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Journal of Hazardous Materials 110 (2004) 113–118

Journal of Hazardous Materials

www.elsevier.com/locate/jhazmat

A new procedure for treatment of oily slurry using geotextile filters

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Abstract

A new procedure to mitigate the environmental impacts and reduce the cost of disposal of oil slurry is present in this paper. Waste from the petroleum industry has a high environmental impact. Systems for oil–water separation have been used to mitigate the contamination potential of these types of effluents. At the outlet of these systems, the oil is skimmed-off the surface, while the slurry is removed from the base. Due to the high concentration of contaminants, the disposal of this slurry is an environmentally hazardous practice. Usually this type of waste is disposed of in tanks or landfills after removal from the industrial plant. Basically, the proposed procedure utilizes drying beds with geotextile filters to both reduce the water content in the slurry and obtain a less contaminated effluent. Laboratory tests were carried out to simulate the drying system. Four types of filters were analyzed: two non-woven geotextiles, one woven geotextile, and a sand filter.

Keywords: Oil; Oily slurry; Drying bed; Geotextile; Filtration

1. Introduction

Our energy needs are heavily dependent on oil and its derivatives, the waste that is produced in fuel production processes is now concern, but until recently received little attention. These waste materials include sludge and slurry from oil, and especially from lubricants. Some types of sludge/slurry may be reused, recycled, incinerated, co-processed, and even treated. However, even in developed countries, this sludge/slurry is stored in tanks or discharged into landfills almost arbitrarily, since there is no specific environmental legislation on the matter.

Oily effluents produced in the petroleum production chain are treated primarily using traditional oil–water separation systems (OWS) to minimize the oil levels and allow the oil to be recovered and the effluent treated. The equipment that is usually used for this type of treatment is the American Petroleum Institute (API) oil–water separator. This is basically a rectangular tank through which the effluent flows at low speed; therefore, laminar flow predominates. Oil droplets rise, accumulate at the surface and are skimmed-off. The solids settle to the bottom of the tank, are channeled into a ditch and are pumped out. Other types of gravity-based separators exist that are an improvement on the API type, such as the parallel plate interceptor. This separator is filled with plates that accelerate the formation of large oil drops at the surface, improving the effectiveness of oil separation and reducing the size of the separator. While an API separator can supply effluents with 40–150 ppm oil, the parallel plate separator can supply effluents with 20 ppm oil. However, the API separator is much cheaper to buy and operate, which explains why it is often preferred [1].

Regardless oil levels in the wastewaters and water content in the disposal slurry remain high.

A method for treating oily slurry is presented in this paper. The proposed method consists of a dehydration process using drying beds with geotextile filters to separate water from sludge. The aim is to obtain water with a lower oil content, which makes further treatment easier; and, to obtain dehydrated slurry that can be reused in the co-processing of the cement or ceramics industry. Also, reducing the water content of the slurry enables its use as a source of energy. Even if the slurry could not be used in the co-processing, the dehydration would reduce the volume of the final waste to be discharged, minimizing the environmental impacts and costs involved.

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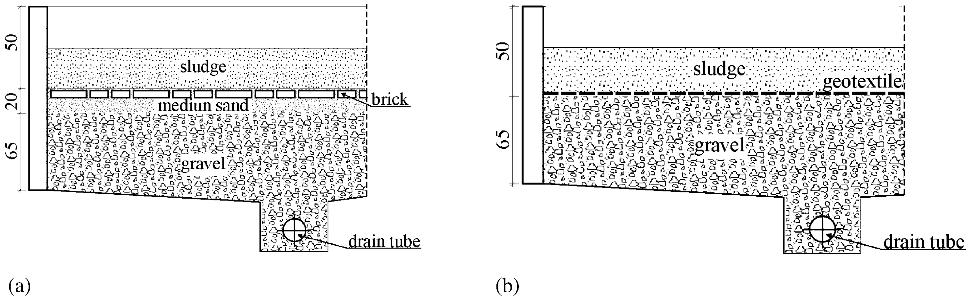
doi:10.1016/j.jhazmat.2004.02.044



(a) (b)

Fig. 1. Cross-section of a drying bed. (a) Drying bed for sewage sludge; (b) proposed drying bed.

2. Proposed treating unit

Geotextiles consist of synthetic fibers (polymeric materials) which are made into flexible porous fabrics by standard weaving machinery (woven geotextile) or are matted together in a random or non-woven manner. They are largely used to perform the function of filtration in drainage systems [2]. In this case, geotextiles need to have an adequate permeability and solid particle retention.

The treatment proposed consists of removing water from slurry using a system similar to a drying bed, which is used for dehydrating sewage sludge in open air [3]. The drying bed is a rectangular unit in which the water content in the sludge is reduced naturally by drainage and evaporation (Fig. 1a). Drainage is the process that removes most water from the sewage sludge. In a conventional drying bed, the sludge (30–60 cm layer) is placed on a sand filter (15–20 cm thick) on top of which a protective layer of bricks is placed. Beneath the sand is a layer of gravel and a perforated tube to collect the drained fluid. The drying bed is operated in batch mode, and for good operation the cake retained on the filter needs to be removed before a new layer is applied. In the proposed process the sand filter and bricks are substituted by geotextile layers (Fig. 1b).

Fig. 2 presents a schematic of the alternative system proposed for treatment of oily slurries. Due to the reduced thickness of the filters when using a geotextile there is greater capacity for slurry treatment. Furthermore, the smaller thickness of geotextiles (some millimeters) means that at the end of the life-span of the filter, the thickness of residue adhered to the geotextile filter would be much smaller than in the conventional sand filter, resulting in less volume of contaminated material to be discharged.

3. Laboratory studies

3.1. Aims

Experimental laboratory studies were performed with the aim of modeling and verifying the performance of drainage systems in a drying bed for dehydrating oily slurry. The basic aim was to analyze the de-watering of the slurry, the contamination level in the drained fluid and the drainage capacity of the filter with time. Four different filters were used, three of which were synthetic (OP-30 manufactured by Bidim, G-300 manufactured by Ober and 4004, manufactured by Amoco) and one granular (sand), see Table 1. The sand was composed of 71% of coarse sand, 26% of medium sand, and 3% of fine sand with dry specific weight of 16.3 kg/m^3.

The oily slurry was collected from a lubricants plant located in the city of Rio de Janeiro. Table 2 presents the basic composition of the oily slurry.

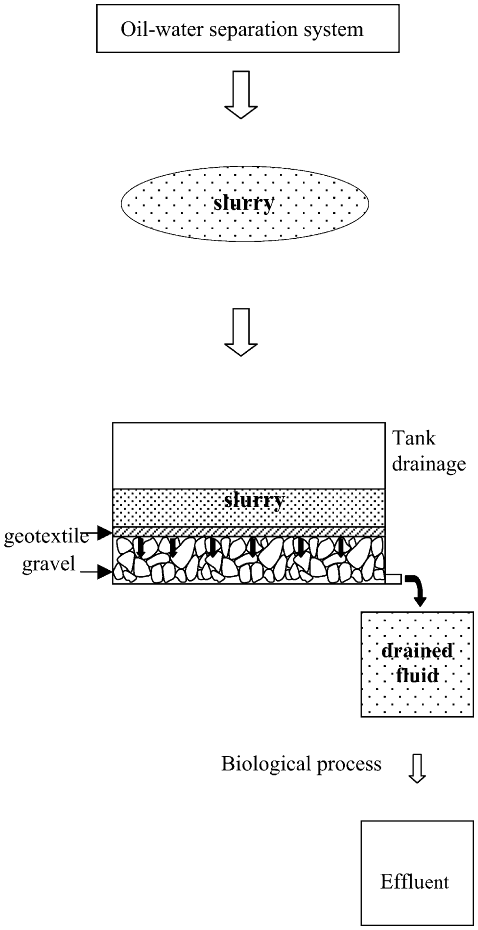


Fig. 2. Schematic drawn of system proposed for treatment of oily slurries. SWO: system of oil–water separation; DF: drained fluid.

Table 1
Properties of the geotextile used in the tests

Geotextile	Polymer[a]	Fabric	Thickness (mm)[b]	Opening size (mm)[c]
OP-30	PET	Non-woven	2.6	0.12–0.17
G-300	PP	Non-woven	2.8	0.11
4004	PP	Woven	0.4	0.8

[a] PP: polypropylene; PET: polyester.

[b] Standard procedures: Brazilian association for standardization (ABNT) NBR-12569 (under pressure of 2.0 kPa) for OP-30 and G-300 and American Society for Testing and Materials (ASTM) D-5199 (under pressure of 2.0 kPa) for 4004.

[c] Standard procedures: ASTM D-4751 for OP-30 and 4004 and French association for standardization (AFNOR) G-38017 for G-300.

Table 2
Characteristics of the oily slurry (before drying)

Analysis[a]	Value
Density (g/ml at 20 °C)	1.04
pH	6.9
Oil and grease (wt.%)	8
Water (wt.%)	82
Solids (wt.%)	10

[a] Measured using Standard Methods (APHA, 1992).

3.2. Methodology

Column tests were performed to evaluate the effectiveness of the filters (Fig. 3). The filtration columns were made of PVC, with a 10 cm diameter and 60 cm height. For the tests with geotextile filters, the base of the columns had a 10 cm thick washed gravel bed upon which the geotextiles were placed. for the sand filter, the bottom of the column was made up of a 10 cm layer of washed sand. After they were assembled, a 3.53 l slurry, corresponding to a 45 cm high column above the filter, was poured into the top of the column. The section below the slurry/filter interface was open to the atmosphere. Measurements of the flow rate, hydraulic head, and chemical oxygen demand (COD) levels in the drained fluid were made, as well as analyses of the characteristics and composition of the original slurry and the dehydrated slurry were done. The measure of cod was used to estimate the amount of oil and grease in the effluent, since COD is related to the amount of organic compounds present in the sample [4]. The tests presented were performed in two stages. In the first stage (stage I), the water was left to drain from the slurry for approximately 3 weeks. In the second stage (stage II), the cake retained in stage I was removed and a new volume of slurry was introduced into the permeameter, without replacement of the filter. This second stage lasted around 1 week. The tests were carried out under an average room temperature of 22 °C.

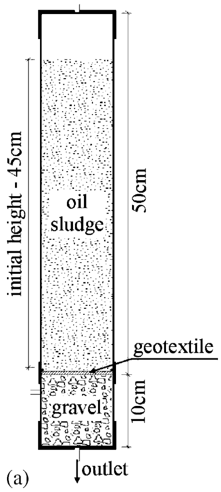


Fig. 3. Schematic diagram of the configuration of the permeameters utilized in the tests: (a) with a geotextile filter; (b) with a sand filter.

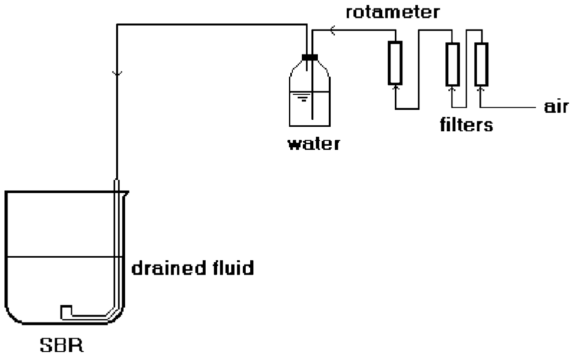


Fig. 4. Experimental system employed in essays of biodegradability of drained fluids; SBR: sequential batch reactor.

Preliminary experiments were conducted in filtration columns with only 900 ml of oily slurry using a geotextile filter Bidim OP-30 in order to assess the feasibility of the proposed treatment method and the geotextile reuse.

The outputs of the filter systems (drained fluids) were evaluated in terms of biodegradability for future discharge into biological treatment systems such as those operated in refineries. The drained fluids were fed to aerobic bioreactors employing activated sludge collected in a sewage treatment station (Fig. 4) as inoculum. Activated sludge was gradually adapted to drained fluids and the soluble COD removal efficiency was monitored after a reaction time of 24 h. The initial pH was adjusted to values around neutrality.

4. Results and discussion

Table 3 shows the results obtained in the eight sequential preliminary experiments. Data presented in Table 3 indicates that a geotextile filter can be reused some times, maintaining the same drainage capability. The results show that on subsequent use of the geotextile filter the residual humidity in the oily slurry at the end of the test increased but the quality of drained fluid became better in relation to COD and suspended materials. This is due to the deposition and accumulation of slurry on the geotextile filter, which reduces

Table 3
Characteristics of the drained fluid and residual humidity of the slurry after eight preliminary experiments

Run	DF volume (ml/l slurry day)	COD of DF (mg/l)	SS in DF	Residual humidity (%)[a]
I	333	805	++	20
II	333	1600	++	24
III	378	1260	++	25
IV	353	680	–	nd
V	367	730	+	8
VI	333	390	+	29
VII	289	530	–	30
VIII	413	400	–	33

[a] Humidity in relation to dry weight of slurry; nd: not determined; (−) very little, (+) some, (++) much; DF: drained fluid; SS: suspended solids.

Table 4
Reduction in the slurry volume at the end of the tests using different geotextile filters

Filter	Reduction in volume, $(V_0-V_f)/V_0$ (%)	
	Stage I (3 weeks)	Stage II (1 weeks)
OP-30	46.7	32.2
G-300	47.7	36.7
4004	46.9	41.1
Sand	46.2	41.8

the size of the pores available for drainage and increases the filter retention capability.

Fig. 5 presents the variation with time of the drainage capacity of the filtration column, expressed by Q/h, where Q is the flow rate and h the hydraulic head. The results show that the drainage capacity of the column reduced with time for each stage of the test (Figs. 5a and b). The removal of the cake retained on the filter led to a recovery of the drainage capacity of the column in stage II. This indicates that the reducing drainage capacity observed during the test is higher due to the sedimentation of the solids at the top of the geotextile and sand filters, i.e. due to the low permeability of cake itself. There was no significant overall variation in the performance of the filters in the stage II, regarding the drainage capacity of the system.

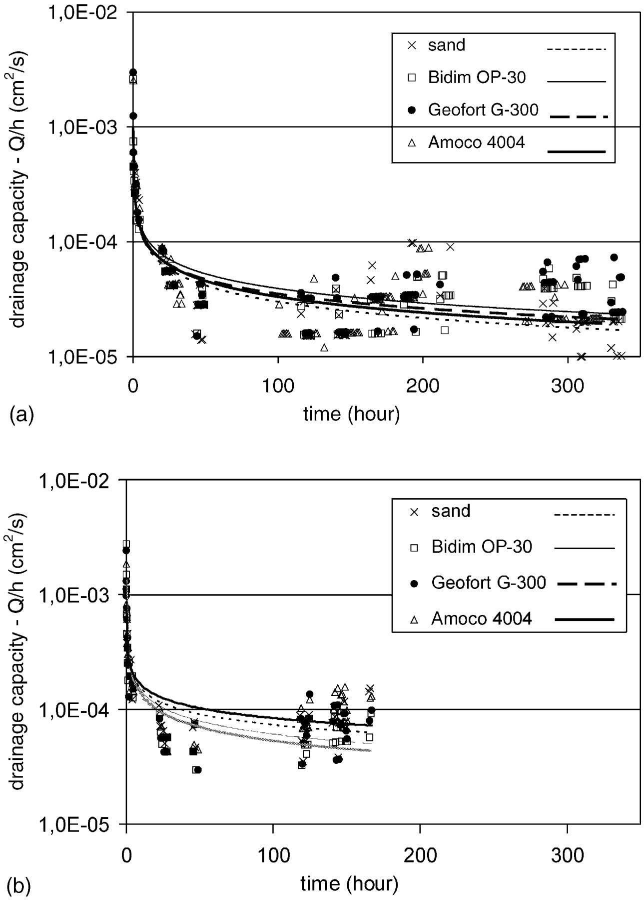


Fig. 5. Variation of the drainage capacity of the filtration column with time: (a) stage I; (b) stage II.

The observed reduction in the volume of slurry at the end of the tests performed using different geotextiles filters is presented in Table 4. The reduction in the volume is expressed as $(V_0-V_f)/V_0$, where V_0 is the initial slurry volume and V_f the volume at the end of the test. A considerable reduction of the initial slurry volume was observed. Following the first stage (end of 3 weeks), the slurry volume reduced by 46–48%, depending on the filter type used. In the second stage, after one week, the volume reduction was also very high (32–42%). These results from stage II indicated that the performance of the reused filters was slightly worse in terms of reduction of the water content of the slurry. It was noticed that small differences were higher for non-woven geotextiles.

Table 5 shows the variation in the water content of the slurry at the end of the test, expressed by $(w_0-w_f)/w_0$, where w_0 is the initial water content in the slurry and w_f the water content at the end of the test. The variation in the water content obtained at the end of the first stage of the test was considerable, varying from a 46.8% reduction retained by the sand filter to 58% for the G-300 filter.

Table 6 shows the results of analyses of oil slurry both initially and after the process of drying for the different filters. The slurry is analyzed for oil and grease (O&G), and water and solids content. Table 7 presents the results of a more complete analysis carried out on the oily slurry after the drying process. Besides the humidity reduction in the treated slurry, there was a factor 5–10 increase in the concentration of O&G, which contributes to its high calorific value:

Table 5
Variation in water content in the slurry after stage I

Filter	Variation in water content, $(w_0-w_f)/w_0$ (%)
OP-30	49.2
G-300	58.0
4004	50.4
Sand	46.8

Table 6
Contents of O&G, water, and solids in oily slurries

Slurry	O&G (%)[a]	Solids (%)	Water (%)
Initial	3.6	16.2	80.2
OP-30	22.0	23.6	54.4
G-300	35.8	9.8	54.4
4004	17.6	25.0	57.4
Sand	33.9	11.8	54.3

[a] Three cold extractions with 20 ml *n*-hexane; average values of analysis made in samples collected at base and top of the columns.

4326 kcal/kg or 18.1 MJ/kg. This value is similar to that obtained for sugarcane waste (18.9 MJ/kg), cuts of eucalypte (19.6 MJ/kg), barks of eucalyptum (16.8 MJ/kg), and sawdust (18.7 MJ/kg). Meanwhile, the ash content of the oily slurry (36.3%) is higher than values obtained for these other fuels, in the range of 0.6–4.0% [5].

The average values and respective standard deviations for the COD of drained fluids before and after aerobic degradation can be seen in Table 8. Higher values for the final COD were observed in the drained fluid for the test with the sand filters, which indicate that the geotextile filters have a greater retention capacity for the oil and grease present in the sludge. Therefore, it is more probable that the drained fluid can then be treated in the conventional systems that are usually available in industrial facilities.

The values obtained for COD removal efficiencies in aerobic bioreactors indicate that these effluents are not totally biodegradable. This may be due to the direct contact between aqueous and oily phases over a long period before drying treatment, which leads to many of the compounds (hydrocarbons, phenols, thio-phenols, metals, sulfides, mercaptans) becoming dissolved and passing to aqueous phase. However, since these drained fluids may be mixed with other effluents generated in refinery or petrochemical industries before biological treatment, thereby reducing toxicity and facilitating microbial action, minor values of residual COD may be obtained after treatment.

Table 7
Characteristics of the oily slurry after drying process

Parameter	Value (mg/kg)	Parameter	Value (mg/kg)
Silver	<42	Indium	<7.4
Aluminum	1068	Potassium	<18
Arsenic	<30	Lithium	<0.33
Boron	<90	Magnesium	2252
Barium	154	Manganese	139
Berilium	<16	Nickel	20.85
Bismuth	<3.9	Lead	419.8
Calcium	4412	Antimony	<40
Cadmium	8.8	Selenium	412.1
Cobalt	4.3	Stan	<30
Chromium	832.4	Thallium	<10
Copper	47.3	Vanadium	39.95
Iron	10.380	Zinc	1227
Gallium	<7.1	Chloride (%)	0.23
Mercuric	<12	Sulfur (%)	2.13

Characteristic	Value
Calorific value (kcal/kg)	4326
Humidity (80 °C, %)	45.2
Ash (850 °C, %)	36.3
Chloro-organics	nd
Physic state	Solid

Table 8
Average values and standard deviations for different percentage of drained fluids in aerobic bioreactors feed

Percentage DF in feed	Initial COD (mg/l)	Final COD (mg/l)	COD removal (%)[a]
DF of OP-30			
20	139 ± 46	67 ± 8	47 ± 22
30	126 ± 9	81 ± 24	35 ± 24
40	101	73	28
50	138 ± 1	82 ± 7	41 ± 5
60	167 ± 21	120 ± 11	28 ± 5
70	194 ± 4	124 ± 9	36 ± 6
80	186 ± 12	133 ± 6	28 ± 4
90	244 ± 37	143 ± 10	41 ± 8
100	297 ± 55	157 ± 16	46 ± 9
DF of 4004			
20	145 ± 36	77 ± 7	44 ± 14
30	155 ± 7	88 ± 49	43 ± 34
50	184 ± 10	112 ± 37	39 ± 20
60	190 ± 3	135 ± 7	29 ± 4
70	197 ± 7	127 ± 2	35 ± 2
80	190 ± 7	133 ± 7	30 ± 3
90	259 ± 42	153 ± 30	41 ± 8
100	333 ± 27	179 ± 30	46 ± 8
DF of G-300t			
20	100 ± 2	62 ± 6	38 ± 6
30	120 ± 6	77 ± 16	35 ± 17
50	141 ± 18	93 ± 24	33 ± 21
60	166 ± 24	115 ± 8	30 ± 6
70	198 ± 11	122 ± 8	38 ± 7
80	181 ± 14	133 ± 13	26 ± 9
90	242 ± 38	152 ± 14	37 ± 7
100	295 ± 16	169 ± 14	43 ± 4
DF of sand			
20	97 ± 4	64 ± 14	35 ± 13
30	114 ± 3	64 ± 13	44 ± 10
40	110	92	16
50	154 ± 7	98 ± 2	37 ± 3
60	170 ± 7	119 ± 2	30 ± 3
70	197 ± 5	124 ± 8	37 ± 4
80	181 ± 5	147 ± 10	19 ± 10
90	263 ± 52	170 ± 29	34 ± 11
100	337 ± 48	193 ± 16	43 ± 4

[a] After 24 h of aeration; DF: drained fluid; COD: chemical oxygen demand.

5. Conclusions

In general, the results of the tests carried out indicated a satisfactory performance of the proposed treatment process for oily slurry using drying beds and geotextiles filters. The drying process of the slurry leads to a considerable reduction in its water content, greater than 47%. Consequently, a variation of more than 46% was obtained in its volume, considerably reducing the volume of the waste to be discharged. Regarding the effluents, the system achieved a very satisfactory retention of oil and grease, generating drained fluids with low COD levels and acceptable biodegradability that could be treated in conventional biological systems.

The performance of the four filters used (one geotextile fabric, two non-woven fabrics, and sand) was similar. This is encouraging for the use of geotextiles as filters for drying beds, since geotextiles also have benefit of being easy to handle. Furthermore, the smaller thickness of geotextiles means that at the end of the life-span of the filter, the thickness of residue adhered to the geotextile filter would be much smaller than in the conventional sand filter, resulting in less volume of contaminated material to be discharged. The laboratory results also demonstrate the potential to reuse the geotextile filters after the cake retained on them has been removed.

Acknowledgements

This work is part of the following research programs: CT-PETRO/CNPq (Brazilian Research Council) and FAPERJ (Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro).

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