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Selective Characterization of Sludge Wastes Generated in the Common Effluent Treatment Plants and suitability evaluation for Land Application – an Investigation

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ABSTRACT

Three Common Effluent Treatment Plants (CETP) are in operation around the capital city of Hyderabad, treating about 3050 m^3 industrial effluents per day received from bulk drugs & pharmaceuticals, dye & dye intermediates and other chemical units. During the treatment process of industrial effluents about 2000 T/year sludge waste (dry basis) is generated, which at present is being dumped in the Treatment, Storage and Disposal Facility (TSDF), a secure landfill located at Dundigal (V), Ranga Reddy district of Andhra Pradesh. These sludge wastes have been tested for basic parameters like pH, Electrical Conductivity, Total Dissolved Inorganic Solids (TDIS), Percent Sodium, Sodium Absorption Ratio (SAR) and Boron, necessary for the evaluation of their suitability for land application. The pH values are neutral in nature around 7.0, but the salinity (as measured by Electrical Conductivity & TDIS), %Sodium and SAR values are abnormally high and not advisable to use the sludge wastes for land application.

Keywords: Characterization, Sludge wastes, Investigation.

INTRODUCTION

The three Common Effluent Treatment Plants (CETP) located in industrial development area (IDA), Jeedimetla, Ranga Reddy district, IDA, Patancheru and near IDA, Bollaram, Medak district, and also falls within the 50km radius from the Andhra Pradesh capital city of Hyderabad. These CETPs receives about 3050 m^3 of industrial effluents per day mainly from bulk drugs & pharmaceuticals, dye & dye intermediates and other chemical units, and generating nearly 2000T/year (dry basis) of sludge waste. These CETPs designed mainly to reduce the organic load, in terms of chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of the industrial effluents by means of aerobic biological treatment process in activated sludge process tanks. For effective oxidation / stabilisation / mineralisation of organic matter present in the industrial effluents, domestic sewage is added in sufficient quantity. Addition of sewage also dilutes the dissolved solids content of the industrial effluents, which again helps in the effective treatment of effluents.

Treatment units of the common effluent treatment plant are:

a. Neutralisation / Equalisation tanks.
b. Clariflocculator / Dissolved air flotation (DAF) system
c. Buffer tanks
d. Aeration tanks / activated sludge process (ASP) tanks
e. Final clarifier
f. Sludge thickener
g. Centrifuge
h. Sludge drying beds
i. Secure landfill

Sludge waste is generated mainly in the **(a)** Primary clariflocculator, as a result of coagulation of inorganic and organic suspended and colloidal particles followed by sedimentation by the use of alum or synthetic coagulants. **(b)** Aeration tanks (ASP tanks) as a result of stabilisation / mineralisation / oxidation of organic matter present in the industrial effluent by the action of microorganisms under aerobic conditions. Apart from the above two places, sludge waste is also generated in the neutralisation tanks and buffer tanks, but sludge is removed regularly from primary clariflocculator and aeration tanks (through final clarifier). These sludge wastes are initially in the form of slurry with high moisture content and are thickened in the sludge thickener followed by centrifugation using centrifuge. The sludge waste removed from the primary clariflocculator is referred to as primary or inorganic sludge waste and the sludge generated in the aeration tank (removed through final clarifier) is termed as secondary or biological sludge. These sludge wastes of the three CETPs as such are not treated as hazardous as they are not included in the list of processes or wastes in the Schedule – I of Indian regulatory Hazardous Waste (Management and Handling) Amendment Rules, 2000 [1].However, the sludge wastes of CETP-1 and CETP-2 can be considered as hazardous because they are generated during the treatment process of dye & dye intermediate and pesticide industry effluents, respectively (as per the process 22 bis of waste 22.2bis and 35.2 of process 35 of the Schedule-1). These primary and secondary sludge wastes of the three CETPs have been chosen for the study of characterization and to verify the suitability for various applications. Land application is one among the options verified through this paper.

Objective: These sludge wastes, as said earlier, are expected to contain toxic organic and inorganic constituents as they are produced during the treatment process of toxic industrial effluents. Hence, they are to be made harmless before disposing of them in a secure landfill. However, an attempt has been made to make use of these sludge wastes as fuels, land application as conditioner, raw material in cement and brick making units. Under this study, sludge waste samples have been collected from the three CETPs and tested for basic parameters that are necessary for verifying the suitability of these wastes for land application as conditioner. The parameters tested are pH, Electrical Conductivity, Total Dissolved Inorganic Solids, Percent Sodium, Sodium Absorption Ratio and Boron. The objective of this research paper is to check the suitability of these sludge wastes for land application by comparing the results of the above said parameters with the irrigation water quality standards.

MATERIALS AND METHODS

Sampling: Representative samples of primary and secondary sludge wastes of the three CETPs have been collected in three rounds with in a time span of one year, in the year 2000. Standard laid down sampling procedures have been followed and collected the samples in wide-mouth borosilicate glass bottles.

Sample treatment: The waste samples thus collected are subjected to air-drying to remove moisture and further dried in an air-oven at 105^0C for one hour to remove the entrapped moisture. The dried samples have been ground to fine powder with the help of mortar and pestle. These powdered samples have been divided into two parts:

a) One portion of the dried and powdered samples has been used for the estimation of pH and electrical conductivity.
b) Second portion of the samples has been ignited at 550^0C in a muffle furnace to remove organic matter of the sludge wastes to eliminate color and organic interference during the estimation of rest of the parameters. These burnt samples have been used for the estimation of total dissolved inorganic solids and water-soluble sodium, potassium, calcium, magnesium and boron. These concentrations are later calculated for the samples dried at 105^0C.

Sample Analysis

pH: Aqueous solutions of dried and powdered sludge waste samples in the ratio of 1 : 5 ; solid : liquid have been used for the determination of pH values [2] .
Electrical Conductivity: The above aqueous solutions of the samples have been used for the determination of electrical conductivity of the samples [3].

Total Dissolved Inorganic Solids: About one gram of the dried and powdered samples has been added with sufficient double distilled water in beakers separately and agitate the solutions thoroughly, so that water-soluble solids goes into solution. The contents are filtered through Whatman 41 filter paper and the filtrates are used for the estimation of TDIS [4].

Percent Sodium & Sodium Absorption Ratio: To calculate % Sodium and SAR it is essential to determine the water-soluble sodium, potassium, hardness, calcium and magnesium contents of the sludge wastes. Sludge waste samples burnt at 550^0 C have been dissolved in double-distilled water and filtered. The filtrates thus obtained are estimated for sodium, potassium, hardness, calcium and magnesium [4]. % Sodium has been calculated by using the following formula [5]:

$$\text{Percentage of sodium} = \frac{\text{Na X 100}}{\text{Na + K Ca + Mg}}$$

Sodium Absorption Ratio (SAR) has been calculated by using the following equation [6]:

$$\text{Sodium Absorption Ratio (SAR)} = \frac{\text{Na}}{\text{Ca + Mg/2}}$$

Note: Milliequivalent values of Na, K, Ca, & Mg have been used for the calculation of % sodium and SAR.

Boron: The filtrates have been used for the determination of boron by Colorimetric method using Caramine reagent (Method: 4500-B C), [4].

RESULTS AND DISCUSSION

pH Values: The pH values determined for the 20% aqueous solutions of the dried (105^OC) sludge wastes of the three CETPs are shown in the table1.

Table – 1: pH values of 20% aqueous solutions of sludge wastes dried at 105°c

CETP		Round – 1	Round – 2	Round - 3	Average
CETP-1	Primary	7.7	7.4	8.1	7.73
	Secondary	6.9	7.2	7.5	7.2
CETP-2	Primary	7.0	7.3	7.5	7.27
	Secondary	6.1	7.1	6.7	6.63
CETP-3	Primary	9.3	8.9	7.8	8.67
	Secondary	7.2	6.4	6.7	6.77

The values ranging from 6.1 (secondary sludge waste of CETP-2, collected in the first round) to 9.3 (primary sludge waste of CETP-3, collected in the first round). Rest of the pH values of sludge wastes falls in between these two. If the average values of the three rounds are considered, the secondary sludge wastes of CETP-2 has a minimum of 6.63 and the primary sludge waste of CETP-3 has a maximum of 8.67. Water with pH value range between 6.5 to 8.4 can be used for irrigation purpose without any problem and between 5.1 to 6.4 & 8.5 to 9.5 considered as moderate class (R.S.Ayers et.al, 1976). pH values of the sludge wastes mostly falls within the no problem range of 6.5 to 8.5.

Electrical conductivity: The table 2 shows the electrical conductivity values of 20% aqueous solutions of dried sludge wastes of the CETPs collected in three rounds. The values shows that the primary sludge wastes of CETP-3, collected in the first round has a minimum of 4800 μmhos/cm and the primary sludge waste of CETP-1 collected in the second round has a maximum of 46800 μmhos/cm. The primary sludge wastes of CETP-3 has the minimum of 9867 μmhos cm^{-1} and the primary sludge waste of CETP-1 has the maximum of 39200 μmhos cm^{-1}, if the average values of the three rounds are considered.

Table 2. Electrical conductivity values of 20% aqueous solutions of sludge wastes dried at 105°c (μ mhos cm^{-1})

CETP		Round-1	Round-2	Round-3	Average
CETP-1	Primary	33200	46800	37600	39200
	Secondary	38400	42000	29600	36667
CETP-2	Primary	10800	12400	14800	12667
	Secondary	16400	20800	25600	20993
CETP-3	Primary	4800	12000	12800	9867
	Secondary	14000	19600	39600	24400

The Electrical Conductivity of these 20% aqueous solutions of the dried sludge wastes are above the very high (>4000μmhos cm^{-1}) to excessive saline (>6000 μmhos cm^{-1}) water classification, which are not suitable for irrigation purpose [7].Soils with EC (saturated soil extract) greater than 4000 μmhos cm^{-1} are treated as saline soils [8] and generally these soils are not recommended for irrigation.

Total dissolved inorganic solids: Water-soluble inorganic salts measured in terms of total dissolved inorganic solids (TDIS) estimated for sludge wastes burnt at $550^{O}C$ and later values are corrected to sludge wastes dried at $105^{O}C$ have been given in the table-3. Accordingly to the values of primary sludge wastes of CETP-3, collected in the first round has a minimum of 27410 mg kg^{-1} or 2.74% (w/w) and the primary sludge waste of CETP-1 collected in the first round has a maximum of 215316 mg kg^{-1} or 21.53%(w/w). When the average values of TDIS of the three rounds are considered the secondary sludge wastes of CETP-2 has the minimum of 35469 mg kg^{-1} or 3.55%(w/w) and the primary sludge waste of CETP-1 has the maximum of 191791 mg kg^{-1} or 19.18%(w/w).

Table 3: Total dissolved inorganic solids values of sludge wastes dried at $105^{O}C$ (mg kg^{-1})

CETP		ROUND-1	ROUND-2	ROUND-3	Average
CETP-1	Primary	215316	212635	147423	191791
	Secondary	188190	137971	86139	137433
CETP-2	Primary	44950	36029	35790	38923
	Secondary	32123	35836	38449	35469
CETP-3	Primary	27410	56201	40191	41267
	Secondary	61398	29039	142549	77662

The high values of electrical conductivity suggest that these sludge wastes are rich in dissolved inorganic salts. This was supported by the high values of water-soluble TDIS.

Percent sodium: Percent sodium values of sludge waste samples dried at $105^{O}C$ of the three CETPs are given in the table-4 and as per the table the primary sludge waste of CETP-3, collected in the first round has a minimum of 9.61 and the secondary sludge waste of CETP-1, collected in the third round has a maximum of 89.49. The primary sludge waste of CETP-3 has a minimum %Sodium value of 19.89 and the secondary sludge waste of CETP-1 has a maximum %Sodium value of 83.43, when the average values are concerned.

Table 4. Percent sodium values of sludge wastes dried at $105^{o}c$

CETP		ROUND-1	ROUND-2	ROUND-3	Average
CETP-1	Primary	78.27	78.27	73.3	76.0
	Secondary	82.84	82.84	89.49	83.43
CETP-2	Primary	40.55	40.55	44.34	37.01
	Secondary	76.29	76.29	83.96	81.6
CETP-3	Primary	31.87	31.87	18.18	19.89
	Secondary	77.15	77.15	63.62	66.08

Generally waters with %sodium value above 60 are not considered suitable for irrigation (IS 2296-1963). The %sodium values of all, except the primary sludge wastes of CETP-2 and CETP-3 are above the 60% mark and hence they are not suitable for land application.

Sodium absorption ratio (SAR): The table-5 contain the values of SAR of the sludge wastes samples dried at $105^{O}C$ and according to the values the primary sludge waste of CETP-3, collected in the first round has a minimum value of 2.6 and the secondary sludge waste of CETP-2, collected in the third round has a maximum of 246. When the average values are seen the primary sludge waste of CETP-3 has a minimum of 8.7 and the secondary sludge waste of CETP-1 has the maximum of 184.

Table 5. Sodium absorption ratio (SAR) values of sludge wastes dried at 105^{O}C

CETP		ROUND-1	ROUND-2	ROUND-3	Average
CETP-1	Primary	102	138	111	117
	Secondary	135	194	223	184
CETP-2	Primary	15	29	30	24.6
	Secondary	90	137	246	158
CETP-3	Primary	2.6	16.6	6.9	8.7
	Secondary	42	103	95	80

Soils with SAR values greater than 13 are generally not recommended for irrigation[11]. Water with SAR value of less than 18 can be considered to use for irrigation purpose and this can also be extended upto 26 (IS: 11624-1986). Again the SAR values of primary sludge wastes of CETP-2 and 3 falls with in the permissible range of 26 and rest of the wastes SAR values are far beyond the 26.

Boron: The table-6 contains the values of water-soluble boron content of the dried sludge wastes and the consistency between the 3 rounds of sampling has not been observed. The primary sludge waste of CETP-2, collected in the first round has the minimum value of 0.17 mg kg^{-1} and the primary and the primary sludge waste of CETP-3, collected in the second round has the maximum value 8.49 mg kg^{-1} among the 3 rounds of sampling.

Table 6. Boron values of sludge wastes dried at 105^{O}C (mg kg^{-1})

CETP		ROUND-1	ROUND-2	ROUND-3	Average
CETP-1	Primary	1.01	1.0	0.51	0.84
	Secondary	0.91	0.57	0.98	0.82
CETP-2	Primary	0.17	1.49	2.78	1.22
	Secondary	2.37	3.69	2.44	5.59
CETP-3	Primary	5.59	8.49	0.66	4.91
	Secondary	1.49	0.69	0.72	0.97

Generally boron concentration greater than 2.0 ppm may be a problem for certain sensitive crops [8] and when the average values of 3 rounds are considered the secondary sludge waste of CETP-2 and primary sludge waste of CETP-3 are exceeding.

APPLICATIONS

From these studies we can know the pH values are neutral in nature around 7.0, but the salinity (as measured by Electrical Conductivity & TDIS), %Sodium and SAR values are abnormally high and not advisable to use the sludge wastes for land application.

CONCLUSIONS

The sludge wastes are neutral in nature and the pH values are with in the permissible range for irrigation point of view, but they are not advisable for land application because of the following reasons:

- Salinity, measured in terms of electrical conductivity and TDIS (Table-2 & 3) of the sludge wastes is very high, which means that these wastes are rich in water-soluble inorganic salts.

- The %Sodium values except for the primary sludge wastes of CETP-2 and CETP-3 are also above 60 (permissible limit for irrigation).

- The SAR values of the sludge wastes are above 26 (maximum permissible limit for irrigation) again with the exception of primary sludge wastes of CETP-2 and CETP-3

The high values of percent Sodium and SAR suggest that Sodium is the predominant constituent among the water-soluble cations. Because of the high values of EC and SAR these sludge wastes are rated as Saline-Sodic soils (with the exception of primary sludge waste of CETP-3) and generally are not recommended for irrigation purpose [8]. Apart from the above, these sludge wastes are rich in toxic metals, Cr, Pb, Ni, Cu, Zn, Mn & Fe [9,10] and hence, application of these sludge wastes may result in the enrichment of soils with metals to the phytotoxic level.

In other words, land application of these high EC and TDIS content sludge wastes of the three CETPs not only increases the salinity of the soils but also contributes high concentrations of water-soluble sodium ions (with the exception of primary sludge wastes of CETP-2 & CETP-3), which are detrimental to the growth of the plants. Hence, these sludge wastes of the three CETPs are not recommended for land application.

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