Cost evaluation of sludge treatment options and energy recovery from wastewater treatment plant sludge treating leather taning wastewaters

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ABSTRACT

In this study, sludge treatment and dewatering alternatives for a selected leather tanning wastewater treatment plant were evaluated by evaluating the best available technology for sludge management. In addition, different combinations of sludge treatment alternatives were compared on the basis of investment and maintenance costs.

KEYWORDS

Leather tanning, analysis, sludge disposal, anaerobic treatment, energy recovery, cost analysis

INTRODUCTION

Tannery industry is one of the most important industrial sector in the world. High amounts of process water is required together with various high consumption of chemicals such as chromium, urea, solvents in leather processing industry. The strong characteristics of wastewater exhibits high Chemical Oxygen Demand (COD) and Total Kjeldahl Nitrogen (TKN) levels around 2500 mgCOD/L and 240 mgN/L, respectively after the primary sedimentation (Ateş, 1997; Murat et al., 2002). Considering the EU discharge standards, high treatment efficiencies are required to achieve optimal COD and nitrogen removal. Stringent effluent limitations applied to domestic and industrial wastewaters, often without any concern for the restricting effect of temperature on treatment performance. Industrial scale wastewater treatment systems treating especially high-strength industrial wastewaters face severe limitations, imposed by the nature of biological processes related to COD and nitrogen removal in meeting effluent restrictions (Orhon et al., 1999; Murat et al., 2003). Primary concern is generally placed upon the increase of wastewater treatment efficiency. However, another major problem is the sludge management which generally is an underestimated issue especially during the operation of industrial scale WWTPs. The amount and characteristics (ie. high organics content, toxic materials) of sludge make it difficult to find and apply optimal sludge management strategy in reality.

Considering the municipal wastewater treatment plants achieving nutrient removal, sludge treatment and disposal are often the most important cost factors. The investment costs for the sludge treatment facilities are about one third of the costs of the total wastewater treatment plant. On the other hand, the operating costs for sludge treatment, disposal and reuse stays around 50% of the total operational costs of municipal WWTPs (Nowak, 2005). Accordingly, a reduction of the sludge treatment costs can significantly reduce the total costs of wastewater treatment. In order to minimise odour emissions and reduce the organic content of the sludge sludge stabilisation/treatment is required (CEC, 1986; 2000). The stabilisation can be carried out aerobic or anaerobically (Metcalf and Eddy, 2003).

In this study, most appropriate treatment and disposal alternatives for the sludge originated from leather tanning wastewater treatment plants were evaluated on the basis of process evaluation and cost analyses.

PROBLEM DEFINITION

In this study, the treatment and disposal alternatives for the sludges generated from a preselected leather tanning wastewater treatment plant are evaluated. The layout of wastewater treatment plant is given in Figure 1. Shortly, the WWTP diagram consists of equalization, primary sedimentation, activated sludge reactor, final clarification and discharge unit. The primary sedimentation is incorporated because of particulate COD together with chromium-III removal just before entering the biological unit. The sludge retention time is kept around 12 days by wasting sludge from return sludge. The WWTP has additional gravity thickeners and belt press unit. Primary and secondary sludge have the suspended solids contents around 3% and 1%, respectively. The solids content of PS is 2.7 folds of secondary sludge solids content.

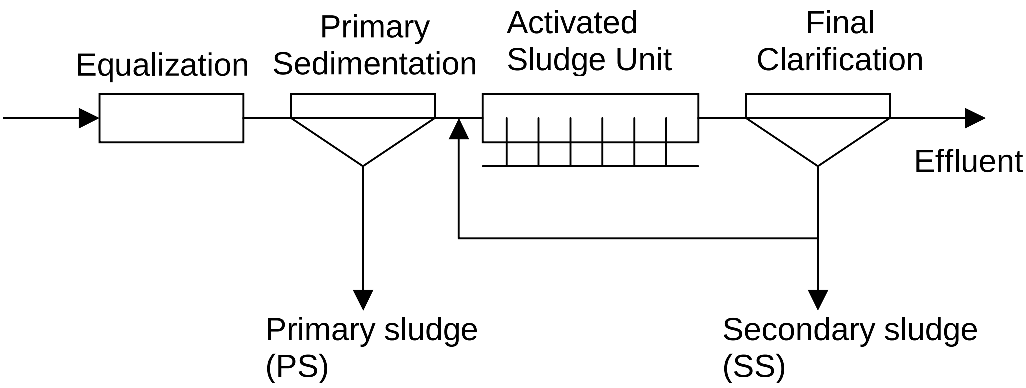

Figure 1. Layout of wastewater treatment plant

The daily capacities of wastewater treated and sludge generation are above 12,000 m^3/day and 2000 tonnes/day, respectively. The sludge treatment (ie dewatering and digestion) was required because of the fact that the sludge treatment costs are more than one third of the operational cost of the treatment plant. The wastewater characteristics with respect to certain parameters are listed in Table 1.

Table 1. Wastewater characteristics after primary sedimentation

Parameter	Unit	Average	Range
Total COD	mgCOD/L	5090	3235-7420
TSS	mg/L	2230	1470-3474
VSS	mg/L	1050	540-1215
TKN	mgN/L	360	112-640
Total Cr	mgCr/L	115	58-213
Alkalinity	mg/L	1350	797-1818
Chloride	mgCl^-/L	10300	6370-12800
pH	-	8.0	6.4-9.9

SLUDGE TREATMENT SCENARIOS

The main objectives in sludge treatment and disposal are regarded as (i) increasing the solids content will result in sludge volume reduction, and (ii) decreasing the organic content of the sludge via sludge stabilization. However, different treatment units can be used to achieve those objectives, however, the combinations of those units may yiled optimal solution. First, different treatment units were discussed below, individually.

Latterly, the combination alternatives for different units were elaborated as best applicable technology for this case.

Sludge treatment units

Different sludge units require variable sludge characteristics mainly the solids content in order to maintain optimal operation conditions. The sludge treatment units and specifications are given in Table 2. The table summarizes the aims of use, energy requirement and design and operational conditions of each unit.

Table 2. Sludge treatment units

Unit	Abr.	Aim/Use	Energy Req.	Design/Operational Conditions
Mechanical Screen*	MS	Coarse particulate material removal to provide clogging	Low	TSS Removal upto 50% depending on screen mesh
Gravity Thickener	GT	Increase the solids content of the sludge upto 2-3%	Low	Sizing depending on surface solids loading
Mechanical Thickener	MT	Increase the solids content of the sludge upto 5-7%	Moderate	Capacity depending upon belt size and type (Polymer)
Decanter Centrifuge	DC	Increase the solids content of the sludge up to 30%	High	Capacity depending upon drum size (Polymer)
Anaerobic Digester	AD	Decrease the VSS content by 50% and generate CH_4, H	Energy Production	4%-%6 solids input; ~%3 solids effluent
Sludge Drier	SD	Decrease the volume of the sludge disposed	Very High	Increases the solids content up to 90%

* MS is applied to raw wastewater

In general, the combinations of those units are used as sludge processing train in order to achieve optimal sludge treatment and to minimize the amount of generated sludge.

Process Alternatives

In this section, process alternatives containing various combinations of sludge treatment units were briefly evaluated. It should be noted that mechanical screen installation is an efficient way to reduce high influent TSS levels in the influent. Selected options are given as follows:

- **1. Mechanical Screen (MS):** is applied in order to remove total suspended solids in the influent wastewater. In that way, sludge production will be reduced based on the removal efficiency of MS.
- **2. MS+ Mechanical Thickener (MT):** In addition to MS, primary and secondary sludges are combined and subjected to mechanical thickener (Belt-press). 20% solids content can be achieved with the addition of polymer.
- **3. MS+MT+Decanter Centrifuge (DC):** Primary and secondary sludges are combined and subjected to mechanical thickener, then introduced to Decanter Centrifug. Upto 30% of solids content can be achieved with the addition of polymer.
- **4. MS+MT+DC+ Sludge Drier (SD):** In comparison to the previous option, solids content can be increased up to 90%. And generated sludge can be incinerated (ie. in cement factories). For this case, no incineration option is considered.
- **5. MS+MT+ Anaerobic Digester (AD):** The anaerobic digesters require 4-6% solids content for the optimal design and operation (Metcalf and Eddy, 2003). Electrical energy can be recovered, mostly by means of combined heat power units (CHP). The organic content of the sludge is reduced. However, few issues have to be considered and necessitate further study for process design. These are mainly the high sulfate (SO_4) concentration in wastewaters around 1500 mg/L, which results in organic matter consumption together with highly toxic H_2S generation during digestion. Second issue is the toxicity level of chromium for methanogens around 300 mg/L (Speece, 1996). In sludge stream, 1500 mg/L total chromium was measured that is higher than reported toxicity level. Hence, before chromium recovery and desulfurization during anaerobic digestion can be required. After anaerobic digestion of sludge, available gravity thickeners and belt press units are to be used before disposal. In this study, only the anaerobic digestion was only applied to the secondary sludge because the primary sludge has very high chromium content.
- **6. MS+MT+AD+Decanter Centrifuge (DS):** In addition to anaerobic digestion, the solids content can be increased upto 90% by decanter centrifuge.

It should be noted that higher solids content results in generation of reduced amount of sludge volume, which will decrease the transportation expeditures.

COST EVALUATION FOR PROCESS ALTERNATIVES

Different alternatives were evaluated on the basis of investment cost, yearly operational cost and payback periods in Table 3. Figure 2 summarizes the total costs as well as yearly savings, which serve as a basis for the calculation of payback periods.

Table 3. Investment and yearly operational costs for different alternatives (USD)

Alternative	Investment Cost	Operational Cost	Total Cost	Payback Period
1. MS	170,000	17,000	187,000	5 months
2. MS+MT	290,000	29,000	319,000	8 months
3. MS+MT+DC	600,000	60,000	660,000	15 months
4. MS+MT+DC+SD	5,400,000	195,000	5,595,000	9 years
5. MS+MT+AD	2,690,000	36,000*	2,726,000	5.5 years
6. MS+MT+AD+DC	3,000,000	66,000*	3,066,000	5.7 years

***** energy recovery from AD is included

Among alternatives, mechanical screen seems to be a better option that can be incorporated in all investment because it requires low investment cost having short payback periods. Moreover, it provides more advantages on the reduction of suspended solids at the beginning. The alternative # 4 is the most expensive solution because of sludge drying unit. As a result, the payback period increases up to 9 years, which does not seem to be feasible compared to others alternatives. In Figure 2, total costs vs yearly savings were illustrated for the alternatives except for the 4^{th} option.

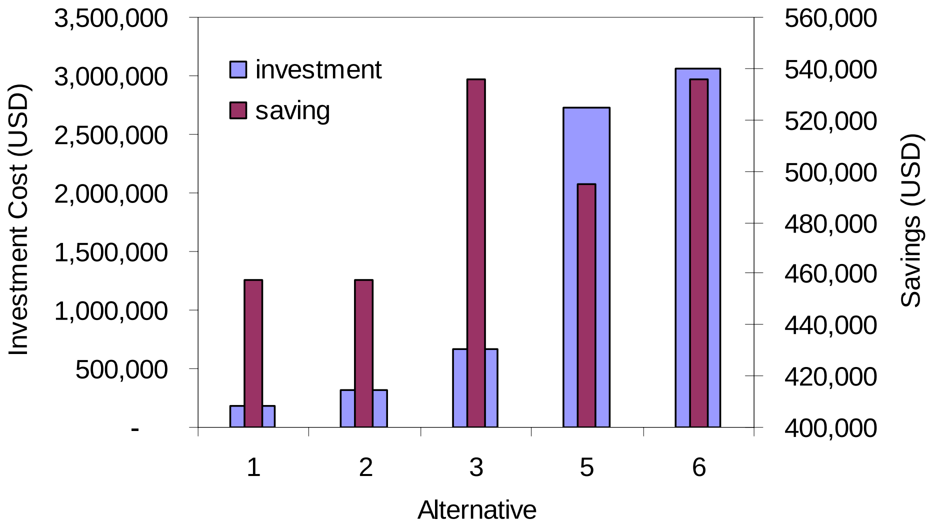

Figure 2. Investment cost and yearly savings for the alternatives

The digestion of sludge anaerobically provides electrical energy and reduces the investment costs. This is also clear from shorter payback periods around 5 years. The payback period migh even be shorter, around 2-3 years, if the primary sludge is regarded in anaerobic digestion. For a shorter period, alternative number 3 seems to an optimal solution. However, much energy can be produced if anaerobic digestion is applied on PS and SS, together. In addition, more stabilized sludge is obtained in terms of pathogens and organic content of sludge to be disposed.

CONCLUSIONS

Sludge treatment and disposal is one of the most important issues in industrial scale wastewater treatment plant. Depending upon the wastewater type and plants operation conditions sludge generation exhibit high variation in terms of production and characteristics. In leather industry different alternatives can be used for the reduction of sludge volume together with and energy generation. Many factors play important role on the selection of best alternative for sludge treatment, dewatering and disposal. Since each treatment plant has different features, the optimal solution would differ from case to case. Anaerobic digestion plays important role in the reduction of solids content as well as energy generation. Thus, the use of primary and secondary sludge should be considered in anaerobic digestion in order to generate energy. Chromium recovery from the sludge and reduction of sulfate can enhance the effectiveness of AD. However, more experimental study is required in order to maximize the energy generation from sludge generated from leather tanning wastewater treatment plant facilities.

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