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# Low-Cost Wastewater Treatment Technology

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**Abstract:** The present study aimed to investigate the using of cement kiln dust and/or rice straw for wastewater treatment. The experimental results showed that, by increasing the dose of cement kiln dust wastewater treatment process affected greatly. The reduction of TSS, COD and BOD was 94.7, 90.6 and 92.4%, respectively with using 2.75 g $L^{-1}$cement kiln dust dose. Also, *listeria*, *E. coli*, *Faecl coliform* and *Faecal streptococci* were not detected when using this dose. On the other hand, using 2 g $L^{-1}$ cement kiln dust dose *E. coli* and *faecl coliform* (FC) densities were 43 and $3.1\times10^2$ MPN/100 mL, respectively and *salmonellae* were not detected. This effluent was complied with WHO guidelines for wastewater reuse. The effluent water quality was improved when using rice straw as a filter (as a secondary treatment step). When using rice straw as the first step followed by treatment with 2 g cement dust, the reduction was 50, 32 and 35.3% for TSS, COD and BOD, respectively and 2 log units for TC, FC, *E. coli*, salmonellae and listeria. But when using rice straw as the second step after the treatment with 2 g $L^{-1}$ cement dust kiln the reduction was 50% for COD, BOD and TSS. Listeria, FC and *E. coli* were not detected in this effluent. Thus, the combination of cement kiln dust and rice straw as a filter is considered as an efficient and low-cost technology for wastewater treatment and reuse.

**Key words:** Low-cost, cement kiln dust, listeria, *E. coli*, *Faecl coliform*, *Faecal streptococci*, COD, BOD, TSS

## INTRODUCTION

Waste materials can broadly be categorized as industrial wastes such as cement kiln dust, wood lignins, bottom ash, fly ash, municipal domestic waste such as incinerator residue, scrap rubber, waste glass and roofing shingles. Waste cement dust or cement kiln dust is the by-product of the manufacture of Portland cement.

It is generated during the calcining process in the kiln. Lime (CaO) constitutes more than 60% of cement by-product dust composition (CBPD). Other compounds include $SiO_2$, $Al_2O_3$, $Fe_2O_3$, $K_2O$, $Na_2O$, $Cl_2$ etc. most of cement company generates high quantities of CBPD every year (Ahmed *et al*., 2006).

Waste material recycling into useful products has become a main solution to waste disposal problems. Major environmental problems arise from the disposal of kiln dust. This dust production is not only unpleasant for the workers but also creates equipment fractures, decrease efficiency and produce maintenance problems (Collins and Ciesielski, 1993).

The cement dust can be used in wastewater treatment. The first stage in the renovation of wastewater involves the removal of suspended solids and colloids by chemical coagulation flocculation and clarification. A substantial reduction in total phosphorus, organic nitrogen, microorganisms and heavy metals are also achieved.

The choice of chemical coagulation is a prime consideration, particularly in relation to be treated (Van-Vuuren *et al*., 1980; Amer, 1997; Ronen, 1978).

Wieehers *et al*. (1980), Grabow *et al*. (1978) and Kelppinger (1993) reported that lime treatment is often used as first process stage in the unit process trains designed for upgrading the quality of wastewater or reclamating wastewater for potable use. The reason for lime treatment's popularity is its ability to remove phosphates, organic matter, magnesium and carbonate hardness and heavy metals from wastewater. The World Health Organization guidelines (WHO, 2005) for microbiological quality of treated wastewater used for this purpose are as follows; (a) Restricted irrigation: $\leq10^5$ *E. coli*/100 mL and ≤1 human intestinal nematode egg $L^{-1}$ (reduced to ≤0.1 egg $L^{-1}$ if children under 15 are exposed), (b) unrestricted irrigation: $\leq10^3$ *E. coli*/100 mL and same egg numbers. The current study is performed to study the effect of using waste cement kiln dust or using straw rice as filter followed by cement kiln dust on wastewater treatment.

## MATERIALS AND METHODS

Three experiments were carried out for the treatment of raw sewage form the 6th of October WWTP.

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The first experiments, various doses of cement kiln dust (1, 1.5, 1.75, 2, 2.5 and 2.75) were used as a standard bench-scale (Jar test). Flash mixing is started at 180 rpm for 3-4 min during which by-pass cement kiln dust has been added with the pre-mentioned concentrations. Flocculation was carried out for 20 min at 40 rpm. Then it left for sedimentation for 1 h (Fig. 1).

The second experimental run was carried out using the effluent of the dose of 2 g $L^{-1}$ cement kiln dust followed through three stages of rice straw (as a filter). Each stage of rice straw was pressed in a plastic funnel with diameter and depth of 10 cm (Fig. 2).

The third experimental run the effluent from the three stages of rice straw filter (as a first step treatment) followed by treatment using 2 g $L^{-1}$ cement kiln dust. Coagulation sedimentation was carried out as in the first experimental run (Fig. 3).

All samples (influent and effluents from each treatment step) were collected and analysed for physico-chemical parameters (pH, TSS, COD and BOD) and bacteriological parameters (TBC, TC, FC. *E. coli.*, FS, salmonellae and listeria). The analyses were carried out according to APHA 1998. Salmonellae and listeria detection were carried out according to El-Taweel *et al.* (2000).

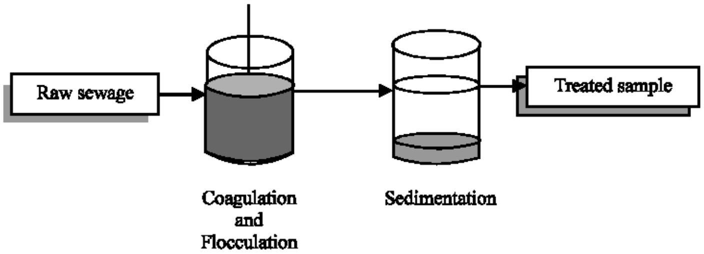

Fig. 1: Flow chart of the first experimental run

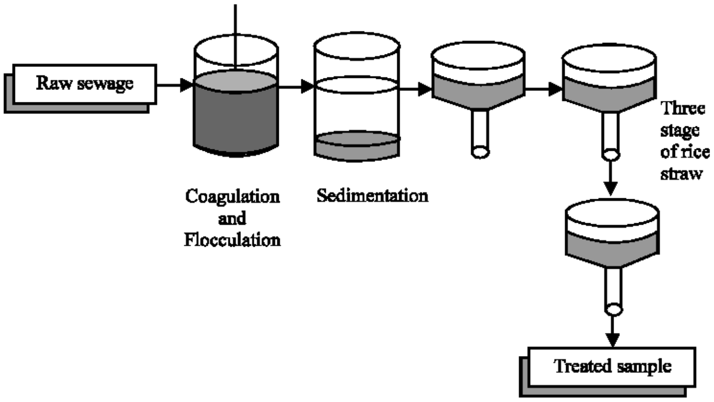

Fig. 2: Flow chart of the second experimental run

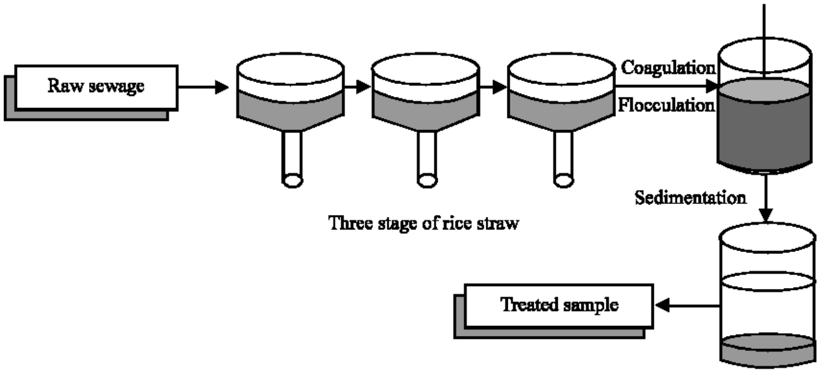

Fig. 3: Flow chart of the third experimental run

## RESULTS

Table 1 summarizes the characteristics of wastewater and the treated effluent from each treatment step. The results showed that, the reduction of TSS, COD and BOD were 94.7, 90.6 and 92.4%, respectively with 2.75 g L$^{-1}$ cement kiln dust dose. On the other hand, the lowest reduction was recorded when using 1 g L$^{-1}$ cement kiln dust dose for TSS (50%), COD (46.6%) and BOD (51.9%).

pH value for wastewater treatment increased with increasing the dose of cement kiln dust which added to wastewater (Table 1). The residual value of COD, BOD and TSS after using 2 g L$^{-1}$ cement kiln dust was 98 mgO$_2$ L$^{-1}$, 56 mgO$_2$ L$^{-1}$ and 86 mg L$^{-}$,$^{1}$ respectively. While the recorded pH value was 9.9.

The results in Table 2 showed that, the reductions in TSS, COD and BOD after filtration through rice straw were 50, 32.4 and 35.3%, respectively. Also the reductions were 63.6% (TSS), 85.8% (COD) and 86.2% (BOD) using 2 g L$^{-1}$ cement kiln dust dose for treatment the effluent of filtration through rice straw. pH value was 9.9 for the final effluent (Table 2).

The reductions using 2 g L$^{-1}$ cement kiln dust dose were 79.5, 85.6 and 86.6% for TSS, COD and BOD. After filtration through rice straw, the reductions were 52.3, 53.1 and 50% for TSS, COD and BOD, respectively. The pH value was 9.6 for the final effluent (Table 3).

From Table 1 the results showed that salmonella were not detected in wastewater treated by cement kiln dust dose 2 g L$^{-1}$.

This dose of cement kiln dust dose, the pH value was 9.9 which affect the removal of classical bacterial indicator and pathogenic bacteria such as total bacterial counts (TBC) (7 log units), TC (6 log units), *E. coli* (6 log units), FS (6 log units) and *listeria* (4 log units).

Generally, the effect of additional cement kiln dust for wastewater treatment on the removal rate of bacterial load which, increased by increasing the dose. The lowest

Table 1: Characteristics of wastewater and effluents using different dose of cement kiln dust

| Unit | pH | TSS (mg L$^{-1}$) | COD (mgO$_2$ L$^{-1}$) | BOD (mgO$_2$ L$^{-1}$) | TBC (37°C) (cfu/ 100 mL) | TBS (22°C) (cfu/ 100 mL) | TC (MPN/ 100 mL) | FC (MPN/ 100 mL) | *E. coli* (MPN/ 100 mL) | FS (MPN/ 100 mL) | Saknibekkae (cfu/ 100 mL) | Listeria (cfu/ 100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Raw sewage | 6.8 | 420 | 682 | 420 | 2.5E+11 | 1.3E+10 | 2.8E+10 | 1.8E+09 | 3.1E+07 | 2.1E+08 | 1.2E+07 | 1.3E+06 |
| 1 g L$^{-1}$ | 8.5 | 210 | 364 | 202 | 3.6E+06 | 2.7E+05 | 4.6E+06 | 2.6E+04 | 1.4E+03 | 1.6E+04 | 2.3E+03 | 4.8E+04 |
| %R | | 50.0 | 46.6 | 51.9 | 99.999 | 99.998 | 99.984 | 99.999 | 99.995 | 99.992 | 99.981 | 96.308 |
| 1.5 g L$^{-1}$ | 9.3 | 154 | 142 | 110 | 1.2E+05 | 2.4E+04 | 1.8E+06 | 3.8E+03 | 4.6E+02 | 1.6E+04 | 1.8E+02 | 1.3E+03 |
| %R | | 63.3 | 79.2 | 73.8 | 99.99995 | 99.9998 | 99.9936 | 99.9998 | 99.9985 | 99.9924 | 99.999 | 99.9 |
| 1.75 g L$^{-1}$ | 9.7 | 120 | 118 | 64 | 1.1E+05 | 1.7E+04 | 1.2E+05 | 2.3E+03 | 2.1E+02 | 4.3E+03 | 9.5E+01 | 1.1E+03 |
| %R | | 71.4 | 82.7 | 84.8 | 99.99996 | 99.9999 | 99.9996 | 99.9999 | 99.999 | 99.998 | 99.999 | 99.9 |
| 2 g L$^{-1}$ | 9.9 | 86 | 98 | 56 | 4.4E+04 | 2.1E+03 | 1.1E+04 | 3.1E+02 | 4.6E+01 | 6.4E+02 | ND | 2.1E+02 |
| %R | | 79.5 | 85.6 | 86.7 | 99.99998 | 99.99998 | 99.999961 | 99.99998 | 99.9999 | 99.9997 | 100.0 | 99.98 |
| 2.5 g L$^{-1}$ | 10.2 | 44 | 82 | 40 | 4.1E+03 | 1.8E+03 | 4.6E+03 | 6.4E+01 | ND | 6.4E+01 | ND | 8.5E+01 |
| %R | | 89.5 | 88.0 | 90.5 | 99.999998 | 99.99999 | 99.999984 | 99.999996 | 100 | 99.99997 | 100 | 99.99 |
| 2.75 g L$^{-1}$ | 10.5 | 22 | 64 | 32 | 1.2E+02 | 1.1E+02 | 1.2E+02 | ND | ND | ND | ND | ND |
| %R | | 94.8 | 90.6 | 92.4 | 99.99999995 | 99.999999 | 99.9999996 | 100 | 100 | 100 | 100 | 100 |

Table 2: Characteristics of wastewater and treated effluent using rice straw followed by cement kiln dust

| Unit | pH | TSS (mg L$^{-1}$) | COD (mgO$_2$ L$^{-1}$) | BOD (mgO$_2$ L$^{-1}$) | TBC (37°C) (cfu/ 100 mL) | TBS (22°C) (cfu/ 100 mL) | TC (MPN/ 100 mL) | FC (MPN/ 100 mL) | *E. coli* (MPN/ 100 mL) | FS (MPN/ 100 mL) | Saknibekkae (cfu/ 100 mL) | Listeria (cfu/ 100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Raw sewage | 6.7 | 440 | 710 | 380 | 2.8E+10 | 1.8E+10 | 2.1E+10 | 2.5E+08 | 6.4E+06 | 4.6E+07 | 2.8E+05 | 1.8E+06 |
| Effluent of straw rice | 6.5 | 220 | 480 | 246 | 6.5E+08 | 4.1E+07 | 9.3E+08 | 1.8E+06 | 4.2E+04 | 3.1E+06 | 4.8E+03 | 2.9E+04 |
| %R | | 50.0 | 32.4 | 35.3 | 97.7 | 99.8 | 95.6 | 99.3 | 99.3 | 93.3 | 98.3 | 98.4 |
| After 2 g L$^{-1}$ | 9.9 | 80 | 68 | 34 | 1.2E+02 | 9.8E+01 | 1.2E+02 | ND | ND | ND | ND | ND |
| %R | | 63.6 | 85.8 | 86.2 | 99.99998 | 99.99976 | 99.99999 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Table 3: Characteristics of wastewater treated with cement kiln dust followed by rice straw

| Unit | pH | TSS (mg L$^{-1}$) | COD (mgO$_2$ L$^{-1}$) | BOD (mgO$_2$ L$^{-1}$) | TBC (37°C) (cfu/ 100 mL) | TBS (22°C) (cfu/ 100 mL) | TC (MPN/ 100 mL) | FC (MPN/ 100 mL) | *E. coli* (MPN/ 100 mL) | FS (MPN/ 100 mL) | Saknibekkae (cfu/ 100 mL) | Listeria (cfu/ 100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Raw sewage | 6.8 | 420 | 682 | 420 | 2.1E+11 | 1.3E+10 | 2.8E+10 | 1.8E+09 | 3.1E+07 | 2.1E+08 | 1.2E+07 | 1.3E+06 |
| 2 g L$^{-1}$ cement kiln dust | 9.9 | 86 | 98 | 56 | 4.4E+04 | 2.1E+03 | 1.1E+04 | 3.1E+02 | 4.6E+01 | 6.4E+02 | ND | 2.1E+02 |
| %R | | 79.5 | 85.6 | 86.7 | 99.999979 | 99.99998 | 99.9999607 | 99.99998 | 99.9999 | 99.9997 | 100 | 99.98 |
| Effluent of straw rice | 9.6 | 41 | 46 | 28 | 4.8E+02 | 1.1E+02 | 6.4E+02 | ND | ND | 9.8E+01 | ND | ND |
| %R | | 52.3 | 53.1 | 50.0 | 98.9 | 94.8 | 94.2 | 100 | 100 | 84.7 | 100 | 100 |

reductions of bacterial load were 4 log units for *salmonellae*, FS, *E. coli* and TC, 2 log units for *listeria* and 5 log units for FC and TBC using 1 g $L^{-1}$ cement kiln dust dose.

On the other hand, the higher reductions of bacterial load were 9 log units for TBC at 37°C, 8 log units for TBC at 22°C and TC and complete reduction for *salmonellae*, *listeria*, FS, FC and *E. coli* using 2.75 g $L^{-1}$ cement kiln dust dose.

The results in Table 2 showed that, the reductions of bacterial load after filtration through rice straw were 2 log units for TC, FC, *E. coli*, *salmonellae*, *listeria* and TBC at 37°C 3 log units for TBC at 22°C and only one log unit for FS.

But the reductions using the dose 2 g $L^{-1}$ cement kiln dust were 6 log for TC and TBC. Complete reduction was achieved for FC, *E. coli*, salmonellae and listeria.

It can be noted from Table 3 that *listeria*, FC and *E. coli* were not detected in the final effluent after filtration with rice straw for the effluent resulting with treatment using 2 g $L^{-1}$ cement kiln dust. The reductions of other bacterial load in the final effluent were one log unit for TBC and FS at 22°C, 2 log units for both TBC at 37°C and TC.

## DISCUSSION

The chemical treatment consists of separation of settleable, floatable and dissolved substances using chemicals. Chemical treatment depends on the nature and concentration of colloidal matters, type of chemical coagulant, dose and pH value (Gambrel *et al*., 1989).

Lime treatment reduces the number of microorganisms by fluctuation in sedimentation or flotation processes and at the same time, the hydroxide alkalinity has an antibacterial effect (Hansen, 1992; Wiechers *et al*., 1980; Gambrel *et al*., 1989; Mignotte-Cadiergues *et al*., 2001).

Generally, the increasing of pH value was proportional to the amount of cement kiln dust added to wastewater. Ahmed *et al*. (2006) reported that, lime (CaO) constitutes more than 60% of cement by-product dust composition and other compounds 40% include $SiO_2$, $Al_2O_3$, $F_2O_3$, $K_2O$, $Na_2O$ and $Cl^-$.

pH value is an important parameter in wastewater treatment. High pH is known to excite molecular oxygen to the ionic form which is toxic (Awuah *et al*., 2002). The cement kiln dust is considered as a coagulant where lime reacts with bicarbonate alkalinity to prehydroxy aptite. Magnesium hydroxide precipitates at high pH value level. Good clarification usually requires the presence of some gelatinous $Mg(OH)_2$ but this does make the sludge more difficult to dewater. The addition of cement kiln dust will enhance coagulation by promoting the growth of large, rapid-settling floc. Thus high pH value which promote the sedimentation (EcKenfelder, 1989).

The reduction of pathogenic bacteria and classical bacterial indicator may be attributed to sedimentation, elevated pH and toxic chemical. Aquatic organisms which play a role in treatment processes are sensitive to pH changes (Awuah *et al*., 2002; Hansen, 1992; Jepsen *et al*., 1997). Mignotte-Cadiergues *et al*. (1992) reported that high and fluctuating levels of pH and dissolved oxygen are detrimental to pathogens in wastewater. Additionally, elevated pH has been found to contribute significantly to FC removal (Amer, 1997).

Generally, using the dose 2 g $L^{-1}$ of cement kiln dust was active in the reduction of Salmonellae. The effluent of this dose contains *E. coli* densities 46/100 mL and FC density $3.1\times10^2$ 100 $mL^{-1}$ which complied with WHO 2005.

The pH value with this dose was 9.9. Thus using rice straw in the filtration of this effluent removed *E. coli*, FC and listeria. This type of treatment enhances the quality of wastewater for reuse. Consequently, rice straw could be used as adsorbent agent for removing the pollutants from wastewater as concluded by Nicolaisen (2002).

## CONCLUSIONS

Generally, the conventional wastewater treatment is inexpensive, simple and rapid technology and the effluent could be used for irrigation. Relatively simple wastewater treatment technologies can be designed to provide low-cost sanitation and environmental protection while, providing additional benefits from the reuse of water.

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