Design of a Paddy Husk Charcoal Adsorption Unit for the Treatment of Parboiled Rice Processing Wastewater

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Introduction

Soaking paddy in water until it attains a moisture content of 30 to 35% by weight is the key unit operation in parboiled rice processing. Wastewater exiting the soaking tanks of the rice mills generally registers chemical oxygen demand (COD) at a very high value, for example, 4500 mg/l, which is well above the permitted COD (< 250 mg/l) for wastewater discharged to surface waters in Sri Lanka (CEA, 1990). However, owing to the location of a majority of rice mills in the relatively environmentally-healthy rural areas of Sri Lanka, no stringent effluent control is imposed on these rice mills. As a result, a good number of the rice mills in Sri Lanka discharge their untreated rice mill effluent (RME) into surface waters, and thereby polluting them.

Since some of the pollutants in the RME are adsorptive, adsorbents such as activated carbon and paddy husk charcoal (PHC) could be used to selectively remove these substances from the wastewater. PHC, containing about 65% carbon is readily available at rice mills. It is a solid waste generated from the boilers which use the paddy husk waste originating from the milling section as fuel. In boilers, about one fourth of the paddy husk mass gets converted into PHC during combustion. It has been shown that PHC could successfully remove COD, pH, odour, colour and TDS in RME (Ariyarathna *et al.*, 2004).

In this study, a detailed investigation was carried out to design PHC adsorption units for commercial-scale parboiled rice processing mills of capacity up to 10,000 kg/day of paddy. A design curve, constructed with the help of experimental data obtained from laboratory-scale PHC adsorption unit, was used to scale up for an industrial-scale fixed bed PHC adsorption column which could reduce COD from 4500 mg/l to 500 mg/l.

Materials and methods

The wastewater sample was collected from the soaking tanks of a commercial rice mill situated in Kalawewa, Mahaweli H zone, Sri Lanka. The initial COD of the sample was measured to be 4500 mg/l and the pH was 4.5. PHC was also collected from the same mill, and sieved to separate particles of size 0.2 to 0.5 mm, which were used as the adsorbent in this study without subjecting to any pre-treatment. A column of 150 cm height and 2.7 cm diameter was fabricated with PVC conduit pipe. Of this column, a height of 120 cm was packed with 75 g of PHC, which was the adsorption media. Wastewater was passed through the bed at the experimentally determined optimum superficial velocity of 5 mm/min. Samples of the column effluent were collected at the bottom of the bed at selected time intervals, and their respective COD were measured. All experiments were at least duplicated. The data so obtained were used to construct the breakthrough curve, showing the profile of the column effluent COD against time; and the principles of adsorption column design were then employed for scale up for the industrial unit (Christie, 1993).

Results and discussion

Figure 1 shows the breakthrough curve obtained with a 5 mm/min superficial flow velocity with the laboratory-scale PHC adsorption column. The ratio of COD of the wastewater leaving the column (c) to the COD of the wastewater entering the column (c_o = 4500 mg/l) was plotted against time. The long time taken for bed saturation (about 3600 min) shows that the rate of adsorption is relatively slow.

The levelling off of the breakthrough curve shown in the Figure 1 close to $c/c_o = 1$ implies that the entire bed of PHC has come to equilibrium with the wastewater fed to it. In which case, according to theory, the total capacity of the PHC packed bed is proportional to the area between the breakthrough curve and the vertical axis (denoted by A_1 = 32). A value of COD is chosen for the column effluent, at which the column operation would cease. This value of the COD is known as the breakthrough COD. It was chosen be 225 mg/l which is below the permissible COD level of discharge water quality into surface water. Since the initial COD of the wastewater was 4500 mg/l, the ratio at the breakthrough point was 0.05, which was reached 240 min (i.e. 4 hours) from the commencement of the experiment, as shown in the figure. The area up to this point gives the usable capacity of the bed (denoted by A_2 = 4). The ratio of the two areas, A_2/A_1, which is the fraction of the total bed capacity or length utilized up to the break point, becomes 0.125. Hence, usable length for selected bed was calculated to be 15 cm (= 0.125 x the PHC bed height). The unusable bed height which remains a constant as long as the superficial flow velocity remains a constant, was then 105 cm.

Table 1 summarises the results obtained for the laboratory-scale column and the corresponding scaled up values for the industrial-scale column for an operating time of three days using the procedure outlined in Christie (1993). Both the columns must have the same input and output CODs, as well as flow velocity during scale up.

The industrial columns were designed for the treatment of 33,000 l of wastewater, which is the maximum volume of wastewater produced per day by the rice-mill (chosen for this study). Therefore, three identical adsorption columns (throughput of each is 11,000 l/day) are needed to be operated simultaneously to treat the above wastewater. Table 1 shows that 677 kg of PHC is required to treat 33,000 l of wastewater with the bed being operated for 3 consecutive days.

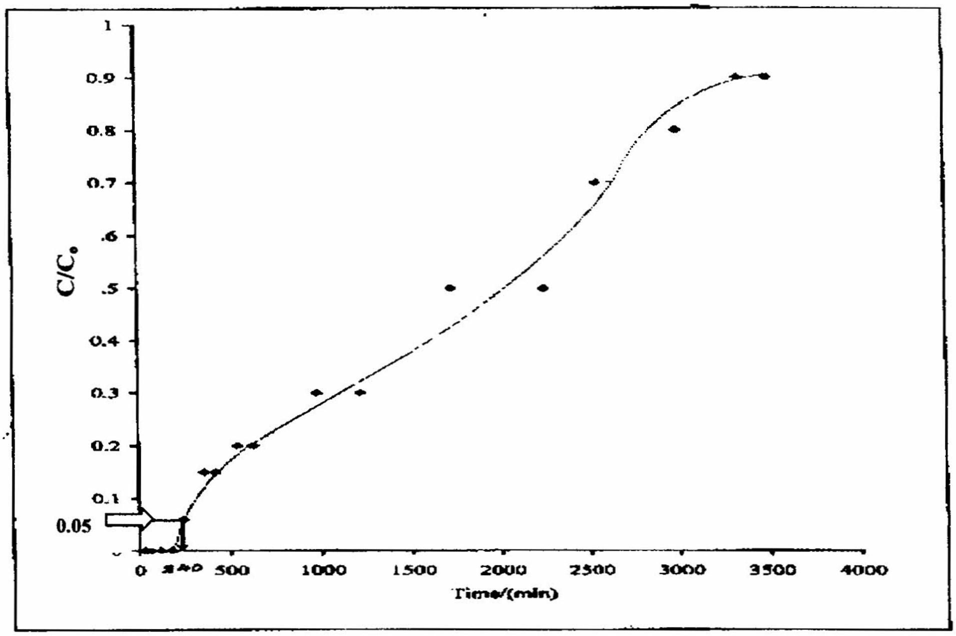

Figure 1. Breakthrough curve obtained with the laboratory-scale PHC adsorption column.

Table 1 Results obtained from laboratory-scale and the industrial-scale columns

Parameters	Laboratory-scale adsorption column	Industrial-scale adsorption column*
Initial COD of the RME, mg/l	4500	4500
Final COD of the RME, mg/l	225	225
Flow velocity of wastewater, mm/min	5	5
Flow rate of wastewater, l/min	3×10^{-3}	7.6
Height of the column, m	1.2	3.8
Diameter of the column, m	2.7×10^{-2}	1.4
Operating (Breakthrough) time of the column, h	4	72
Unused Bed Height, m	1.05	1.05
Required amount of PHC, kg	75×10^{-3}	677

*Three such columns are operated in parallel

However, the rice-mill chosen for this study generates a maximum of 625 kg of PHC per day. Therefore, the amount of PHC generated in the mill itself is not enough to reduce the COD of all the wastewater produced to 225 mg/l. On the other hand, with the available amount of PHC at the mill, the COD of all the wastewater generated could be reduced to 500 mg/l COD with the PHC bed of 1.4 m diameter and 3.6 m height.

Conclusions

The design of the industrial scale adsorption unit carried out in this study reveals that the COD of 33,000 l of wastewater produced in a parboiled rice processing facility could be reduced from a very high value of 4500 mg/l to 225 mg/l, using 677 kg of paddy husk charcoal. Three columns each of 1.4 m diameter and 3.8 m height, operated at a superficial velocity of 5 mm/min for 3 consecutive days, are required for this purpose. However, the rice mill of 10,000 kg/d capacity chosen for this study, producing a maximum of 33,000 l of wastewater, produces only 625 kg of paddy husk charcoal. Using this 625 kg of paddy husk, the strength of the wastewater could be reduced from 4500 mg/l to 500 mg/l in an adsorption column of 1.4 m diameter and 3.6 m height operated at a superficial velocity of 5 mm/min for 3 consecutive days. Research is being carried out at present to reduce the COD from 500 mg/l to the permissible level of 250 mg/l or below by conventional wastewater treatment methods such as biological treatment or activated carbon adsorption.

Reference

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