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Agro-substances and non-agro-substances as efficient and cost-effective materials for wastewater treatment

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ABSTRACT

Natural waste materials have potential as inexpensive sorbents for organic loads removal from wastewater. Some agriculture by-products and industrial wastes were used as good sorbent agents. Recycling of these waste materials as useful products has become a main solution to waste disposal problems. Thus, this work was devoted to study the utilization of the agricultural by-products (rice straw) and industrial wastes (kiln dust and chrome shavings) as sorbent agents for organic loads removal from wastewater. Cement kiln dust was used as a primary treatment step followed by rice straw or chrome shavings column as a secondary treatment step. The results indicated that chemical oxygen demand (COD), biological oxygen demand (BOD) and total suspended solids (TSS) were decreased from 471.3, 317.5, and 180.6 to 160.5, 85.1, and 48.5 mg/l with percentage removal of 66, 73.2, and 73%, respectively, with 1.5 g/l cement kiln dust. On the other hand, faecal coliform (FC) counts were reduced from 6.1×10^7 to 1.1×10^6 MPN/100 ml with only one log unit removal. The primary treated effluent still contains considerable organic and bacterial loads. The levels of COD, BOD, and TSS were reduced by 62.1, 69, and 85% for rice straw and 64.5, 71.4, and 85% of cement kiln dust, respectively. The corresponding concentrations were 60.8, 26, and 7.2 mg/l for rice straw and 57, 24.3, and 7.2 mg/l for cement kiln dust, respectively. FC counts were reduced by two log units. The results indicated that cement kiln dust, rice straw, and chrome shavings may be used as low-cost materials for wastewater treatment. Disinfection step should be used for reducing the bacterial load in the treated wastewater to be used safely.

Keywords: Wastewater; Low cost; Cement kiln dust; Chrome shavings; Rice straw; Fecal coliform; COD; BOD; TSS

1. Introduction

The problems of water shortage have led to the need for developing strategies, technologies, and management of water usage. Most of conventional technologies used for wastewater treatment, including chemical precipitation, ion exchange, membrane separation, and adsorption by activated carbon, are suffering from some drawbacks such as high capital or high operational cost or disposal of resulting sludge. Due

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to both environmental and economical points of view, special attention has been focused on the use of natural adsorbents as an alternative for replacing the conventional adsorbents [1,2]. Certain waste products from industrial or agricultural operations and natural or biological materials that are available in large quantities may have potential as inexpensive sorbents for removal of heavy metal and organic loads from industrial wastewater. Peanut shells, rice husk, wheat straw, apple residues, sawdust, fungal biomass, and seaweed have the advantage of being inexpensive, readily available and can be used as sorbent materials. Applications of these waste materials could result in decreasing treatment cost and waste minimization [3]. Due to their low cost and reuse option, they can be disposed of without expensive regeneration. The abundance and availability of agricultural by-products make them good sources of raw materials as a natural sorbents [4].

Adsorption technology using low-cost materials showed a promising trend for the treatment of wastewater [5,6]. Recycling of waste material as useful products has become a main solution for waste disposal problems. Waste cement dust or cement kiln dust is the by-product of the manufacture of Portland cement. Kiln dust causes a serious environmental problem. This dust production is not only unpleasant for the workers but also creates equipment fractures, decreases efficiency, and produces maintenance problems [7]. 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 [8]. This work was devoted to study the agriculture by-products (rice straw) and industrial wastes (kiln dust and leather shavings) as good sorbent agents.

Leather producers have been dominated to reduce the environmental impact resulted from their production and techniques. The solid chromium wastes are the main concern from an environmental standpoint of view, because chrome wastes possess a serious environmental and significant technological problems [9,10]. According to the current legislation on the environment, the conventional treatments still do not meet the required limits to remove the chromium pollutants [11,12]. Chrome shavings are the major stumbling block for many of the tanneries around the world due to the stringent environmental regulations [13,14]. For this reason, the feasibility of sewage treatment by the utilization of the solid chromium waste as useful product is the main goal of this work.

2. Materials and methods

2.1. Coagulation sedimentation process

The primary treatment step was the coagulation sedimentation process using different doses of cement kiln dust. The used doses of cement kiln dust were 1.0, 1.5, and 2.0 g/l. Flash mixing for 30 s followed by flocculation for 20 min at 40 rpm was carried out. The mixture was left for sedimentation for 1 h.

The secondary treatment step was carried out using either rice straw or chrome shavings (as a filter). Rice straw was activated using the procedures of Bhattacharya et al. [15]. Fig. 1 shows the dimensions of the column packed with grinded rice straw or chrome shaving (filter). Rice straw was ground and sieved to a particle size range of 2–4 mm. It was then dried in an oven at 105˚C for 24 h. The grinded rice straw was washed five times using hot distilled water (60–80˚C) and then dried at 50˚C for 24 h [16]. Chrome shavings were grinded and sieved to adjust the particle size to 2–4 mm. The grinded chrome shavings were washed five times as indicated in rice straw. Fig. 2 summarizes the treatment steps.

As shown from Fig. 3, the effluent from the cement kiln treatment step was treated using rice straw or the chrome shavings filter as a second treatment step.

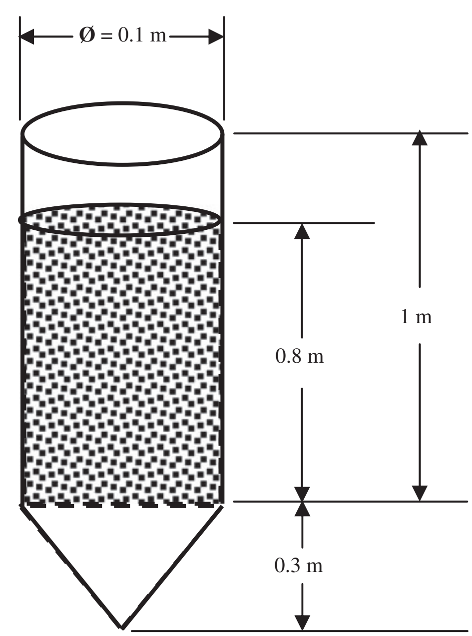

Fig. 1. Dimensions of the filter.

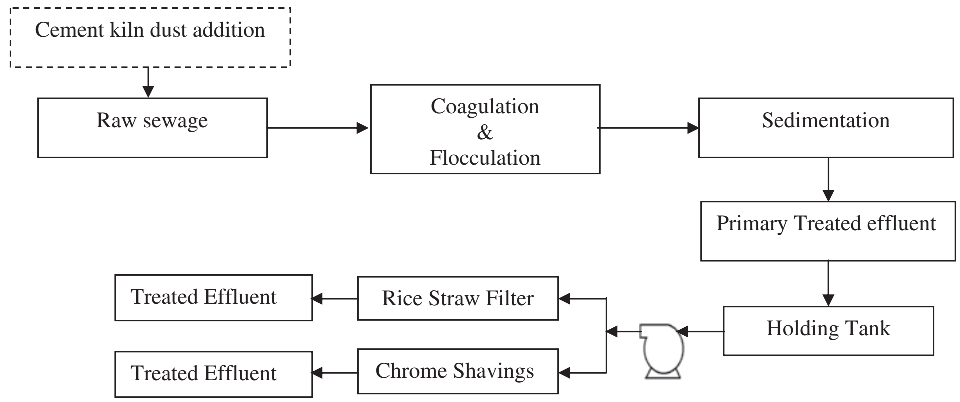

Fig. 2. Flow chart of the treatment steps.

2.2. Operating conditions

Table 1 shows the operating conditions of the proposed treatment procedures.

All samples (influent and effluents from each treatment step) were collected and analyzed for chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia, and fecal coliform (FC). The analyses, unless otherwise specified, were carried out according to the American Public Health Association for Examination of Water and Wastewater, (APHA) [17]. Phosphate was measured using Sequoia-Turne Model 340, spectrophotometer. While TKN was done using Velb instrument, COD was measured using HACH spectrophotometer model DR 3000. FC determination was carried out using modified MacConkey broth with the MPN method [18].

3. Results

3.1. Wastewater characteristics

Figs. 3 and 4 summarize the main characteristics of raw sewage. The results showed that the concentration of organic load represented by COD, BOD, and TSS ranged from 436 to 523 mg/l, 290 to 350 mg/l, and 155 to 220 mg/l, respectively. The BOD/COD ratio was found to be 0.67. The averages of TKN, ammonia, and TP concentrations were found to be 55.9, 48, and 5.7, respectively. The calculated concentration of organic nitrogen was about 8 mg/l. It is obvious that the wastewater subjected to the treatment is classified as a medium strength wastewater [19].

The FC density of the raw wastewater used in the study is shown in Fig. 6. FC density was varied from 1×10^7 to 1.5×10^8 with an average of 6.1×10^7 MPN/100 ml.

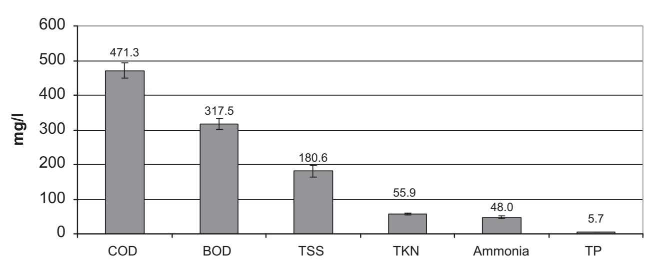

Fig. 3. Characteristics of raw wastewater (average of 30 samples).

Table 1
Operating conditions for column experiment

Parameters	Unit	Value
Surface area (SA)	m^2	0.27
Volume (l)	m^3	0.1256
Hydraulic surface loading rate (HSLR)	$l/m^2/h$	19.4
Organic surface loading rate (OSLR)	$g\,BOD/m^2/h$	1.555
	$g\,COD/m^2/h$	3.113
Flow rate	m^3/day	0.47

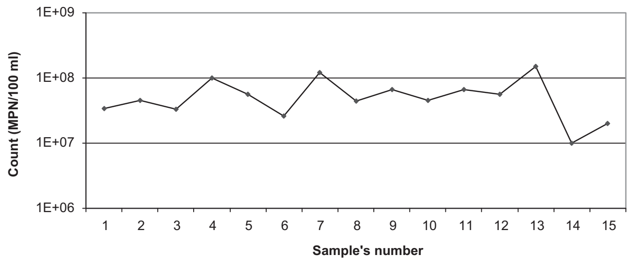

Fig. 4. Variation in FC counts of raw sewage (average of 15 samples).

3.2. *Selection of optimum dose of cement kiln dust*

Fig. 5 summarizes the treatment efficiency of the wastewater using different doses of cement kiln dust. The results showed that the reduction in COD was 59, 65, and 67% for 1.0, 1.5, and 2.0 g/l, respectively. On the other hand, the corresponding removal values of TSS were 65, 71, and 71%.

The doses of 1.5 and 2 g/l of cement kiln dust show relatively similar effluent quality. Consequently, from economic point of view, 1.5 g/l cement kiln dust dose was chosen as the optimum dose.

3.3. *Efficiency of combined cement kiln dust and rice straw or chrome shavings filter*

3.3.1. *Efficiency of Coagulation sedimentation process*

Coagulation sedimentation process using 1.5 mg/l cement kiln dust was chosen as the first treatment step to reduce the concentration of TSS for preventing clogging of filtration column. The obtained result was in a good agreement with that obtained by Mahmoued [7]. Fig. 6 illustrates the characteristics of wastewater and cement kiln dust treatment effluent.

The results showed that the reduction in TSS, COD, and BOD was 73, 66, and 73.2%, respectively with 1.5 g/l cement kiln dust dose. Fig. (7) shows that the addition of cement kiln dust increased the pH from 7.3 to 8.1.

The counts of FC were reduced from 6.1×10^7 to 1.1×10^6 MPN/100 ml. The corresponding average removal rate was found to be 98.2%. Lime treatment reduces the number of microorganisms by fluctuation/sedimentation [20–23]. The reduction in FC bacteria may be attributed to sedimentation, elevated pH, and toxic chemical [19,24,25]. The use of a microbial indicator such as FC bacteria till now extends beyond indicating potential health risks due to fecal contamination. In addition, FC is used as indicators for treatment efficiency and to determine the fate of pollutant in the environment [23]. In most cases, only one log unit reduction in FC count was obtained. Consequently, secondary treatment step is of vital importance.

3.4. *Comparison between the efficiency of rice straw and chrome shavings effluent*

In an attempt to enhance the quality of the effluent, the use of rice straw or chrome shavings as filtration medium was carried out (Fig. 8).

The obtained results indicate that the chrome shaving is slightly efficient for removal of COD, BOD, TKN, and ammonia. While, TSS and TP removal was found to be similar in both systems. COD reduction in the rice straw and chrome shavings filters ranged from 53.3 to 69.6% and 58 to 69.4% with an average value of 62.1 and 64.5%, respectively. Mean residual COD and BOD in the rice effluent were 60.8 and 26 mgO_2/l, respectively. Corresponding values for the chrome shavings effluent were 57 and 24.3 mgO_2/l (Fig. 9). TSS value followed more or less the same trend (Fig. 8). During the filtration process, the removal of the suspended solids, COD, and BOD is accomplished by a complex process including one or more mechanisms such as straining, sedimentation, interception, impaction, and adsorption. The

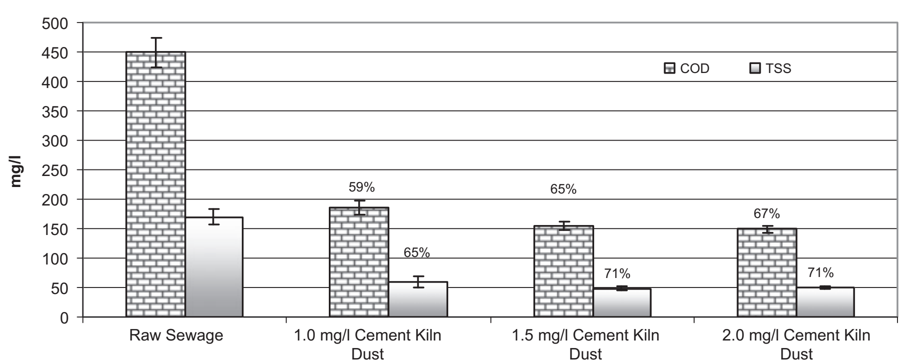

Fig. 5. Efficiency of cement kiln dust for the treatment of wastewater.

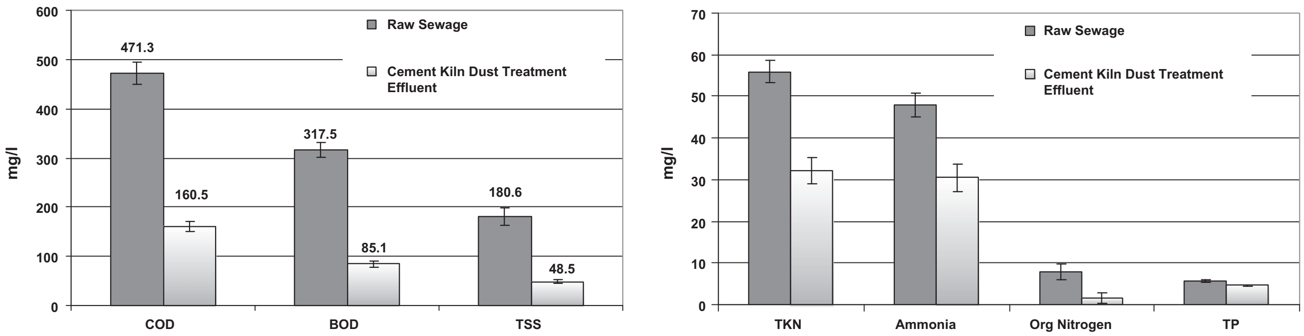

Fig. 6. Efficiency of cement kiln dust for the treatment of raw sewage.

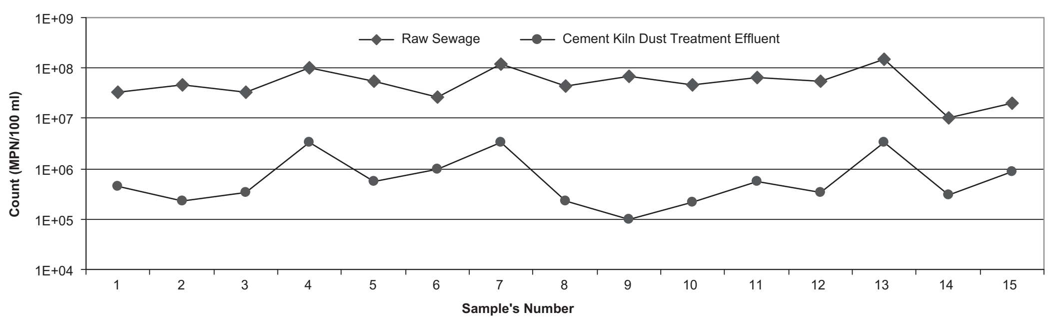

Fig. 7. Variation in FC counts of raw sewage as well as cement kiln dust-treated effluent (average of 15 samples).

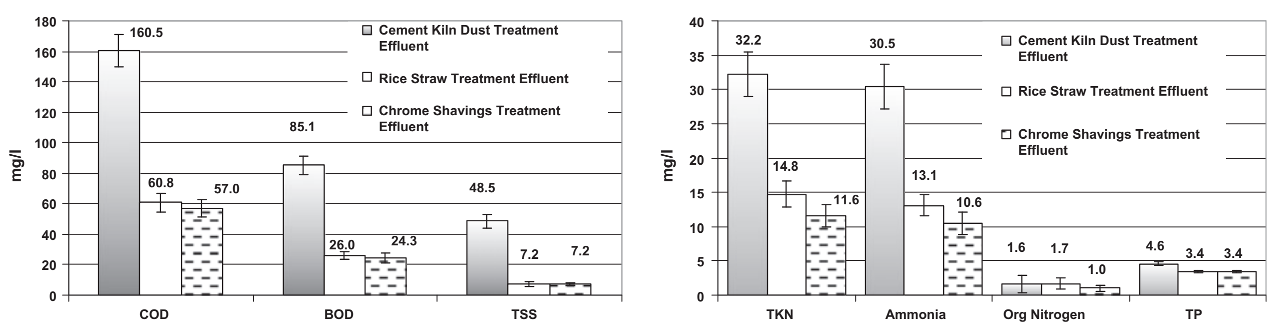

Fig. 8. Chemical characteristics of treated samples (average of 15 samples).

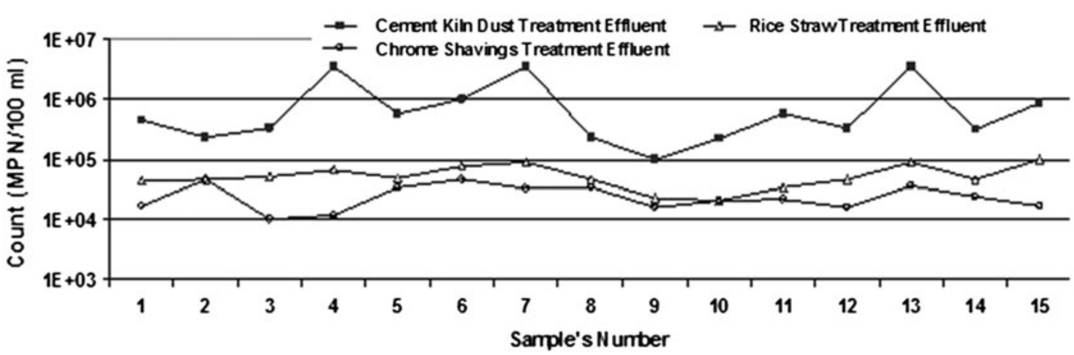

Fig. 9. Variation in FC counts of the different treated effluents (average of 15 samples).

adsorption of COD mechanism is complicated and, although the attraction is primarily physical, is a combination of physical, chemical, and electrostatic interactions between the filtration media and the organic compounds [7].

FC counts were reduced by 4 log units in both filters. The results of 15 samples averaged 5.5×10^4 and 2.6×10^4. The characteristics of the rice straw as well as chrome shaving treated effluents are summarized in Fig. 9. It was observed that the finally treated effluents still contained significant counts of FC. The FC counts are greater than the permissible limit (log 3 or 1,000 MPN/ml) specified by WHO for unrestricted irrigation [26]. The use of disinfectant treatment step is of vital importance to meet the WHO standards for treated effluent reuse.

4. Conclusions

The study showed that the use of some of agricultural (rice straw) and industrial (cement kiln dust and chrome shavings) has a promising capacity as low-cost materials that could be used for the treatment of wastewater. Disinfection step could be used for safe reuse of the treated effluent. More work has to be carried out for the pretreatment of such materials to enhance their capacity for the treatment of different wastewater sources.

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