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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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PROGRAMME ON PURIFICATION OF INDUSTRIAL WASTE WATER

COUNTRY PAPER: BOTSWANA*

Prepared by

F. Magibisela
UNIDO National Expert

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*The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

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INTRODUCTION

Botswana is a landlocked country which straddles the tropic of Capricorn in the center of the Southern African plateau. The total land area of the country is 582,000 km2 and the population is about 1.3 million inhabitants. The climate is mainly arid or semi-arid. Most rivers are ephemeral and the water supply comes mainly from several thousand boreholes. A few dams have also been constructed to satisfy the ever increasing need for water in the urban areas, industrial as well as irrigation uses. Water is a very scarce commodity in Botswana and it has to very well protected from any kind of pollution. This need is emphasized by the fact that a lot of wastewater is being generated due to rapid rate of industrialisation because of favourable economic situation for the past few years.

The main industries are at present mining and livestock industries. Besides tanning, metal plating, dairy and chemical industries, breweries are also causing pollution problems as well as oils and chemicals used in industries, garages and agriculture.

Water Pollution Control Legislation

At present there is noverall environmental protection legislation in Botswana. In place there are only sections, regulations and by-laws related to solid and liquid waste management which are scattered and the coverage of legal means to protect the environment is not yet adequate. However effort is being made to try and improve the current legislation. The existing legislation in Botswana provides no orderly institutional means for dealing with problems of waste discharges and water pollution. However, a few random provisions are found in the Water Act dealing very generally with pollution and with the return of water used in mining and forestry operations, a few random provisions are found in the Waterworks Act dealing with pollution of domestic water supplies and a few provisions are found in the Public Health Act.

Water pollution in Botswana is still a confined problem, but increasing water use for different industrial and municipal purposes is beginning to increase the visibility of the problem. As Botswana continues to develop the management of wastewater discharges will assume even greater importance. At present the most rational way of dealing with water pollution is at an early stage of a planned activity.

Proper siting of an establishment for instance, a new industry is in many ways, a key element in avoiding or reducing the costs of water protection. The seperation of different industrial wastewater streams, the use of ecologically suitable wastewater pretreatment processes and land disposal, where applicable. The Water Apportionment Board is the sole body responsible for enforcing the water legislation in Botswana. Provisions that the Water Apportionment Board rely on to enforce water pollution control are found in the Water Act, sections 9, 17, 27, 28, 36 and 37, in the Waterworks Act, sections 14, 21, 28 and 29 and in the Public Health Act, sections 43, 44, 45, 46 and 57.

The Water Act

Section 9

'Anybody who discharges effluent into public water shall be guilty of an offence and the offender shall be liable to a fine of P1000 or one year imprisonment.'

Section 17

'The water used for mining, forestry or industrial purposes or for the generation of power shall not be polluted with any matter derived from such use to such extent as to be likely to cause injury either directly or indirectly to public health, livestock, animal life, fish, crops etc., which are irrigated by such water or to any product in the processing of which such water is used. Anybody who contravenes or fails

of P500 or six months'.

Section 36

'Any person who interferes with or alters the flow, pollutes or fouls any poison in any public water to which any member of the public or domestic animal has access to whether lawfully or unlawfully shall be guilty and liable to a fine of P1000 or one year imprisonment.

Waterworks Act

' Anybody who pollutes public water or causes risk of pollution to any such water or allows any foul liquid, gas or other noxious matter to enter into waterworks or any pipe fitting shall be guilty of an offence and liable to a fine of P2000 and to six months imprisonment'.

Public Health Act

' No person shall cause or allow any noxious matter or wastewater flowing or discharged from any premises wherever situated, into any public street or into the gutter or side channel of any street or into any water course or irrigation channel not approved for the reception of such discharge'.

The existing legislation provide some authority to the Water Apportionment Board to take steps to control pollution. However, this power needs to be strengthened by giving the board the authority to issue waste discharge permits and the authority to examine and if necessary to modify, the details of any proposed work, including siting, its constituent

contents, the industrial processes, the quantities of wastewater and the treatment of wastewater if any proposed by the discharger. Compliance with appropriate effluent limitations which will eliminate or minimise pollution impact of the discharge should be made a condition of any permit issued. Such waste discharge permit should be required before any proposed discharge is commenced. Furthermore, the existing penalties for pollution now found in the Water act, the Waterworks act and the Public Health act should be strengthened and the new legislation should provide for compensation to government (for environmental damages) and third parties (for private damages) injured by unauthorised waste discharges.

An increasing problem in Botswana is the need to provide protection for existing boreholes and catchment areas of dams used for water supplies. A study on 'Creation of Protection Zones for major Acquifers and Dams' is expected to start late 1990. The Department of Water Affairs has an on-going study on assessment of the 'Magnitude and Sources of Water Pollution in Botswana'. This study will identify all industries that produce wastewater and then assess the amounts produced as well as quality of the effluent.

Locations of Industries to be Assessed

In this report an assessment will be made of nine industries. These industries are, the Lobatse abbattoir and tannery located about 70 kms from Gaborone, BGI tannery located in Francistown about 400 kms, Francistown abbattoïr also located in Francistown, Maun abbattoir located about 900 kms, Shashe Silk factory located about 400 kms from Gaborone, Pilane Leathers tannery located about 30 kms from Gaborone, Botswana breweries located in Gaborone and finally the Kgalagadi breweries also located in Gaborone. The two brewery suggested are quite different. One brews traditional beer the other brews normal type beer.

PILANE TANNERY

Pilane tannery is operated by Pilane Leathers as the owner and it is situated about 30 kms from Gaborone. This tannery produces finished leather (i.e. tanned hides) from raw and green hides purchased throughout Botswana. In undergoing the transformation from a raw hide to a finished leather suitable for leather goods manufacture, e.g. shoes, bags, the following process operations are involved ;

- Salting/Soaking (addition of Sodium Chloride + Enzymes)
- Liming (addition of Lime + Sodium Sulfide)
- De-Liming (addition of Ammonia Sulfide + Sodium Bi-sulfide + Enzyme)
- Pickling (with Sodium Chloride + Formic Acid + Sulphuric Acid)
- Chrome Tanning (with Sodium Bi-carbonate + Chromium Sulphate
- Re-tanning (with Chrome)

Each process produces very polluted liquid wastewater and some such as tanning wastewater are toxic because of the chrome. The tannery owners intend to increase the output of hides to some 6000 kg/d in the near future by expanding the present facilities. In so doing the volume of liquid wastewater produced will also increase and it is intended, as part of the expansion programme, to undertake treatment of

the wastewater coming out of the processes.

Existing Wastewater Treatment System

At present liquid wastewater coming from the various process operations are discharged virtually untreated from the factory. The combined wastewater streams, which are obnoxious in appearance and smell, flow into an open channel through the site and then discharged into open grounds to the rear of the factory. As well as being offensive in nature these effluents are hazardous to the environment as well as to the inhabitants of the area. An analyses of the quality of the different wastewater streams are shown on Table 1. Some rudimentary facilities for pre-treatment of the effluent do exist but they lack the requisite mechanical equipment to allow their use. At present there are frequent complaints by members of the public about the obnoxious smells and these are are bound to increase as the factory expands. The flow of wastewater coming out of the plant is predicted to be about 100 m3/d, and as such it was agreed that a proper wastewater treatment facility be constructed to facilitate for protection of the environment.

Table 1

Source\ Constituent	Lime liquor	De-lime liquor	Soak liquor	Chrome liquor
pH	11.5	8.8	7.0	3.9
Elect. conduct.	12780	10870	13070	11810
TDS	8307	7066	8496	7677
TSS	1480	104	393	2986
Chloride	21.3	21.3	13.5	350344.8
Carbonate	1872	792	-	-
Bi-carbonate	494	256	-	-
COD	49200	16800	14400	15200
BOD	5200	11600	3600	5800

All concentrations are in mg/l except pH and Electrical conductivity.

PROPOSED WASTEWATER TREATMENT PROCESS

The proposed wastewater treatment will involve separation of the chrome stream and then recircling it back into the plant. Then the second step will be simple pre-treatment of wastewater on-site by screening to remove solids, balancing and aeration to oxidize the odiferious sulfides to sulphates. The pre-treatment will then be pumped to the off-site evaporation ponds where the water will evaporate leaving a residue of solids which will be collected annually or bi-annually and disposed off by sanitary landfill.

Three ponds are proposed with a total surface area greater than the total annual wastewater discharge volume divided by the nett annual evaporation rate recommended. The ponds will be lined to prevent leaching of effluent into the surrounding streams or acquifers. A sketch of the proposed system is shown next page. This treatment facility will be quite adequate for treatment of the tannery wastewater.

SHASHE SILK FACTORY

The Shashe Silk Factory is owned by Botswana Game Industries (BGI) company. This factory is situated in Shashe which is about 400 kms from Gaborone. The processes involved are are as follows ;

. Degumming of the cocoons to release the silk fibre for processing. This is achieved by boiling the cocoons in an alkali solution.

. This is then followed by washing the silk waste produced.

WATER FLOWS THROUGH THE PLANT

Flow 1

This comprises water from the degumming section. The estimated volume of about 45 m3 per 9 hour working day with the following load ;

. Proteinaceous matter, pupal debris, dirt - 0.97 % m/v

. Alkali (caustic soda & sodium carbonate) - 0.20 % m/v

. Soap (mixed natural and synthetic non-ionic) - 0.20% m/v

. The pH of the solution will be approximately 10.

Flow 2

This comprises water from the silk washing section. The estimated volume is about 125 m3 per 9 hour working day with the following load ;

. Addition of acetic acid of about - 0.018 % m/v

. The liquid contains a variable, but light load of silk dust and fibre.

. The liquid has a pH which is on the alkaine side of about 8.5

The BGI company intends to expand its production to full capacity in the near future. It was agreed with Government that a temporary wastewater pre-treatment facility be inplaced at the site to take care of the current wastewater. And that in the meantime the company should engage a wastewater treatment consultant to look into a longterm solution to the problem.

Existing Wastewater Treatment Facility

The existing wastewater treatment facility 1 3 H c ompri following ;

- Stream A, from the degumming tank sump is used for irrigation.
- Stream B, from the washing table sump, the bulk of this liquid is pumped to the degumming tanks for re-use and the balance is mixed with stream A.
- Stream C, from the neutralisation tank sump is mixed with stream A and then used for irrigation.

In order to monitor the effect of this effluent on the irrigation area several surface samples and sub-surface samples are taken every half year (see attached table of analyses).

PROPOSED WASTEWATER TREATMENT FACILTY

The company is currently looking at three possibilties. These are ;

Option 1

Using an anaerobic pond whose outflow feeds a series of aquaculture/algaculture ponds whose outflow feeds a conventional crop irrigation system.

Option 2

Using a wetland whose outflow feeds a series of aquaculture/algalculture ponds whose outflow feeds a conventional crop irrigation system.

Option 3

Using a bulk fodder treatment facility. The idea behind is that a highly alkaline solution can be beneficially sprayed onto bulk fodder in order to assist and enhance its digestibility to cattle.

All these three options are still being studied by the company to see which will be feasible and be able to generate some income for the company. The most effective treatment system would be the option 1.

FRANCISTOWN TANNERY

The Francistown tannery is located in Francistown which is about 400 kms from Gaborone and it is owned by Botswana Game Industries (BGI). This tannery uses only game skins in the tanning process. The operation can be divided into two main tanning processes which are :

a. Chrome Tanning

b. Re-tanning

For Chrome tanning, the following processes are involved :

. Liming

. Deliming

. Pickling

. Chrome Tanning

. Re - tanning

. Dyeing

For Liming the following processes are involved :

. The sulphide reacts with the acid from the chrome tanning operation resulting in converted sulphate.

. Lime precipitates chrome salts into chromium hydroxide which is pumped out of the system regularly.

The skins that are used in the tanning process are dry salted and sun dried, which minimises excessive salt concentration. In the tanning process self basified tanning salts are used, which results in high chrome exhaustion and hence the effluent has reduced chrome content.

The chemical consuption on monthly basis is as follows :

. <200 kg Sodium Sulphide

. <200 kg Lime

. > 150 kg Sulphuric Acid

. > 72 kg Formic Acid

. > 960 kg Kromex Aza

. > 216 kg Syntan

. > 216 kg Oils

. 800 kg salt

The total astewater produced by all the different tanning processes is about 48 000 litres per day or more.

Existing Wastewater Pre-treatment Facility

The wastewater from the plant goes through a series of manholes which also help in sedimentation of solids before it goes into a series of sedimentation tanks. The sedimentation tanks settles most of the suspended solids and they are periodically emptied by the town council vacuum truck. From the sedimentation tanks the wastewater is discharged into the municipal sewer.

- Observations

The laboratory analysis of this tannery effluent have shown that it has a very high concentration of salts, of about 5068 mg/l of total dissolved solids. This is the main consent since most of chrome is used up and it can only be rectified by a Trade Effluent Agreement between the town council and

the tannery, where effluent standards can be set.

BMC LOBATSE ABATTOIR AND TANNERY

The Lobatse abattoir is owned by the Botswana Meat Commission (BMC) company and it is the largest in Botswana with a total kill of about 1400 beasts per day. It is situated about 70 kms from Gaborone. The BMC company also operates a tannery with a capacity of 28 200 kgs hides per day.

Lobatse Abattoir

The abattoir in Lobatse makes a total kill of about 1400 beasts per day. This results in production of wastewater volume of about 1900 m3 per day. About 20% of the total daily effluent volumes occurs after the kill has stopped and more than 50% of the effluent originates from the process floor (Please Figure 2). A water usage of 1350 l/head for slaughtering and all its associated processes. The abattoir complex produces about 14 tons of chemically oxidizable organic matter (COD) or about 6.5 tons of biologically oxidizable organic matter in the effluent per working day.(Please see table 2) . The corresponding inorganic pollution loads are given in table 3.

TABLE 2

DAILY AVERAGE FLOW AND ORGANIC CONCENTRATIONS IN ABATTOIR EFFLUENTS FOR A 1400 KILL

	Abattoir 12hours/24 hours	Paunch/lairage 12 hours 24 hours	Tannery 24 hours	Total 12 hours, 24 hours
Flow (m3)	723/1010	545/630	245	1513/1885
Water used/head (l)	721	450	175	1346
Distribution (1%)	54	33	13	100
COD: (kg) (mg/l) (kg/head)	4982 4933 3.56	5046 8010 3.6	4172 17028 2.98	14200 7533 10.14
BOD: (kg) (mg/l) (kg/head)	2200 2180 1.57	1320 2095 0.94	2980 12100 (2420) 2.13 (0,43)	6500 3448 4.64 (2,94)
Settlable solids (m3)	145	430	?	612
BOD:COD	1:2.26	1:3.82	1:1.40	1:2.18

TABLE 3

DAILY AVERAGE INORGANIC CONCENTRATIONS IN ABATTOIR EFFLUENTS FOR A 1400 KILL

	Abattoir 12hours/24 hours	Paunch/lairage 12 hours 24 hours	Tannery 24 hours	Total 12 hours, 24 hours
Flow (m3)	723/1010	545/630	245	1513/1885
TDS (kg)	1134	1391	2462	4987
(mg/l)	1568/1123	2552/2208	10049	3296/2646
Ra (kg)				1245
(mg/l)	79,56	451,373	3902	825/662
Ca++ (kg)	16	40	131	187
(mg/l)	22/16	73/64	535	123/99
Cl (kg)	123	91	948	1162
(mg/l)	170/122	167/144	3869	768/616
SO4 (kg)	198	457	2199	2854
(mg/l)	273/196	839/754	8976	1886/1514

Lobatse Tannery

This tannery is also the property of Botswana Meat Commission and it has a full capacity to process 28 200 kgs hides per day. The following are the processes involved in the tanning ;

Liming

- 43.2 kgs vinkol Enzymic preparation for soaking
  or 72.0 kgs erhazym c Enxymic preparation for soaking
- 90 kgs caustic soda NaoH 50% solution
- 54 kgs tetrapol ww - non - ionic surfactant
- 288 kgs sodium hydrosulphide - NaSH - 72% conc.
- 372 kgs sodium sulphide - Na_2S - 60% conc.
- 900 kgs hydrated lime - $Ca(OH)_2$
- 30 m^3 + 90 m^3 wash water.

This wastewater stream has a pH of 13

Deliming and Bating

The following chemicals are used ;

- 1 008 kgs ammonium sulphate (21% N)
- 204 kgs sodium metabisulphite
- 54 kgs tetra ww
- 20.4 kgs oropon ON2 - enzymic preparation
- 288 kgs hydrochloric acid - 30% conc.
- 288 kgs formic acid - 85% conc.

The total volume is 42 m^3+42 m^3 has a pH of 8.5

Prickling and Tanning

- 1 500 kgs sodium chloride
- 402 kgs sulphuric - 98% conc.
- 144 kgs formic acid - 85% conc.
- 96 kgs copicol DXM - Fat preparations - Totally exhausted
- 1 524 kgs Kromex AZA - 21% Cr_2O_3 - 26% Na_2SO_4
- 780 kgs Kromex CLZA - 9% Cr_2O_3 - 15% Na_2SO_4
- 87 kgs preventol L - fungicide - Totally exhausted

The total volume is 21 m^3 and the pH is 3.8

This shows that about 5 tons of soluble inorganic salts (TDS) are produced per day.

Existing Wastewater Treatment Facility

BMC Abattoir

The present wastewater treatment facility consists of pre-treatment and the effluent is used for irrigation of grass. The pre-treatment consists of a series of anaerabic ponds followed by a two stage biological filtration.(Fig 3). The design criteria for this system is shown on table 4.

It has been agreed that as soon as land is available the effluent coming from the pre-treatment scheme will be connected to the municipal sewerage Oxidation ponds for final polishing before being used for irrigation.

The design capacity of the wastewater treatment plant compared to present effluent conditions are given in Table 3

TABLE 4

DESIGNED CRITERIA AND PRESENT LOADING CONDITIONS OF BMC'S BIOLOGICAL WASTEWATER TREATMENT PLANT

	Plant design criteria	Present situation
Maximum kill/day	1000	1400
BOD contribution (kg/head/day)	2,95	4,54 (2,94)
BOD load (kg/day)	2950	6500 (4120)
BOD concentration (mg/l)	3600	3450 (2185)
Volume effluent (l/head)	810	1346
Average effluent (m3/d)	818	1885
Total retention time in ponds (d)	23	9.95
BOD reduction through ponds (%)	85 (expected)	76
BOD reduction through biofilters (%)	90 (expected)	83
BOD final effluent (mg/l)	54 (expected)	140 (measured) (84)

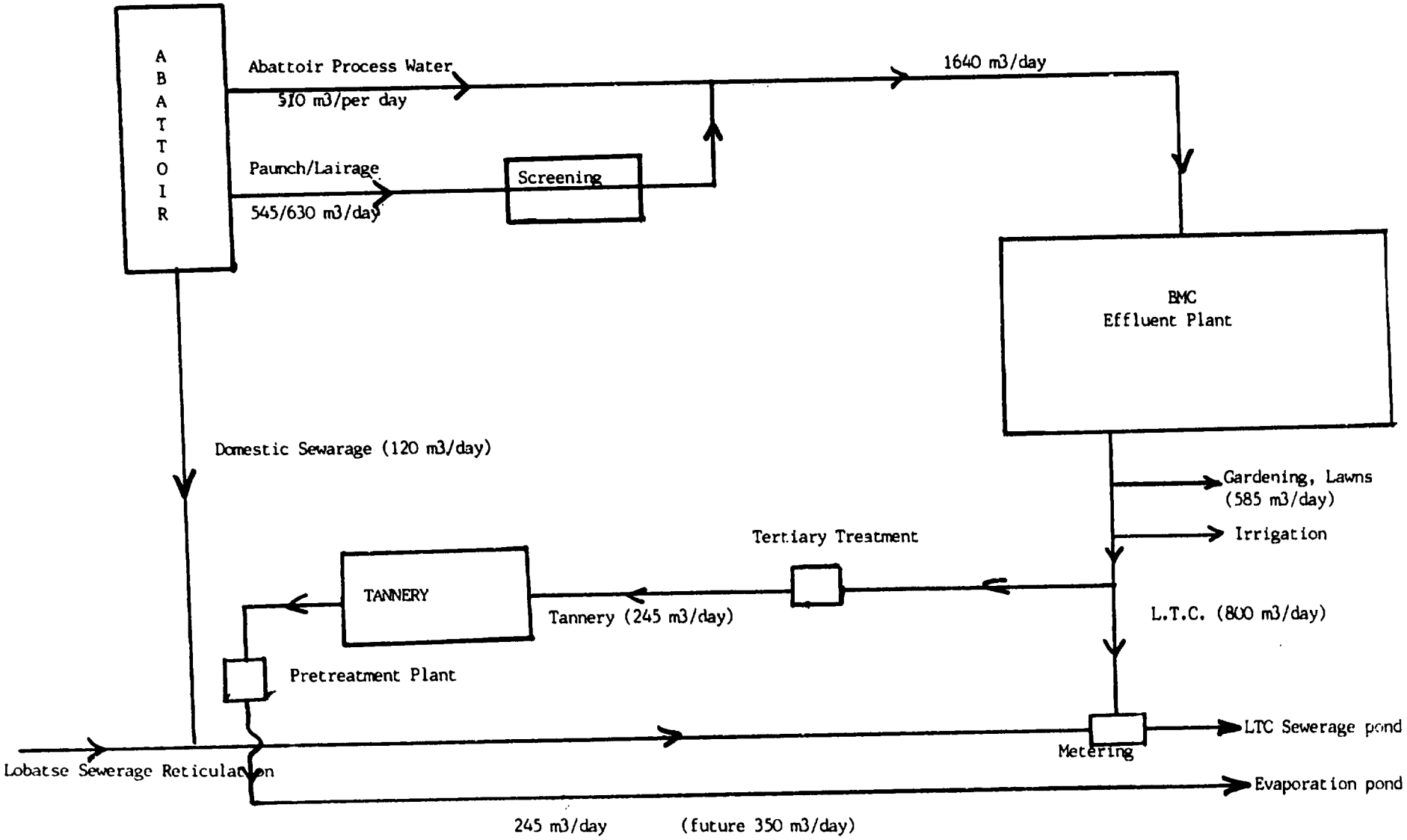
TABLE 5

EXPECTED EFFLUENT QUANTITIES AND QUALITIES WITH PARTIAL INDUSTRIAL RE-USE

	Volume (m3/d)	BOD (kg/d)	(mg/l)	TDS (kg/d)	(mg/l)
Abattoir Effluent Raw	1010	2200	2180	1134	1123
Paunch/Lairage Effluent: Raw	630	1320	2095	1391	2208
Combined Effluent Raw	1640	3520	2146	2525	1540
Treated = Industrial	1630	100	60	1540	1558
Industrial water to tannery	245	15	60	382	1558
BMC effluent to LTC	800	50	61	1250	1558
BMC effluent (irrigation)	585	36	61	912	1558

Botswana Meat Commission

Effluent Flow Diagram (kill 1400)



Existing Wastewater Treatment schem00He_

BMC Tannery

Previously the tannery effluent after undergoing treatment was disharged for further treatment into the pre-treatment plant of the Abattoir. However this situation has changed, the effluent from the tannery now goes to the evaporation ponds. The pre-treatment for the tannery consists of a balancing tank, then aeration tanks and then from aeration it goes through a small plant where small amounts of ferric chloride and polymer are added. This pre-treatment scheme removes most of the proteins. The effluent from the pretreatment is then taken futher for evaporation at an off-site location. The evaporation ponds are planned in such a way that they are filled one after the other to allow for desludging of the ponds. This system as it is now is operating satisfactorily.

Francistown BMC Abattoir

The Francistown abattoir is owned by the Botswana Meat Commission (BMC) and it is located in Francistown. The present capacity is 400 beasts killed per day. The total volume of wastewater produced is 600 cubic meters per day. There are three different types of wastewater streams, the process wastewater, the pauch wastewater and the lairage wastewater.

The breakdown of effluent streams is as follows :

Effluent Stream	BOD Concentration (mg/l)
Bloodwater	2400
Pauch & Lairage	2000

Existing Wastewater Pre-treatment Facility

The process wastewater is collected in a sump, from the sump the water goes through a rough screen, from the rough screen it goes through a fine screen of 0.75 mm mesh and then it goes into a surface aeration cavitator where fat is recovered before it is discharged into the municipal sewer. The pauch wastewater goes through a rough screen and from there it goes through a fine screen of 0.75 mm mesh before being discharged into the the municipal sewer. The lairage wastewater is taken through a fine screen before being discharged into the sewer and the solids from the screens are taken away to be

burnt.

The system as it operates now is working fine because the municipal oxidation ponds were designed to cater for the wastewater coming from the abattoir. The effluent from the ponds is used for irrigation in the adjacent farm.

Maun BMC Abattoir

The Maun abattoir is also owned and operated by the Botswana Meat Commission. And it is located in Maun. The present capacity of this abattoir is about 200 beasts killed per day. Like the other abattoirs there are three different types of wastewater streams, the process wastewater, the pauch and the lairage wastewaters. The total wastewater produced is about 200 cubic meters per day. The quality of the wastewater is the same as the other abattoirs with a BOD of about 2400 mg/l for the process wastewater and the pauch and the lairage, a BOD of about 2000 mg/l.

Existing Wastewater Treatment Facility

The wastewater from the abattoir goes through a screen and then it into a surface aeration flotation cavitator where tallow is recovered. From the cavitator the wastewater goes into an anaerobic pond and from the anaerobic pond it goes into an oxidation pond. The final effluent is used for irrigating grass. The wastewater treatment facility as it operates now is quite adequate and there is no discharge into the environment.

Botswana Breweries

This brewery is run by Botswana Breweries Ltd and it is is located in Gaborone. The company is engaged in the manufacture of traditional beer which is sold under the trade name of 'Chibuku'. The raw materials which are used in the process are primarily maize grits and sorghum malt together with small quantities of brewer's yeast and commercially prepared enzymes.

These materials are intially mixed in a stainless steel vat to which water is added, the mixture then being pumped into a large stainless steel vessel where it is cooked for two hours at 98^{o}c. The mixture is then allowed to cool for another hour, before being strained and centrifuged. The mixture is then transferred to fermenting vessel, where the temperature is raised to 80^{o}c for 20 minutes. The mixture is allowed to cool down to 33^{o}c in two hours. Yeast is added and fermenting is allowed to take place over a period of 6 hours. The liquid is transferred to a maturation vessel and finally the product is packaged in waxed cardboard cartons.

According to 1988 consumption figures, the mean daily water consumption is 158 m^3 per day. The brewery operates 24 hours per day and produces between 4 and 8 brews per dayThe higher figure applies to weekend and holiday production. Each brew involves some 15 m^3 of water such that maximum production 120 m^3 go out as product. The brewery estimated that their effluent to product ratio was 2:1. On this assumption, the mean daily effluent would lie between 120 m^3 per day (4 brews) and 240 m^3 per day (8 brews). Unfortunately a more accurate estimate of the rate of discharge of the effluent was not available.

Apart from the product water, large quantities of water are used in the washing and rinsing of the cooling, fermentation and maturation vessels. Water was also required in the production of steam which was then used to heat the cooking and fermenting vessels and to sterilise the same vessels. Floor washing was another activity requiring copious amounts of water. In the packaging of the Chibuku beer, water was not required for rinsing of beer cartons. This accounted for a much lower effluent to product ratio from this brewery as compared to normal type brewery since can rinsing was not necessary.

The results of the tests are shown in a table below ;

	Hr	BOD_5 (20^O) (mg/l)	COD	TSS (mg/l)	pH (mg/l)	Temp (^oc)
8	64	490	730	7.8	14	
10	184	428	80	8.1	19	
12	224	397	80	11.6	34	
14	9440	50337	5729	5.8	17	
16	4240	44030	2910	5.2	15	
18	6240	42721	8000	5.1	17	
20	11580	45339	2000	5.1	14	
22	13400	44982	7000	8.3	25	
24	9840	40341	2670	7.4	18	
2	5040	46648	1200	7.5	15	
4	7400	45458	3100	7.1	17	
6	5340	39508	3900	7.6	15	
8	130	535	370	8.1	16	
composite sample	5600	38555	2700			

The results from above table show that the effluent from this brewery has very high BOD, COD and TSS associated with it. However, the readings at 0800, 1000 and 1200 hrs had

significantly lower values of BOD, COD and TSS. The reason for this was that the beer was being brewed during this period and that there were significant effluent flows. After 1200 hrs, there were large effluent flows due to cooker and fermenter washing and rinsing. These flows probably accounted for the high BOD, COD and solids content.

The table below shows analyses of a composite sample taken from the brewery to check other parameters.

Parameter	concentration (mg/l)
Chloride	142
sulphate	12
Heavy metals	< 0.01
Cyanide	< 0.01
Ammonia	22
Nitrate	6
Phosphate	3
Oil, grease, fat	24

From the table above it is apparent that the effluent is very low in nitrate and phosphate and therefore biological treatment systems would be likely to be affected. However,

dilution with domestic effluent would improve the effluent to make treatable.

Existing pre-treatment system

At present the brewery discharges its effluent into the municipal sewerage system where it is further treatment on Oxidation ponds. However before the effluent is discharged in the municipal sewers it goes into a horizontal sedimentation tank. The tank consists of two compartments which each has a capacity of 5.9 m^3. The tanks are used alternately and the idea is to remove most of the spent grain and yeast from the effluents. Periodically the tanks are emptied when full of spent grain. The sizes of this tanks do not seem to able to cope with the wastewater coming out of the brewery and it is very likely that the effluent goes into the public sewers without proper pre-treatment. This can be rectified by the company signing a trade effluent agreement with the municipality to ensure that a proper pre-treatment facility is installed. A well designed sedimentation tank will remove 90% of the suspended matter and reduce the BOD.

Kgalagadi Breweries Ltd

The Kgalagadi brewery is owned by Kgalagadi Breweries Ltd. This brewery is located in Gaborone. The brewery is engaged in the production of clear beers and carbonated soft drinks. Most of the products are manufactured under licence. It employs some 300 staff and is the largest brewery in the country.

The manufacture of beer is in batch basis and the general production is in the following steps ;

1. Crush malt in mill
2. Soak malt in hot water 1-2 hours which releases an enzyme that allows the conversion of starch to sugar.
3. Steep malt for two hours in a lauter tank (converts the starch in the malt into sugar.
4. the spent malt is pumped using an archimedian screw to a hopper.
5. The steep liquor from the lauter tank is mixed with hops, sugar, caramels and other ingredients and is then cooked at over $90^{o}C$ for about four hours.
6. The wort vessel is drained and the liquid (wort) is pumped to a spiral flow tank in which the 'trub' (precipitate of cooking) is removed.

7. The wort is cooled by a heat exchanger. The hot liquid from the heat exchanger is returned for reuse in the soaking of the malt. (stage 2)

8. The yeast is mixed and it is then added with the wort in the fermenting vessel. the beer is left to ferment for 20 to 22 days.

9. The beer is then racked and stored for up to 6 weeks.

10. The beer is filtered to remove any yeast left from the fermenting stage.

11. The beer is stored in a bright beer vessel prior to bottling or canning.

12. The cans are initially rinsed with hot water before being filled with beer.

13. The cans are sealed and finally pasteurized to ensure there are no viable yeast cells.

14. The cans are packaged and then stored prior to distribution.

The production of beer and the waste streams arising from each stage is shown below.

Process	Wastes	Useful Byproducts
Mill in malt		
Soak malt in hot water for 1-2 hours		
Steep malt in lauter tank	Spent grain liquor Wash and rinse water	Spent grain
Boil wort + hops + sugar + caramel	'Trub' liquors	
Remove trub in spiral flow tank	'Trub' liquors	
Heat exchanger	Hot water	
Mix yeast	rinse & wash waters	
Ferment beer in 48 m^3 vessel for 20 days	Spent yeast liquor rinse and wash waters	Spent yeast CO_2
Store beer in storage vessel	rinse and wash waters product	
Use filter presses to extract yeast	Product spent yeast filters rinse waters	Spent yeast
Store beer in bright beer tank	Product rinse water	
Can beer	Product considerable quantities of wash	

Pasteurize

Packaging Floor washing, etc

Manufacture of soft drinks

The process used to manufacture carbonated soft drinks is described below.

1. The water in the manufactureof carbonated soft drinks must be completely free of bacteria or other viable micriorganisms to prevent contamination of the final product.

2. Activated carbon is used to remov chlorine and chlorine compounds used for disinfection.

3. The main ingredients for carbonated soft drinks are highly concentrated fruit syrup, sugar and water which are mixed in a large stainless steel vessel.

4. The mixed liquid is de-aired, cooled and then carbonated using carbon dioxide, obtained as a byproduct of fermenting beer.

5. The mixture is transferred to a canning machine in which cans are initially washed with hot water, filled with product, more carbon dioxide is injected and finally the tins are sealed.

6. The tins are heat dried to remove the excess moisture on the outside of the tin to prevent rusting.

7. The tins of the soft drink are packaged and stored prior to distribution.

Analyses of Wastewater from Kgalagadi Breweries

An analyses of the effluent has been carried out and the results are as follows;

Hr	$BOD^5(20_o$ (mg/l)	COD	TSS (mg/l)	pH (mg/l)	Temp.	($_oC$)
0	7920		13090	215	7.98	26
2	6720		11620	585	8.50	27
4	6560		8568	205	9.41	29
6	7360		8925	855	6.80	29.5
8	9440		11443	195	6.90	32
10	8320		16164	655	6.5	26
12	7920		9520	335	9.20	33
14	5920		14161	305	9.40	34
16	7680		19873	375	7.50	26
18	7680		14756	195	7.20	27
20	6400		12494	365	6.11	27
22	7280		11781	305	6.05	28
24	5360		7021	445	6.70	30
Composite Sample	6000		12614	505	-	-

The data from the table show that the effluent from this brewery has a very high oxygen demand. The BOD strength varied between 5360 and 9440 mg/l and the COD varied 7021and 19873 mg/l on the day the samples were taken. The composite sample had BOD and COD values of 6000 mg/l and 12614 mg/l, respectively. The total suspended solids were also high at between 195 and 855 mg/l. The range of data relating to pH and the temperature were acceptable. The balancing tank appeared to be maintaining reasonably constant values of pH and temperature.

The table below shows the parameters measured on a composite sample.

Parameter	Concentrations (mg/l)
TDS	1088
Chloride	69
Heavy metals	< 0.01
Cyanide	< 0.01
Ammonia	9
Nitrate	3
Phosphate	1
Oil, grease, fat	24

The data in the previous table show that the brewery effluent has low concentrations of Chloride, Sulphate, Ammonia and negligible concentrations of heavy metals. Additionally, the low concentrations of nitrate and phosphate are typical of a brewery effluent which have a high concentration of carbohydrates. The ratio of BOD to nitrate to Phosphate would normally be 100:7:1 for domestic effluent, but the ratio of the brewery is 600:3:1.

Overall, these data show that the brewery is producing an effluent with an unacceptablly high oxygen demand and the suspended solids is also too high. It is also apparent that there is a gross deficiency in the concentration of nitrate and phosphate which may inhibit the biological oxidation of the trade wastes at the municipal waste stabilisation ponds. To some extent, the deficiecy of nitrate and phosphate may be improved by mixing with domestic effluent in the public sewer, there was still concern about shock loading by the brewery effluent on the municipal oxidation ponds.

Samples of effluent were also taken from four of the brewery's main streams of concern : the spent liquor, the trub liquors from the wort vessel and spiral flow vessel, the yeast and the filter room, the bottling area and fermenting vessels. And table below shows the results of the analyses.

Sample point	pH	BOD (mg/l)	COD(unfilt) (mg/l)	COD(filt) (mg/l)	TSS (mg/l)
Trub effluent from spiral tank	5.22	12400	184000	11300	-
Spent grain liquor	3.88	5800	8080	-	-
Wort kettle effluent	5.30	60000	2000000	-	17000
Yeast + filter room effluent	4.82	20000	32130	-	300
Canning + bottling plant effluent	6.62	7440	28927	-	40

The results show that the trub liquors from the spiral flow tank and wort kettle are producing the most polluting effluents in the brewery. The trub liquor has a high concentration of solids, is also acidic and has an incredibly high COD. Of equal concern was the effluent from the canning

plant. The high BOD and COD in the effluent suggests that there must be substantial dilution of product in the effluent. This product is probably due to the overfilling of beer cans and soft drinks. In particular, high concentrations of spilt sugar and syrup from the soft drinks would contribute a high BOD to the effluent. Finally the effluent from the yeast and filter areas had high BOD and COD. Beer and yeast would contribute to a high BOD and COD if the dilutions in the effluent were high.

Existing system of Sewage pretreatment

At present, all the effluent from the brewery passes through a 60 m_3 balancing tank. From the balancing tank, the effluent is pumped via two submersible pumps to a manhole. From the manhole, the effluent flows under gravity to another manhole where it mixes with domestic effluent before it finally discharged to the public sewer. At the brewery there are no primary or secondary treatment facilities for the trade effluent.

It was doubtful that the balancing tank was capable of producing a very balanced effluent. The capacity of the tank was such that the hydraulic detention was only 1.5 hours at the mean daily discharge rate of 938 m_3. The balancing tank would have a limited effect on damping pH, temperature or COD shock loads.

The effluent produced by Kgalagadi breweries has an unacceptably high oxygen demand and suspended solids content. The effluent requires pretreatment before it is discharged to the public sewer. The section of the brewery that has the highest water usage is the bottling/canning plant. Considerable quantities of water are used for the rinsing of the cans, the washing of floors and for the production of steam. All of the effluent from this area is discharged to the sewer. A proper pretreatment plant is required before this wastewater is discharged into the public sewer. A well designed sedimentation tank will remove most of the suspened matter and hence reduce the BOD.

Recommendations

According to recommendations made by the Department of Water Affairs, whenever possible industries should be connected to the public sewage reticulation system. By doing so the wastewater discharges can usaully be controlled better and the amounts of discharge points can be minimized. For bigger amounts of industrial effluents and for the effluents containing toxic substances, pretreatment measures are required before discharging into public sewers.

The level and type of pretreatment should be determined according to the requirements of effluent reuse and discharge from the whole system. Pretreatment is also needed to protect the sewers from corrosion, to keep the metal concentrations of sewage sludge at acceptable levels and to prevent inhibitory disturbance of biological treatment processes in the treatment plant. The required pretreatment should be decided on an individual basis.

According to the Water Act the sewage works are required to meet effluent standards layed down by the Director of Water Affairs. In general most of the industries in Botswana do not comply with pollution control measures. The main problem is the legislation, which is very weak. However an effort is being made to try and rectify the present legislation.

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