ELSEVIER

Journal of Cleaner Production 7 (1999) 43–47

Journal of Cleaner Production

Industrial waste minimization initiatives in Thailand: concepts, examples and pilot scale trials

S. Vigneswaran [a,*], V. Jegatheesan [a], C. Visvanathan [b]

[a] *Environmental Engineering Group, Faculty of Engineering, University of Technology-Sydney, PO Box 123, Broadway, NSW 2007, Australia*
[b] *Environmental Engineering Program, Asian Institute of Technology, GPO Box 2754, Bangkok 10501, Thailand*

Received 12 January 1998; accepted 27 July 1998

Abstract

Industrial waste pollution control is a major issue in waste management. To comply with the specific effluent standards, industries are forced to treat their waste before discharge. This is neither a cost effective nor an environmentally friendly solution. The first part of this paper presents different techniques by which the waste minimization can be achieved with examples. The second part of the paper highlights the waste minimization efforts made in three different types of industries, namely paper and pulp, tapioca starch and palm oil. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Industrial waste; Thailand; Pilot scale trials

1. Introduction

Along with rapid industrialization, which has resulted in the rise of pollution, there is a growing concern about the quality of the living environment. Requirement on good quality of the living environment has resulted in the change in thinking of the whole concept of pollution control. Industries have traditionally treated the waste products before discharging them to the environment. Because the treatment occurs after the production of waste, this type of treatment is called 'end-of-pipe' treatment and this is being seriously questioned. The alternative solution, 'waste minimization', aims at reducing the pollution problem by dealing with it during the manufacturing process itself. There are many ways by which waste minimization can be achieved and they are discussed in the subsequent sections.

2. Waste minimization methodologies

Past experiences have proven that the following measures have been successful in achieving waste minimization: improved housekeeping, changing process technology, changing product, changing input material, recycling process chemicals and raw materials, recovering by-product/waste and reducing input to the process. The appropriate technology depends on the type of industry and its size and location.

2.1. Improved housekeeping

Good housekeeping in an industry implies that the management and employees of the company are diligent in ensuring that they comply with all environmental regulations, and in seeking ways in which the waste they generate and the resources they use are kept to a minimum. The following steps in housekeeping can lead to significant waste minimization: (1) an improvement in monitoring and operations of all phases of the production process, (2) schedule process in view of equipment cleaning (for example, formulation of light paints before dark paints will need no cleaning of vat before batches), and (3) improved management of raw material and products inventory. Apart from that, reduction in raw material and product loss and provision of training to the employees can be effective means to improve housekeeping.

* Corresponding author. Tel.: + 61-2-95142653; Fax: + 61-2-95142633; E-mail: s.vigneswaran@uts.edu.au

PII: S0959-6526(98)00035-3

2.2. Changing process technology

This is an important technique for reducing waste volume and strength. Some examples are: (1) alteration in washing/cleaning procedure such as using counter current washing, recycling of used solvent and reducing the cleaning frequency, (2) employing new methods in production line cleaning, (3) changing waste transport method (waste from a poultry farm can be transported by mechanical means instead of using water), and (4) introducing biological degreasing in metal parts cleaning.

2.3. Changing product

Changing products which can serve the purpose of those which they substitute can bring waste minimization as in the cases of batteries (non-rechargeable to rechargeable), spray cans (volatile chemicals to water soluble formulations) and refrigerators (chlorofluoro-carbons to ammonia or environmentally safe materials).

2.4. Changing input material

1. In printing, water based inks can be substituted for chemical solvent based inks to bring waste minimization in solvents and to prevent air pollution due to the evaporation of solvents;
2. in textiles industries, the phosphate-containing chemicals can be reduced;
3. water based film developing systems can be replaced with dry systems in electronic components; and
4. in painting of electrical light components, powder paints can be used instead of organic solvent based paints [1]. Table 1 gives the annual painting cost before and after the implementation of pollution prevention. From the table it can be seen that the payback period for the powder paint equipment is less than a year.

2.5. Recycling process chemicals and raw materials

Following are the examples in recycling: (1) vapour recovery in printing, (2) dye recovery in the textile industry, (3) copper recovery in electroplating, (4) paint and water recovery in the car painting industry, (5) cutting oil recovery in machine workshops, (6) dye recovery in the jeans industry, and (7) water recovery in the red meat abattoir industry.

Table 2 summarizes the membrane requirement and its cost and the amount of indigo dye recovered in the jeans industry [2]. From the figures given in the table, it is clear that the payback period for the ultrafiltration system is about a year and after this the savings every year will be around US$400,000. Similarly, Table 3

Table 1
Economic benefit due to the introduction of pollution prevention in painting of electrical light fixtures (adopted from Ref. [1])

Parameter	Cost (SEK)	Total (SEK)
Annual painting cost before the implementation of pollution prevention		
Paint (53,000 l)	1,993,200	
Paint thinner (18,000 l)	135,500	
Painting equipment cleaning	88,200	
Waste management costs	254,400	
Powder paint (21,000 kg)	684,000	
Four painters (full time)	1,200,000	
Combustion system fuel	240,000	4,535,300
Annual cost after the implementation of pollution prevention		
Powder paint (50,000 kg)	1,644,000	
Two painters, full time	600,000	2,244,000
Savings in the first year:		
Operating cost		2,300,000
For not having to pay the start-up costs for the combustion system		204,000
Total		2,504,000
Investment in the powder paint equipment		2,300,000
Savings in the first year		204,000
Payback period for the powder paint equipment is less than a year		

Table 2
Savings from indigo dye recovery in jeans manufacturing industry

Item	
Cost of membrane modules	US$100,000
Cost of membranes	US$300,000
Indigo recovery	20,000 kg/year
Savings @$20/kg indigo	US$400,000
Payback period of ultrafilter system	1 year

Table 3
Cost estimation for the recovery of paint and rinse water in a car industry (adopted from Ref. [3])

Capital cost	
Modules, pumps, control units, etc.	$450,000
If the amortization period is 5 years, then amortization/year	$90,000/year (a)
Operating cost	
Energy: 3 pumps at 18 kW $\times$ 8000 h/year $\times$ 6 cents/kW/hr	$25,920/year
Maintenance: changing membranes once in 3 years	$23,000/year
Annual operating and maintenance cost	$48,920/year (b)
Material recovery	
Paint: 9 g/m^2 $\times$ 4500 m^2/h $\times$ 3500 h/year $\times$ $0.01/g	$1,417,500/year
Demineralized water	$135,000/year
Annual saving	$1,552,500/year (c)
Economy due to material recovery [(c) $-$ (a) $-$ (b)]	$1,413,580/year

shows the cost estimation in the implementation of raw material recovery (paint and rinse water) in a car industry that adopted cathodic painting [3]. An economy of US$1.41 million was envisaged for the first five years due to amortization of ultrfiltration unit and the economy increased to US$1.55 million after five years.

2.6. Recovering by-product/waste

Some industries applying this technique are: pulp and paper, dairy, pig farms, and food processing industries such as pineapple, soup and desiccated coconut.

3. Waste minimization efforts in pulp and paper industry

3.1. Waste recovery and wastewater recycling

In the Siam paper industry in Thailand, a feasibility study indicated that installation of a settling cone not only reduced the extent of waste treatment but also permitted the wastewater recycling [4]. The settling cone allows use of 100% of waste paper as raw material and recycling of 15,000 m^3/day of treated wastewater. This leads to a saving of 73% of the annual operating cost (A$500,000/year).

3.2. Change in process chemical

About 50% of the pollution load (COD) of the pulp and paper industry is due to bleaching. In chlorine/caustic bleaching, 80% or more of the total bleach plant COD comes from the chlorination and alkaline extraction stages. Moreover, toxic, mutagenic or carcinogenic effects of bleaching effluents are primarily caused by organic chlorine compounds formed in the prebleaching stages. Therefore, it is necessary to reduce the pollution load of these stages. Oxygenated water (H_2O_2) was found to be an efficient bleaching agent at a comparable cost (A$87.5/ton), although handling of H_2O_{22} was a problem.

3.3. By-product recovery

Black liquor (a high strength waste generated in digestion process) contains both high and low molecular weight lignosulfonates. Fig. 1 shows the implementation of ultrafiltration to segregate higher and lower molecular weight lignosulfonates in a paper mill in France [5]. A study made by Bang-Pa-In pulp and paper industry in Thailand has shown that high molecular weight lignosulfonates can be separated from the low molecular ones by using an ultrafiltration process with a membrane of molecular cut-off size of 2000. This not only leads to the treatment but also to by-product recovery of commercially valuable high molecular weight lignosulfonates.

4. Waste minimization in the tapioca starch industry

Tapioca starch production is one of the major food industries in South East Asia. Thailand is a major producer and earns more than 1500 million Baths (A$750 million) per year from the exports of tapioca starch [4]. During the production process, wastewater originates from both the root washing stage and from separators. The combined wastewater from these two sources amounts to an average of 20 m^3/ton of starch. Its BOD range is 3000–16,000 mg/l (COD ranges from 5000 to 36,000 mg/l). The conventional treatment method adopted is a ponding system: anaerobic followed by facultative and aerobic ponds. The other possible treatment methods include aerated lagoon and rotating biological contactor (RBC). Treatment using torula yeast with reclamation of single cell protein, anaerobic digestion with biogas production and fermentation for ethanol production are other alternatives with by-product recovery.

4.1. Reuse of root wash water after sedimentation

In the production process, it is possible to reuse the root wash water. It mainly contains cork cells, sand and clay particles. The BOD_{55} values of this washing water range from 200 to 500 mg/l during the dry season. This water can be reused again in the washing process after treating it using sedimentation. During the wet season, BOD_{55} is about 1700 mg/l. It is suggested that chemical coagulation followed by sedimentation is likely to produce a treated wastewater suitable for recycling.

4.2. By-product recovery of yeast from tapioca wastewater

Single cell protein can be produced from organic wastes. Torula yeast can be used to treat tapioca starch separator waste. Torula yeast could acclimatize and grow predominantly in the waste, reducing sugar and volatile acids being readily removed. By this treatment, overall COD reduction was about 73%. The yeast mass produced contained about 50% protein with a yield of 0.5 kg/kg COD removed. But nitrogen addition of 1 kg/50 kg COD removed is required. If nitrogen is not added, the protein content of the yeast decreases significantly. The effluent of yeast production process still contains relatively high residual COD and would require further treatment before discharge.

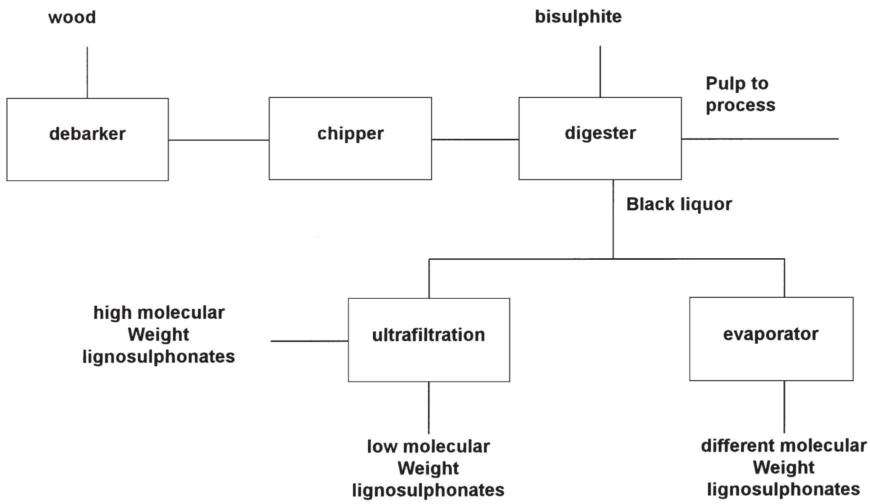

Fig. 1. Preindustrial implementation of ultrafiltration of black liquors in a paper mill, Landes, France [5].

4.3. Biogas production

The anaerobic treatment of tapioca starch wastewater in the filter reactors is feasible according to the study conducted at King Mongkut's Institute of Thailand. The results also indicate that: (1) even after 13 months of operation, there was no significant clogging and sludge accumulation, and (2) the capital recovery of installation of anaerobic digester is less than five years for tapioca factories with 100 t/d capacity. The performance of anaerobic filter at various organic loadings and hydraulic retention times are given in Table 4 and gas yield is presented in Table 5. Further, a pilot scale study conducted with an anaerobic filter and an ultrafilter as post treatment unit indicated that a superior removal efficiency of COD can be achieved. For example, when an ultrafilter with a molecular weight cut-off size of 1,000,000 was used the COD was reduced to less than 200 mg/l.

Table 5
The amount of gas yield from tapioca starch wastewater of various strengths

HRT (day)	Wastewater strength, COD (mg/l)	Gas yield (m^3/m^3 digester)	Gas yield (m^3/m^3 wastewater)
8	13,000	0.50	6.7
	17,000	0.60	8.0
	25,000	0.82	10.8
	35,000	1.70	22.8
6.3	29,000	1.01	11.0
	43,000	1.60	17.6

4.4. Ethanol production

A study conducted at King Mongkut's Institute of Thailand revealed that alcohol production from tapioca

Table 4
The performance of 20 l downflow anaerobic filter reactor at various organic loadings and hydraulic retention time (HRT)

HRT (day)	Organic loading (kg COD/m^3 digester)	Gas production/day			COD reduction (%)
		(m^3/m^3 digester)	(m^3/kg COD loaded)	(m^3/kg COD utilized)	
12	0.60	0.50	0.94	1.13	83
	0.80	0.60	0.82	1.00	80
	1.20	0.90	0.84	0.96	88
8	0.90	0.50	0.61	0.76	79
	1.30	0.82	0.64	0.86	75
	1.90	1.12	0.58	0.82	72
	2.60	1.70	0.64	0.86	75
6	2.40	2.04	0.85	1.24	68
4	1.90	1.15	0.60	0.70	87
	3.25	2.00	0.60	0.72	88

wastewater is a possible alternative to reduce effluent treatment in the industry. Although technically feasible, further research and development are necessary to determine its economic feasibility. The production process consists of three steps: (1) hydrolysis, (2) fermentation, and (3) distillation.

5. Waste minimization in palm oil industry

The palm oil industry is a major one in Thailand and Malaysia [4]. Malaysia itself produces about 3.5 million tons of palm oil per year and the industry contributes 83% of the industrial organic pollution load and ranks as the country's single largest polluter. Reuse and recycling of waste were found to be viable alternatives leading to a clean technological solution.

5.1. Water conservation

In most palm oil mills, water consumed is more than the required amount. It must be limited to cut down waste quantities. The following methods can be adopted to reduce water consumption to considerable extent: (1) reusing turbine cooling water, overflow from vacuum dryers and steam condensate from boiler house after cooling in a storage tank; they may be reused in processing, cleaning and washing; (2) stopping overflows from the overhead tanks with the use of floating valve, in the press station and oil clarification room; and (3) providing proper fittings and taps to prevent wastage through leakages, etc.

5.2. Waste strength reduction

Strength of wastewater is influenced by the oil and grease content. As much oil and grease as possible should be recovered to reduce the strength of wastewater by installing oil traps, etc.

5.3. Process modification at clarification

A decanter can be provided between the vibrating screen and the oil clarifier to separate minute solid materials from crude oil prior to oil clarification. The settled oily sludge from oil clarifier is discharged into a three-phase nozzle centrifuge, where it is centrifuged to recover oil which is then pumped back to the clarifier. Sludge is produced as a solid waste which can be disposed on land and the liquid phase recycled back to press and oil clarifier to make up dilution water. Hydrocyclone is used to separate kernels from cracked shells resulting in a continuous discharge of wastewater. This is known as the wet process. Dry process can also be used whereby a wind silo (where air is blown from the bottom) is used to separate kernels from cracked shells by gravity.

5.4. Resource recovery and reuse

1. Palm oil mill waste has been found to be quite suitable for animal feed when properly prepared and treated. The animal feed can substitute maize;
2. the recovered fibre is used as fuel for production of steam in boilers;
3. the sludge would be suitable as fertilizer due to its nutrient content and can be used as a source of nitrogen, potassium and magnesium for the palm oil plant itself; and
4. methane can be produced as a by-product through anaerobic digestion. This can be utilized for domestic purposes or in the industry itself.

6. Conclusion

All the case studies illustrated above clearly indicate that simple waste minimization techniques can lead to a sustainable solution for waste management.

References

[1] Huisingh D, Bass LW. European Water Pollution Control 1991;1(1):24.
[2] Vigneswaran S, Visvanathan C, Jegatheesan V. Industrial waste minimization. Environmental Management and Research Association of Malaysia (ENSEARCH), Petaling Jeya, Malaysia, April 1998, 1557.
[3] Roulet M. Les applications industrielles de l'ultrafiltation, techniques separatives sur membranes. Lyon: Cycle ICPI, 1984.
[4] Vigneswaran S, Muttamara M, Srianandakumar K, Ben Aim R. Low waste technologies in selected industries. Thailand: Environmental Sanitation Information Center (ENSIC), Asian Institute of Technology, Bangkok, Thailand, 1989, 867.
[5] Ben Aim R, Vigneswaran S. ENFO, Environmental Sanitation Information Center (ENSIC), Asian Institute of Technology, Bangkok, Thailand, 1988, Vol 10, No 1, pp 1–3.