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Assessment of the Efficiency of Fly Ash Amended Soil for Distillery Effluent Treatment

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ABSTRACT

A lysimetric experiment was conducted to assess the effectiveness of soil amended with fly ash, to remove different contaminants of distillery effluent. Four lysimeters containing amended soil mixtures were prepared by mixing top layer of normal soil and fly ash in different ratios, i.e. S_{95} (pure soil:fly ash, 95:5), S_{90} (pure soil:fly ash, 90:10), S_{85} (pure soil:fly ash, 85:15) and S_{100} (pure soil). Secondarily treated distillery effluent was used for irrigating the prepared lysimeter and leachate was collected to analyse the various relevant parameters, viz. pH, BOD, COD, TDS, N, P, K, Ca, Na, Mg, NO_3^-, SO_4^{2-}, Zn and Fe. The results depicted that fly ash amended soil was effective to enhance the potential of normal soil to remove the pollutants from effluent. Soil with lowest fly ash content, i.e. S_{95} was recorded to be the best for land disposal of the effluent. With an increase in the amount of fly ash, i.e. soil S_{90} and S_{85}, leaching of pollutants was observed indicating the possibility of contamination of groundwater.

INTRODUCTION

Effluent irrigation is one of the good methods to improve crop yield vis-a-vis save water and reduce the use of fertilizers. But, sometimes the soil capacity to retain the organic and inorganic content of effluent is low and thereby it allows the contents to percolate through soil matrix and impart changes in the quality of groundwater. Percolation of the effluent through soil column decreases the availability of N, P, K to plants, and hence the expected outcome of effluent irrigation decreases. In such case, it is required to improve the soil structure by amending it with different stabilizing agents like fly ash, cow dung, sludge, etc. Sewage sludge is used to improve soil properties and make it more suitable for agriculture (Logan & Harrison 1995). However, untreated sludge contains many toxic metals and soluble salts that become a problem later (Chaney 1983, Elseewi & Page 1984). Coal fly ash has a high amount of CaO and MgO, which makes coal fly ash a potential stabilizing material with sewage sludge (Reynolds et al. 2002, Truter 2002). Fly ash is one of the options used to improve the texture and water holding capacity of soils (Goswami & Mahanta 2007). It consists of Al, Fe, Si, O, Ca, Mg and small amounts of many plant essential trace elements, such as B, Se, Cd, Mo and As (Terman 1978, Ritchey et al. 1998). The fly ash has been effective in improving the texture, including increased air-filled porosity, decreased bulk density and improved moisture retention capacity (Bhumbla et al. 1993). The addition of fly ash, at 70 tons/ha to soil altered the texture of sandy and clay soils to loamy soils (Jala & Goyal 2006). The addition of fly ash generally decreased the bulk density of soils, which in turn improved the soil porosity and workability and enhanced the water retention capacity (Page et al. 1979). Therefore, it is worthwhile to assess the role of land/soil and soil amendments in the treatment of pollutants present in the effluents.

MATERIALS AND METHODS

Lysimetric set-up: Lysimeter consists of galvanized sheet having 1.5 m length, 0.8 m width, and a basement and open top (Fig. 1). On one side, near basement, there is an outlet of 5 cm diameter for removal of excess water, if any. There is a 8 cm diameter pipe erected as piezometer attached on the side of this cabinet internally up to full height, i.e., 1.5 m whose base is perforated up to 30 cm. The lysimeter was filled with soil, in accordance with various soil textures required as shown in Fig. 1.

Sampling of effluent: The secondarily treated effluent was collected from the main outlet point of a distillery industry. Effluent samples at the point of discharge were collected in clean plastic containers. Immediately after collection, the samples were brought to the laboratory and stored at 4°C in a refrigerator until their further use.

Experimental layout: Lysimetric trial was conducted to assess the effectiveness of soil amended with fly ash against distillery effluent. Four lysimeters with amended soil mixtures were prepared by mixing normal soil and fly ash in different ratios, i.e. S95 (pure soil:fly ash, 95:5), S90 (pure soil:fly ash, 90:10), S85 (pure soil: fly ash, 85:15) and S100 (pure soil). Secondarily treated effluent was used for irrigating these amended soil mixtures filled in lysimeter. Leachate was collected after effluent irrigation and various relevant parameters, viz. pH, BOD, COD, TDS, N, P, K, Ca, Na, Mg, NO_3-, SO_4^{2-}, Zn and Fe were analysed following standard methods of American Public Health Association (APHA 1995).

RESULTS AND DISCUSSION

The finding of this research marks high values of the certain parameters namely BOD, COD, N and P in the secondarily treated effluent of the distillery industry (Table 1). The Central Pollution Control Board (CBCP) has set-up general standards for discharge of effluent in the environment. These parameters are not fulfilling CBCP standard and were found above the permissible limit. Effluent used in the present study shows significantly high values of nitrogen (91.5 ppm), potassium (23.2 ppm) and phosphorus (38.3 ppm), which will be considered as pollutants, if discharged directly in an aquatic system without treatment. But, if this same effluent is reused as a water source for irrigating crops, these values of NPK will act as fertilizers, thereby enhancing the crop yield.

The effluent with a high value of BOD, COD, N and P was used in lysimeter to assess the ability of different fly ash amended soils to remove the pollutants. The results showed that all types of soil amendments were able to check the concentration of pollutants present in the effluent. By the mixing of 5, 10 and 15 percent fly ash, the rate of percolation was decreased because the pore size was decreased by mixing of fly ash, resulting in slow leaching of effluent from the soil column. Slow leaching of effluent provides proper time for the treatment of pollutants present in the effluent. Among the different soil-fly ash combinations, S_{95} soil was found efficient to reduce different parameters significantly as compared to other combinations. The trend of removal efficiency of soil was $S_{95} > S_{90} > S_{85} > S_{100}$ (Table 2). This clearly explains that fly ash influenced the soils properties like soil structure, bulk density, pore space, sorption, chemical precipitation, water retention capacity and microorganism activity (Reddy & Reddy 1999). In case of S_{95} soil, the percent reduction in TDS, BOD, COD, SO_4^{2-}, N, P, K, Ca, Mg, Na, Zn and Fe were 28.0, 51.9, 26.2, 59.2, 47.0, 45.8, 45.3, 77.3, 76.4, 82.2, 38.3 and 47.6 %, respectively. While with S_{100} soil, the corresponding values for these parameters were noticed to be only 21.0, 23.2, 15.2, 43.4, 30.9, 33.5, 27.1, 61.1, 65.2, 65.5, 13.3 and 10.9 %, respectively. For S_{90} soil, TDS, BOD, COD, SO_4^{2-}, N, P, K, Ca, Mg, Na, Zn and Fe were reduced to 26.8, 45.6, 23.0, 52.2, 40.0, 41.1, 39.0, 70.3, 73.5, 77.4, 35.8 and 38.7 %, respectively, while with S_{85} the values were 22.5, 40.7, 15.2, 51.5, 34.3, 33.5, 28.9, 66.8, 66.5, 65.8, 17.5 and 14.1 %, respectively (Fig. 2). The lysimetric study conducted by Kumar et al. (2004) showed significant reduction of EC, colour, BOD, COD, TS, TDS, P, K, Na, Ca, Mg and lignin by normal soil after irrigation with 25% effluent of a pulp and paper mill effluent.

Table 1: Physico-chemical characteristics of secondarily treated distillery effluent.

Parameters	Effluent	Permissible limit before discharge (CPCB)
pH	7.8±0.2	5.5 to 9.0
TDS ppm)	754±14.5	-
BOD (ppm)	46.4±5.1	30
COD (ppm)	260±10.4	250
SO_4^{2-} (ppm)	68.3±5.6	-
N-nitrate (ppm)	101.5±8.1	10
P (ppm)	68.3±5.7	5
K (ppm)	83.2±6.7	-
Ca (ppm)	31.4±2.9	-
Mg (ppm)	24.2±3.1	-
Na (ppm)	29.3±3.0	-
Zn (ppm)	2.40±0.1	3.0
Fe (ppm)	1.91±0.09	5.0

± indicates SE of mean; - not available

The different contaminants present in the effluent, when passed through the soil matrix, are offered treatment by different components of soil. The value of BOD and COD is majorly because of the organic content like cellulose present in the effluent. When the effluent passes through different layers of soil, the microorganisms present in the soil utilize them as the source of energy, and hence reduce their concentration in leachate. During percolation of industrial effluent, the cations like Na, K, Ca, and Mg get attached on

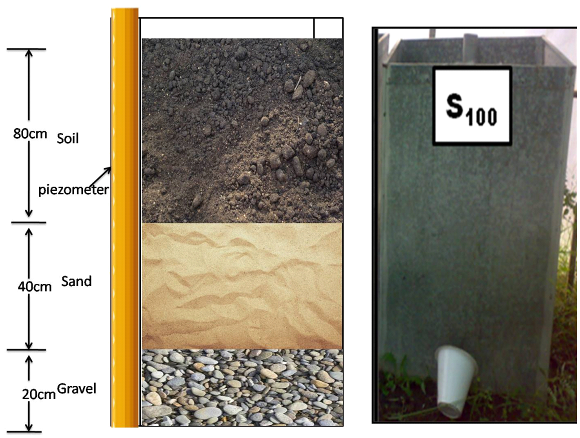

Fig. 1: Lysimeter used in the study.

Table 2: Physico-chemical characteristics of leachate collected after effluent treatment with soil S100, S95, S90 and S80.

Parameters	Effluent	After effluent treatment			
		S100	S95	S90	S85
pH	7.8±0.2	8.0±0.3	8.0±0.2	7.9±0.1	7.7±0.1
TDS ppm)	754±14.5	595.1±14.1	542.2±9.8	551.5±14.8	584.1±11.9
BOD (ppm)	46.4±5.1	35.6±2.8	22.3±2.1	25.2±2.4	27.5±2.5
COD (ppm)	260±10.4	220.3±11.1	191.7±7.4	200.1±13.4	220.3±12.2
SO_4^{2-} (ppm)	68.3±5.6	38.6±2.9	27.8±2.5	32.6±3.2	33.1±3.1
N (ppm)	101.5±8.1	70.1±6.0	53.7±4.5	60.8±8.4	66.6±4.7
P (ppm)	68.3±5.7	45.4±4.0	37.0±3.3	40.2±3.6	45.4±4.1
K (ppm)	83.2±6.7	60.6±4.2	45.5±2.5	50.7±5.2	59.1±6.1
Ca (ppm)	31.4±2.9	12.2±1.2	7.1± 0.9	9.3±0.8	10.4±1.2
Mg (ppm)	24.2±3.1	8.4±0.6	5.7±0.8	6.4±0.7	8.1±0.9
Na (ppm)	29.3±3.0	10.1±0.9	5.2±0.6	6.6±0.5	10.0±1.1
Zn (ppm)	2.40±0.1	2.08±0.07	1.48±0.04	1.54±0.04	1.98±0.07
Fe (ppm)	1.91±0.09	1.70±0.03	1.0±0.01	1.17±0.02	1.64±0.02

± indicates SE of mean

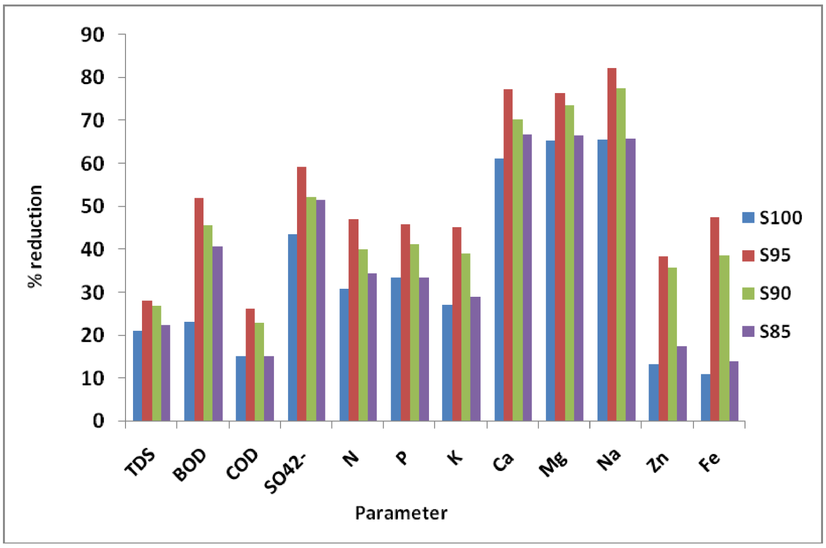

Fig. 2: Percent reduction in different physico-chemical parameters after soil treatment.

the negative binding sites of clay particles, and thus their concentration is reduced in leachate. Total solids are filtered by the soil as it acts like a sieve. Nutrients like nitrate and phosphorus are utilized by plants and microbes for different metabolic activities hence a significant reduction of nutrient content in the effluent is seen. Many of the contents of the effluent act as macro and micronutrients for plants and are involved in various metabolic activities of microorganisms present in the soil. Hence, in the due course of time, the nutrients will be uptaken by the plants and microorganisms of soil, thereby creating further space for the more. Liaghat & Prasher (1996) have also reported that a large amount of pollution load from the effluent is reduced by land treatment.

Percent increase in the removal efficiency of normal soil (S_{100}) with different amended soils S_{95}, $S_{90}$and S_{85} was also calculated (Fig. 3). It was recorded that when normal soil was amended with fly ash, the efficiency of soil to remove the pollutants from the effluent increased as compared to control (S_{100}). Among different amendments, the addition of 5% fly ash in normal soil, i.e. S95 soil gave the best results. Increase in the efficiency of reduction in normal soil with 5% fly ash in normal soil, i.e. S95 for TDS, BOD, COD, SO_4^{2}, N, P, K, Ca, Mg, Na, Zn and Fe were 9.8, 59.6, 14.9, 38.8, 30.5, 22.7, 33.1, 71.8, 47.3, 94.2, 40.5 and 70%, respectively. The fly ash acts as a stabilizing agent, and hence enhances all the physical, chemical and biological properties of soil making it more effective to treat effluent.

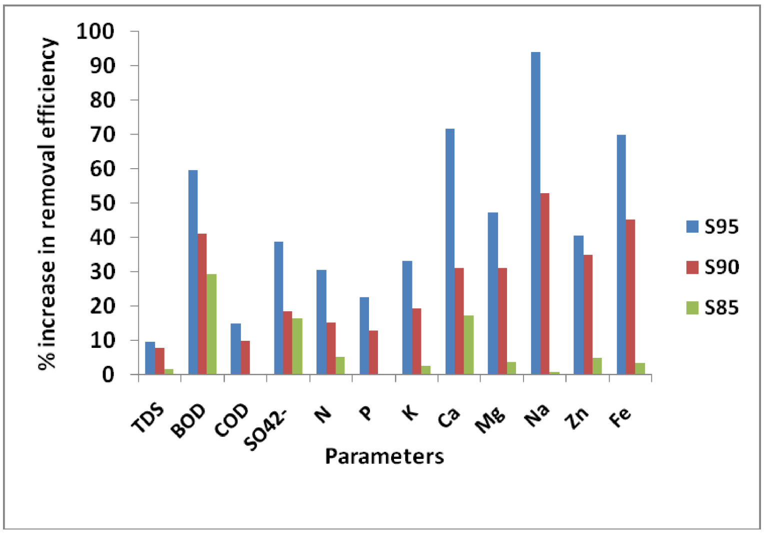

Fig. 3: Percent increase in the removal efficiency of different soil amendments over control.

CONCLUSIONS

Based on the results of this study it may be concluded that soil/land is a better option for treatment of secondarily treated effluent. Further addition of small amount of fly ash can enhance the treatment efficiency of normal soil. Fly ash helps to improve the structure of soil that further supports the removal of pollutants from the effluent. This lysimetric study reveals a significant reduction in the effluent contents that otherwise could percolate and contaminate groundwater. Land treatment of different soils has different results depending on the type of soil and effluent.

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