A compatibility study of the effects of dairy and brewery effluents on the treatability of domestic sewage

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Abstract

It is generally accepted that industrial waste waters are more complex than domestic sewage, and relatively more difficult to treat. While the organic matter component of domestic wastes can generally be classified into 65% protein, 25% carbohydrates, and 10% fats; industrial effluents vary in composition from one industry to another because of differences in starting materials (products handled) and manufacturing processes. This wide variability often presents serious problems in waste-water treatment plant design and operation. However, not all industrial wastes are detrimental to the efficient operation of biological treatment processes.

A study of the treatment of domestic, dairy, and brewery waste waters, as well as 50/50 mixtures (by volume) of the domestic with the dairy and separately with the brewery waste water in laboratory-scale anaerobic ponds was carried out. Five model anaerobic ponds, each with a working capacity of 48 ℓ were used for the treatment studies. The ponds which were in continuous use for about 3 months were operated at average retention time of about 4 d and volumetric organic loading rates ranging from 0,081 kg BOD/m^3·d (for the pond treating the domestic sewage) to 1,147 kg BOD/m^3·d (for the pond receiving the brewery waste water).

The results show the average COD and BOD reduction efficiencies to be generally higher than 60% and the BOD/COD ratios for the 5 influent feeds as well as the effluents from the model ponds to be greater than 0,50.

The relative degree of biodegradability of the 5 influent feeds was assessed on the basis of the values of the BOD/COD ratios. The results indicate that the dairy and the brewery wastes have no adverse effect on the treatability of the domestic sewage. Furthermore, the effluents from the 5 ponds have BOD/COD ratios within ranges that are generally accepted as indicating a high degree of biodegradability. They would therefore not be expected to have any adverse effect on the efficiency of secondary biological treatment processes.

Abbreviations

BOD = biochemical oxygen demand
COD = chemical oxygen demand
DO = dissolved oxygen
Eff. = effluent
Inf. = influent
KCC = Kenya Co-operative Creameries

Introduction

Industrial effluents may have 3 major effects on sewers and waste treatment plants:

- They may pose great risks to the health and safety of sewer operators
- They may cause the degeneration of the structural strength of sewers
- They may result in reduction of the efficiency of the treatment works.

It has therefore been generally suggested and widely accepted that industrial effluents must be pretreated to acceptable standards before discharge into the municipal sewers.

Industrial effluents can generally be classified into 4 broad groups (Kilani,1985):

- Effluents from food and drink industries, e.g. dairy
- Effluents from industries using animal or vegetable materials as raw material; e.g. paper pulp mill and tannery
- Effluents from metal industries, e.g. iron and steel rolling mills
- Effluents from chemical industries, e.g. petroleum and pharmaceutical.

Waste water from the first 2 classes is generally biodegradable while effluents from metal industries are not easily biodegraded and are often toxic, even at very low concentrations. Wastes from chemical industries are very complex because of the non-uniformity of most of their products. Since all dissolved or colloidal organic matter does not oxidise at the same rate, with the same ease, or the same degree, the rate of decomposition of biodegradable industrial wastes, such as food, and animal or vegetable-based industries could either be faster or slower than that of sewage organic matter. Sanitary engineers do believe that this difference must be considered in the design and operation of biological units. Unfortunately, however, most municipal waste-water treatment plants are often designed, constructed and operational, long before requests from industrial establishments for admittance of their effluents into the domestic sewer system are made to the municipal authorities.

Municipal authorities will be wise not to accept any waste discharges into the domestic sewer system without first learning the facts about the characteristics of the wastes, the sewage system's ability to handle them, and the effects of the wastes upon the system. They must take into consideration the oxidisability or biodegradability of such wastes before embarking on a joint disposal venture with private industries. A useful approach for this assessment is presented in this paper, based on investigation of the treatability of sewage/dairy and sewage/brewery wastes mixtures. The domestic sewage sample was from influent to the Kariobangi Sewage Treatment Works in Nairobi, Kenya while the dairy and the brewery effluents were respectively from the Kenya Co-operative Creameries at Dandora and the Tusker Brewery at Ruaraka, both being suburbs of Nairobi.

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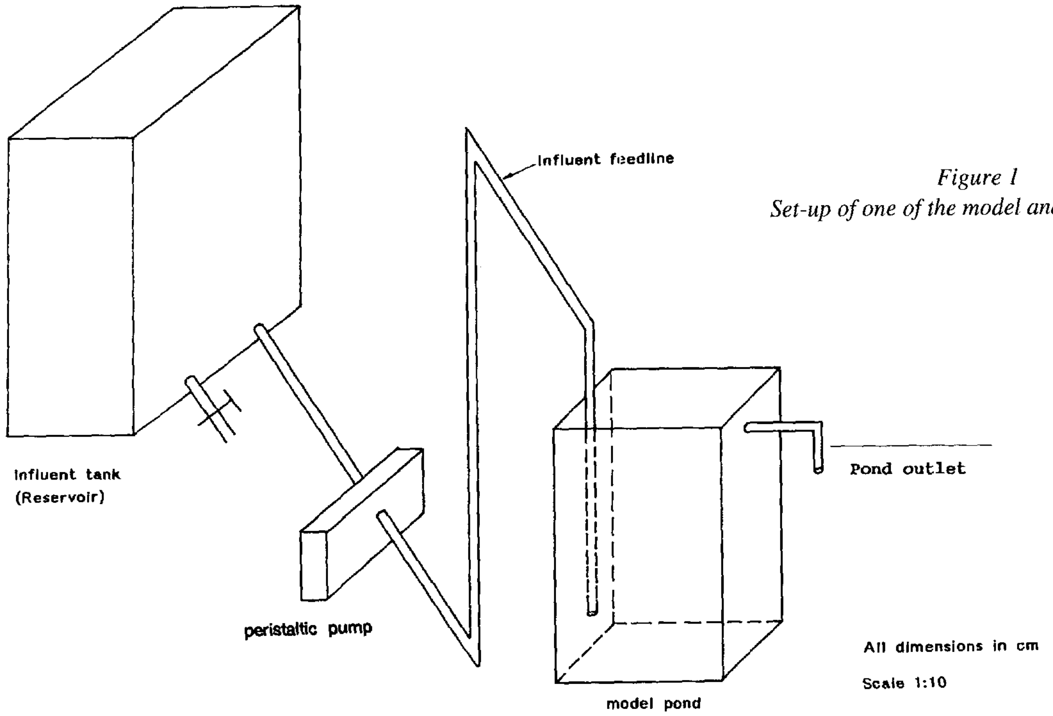

Figure 1
Set-up of one of the model anaerobic ponds

Biodegradability of dairy and brewery effluents

The biodegradability of dairy plant effluents has long since been established by many investigators (Kilani, 1985). Because of their composition, wastes from dairy plants are considered to be almost perfect foods for micro-organisms. With the exception of components such as detergents, caustic cleaning agents and bactericides used in hygiene control, dairy wastes have been reported (Herzka and Booth, 1981) not to pose any difficulty in treatment plants. Providing that suitable dilution with other waste streams is practised, even the above components usually have no adverse effect on treatment efficiencies.

Investigators (Groenewold, 1982; Harding, 1982; Jones, 1974; Nzainga, 1989) consider dairy wastes to be about the easiest industrial effluents to treat by biological methods. A BOD:N:P ratio of 100:3,2:1 has been reported (Kilani, 1985) for an effluent from a dairy food plant in Ontario. Jones (1974) reported BOD/COD ratios ranging from 0,10 to 0,88 with an average of 0,53 for industrial dairy food plant wastes. A report in literature (Kilani, 1985), based on analysis of wastes from 11 dairy plants, concluded that dairy wastes are rapidly and easily treated biologically because the BOD/COD ratio was found to be 0,63 and the BOD:N:P ratio to be 100:5,4:0.9. Other documentation of BOD5/COD ratios in the literature (Jones, 1974; Kilani, 1985; Nzainga, 1989) include: a value of 0,51 for effluents from 10 plants producing different types of dairy products, a range of 0,53 to 0,57 from laboratory analysis of effluents from 7 different Kraft dairy plants, and an average of 0,59 for waste water from a multi-product dairy plant. It is obvious from literature reports that dairy effluents generally have BOD/COD ratios higher than the minimum value of 0,5 recognised as indicating that a given waste water is biodegradable.

Wastes from the brewing industries have the advantage of containing materials that have very high reuse value. For example, the by-products from malting consist of germinated barley and malt dressings which have an attractive nutritional composition and could be sold as animal feed. Herzka and Booth (1981) listed the main by-products from brewing as: spent grains, surplus yeast, carbon dioxide, spent hops and broken glasses from bottling operations. Broken glasses could be recycled to the bottle manufacturer while a limited amount of spoilt beer is used in vinegar manufacturing. Spent grains are sold wet to farmers for direct feeding to livestock while surplus yeast is reported (Herzka and Booth, 1981) to be useful to specialist manufacturers for manufacturing products such as: Marmite,Vitamin B tablets and savoury biscuits. Carbon dioxide, produced in large quantities from beer fermentation, could be purified and liquified for internal brewery use, beer dispensing and carbonation of soft drinks.

The large volumes of strong effluents emanating from brewery plants, after recovery of by-products, are reported in literature to be readily biodegradable. Isaac and McFiggerns (1980) reported BOD/COD ratios greater than 0,5 for brewery effluents and concluded that brewery wastes are not very different from domestic sewage and could therefore be treated by the normal methods of biological treatment.

Experimental investigations

Five laboratory model anaerobic ponds were set up, as shown in Fig. 1, in one of the treatment site laboratories of the Nairobi City Commission. The rectangular models were made of 6 mm thick clear perspex and had top dimensions of 0,2 m x 0,4 m and a depth of 0,6 m. These gave each pond a working capacity of 48 ℓ.

The ponds together with their corresponding influent tanks and pumps were arranged on a bench about 800 mm above the floor. The model ponds were completely covered, all round, with black polythene sheets to exclude light. The 5 ponds labelled A, B, C, D and E (Fig.2) were fed with domestic sewage, dairy waste, brewery waste, 50/50 mixtures (by volume) of sewage and dairy waste, and sewage and brewery waste respectively.

Influent feeds

Domestic sewage

The sewage used for this investigation was obtained from the influent channel of the Kariobangi Sewage Treatment Works in Nairobi, for two reasons. First, the investigations were conducted at the Kariobangi Treatment Works laboratory; thus the influent to this treatment plant provided easy access for raw sewage samples. Secondly, because of the location of this plant, it is the least influenced by industrial effluent discharges.

Dairy waste

The dairy waste was obtained from the KCC at Dandora, Nairobi. The KCC plant which is located about 12 km from the city centre on the eastern side of Nairobi, has a daily production rate of about 300 000 ℓ/d and operates for 24 h, 7 d a week.

Before the commencement of the treatment studies reported in this paper, investigations based on an extensive sampling and analysis to determine the nature and characteristics of the waste were carried out and the results of these analyses are discussed in an earlier publication (Kilani et al., 1989). As at the time of this study, the waste water from KCC plant was discharged, without any form of pretreatment, to the trunk sewer leading to the Dandora waste stabilisation pond system.

Brewery waste

The brewery effluent used in this investigation came from the largest brewery plant in Kenya. The Tusker Brewery located at Ruaraka (about 6 km from Nairobi City Centre) produces about 2,25 million ℓ of beer per day.

The major waste-water generation activities at the Ruaraka plant are brewing, fermentation, bottling and washing. Because the waste water from the plant is discharged through 2 outlets, with the effluent from fermentation and brewing separated from that of the bottling and washing operations, the influent feed used in this treatment studies was made of a combined waste water based on a mixture of 50/50 by volume of the two separate discharges. Results of a 4-month monitoring of the effluents from the Ruaraka plant and the effects of the effluents on the Ruaraka River have been fully discussed in earlier publications (Kilani et al., 1989; Kilani and Otieno, 1991).

Treatment studies

During the start-up of the experiment, each of the 5 ponds was initially half filled with raw sewage from Kariobangi Sewage Treatment works, and filled up with the respective waste it was intended to treat (i.e. pond A was topped up with the same sewage while ponds B,C,D and E were topped up with the dairy waste, brewery effluent, sewage/dairy mixture and sewage/brewery mixture respectively). The ponds were then completely covered with black polythene sheets and left for about 2 weeks before continuous feeding with the respective influent feeds commenced. They were fed continuously, using peristaltic pumps at the rate of about 10 ℓ/d. Because of the highly biodegradable nature of the wastes, contents of the influent reservoirs were replenished each day with fresh influent feeds, taking care to store only the quantity of feeds required for each day's operation.

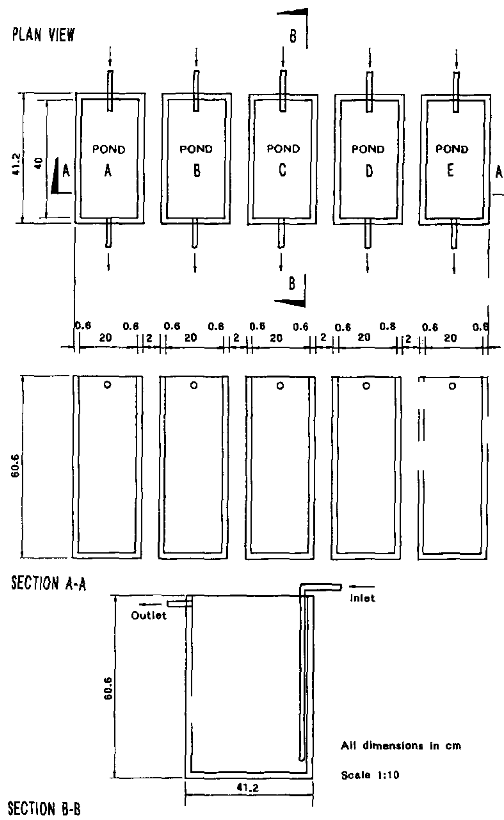

Figure 2
Layout of the 5 laboratory ponds

Sampling of the influents and effluents of the ponds commenced a week after continuous feeding had begun. Although the ponds were originally intended to operate at a constant retention time of about 5 d, the flow rates were found to be constantly changing as a result of frequent clogging of the influent tubes. Thus, daily measurement of the flow rates was made an integral part of the data collection.

The influents and effluents of the 5 ponds were sampled at alternate days and analysed for BOD, COD, SS, pH and alkalinity in accordance with *Standard Methods* (1975). Sampling was discontinued when sufficient data had been collected at quasi-steady-state conditions. Quasi-steady-state was considered to have been reached when not more than 5% variability occurred on 3 consecutive samples of effluent COD and this generally occurred after about 2 weeks from the commencement of continuous feeding.

Results and discussion

Table 1 gives the COD and BOD removal efficiencies for the 5 ponds while Table 2 shows the summary of the average characteristics of all the influent feeds and treated effluents from the ponds. Figures 3 and 5 show the variations in COD and BOD of the influent feeds. The variations in the COD and BOD of the effluents from the 5 ponds during quasi-steady-state conditions are shown in Figs. 4 and 6 respectively.

A careful look at the average BOD/COD ratios for the 5 influent feeds (see Table 2) shows that all of them have BOD/COD ratios higher than 0,5 indicating that they are

TABLE 1
PERFORMANCE OF THE MODEL ANAEROBIC PONDS

Pond	Influent quality COD (mg/ℓ)	Influent quality BOD (mg/ℓ)	Effluent quality COD (mg/ℓ)	Effluent quality BOD (mg/ℓ)	Removal Eff. (%) COD	Removal Eff. (%) BOD
A	610	325	243	121	60	63
B	2 853	1 920	990	585	65	70
C	8 299	4 589	3 319	1 733	60	62
D	1 722	1 151	653	375	62	67
E	4 442	2 538	1 777	1 001	60	61

TABLE 2
CHARACTERISTICS OF RAW AND TREATED WASTES

Waste type	Average BOD (mg/ℓ)	Average COD (mg/ℓ)	Average BOD/COD ratio
Raw sewage	325	610	0,53
Raw dairy	1 920	2 853	0,67
Raw brewery	4 589	8 299	0,55
Sewage/dairy (raw)	1 151	1 722	0,67
Sewage/brewery (raw)	2 538	4 442	0,57
Treated sewage	121	243	0,50
Treated dairy	585	990	0,59
Treated brewery	1 733	3 319	0,52
Sewage/dairy (treated)	375	653	0,57
Sewage/brewery (treated)	1 001	1 777	0,56

biodegradable. While the brewery waste water had an average BOD/COD ratio of 0,55 which is of the same order as for the domestic sewage (0,53), it is clear that the dairy waste with a BOD/COD ratio of 0,67 will degrade faster than the domestic sewage. The corresponding COD and BOD removal efficiencies of (65%, 70%); (60%, 63%); and (60%, 62%) reported in Table 1 for the dairy, domestic and brewery waste waters respectively, confirm the expected trend of biodegradability of the 3 wastes.

Most significant is the fact that the dairy and the brewery wastes do not seem to have any adverse effects on the biodegradability of the domestic sewage. The results show that there was little difference between the percentage COD reductions achieved for ponds D and E receiving the waste mixtures and pond A receiving the domestic sewage. However, the percentage BOD reduction achieved for pond D (67%) which had been fed on the mixture of domestic and dairy wastes was higher than those achieved in Pond A (63%) receiving the domestic sewage and Pond E (61%) which had been receiving the mixture of domestic and brewery wastes.

Clearly, the domestic waste appeared to have a positive influence on the 2 industrial effluents. While anaerobic pretreatment of the dairy waste could be expected to result in reductions of COD and BOD concentrations from 2 900 to 1 000 mg/ℓ and 1 900 to 600 mg/ℓ respectively, a 50/50 by volume dilution with domestic sewage resulted in average COD and BOD concentrations of 1 700 and 1 200 mg/ℓ for the composite waste water which represent about 40% reductions in the respective COD and BOD concentrations of the original dairy waste. The effect of the domestic sewage on the brewery waste is even more pronounced, where a 50/50 by volume dilution resulted in lowering the COD and BOD concentrations of the brewery waste from 8 300 mg/ℓ to 4 500 mg/ℓ and from 4 600 mg/ℓ to 2 500 mg/ℓ respectively, representing reductions of about 45% in both parameters.

The average BOD/COD ratios reported in Table 2 for the effluents from the 5 model ponds show that they are not likely to have any adverse effect on the subsequent biological treatment stage. The treated sewage/dairy mixture has COD (650 mg/ℓ) and BOD (380 mg/ℓ) concentrations of the same order as the raw sewage (610 mg/ℓ and 320 mg/ℓ respectively). Thus any biological waste-water treatment system suitable for treating domestic sewage should be able to handle the pretreated domestic/dairy waste mixture without any modifications in its capacity or operational parameters. However, secondary biological processes required to treat pretreated dairy and brewery wastes, as well as domestic/brewery wastes mixture will require slightly higher capacities to handle expected increases in organic and hydraulic loading rates.

It is significant to note from the results that mixing the treated dairy and brewery effluents with raw sewage is likely to result in composite wastes that can easily be handled by biological sewage treatment systems without any need for modifications. Therefore, the current practice of discharging the KCC waste into the municipal sewer without any form of pretreatment, with the resultant over-loading of the Dandora Sewage Treatment works, should be discouraged.

Conclusion

The treatment of dairy and brewery waste waters in model anaerobic ponds was found to be very successful, and the 2 industrial effluents have no detrimental effects on the biodegradability of domestic sewage. The results show that COD and BOD removals of about 65% and 70% respectively could be achieved when the dairy waste is treated in an anaerobic pond with an average retention time of about 4 d and volumetric organic loadings as high as 0,48 kg BOD/m^3·d. In the case of the brewery waste, COD and BOD removals of about 60% each could be achieved when treated in anaerobic pond operating at a 4-d retention time and organic loading of about 1,15 kg BOD/m^3·d. These results clearly lend credence to further work to assist in solving problems relating to industrial effluents disposal currently facing most developing countries.

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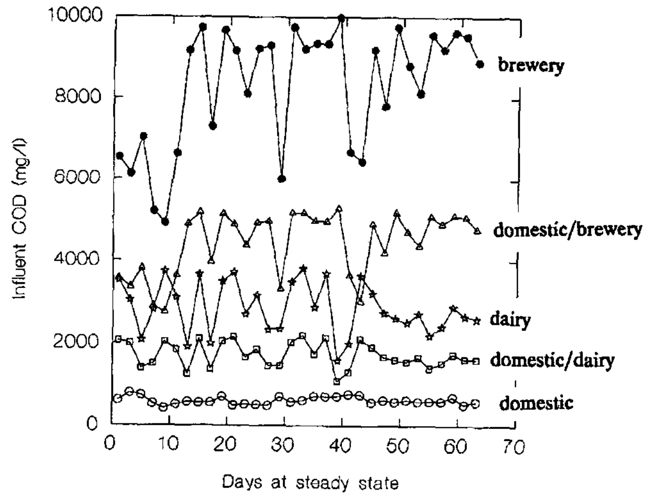

Figure 3
Influent COD for the model ponds

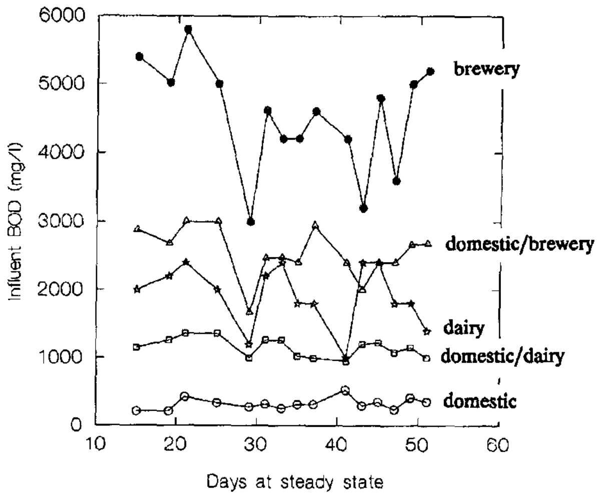

Figure 5
Influent BOD for the model ponds

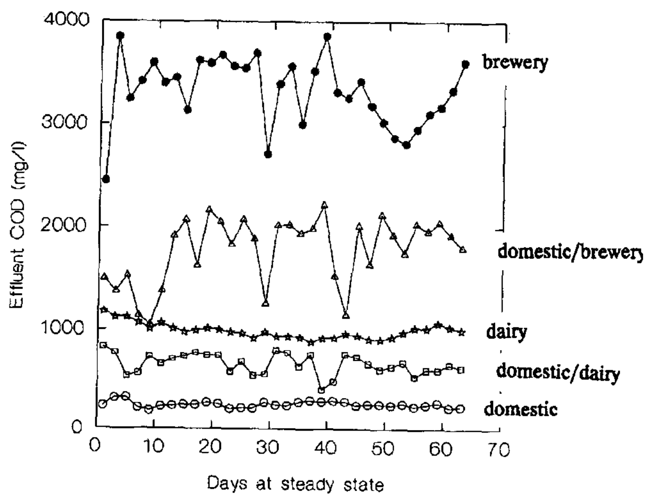

Figure 4
Effluent COD for the model pnnds

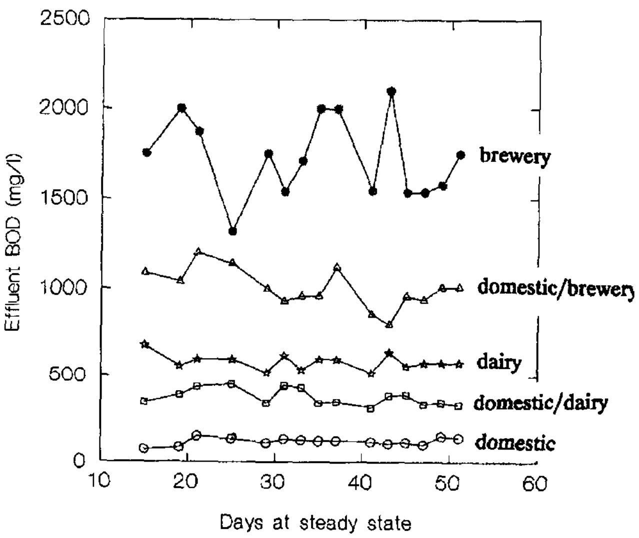

Figure 6
Effluent BOD for the model ponds

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