage of cement kiln dust was at the range of 2.5 to 3 g/l.
- The effluents in water can be removed to about 30 to 70% when using cement kiln dust as a coagulant.
- The water treated from the coagulation- flocculation process can be used for irrigation as it meets the standards.
- For a complete treatment of the wastewater, addi- tional processes are required after the coagulation-flocculation.

- The cement kiln dust can be reused for an applica- tion like wastewater treatment, as it can pave way for low cost wastewater treatment technology.

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