The Importance of the Choice of Rum Refinery Effluent Disposal Techniques in Fisheries Management, Coastal Zone Management and Biodiversity Conservation

GOBIND RAMESHWAR and L.E. CHINNERY
Department of Biological and Chemical Sciences
Faculty of Science and Technology,
The University of the West Indies
POB 64, Bridgetown, Barbados

ABSTRACT

Sugarcane molasses distillery effluent is produced in large volumes by refineries in Barbados and other territories in the region throughout the year. Because of its smell and colour, it has a negative effect on the aesthetic appeal of the environment. Most is disposed into the sea and as result of a combination of high biological oxygen demand, chemical oxygen demand, suspended solids and dissolved solids, elevated temperature and low pH, it degrades the marine ecosystems on which it impacts. This, in turn, affects fisheries management, coastal zone management and biodiversity conservation. Studies have shown that by suitable treatment, distillery effluent can be converted to fuel, fertilizer, animal feeds and food yeast thus reducing the hazards associated with discharging rum refinery effluent in both terrestrial and marine environments. This paper reviews methods of disposal and uses of sugarcane molasses distillery effluent. An attempt is made to show how the utilization of rum distillery effluent in agriculture can enhance fisheries development, promote integrated coastal zone management and fortify biodiversity conservation in Caribbean territories.

KEY WORDS: Pollution, recycling, stillage

INTRODUCTION

In the Caribbean, millions of gallons of molasses rum refinery effluent are being dumped into the sea from refineries. The refineries generally operate for more than 300 days each year and 24 hours per day. Studies have shown that this molasses rum distillery effluent (also called slops, vinasse, stillage, dunder, or lees) is potentially hazardous to the fisheries and tourism industries (Biamon and Hazen, 1983). Moreover, with the renewed commitment to integrated coastal zone management and species protection by small island developing states (SIDS), more prominence is being given to the negative effects of molasses distillery effluent to the environment. The latter concerns are attributed mainly to the high biological oxygen demand (BOD), high chemical oxygen demand (COD), elevated temperature, low pH and dark colouration of the effluent, which cause it to threaten the viability of many aquatic life forms, and significantly hamper some aquatic ecosystems that are important to fisheries and tourism. Thus, the choice of rum refinery effluent disposal technique is important in fisheries management, coastal zone management and biodiversity conservation.

Laboratory trials by researchers in India, Puerto Rico, Brazil and elsewhere have shown that distillery effluent can be converted to useful commodities, such as fuel, stock feeds, and fertilizers (Sheehan and Greenfield, 1980). Hence, the options for handling distillery effluent include both disposal and conversion into useful products. The latter can lead to a reduction in importation of these items and, by removing the bad odours and discolouration, render the environment more conducive to tourism.

To appreciate the concerns in disposal of distillery effluent fully, it is important to consider its composition (Table 1). The chemical composition of the effluent is determined by the processing techniques and additives used in the fermentation system and the molasses from which it was produced. The composition of the latter is directly dependent on a number of factors such as the composition of the sugarcane juice from which it was made. This, in turn, depends on the variety of sugarcane, soil type, and climatic conditions. Thus, the composition of molasses (Table 2) and distillery effluent can vary widely according to its source of origin.

Table 1. Inorganic constituents of rum distillery effluent, %w/w (Bieske,1979).

Component	Millaquin Distillery Queensland, Australia	Brazil (Average Values of a Number of Samples)
Ash	3.200	1.920
N	0.310	0.090
P	0.002	0.005
K	0.860	0.400
Ca	0.110	0.180
Mg	0.150	0.050

Table 2. The variation in composition of final molasses from eight sugar factories in Barbados (Blackburn, 1984).

Range	% by weight			
	Sucrose	Glucose and fructose	Water	Sulphated ash
High	36.48	30.19	19.95	11.2
Low	31.93	22.34	17.18	9.81

METHODS FOR DISPOSAL OF RUM REFINERY EFFLUENT

There are four main ways of disposing of distillery effluent:

i) direct discharge to an adjacent water body or land space,
ii) discharge into the sea at a considerable distance from shore, via a marine outfall or by barging,
iii) lagoon treatment, and
iv) treatment with sewage or municipal waste

Discharge into an adjacent water body or land site

Discharge of effluent either into an adjacent water body or adjacent land is usually the cheapest of the various "discharge options." However, disposal of rum refinery effluent on land has often encouraged the proliferation of flies, including *Musca domestica* Linn., which can be hazardous to human health (Usher and Willington, 1979). In the Caribbean, including Puerto Rico, the chief method of disposal is into the sea or river (Cooper and Prasad, 1976; Burnett, 1973). Apparently, the prevailing climatic conditions and the strength of current flow are very important in determining the efficiency of dilution of the effluent by this method (Bieske, 1979). Thus, for example, while there has been concern over the severe pollution of coastal waters by rum refinery effluent in Puerto Rico (Burnett, 1973) and the Caroni river in Trinidad (Cooper and Prasad, 1976), there has been no evidence of adverse environmental effects on the Burnett River in Australia, into which rum refinery effluent has been discharged by the Millaquin Distillery since 1889 (Bieske, 1979). It has been suggested that the strength of the stream flow in the latter case is sufficient to maintain a constant flow of diluted effluent into the ocean.

Although the significant adverse environmental effects of rum refinery effluent on water quality, and aquatic ecosystems have been recognised (Table 3), it is generally acknowledged that dilution in a conveniently located water body, such as a river or the ocean, is an acceptable interim method of disposal, while suitable options that will ensure product recovery, and lessen environmental hazards are being investigated (Bieske, 1979; Willington and Marten, 1982)

Discharge via a marine outfall or barging

Distilleries which are in close proximity to the sea, have the advantage of a low cost method of disposal via a marine outfall or via barging and deep water dumping. The latter, which according to Mr. C. Bynoe, former director of Mount Gay Distilleries Ltd. (pers. comm.) was once used in Barbados, requires a high operating cost and is dependent to some extent on the weather, and these factors tend to restrict its use (Willington and Marten, 1982).

The more popular option seems to be the use of offshore diffuser systems such as marine outfall pipes the design and location of which are determined after appropriate surveys of local tidal conditions, current profiles, and the sea floor, along with environmental impact studies on the adjacent ecosystems, particularly coral reefs that are known to be sensitive to nutrient loadings and reduced water quality. This method of disposal is enhanced by the proximity of large water depths and by strong currents in the area (Willington and Marten, 1982).

Table 3. Environmental impacts of alcohol stillage upon water quality and aquatic ecosystems (*Most significant impacts) (after Willington and Marten, 1982).

* Depletion of dissolved oxygen
* Discoloration
* Odours
Eutrophication
Salinization (in fresh water)
Acidification
Increase in water temperature (locally)
* Changes in species composition of aquatic flora and fauna
Fish kills (in extreme cases)

Lagoon treatment

In this method large volumes of effluent are subjected to anaerobic digestion in lagoons either situated singly or in sets of two or more in series. It is noted that this method of disposal requires a large amount of land space, and this may be limited by the high cost of land near to the distillery. It is estimated that approximately 4000 m^2 of land are required to treat 100,000 l of distillery effluent, with a minimum retention time of 20 days. In addition, there are likely to be odour problems, which may be significant when distilleries are located in urban areas (Sheehan and Greenfield, 1980) or near to tourist hotels. Dubey (1974, in Sheehan and Greenfield, 1980), however, indicated that lagoon treatment using sodium nitrate to reduce the BOD made it possible to reduce, and confine, the bad odours associated with rum refinery effluent.

Lagoon treatment has been adopted in several parts of India (Subba Rao, 1972) and Brazil (Willington and Marten, 1982) because of its advantage of providing fertilizers. Subba Rao (1972) demonstrated that the high BOD of stillage can be considerably reduced by using anaerobic lagoons, using cow dung as the seeding inoculant. This also has the benefit of reducing the negative aesthetic effects of the bad odour of farm manure.

Treatment with sewage

The method of aerobic treatment of distillery waste with domestic sewage, utilises the fact that the latter will facilitate dilution of the effluent, increase its pH, and provide bacteria, nitrogen and phosphorus, which are usually present in low concentrations in stillage, and render biological treatment difficult (Burnett, 1973). The efforts of several researchers, who used different ratios of stillage and sewage, were reported by Sheehan and Greenfield (1980). It has been found that when the percentage of distillery effluent in sewage is low (10%), the BOD removal is greatest. Though this method has the advantage of shorter retention times, as compared to anaerobic methods, and also facilitates biological treatment by cooling the hot stillage, in cases where treatment is done at the distillery plant, it is at present considered uneconomical, though research work is still being pursued in this area (Sheehan and Greenfield, 1980).

Other methods of treating stillage

Trickling filter treatment, the use of rotating biological contactors and physico-chemical treatment (details of which are given in Sheehan and Greenfield, 1980) have been shown to be generally uneconomical and/or inefficient.

UTILIZATION POTENTIAL OF MOLASSES DISTILLERY EFFLUENT

Anaerobic digestion to produce biogas

This method of effluent disposal is the most widely studied of the various techniques employed to dispose of rum refinery effluent by producing a useful by-product and was the first method to have reached pilot plant scale experimentation (Burnett, 1973). Operating details, such as loading time and retention time, are given in the literature (Hiatt *et al.*, 1973; Burnett, 1973; Sheehan and Greenfield, 1980). A wide range of possible sources of anaerobic bacteria may be employed with success, e.g. mangrove lagoon soil, fresh sewage, digested sewage sludge, horse manure, pig manure, and cow dung (Burnett, 1973).

With anaerobic digestion BOD reduction of up to 90% may be achieved and field trials have shown the resultant slurry to be an excellent crop fertilizer

(Boyce, 1988). Also, the methane gas produced is storeable, transportable, and burns with a clean flame (Willington and Marten, 1982). According to Keenan and Korni (1977), between 1.2 and 1.4 kilojoules of energy may be obtained from every gram of organic matter digested. Methane produced in excess of the refinery plant requirement may be sold either to other industries or to domestic consumers.

Vegetable matter has been successfully used in the anaerobic digestion of stillage in Martinique (Monteiro, 1975), while bagasse has been used for the same purpose in Jamaica (Sheehan and Greenfield, 1980).

Recycling

Stillage may be reused in several ways. For example, stillage can be used to make up part of the sugarcane wash water, in cases where the distillery and sugar mill exist at the same location (Sheehan and Greenfield, 1980) or to dilute molasses prior to fermentation, to the extent of 10 to 20% of the total volume of water normally used (Kravets *et al.*, 1970, in Sheehan and Greenfield, 1980). Utilization of recycling in either of these methods is estimated to result in a significant saving of water whilst reducing the volume of stillage by up to 50%.

Also, a significant amount of the organic and inorganic constituents are removed in this way, thereby reducing some of the concerns associated with these substances. It is worth remembering that in most of the small islands of the Caribbean there are problems arising from the scarcity of potable water and water for agricultural sectors, e.g. vegetable cultivation and livestock production.

Direct land application

There are accounts of the direct application of stillage on land in some countries, including Brazil, India, Puerto Rico, and Trinidad. Research in this field, which has been vigourously pursued globally for over seventy years, has enabled scientists to calculate treatment regimes for different soil types.

Fertilizer production

Stillage may be either evaporated, or incinerated to produce fertilizer. Various comprehensive schemes have been proposed, but these usually require very high energy requirements. Basically, the principle involved is reduction in waste volume, and concentration of the nitrogen, phosphorus and potassium compounds for use as crop fertilizer. Montanari (1954, in Monteiro, 1975) has shown that these methods are generally uneconomical.

Production of animal feeds

The possibilities of using stillage as an animal feed have been widely investigated and various recommendations made. Dry stillage has been used in many developed countries, e.g. Holland, Italy, France, Belgium, and the U.S.A., as part substitute for molasses in the cattle industry and has been reported to result in increases in live weight and milk production in the beef and dairy industries (Sheehan and Greenfield, 1980). Stillage has also been used to produce fodder yeast, which is a high protein additive for animal feeds by a method which utilises *Candida utilis* (Henneberg) cultured in well aerated stillage (Willington and Marten, 1982).

Adhikary and Sahu (1985) showed that cell protein content of filamentous cyanobacteria, *Anaebaena* spp., which grow in some aquatic areas where effluent is discharged, can be increased by cultivating it in distillery media. They have found that the bacterium, which is rich in B vitamins, minerals, and protein, can be processed and used directly, without isolating the protein, e.g. incorporation into diets with cereals and legumes, and that very promising possibilities existed in this area. These findings are very significant since a substantial amount of land and water are generally required to cultivate the grains required for livestock production that contributes significantly to the protein content of the diet of most territories. Harnessing the protein potential of refinery effluent thus will result in significant savings in land space, water, electricity and labour costs.

Vehicle for herbicides

Distillery effluent is sometimes used as a carrier vehicle for herbicides, with the advantage of reducing the cost required for special equipment to apply the herbicide. In addition, this method has been shown to reduce the negative effects of winds on herbicide application, and also reduce soil compaction (Brieger, 1979).

DISCUSSION

The first concern about direct discharge of refinery effluent into the inshore environment must be that on the health of recreational users, including tourists, of the beach. Research has shown that the densities of pathogenic bacteria such as *Aeromonas hydrophila* (Chester) Stanier, *Vibrio cholerae* (Pacini) and *Klebsiella pneumoniae* (Shroeter) Trevisan are increased by the presence of rum distillery effluent, which has also been found to enhance the entire bacterial community (Biamon and Hazen, 1983).

V. cholerae is the causative agent of cholera. An outbreak of this disease in one Caribbean territory would not only have a devasting effect on the tourist and fishing industries of that country but would also negatively impact on those throughout the region. *A. hydrophila* is regarded as the primary causative agent for red sore disease in fish (Hazen *et al.*, 1978 in Biamon and Hazen, 1983), that has often resulted in the loss of massive amounts of fish in the U.S.A. (Miller and Chapman, 1976 in Biamon and Hazen, 1983). Furthermore, Biamon and

Hazen (1983) have cited the findings of several researchers that show that *A. hydrophila* also causes disease in frogs, lizards, alligators, turtles, and cattle. This bacterium also causes gastroenteritis and wound infections in humans.

A significant amount of research has been done on the toxicity of distillery effluent to fish. Durve and Jain (1980) demonstrated the toxicity of distillery effluent to the Cyprinid Weed fish, *Rasbora daniconius* (Ham.), and indicated that many similar experiments have been done in many parts of the world on other species of fish, such as *Cirrhina mrigala* (Hamilton Buchanan), *Puntius sophore* (Hamilton by Bleeker), *Mystus vittatus* (Bloch), and *Cyprinus carpio* (Linnaeus). Haniffa and Sundharavadhanam (1984) demonstrated the serious damage to tissues of the gill, kidney and intestinal villi of the freshwater fish *Barbus stigma* (Cuvier and Valenciennes) grown in concentrations of effluent in the range 0.1 to 0.5% in glass jars in the laboratory over a period of one month.

David and Ray (1966, in Haniffa and Sundharavadhanam, 1984) attributed the precipitation of ferric ions from the effluent, with deposition on the gills, as the cause of the respiratory problems noted. Verma and Dalela (1975, in Haniffa and Sundharavadhanam, 1984) felt that damage to the gills could have been caused by suspended solids in the effluent, while Klein (1972, in Haniffa and Sundharavadhanam, 1984) felt that the large amount of dissolved solids, could have adversely affected osmoregulation, resulting in suffocation, in spite of a good supply of dissolved oxygen. Haniffa and Sundharavadhanam (1984) felt that there was need for much more work in this area, perhaps to facilitate the compilation of a comprehensive information base, comparable to those arising from research on the effects of pesticides and heavy metals on fish biology.

Very importantly, Durve and Jain (1980) have stressed the importance of attempting to find out the fate of distillery effluent in different aquatic food chains, and determining the minimum lethal dose of distillery waste that kills various test species, to set appropriate emission standards for the waste. In this regard it is worth noting that the reef fishery is particularly vulnerable to the disposal of waste in the near shore coastal waters (Oxenford, 1991).

All the polluting aspects of the effluent can negatively affect organisms in the marine environment. Sediment loads, elevated temperatures and acidification can all have detrimental impacts on corals which combined with enhanced algal growth resulting from the nutrient load may lead to the destruction of the reefs. This, in turn, can enhance beach erosion.

It is obvious that the best solution is to use the effluent to produce a useful, potentially valuable, product. In addition to those described above, rum refinery effluent can be composted with vegetable matter, to produce manure (Monteiro, 1975). Tree trimmings, fallen fruits, dead leaves etc. are usually available year-round in Caribbean territories. These can be suplemented with waste from agro-processing, e.g. citrus juice production. Gathering these materials would enhance the aesthetic appeal of the environment thereby improving tourism value, as well as assisting the local drive to create more employment for local people.

Scientists in India have carried out experiments using marine bacteria to detoxify rum refinery effluent (Arora *et al.*, 1992). Thus, the effluent can be detoxified before composting, thereby improving the fertilizer value of the compost. Within CARICOM arrangements could be made to use the effluent to produce agricultural fertilizers that are required to meet the growing demands of a diversified agriculture. Rum refinery effluent can be shipped to other territories, in the same way that molasses is shipped to the territories that have rum refineries, to produce fertilizer.

In addition, the fertilizers produced may either be distributed locally or shipped overseas to neighbouring territories to support agricultural activities. In this regard the management of the refineries may be enlightened about "the polluter pays principle," in which the polluter is made to compensate for the pollution their enterprise causes to the environment.

It should not be very difficult to get the management of the refineries to comply, since there is a growing eagerness in the business community to sponsor activities aimed at improving environmental management, even though their efforts are usually aimed at improving their own interests, rather than because of a sustained interest in the well being of the environment. Thus the Caribbean may become developed in the way the members of the CARICOM fraternity desire, i.e. with specially chosen sites for agriculture, tourism, etc. and the income earners that are presently threatened by the dangers of improper disposal of effluent, will be given a chance to develop and grow unimpeded.

In addition, the fertilizer produced may be used to grow fodder for herbivores, such as sheep, goats and cattle, and grains for fowls, ducks, geese etc. on a large scale. Furthermore, the availability of cheap fertilizer will undoubtedly enhance efforts aimed at reforestation in the Caribbean. Reforestation will protect watersheds and reduce the soil erosion that is damaging sea grass beds and coral reefs in the near-shore environment.

Composting is a simple technology that can be adopted now while the greater value added products, such as animal feed production, are developed. Other innovative ways of using rum distillery effluent, possibly with by-products of other industries, may be developed in the future. If the option is adopted whereby effluent is converted to useful products rather than disposal into the marine environment, fisheries management, coastal zone management and biodiversity conservation will be facilitated.

LITERATURE CITED

Adhikary, S.P. and J. Sahu. 1985. Effect of distillery effluent on the growth of blue-green algae *Anabaena* in light and dark. *Environment and Ecology* **3**:580 - 590.

Arora, M., D.K. Sharma, and B.K. Behera. 1992. Upgrading of distillery effluent by *Nitrosococcus oceanus* for its use as a low-cost fertilizer. *Resources, Conservation and Recycling* **6**:347 - 353.

Biamon, E.J. and T.C. Hazen. 1983. Survival and distribution of *Aeromonas hydrophila* in near- shore coastal waters of Puerto Rico receiving rum distillery effluent. *Water Resources* **17**:319 - 326.

Bieske, G.C. 1979. Agricultural use of dunder. *Proceedings of Australian Society of Sugar Cane Technologists* **1979**:139 - 141.

Blackburn, F. 1984. *Sugar Cane.* London: Longman.

Boyce, I.A. 1988. *The production of biogas and its environmental consequences.* Ph.D. Dissertation, CERMES, University of the West Indies, Barbados.

Brieger, F.O. 1979. The distribution of distillery slops in São Paolo, Brazil. *Sugar y Azucar* **74**:42 - 49.

Burnett, W.E. 1973. Rum distillery wastes: Laboratory studies on aerobic treatment. *Water and Sewage Works* **120**:107 - 111.

Cooper, B.R. and M. Prasad. 1976. The use of distillery waste as fertilizer for sugar cane in Trinidad. *Proceedings of the West Indies Sugar Technologists - Sugar Association of the Caribbean* **1976**:53 - 59.

Durve, V.S. and S.M. Jain. 1980. Toxicity of distillery effluent to the cyprinid weed fish *Rasbora daniconius* (Ham). *Acta Hydrochim. Hydrobiol.* **8**:329 - 336.

Haniffa, M.A. and S. Sundaravadhanam. 1984. Effect of distillery effluent on histopathological changes in certain tissues of *Barbus stigma. Journal of Environmental Biology* **5**:57 - 60.

Hiatt, W.C., A.D. Carr, and J.F. Andrews. 1973. Anaerobic digestion of rum distillery wastes.*Engineering Bulletin, Purdue University Engineering Extension Series* **142**:916 - 976.

Keenan, J.D. and I. Korni. 1977. Methane fermentation of brewery by-products. *Biotechnology and Bioengineering* **19**:867 - 878.

Monteiro, C.E. 1975. Brazilian experience with the disposal of waste water from the cane sugar and alcohol industry. *Process Biochemistry* **1975**:33 - 41.

Oxenford, H.A. 1991. Management of marine resources for sustainable development in theCaribbean. Pages 2.120 - 2.126 in: E.A. Moore and J. Rudder (eds.) *Sustainable Development for the Caribbean* CERMES, University of the West Indies, Barbados

Sheehan, G.J. and P.F. Greenfield. 1980. Utilisation, treatment and disposal of distillery wastewater. *Water Research* **14**:257 - 277.

Subba Rao, B. 1972. A low cost waste treatment method for the disposal of distillery waste (spent wash). *Water Research* **6**:1275 - 1282.

Usher, J.F. and I.P. Willington. 1979. The potential of distillery waste as sugar cane fertilizer. *Proceedings of Australian Society of Sugar Cane Technologists* **1979**:143 - 146.

Willington, I.P. and G.G. Marten. 1982. Options for handling stillage waste from sugar-based fuel ethanol production. *Resources and Conservation* **8**:111 - 129.