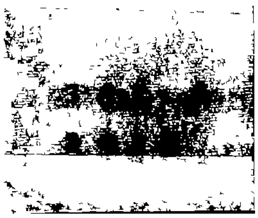

INDUSTRIAL WASTE WATER DISCHARGES WITH SPECIAL REFERENCE TO LEATHER INDUSTRY IN KENYA

by

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To my youngest sister

Nyambura daughter of Gathuo.

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SUMMARY

It is the aim of the government of the Republic of Kenya that by the year 2000 or earlier if possible, the entire population will have access to a safe water supply at close proximity. However, investigations carried out in 1983 show that only 23 % of the total population has piped water supply and the vast majority in the rural areas obtain water directly from rivers. It is therefore apparent that there will be serious health risks if waste waters from expanding industries and increasing urbanisation are not treated and control enforced during the interim period.

In this report a review has been made of the existing industrial discharge control systems both international and local. It was found that the foundation of a good control system must be a specification of the quality of waters on which legitimate uses depend. Thus it is necessary that ambient water quality standards for all streams be established.

Discharge standards for most of the industries in Kenya have already been set. But a survey of industrial effluent quality of all three tanneries studied showed that none of them meets the allowed limits. In Bulleys Tanneries', for example, the allowed discharge quality is 20 mg O_2/l BOD_5 amd 30 mg/l suspended solids. The lowest values out of five grab samples analysed were 460 mg O_2/l BOD_5 and 117 mg/l suspended solids. Chromium concentration should not exceed 0,05 mg/l but the observed chromium ranges from 1,25 - 35 mg/l.

It must be noted however that these standards mostly originate from foreign sources. The "20/30" rule has its origin in a report of river pollution in England and Wales by a Royal Commission on Sewage disposal that was set up as far back as 1898. Effluent guide lines which are proper for Kenyan conditions, taking into account hydrological, climatic, sociological and economic situation of the country, should be developed.

Industry should pay for damaging the environment. The less it damages the less it has to pay. The same is true if the damage is great the more unprofitable it is for the industry. All these economic incentive methods are not being used in Kenya. For example, even after recommending the use of Mogden's formula as the basis of charging industrial effluent. When it is discharged into municipal sewerage system, way back in 1972, Fur and Wools Tannery still pay their sewerage charges according to the hydraulic loading, regardless of whether the effluent is stronger than domestic sewage.

However, industry should be forced to build waste water treatment facilities which they are going to operate and maintain. But the government should also realize that industry does not make direct profits from waste water treatment facilities and hence it should provide more attractive measures to industry by waiving and reducing taxation on equipment, machinery and chemicals which are going to be used solely for the purpose of environmental protection.

In-plant measures for reducing discharges and wastes from tanneries have been discussed. A survey in all three tanneries studied showed that these measures have very rarely been applied. In Double Diamond tannery recirculation of chromium liquors has been practiced and an attempt is being made to recover chromium from the sludge. Water and chemical consumption in the industries is still quite high though technologies exist for reducing the inputs and still maintaining the required product quality.

Technologies exist for treating tannery waste waters to the required design quality. In all the three cases studied, none of the effluents had a quality anywhere near the design conditions. For example Bulleys Tanneries effluent treatment plant was designed to achieve an effluent quality of "20/30" standard. The lowest values obtained from five grab samples analysed were 460 mg O_2/l BOD_5 and 117 mg/l suspended solids. In Fur and Wools tannery only trace of chromium is allowed in the discharge. The observed chromium concentration ranges from 1,3 to 39 mg/l. Facilities exist for raising pH with lime to optimize chromium hydroxide precipitation but are rarely if ever used.

Double Diamond tannery has been disposing its waste waters on land by spray irrigation. The sodium absorption ratio of this waste water ranges from 30 - 70. The electrical conductivity ranges from 4000 μS/cm - 10000 μS/cm. This shows that the water is not suitable for irrigation of crops. From the soil analysis conductivity was quite high and calcium was also quite high (259 g/kg calcium). A thorough study on the effect of waste waters on soil should be made. However, from a water pollution point of view irrigation could still be a means of waste water disposal if it has no effect on water sources.

The responsibility of monitoring should be shared by both Water Pollution Control Authority and industry. The industry should bear in mind the benefits it can get from a comprehensive monitoring programme.

Lastly, the legal system at the moment needs a lot of adjustment. Upto now it fails to define what is pollution and hence the enforcing officers cannot be able to do their work as effectively as they would wish.

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1. INTRODUCTION

No activity - manufacturing process, residential activity, agricultural operation, transforms 100 per cent of inputs into desired products and services. There is always something "left over", a residual that must be disposed off in some manner. More often disposal is to one or more of the environmental media, air, land or water.

In all countries there is increasing pressure on the finite water resources, as a result of increasing withdrawals and increasing discharges. As demands grow in relation to supply, there will be increased patterns of interaction among users and increased incidence of conflicts. Because the assimilative capacity of the environment is essentially fixed, ignoring long-run climatic changes that capacity will only become more scarce in the future relative to the demands on it.

Water pollution control, which is an integral part of water resources management, must be carried out with explicit considerations of air and land resources, because all forms of residuals and the three environmental media are interrelated. One form of residual can be transformed into another media but that does not solve the environmental problems.

All the present level of development in Kenya, pollution control can be considered more important than in developed countries where virtually the entire population normally has access to a safe treated water supply.

Investigations in Kenya have shown that only 23 % of the total population has a piped water supply and the vast majority in the rural areas obtain water directly from rivers /1/. Although it is the aim of the government that by the year 2000 or earlier if possible the entire population will have access to a safe water supply at close proximity, there will be serious health risks if waste from expanding industries and increasing urbanisation are not treated and control enforced during the interim period.

During the 1960's Kenya did not have serious river pollution problems with the exception of Nairobi River which had reached the stage of gross pollution even in the 1950's. The policy of distributing industries to municipalities outside the capital of Nairobi and also within the densely populated rural areas during the past few years have been a major cause of the current concern following the serious incidents from the 70's and beginning of the 80's. In Western Kenya there was excessive pollution from two sugar factories discharging waste waters into rivers used directly for drinking water by thousands of people downstream. In one case the fish population of the receiving river was also destroyed along a 24 km reach /2/.

At about the same time oil pollution of Lake Nakuru in the Rift Valley occured. Lake Nakuru is the feeding ground for the world's largest concentration of lesser flamingo (Phoeniconias Minor Godffrey) and provides one of its principle tourist attractions /2/. Tourism is now Kenya's largest foreign exchange earner after coffee.

The problems generated by industrial water pollution in developed countries are as serious as they are complex. In an attempt to get the situation under control, many of these countries have enacted legislation governing air and water pollution. The developing nations, like Kenya, should therefore be guided by the measures taken in the industrialized countries in taking pre-emptive steps to ensure that their emerging communities are spared difficulties similar to those which seem to be inseparable from industrial progress and raising standards of living. In the developing countries there should be an awareness of the pollution problem and measures prescribed to maintain it within acceptable limits. An effective way would appear to be a close integration of legislative and organisation control of effluent disposal in an overall national water policy.

2. ESTABLISHMENT OF AMBIENT WATER QUALITY STANDARDS

The basis of a pollution control system must be a specification of the quality of waters on which legitimate uses depend. Ambient water quality standards may be established for all types of water bodies including ground waters, rivers, lakes, estuaries and coastal waters. Three levels of ambient water quality standards can be identified in terms of increasing degrees of specifity: 1) no ambient water quality standards, 2) general water standards using terms such as "protected", "controlled", "restricted" or terms relating to use of the water body such as for drinking water, bathing, agriculture and; 3) quantative limits for a number of specific water quality indicators with or without linkage of the quantative limits to specific water uses.

Sweden has not established ambient water quality standards, except as standards are implied in such language as, "disturbances must be prevented" and nuisances should be avoided or rectified /3/. The New South Wales (Australia) Clean Waters Act (enacted 1972) represents the use of general water quality standards. This act provides for the following classification of waters:

Class S, specially protected waters
Class P, protected waters
Class C, controlled waters
Class R, restricted waters
Class O, ocean outfall waters and
Class U, underground water /3/.

In Hungary zones of water quality protection have been identified and their importance is dependent on the ranking of the uses of which the water resources are put. These are:

I	The catchment of Lake Balaton
II	Sources of domestic water supply and recreational areas
III	Industrial agglomerations
IV	Sections of Danube and Tisza rivers of inferior significance
V	Areas of inferior water management significance /4/.

The third degree of specificity, that is, where water quality standards are expressed in terms of quantative limits for a number of water quality indicators is exemplified by the Japanese system, the United States system and recently by the United Kingdom /3/.

In Japan, ambient water quality standards are divided into

1. those related to protection of human health and
2. those related to conservation of the living environment.

Table 1. Japanese ambient water quality standards for protection of human health, as of February 1975.

Water quality indicator	Standard (a)
Cadmium	0,01 mg/l or less
Cyanide	Not detectable (b)
Organic phosphorus (c)	Not detectable
Lead	0,1 mg/l or less
Chromium (hexavalent)	0,05 mg/l or less
Arsenic	0,05 mg/l or less
Total mercury (d)	0,0005 mg/l or less
Alkyl mercury	Not detectable
PCB	Not detectable

a) Maximum values. With regard to total mercury, the standard is based on the yearly average value.

b) "Not detectable" means that the substance is below the level detectable by the specified method of measurement.

c) Organic phosphorus includes parathion, methyl parathon, methyl demeton and E.P.N.

d) The standard for total mercury is 0,001 mg/l or less in case it is obvious that pollution in rivers is caused by natural factors. /3/

In Kenya there are no ambient water quality standards. However, it should be noted that if any system were to be comprehensive and kept up-to-date with the advancing knowledge of water quality needs, it would be very extensive and regularly expanding in coverage and complexity.

Yet the specification needs to be as simple and efficient in operation as possible. Overall then, the sensible course of action is to formulate the simplest workable and effective specifications accepting the limitations of the product and the fact that refinement must take place and fairly quickly.

In this limited approach the first task is to simplify the consideration of water quality relating to the various uses. Of the legitimate uses of surface waters, four broad categories are of fundamental importance:

I Water supply uses (domestic, industrial and agricultural)

II Fisheries use

III Environmental uses, including amenity and recreation and environmental protection

IV Use of disposal and conveyance of waste waters. In general, this use is in competition with the others.

Yet, if the effects of waste water disposal are controlled, so that the public supply and fisheries uses are safeguarded, all other uses usually will be likewise safeguarded.

However, it must be borne in mind that in any given catchment area, the water quality needs of fisheries and of environmental uses are relevant to all lengths of sizeable streams. In contrast the extent of water quality needs for public supply purposes at any point varies with the distance between that point and location of the abstraction for public supply. There may be of course on any given length of river a multiplicity of abstraction points for industrial and agricultural purposes, but the specific needs of such abstractions do not normally require special considerations because these will be usually protected by the general safeguard afforded to fisheries and environmental needs.

Thus a general specification of surface water quality substantially to meet all user needs, will be adequate if it is directed to meeting the water quality needs of public supply, fisheries and environmental protection. There will be, of course, exceptional cases requiring special attention to be taken into account from time to time.

3. ESTABLISHMENT OF DISCHARGE CONTROLS

Since the major objective is to improve or maintain surface water quality, the polluting potential of effluent discharges should be controlled.

The characteristics of the control system must be

a) to ensure the maximum practicable equity between competing demands for use of waters
b) to be as simple and as understandable in concept and operation as possible
c) to be readily adaptable to meet foreseable future requirements
d) to be as efficient as possible in the use of resources.

Discharge controls can be discussed within various headings. The most important being

1. Effluent discharge standards
2. Economic incentive methods
3. Industrial water pollution control technology which includes
    a) "Better environment processing"
    b) Waste water treatment technology.

To be able to efficiently administer this control system, the management should have

1. an efficient monitoring system
2. a legal system which is both clear and precise to enable the enforcement of the control system.

All this cannot succeed without the joint participation of the public and the industry, and this is only possible with increased public and industrial awareness of the water pollution problem.

4. EFFLUENT DISCHARGE STANDARDS

4.1 Factors to be considered in establishing discharge standards

- Assimilative capacity of the water body and its variation by time of the year.
- Existing ambient water quality standards.
- Use of water body and associated benefits.
- Available production process and residual modification technology, both domestic and international.
- Variable in residuals generations.
- Whether or not toxic residuals are generated.
- Costs to discharger of reducing discharges in relation to present and future profitability of enterprise.
- Employment effects in region if costs of reducing discharges were to "sink" the enterprise.
- State of the national economy.
- Effect on international competitive position.

Discharge standards for direct discharges into surface or ground water bodies should be developed and imposed in relation to the desired water quality standards to be achieved. This requires one or more water quality models which transform the time and spatial patterns of ambient water quality. However, where rough or simple water quality models, e.g. volumetric, are adequate to indicate that ambient water quality standards can be readily met if all discharges adopt reasonable practices, then analysis using more complex water quality models is not necessary.

In addition, verified water quality models do not exist for all types of discharges. At present, the behaviour of degradable organic materials, suspended solids, total dissolved solids and nutrients (N&P) have been with some success modelled.

Standards imposed on discharge of effluents can be expressed in various ways, both with respect to discharges directly to surface and ground water bodies and with respect to discharges to municipal facilities. It is also important to distinguish between direct discharge standards and indirect standards. Direct standards are those standards which are related directly to the quantity and/or quality of discharge. Indirect standards are those standards which are expressed in terms of required production processes, limits on types and/or quantities of inputs, specifications of final product outputs, such as prohibiting or limiting the phosphate content in detergents. The application of the physical measures specified by these indirect standards is assumed to result in an acceptable effluent quality.

In Sweden there are no effluent standards /6/. The National Franchise Board for Environment protection makes an assessment of the measures necessary in each individual case. Activities which may have detrimental effect on the environment (such as effluent outfalls from municipal or industrial waste water treatment plants) need a permit from the National Franchise Board. Minor potentially polluting activities are handled by the county administrative boards. Although there are no effluent standards some general tendencies in the discharge permits for municipal waste water treatment plants can be noticed. (Table 2)

Table 2. Typical discharge requirements /8/.

Type of receiving water	BOD_7 removal %	mg/l	Total phosphate removal %	mg/l
Coastal areas with good water exchange and rivers providing very great dilution	60	-	90	0,5-0,6
Other cases including all inland water discharges	90	15	90	0,5

4.2 Effluent standards in Kenya

Until 1972 the only guideline a designer of an effluent treatment plant was given was that the works should be able to discharge a final effluent of 20 mg O_2/l of BOD_5 and 30 mg/l of suspended solids /6/. This "20/30" standard has its origin in a report of river pollution in England and Wales by a Royal Commission on Sewage Disposal that was set up as far back as 1898.

The importance of dilution of the effluent by the receiving stream has since been realised. The reason why Nairobi river is so grossly polluted is that although the city's sewage works at Kariobangi is designed to produce a "20/30" standard effluent, the Nairobi river can contain up to 60 % sewage effluent during the dry weather /6/.

Standards giving maximum concentrations of potentially harmful substances in the effluent are now incorporated in the agreement with the Water Apportionment Board. The standards laid down are based on the assumption that the allowed concentrations will not affect the downstream use of the water. Standards are also considered necessary at the very start of a proposed works so that a goal for the design of the treatment plant can be established.

4.3 Information required for establishing standards

4.3.1 Dilution

The Hydrology Section of the Ministry of Water Development (MOWD) operates a network of gauging the critical dry weather flow which is taken as average driest 10 days (in sequence) in a year with 5 years return period. In Kenya, the standards for rivers are normally made in terms of maximum permissible load discharged over a period of time. When a standard for an average load is given, concentration limits should also be given in order that consent conditions are more easily enforced.

4.3.2 Subsequent downstream use of water

Although it is hoped that by the year 2000 the entire population will have access to a safe treated water supply, investigations during 1983 have shown that only 23 % of the entire population has a piped water supply and the vast majority of rural population, about 80 % of the total population, obtain water directly from rivers and streams /1/. Thus in most cases standards must be set to ensure that any effluent does not affect the river as a source for domestic supply, as opposed to standards in developed countries where the main criteria is that the effluent shall be non toxic to stream biota, recreation and industrial purposes.

It is therefore apparently clear that effluent standards in Kenya ought to be even more rigorous than in developed countries when note is also taken of the meagre water resources available, as compared to developed countries. In dry areas of Kenya stream flows are seasonal and it should be anticipated that in future many effluent discharges should be used for irrigation. Standards in such areas will therefore vary according to crops being grown taking into account the salt tolerances of the plants and public health considerations.

4.3.3 Self purification characteristics of rivers

There was an attempt in 1970 by WHO for a sectorial study for sewage and pollution in Kenya. Part of the study was to survey all the major rivers and compile an inventory on all sewage works and industrial discharges. River velocities, bed characteristics and water depths were some of the parameters measured.

Streeter and Phelps mathematical model for predicting the effects of effluents on the subsequent downstream distribution of oxygen can be used, with appropriate modifications. The streams in Kenya, generally, have only sparse macrophytic populations so that photosynthesis is not important and stream velocities are too high to allow organic solids to settle. Thus the two limitations of the model can be eliminated. Figure 1 shows the dissolved oxygen sag curve.

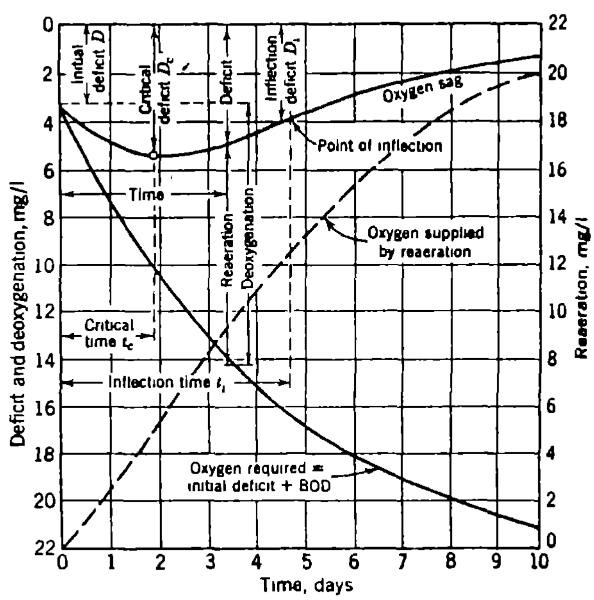


Fig 1. Dissolved oxygen sag and its components deoxygenation and reaeration /7/.

4.3.4 Composition of effluent

Major polluting sources are sewage works, industrial effluent and coffee waste waters. Coffee wastes are particularly the major agro-industrial pollutant. They are widespread especially during the pulping season. Effluent discharges from coffee factories can have a BOD_5 of 4000 mg O_2/l /6/. An inventory of effluent discharges quality, both industrial and domestic, is necessary hence a properly organised waste water monitoring system should be mandatory.

4.3.5 Existing pollution load upstream of outfall

There exists scanty data in the Ministry of Water Development on the level of pollution in rivers. This data should be utilized. There is great need to establish regularly the quality status of the rivers and the quality of effluents discharged. Thus a regular monitoring system is necessary.

To be able to have an idea on the pollution load emmited by a particular industry, the Ministry of Water Development has prepared a questionnaire which should be filled by the industry in question before starting its operation or/and enlargement.

4.4 Standards applied to discharges into municipal facilities

- Limit on total waste water quality per day
- Limit on total waste water quantity per day
- Limit on total quantity of various materials e.g. kg/BOD_7/day
- Limits on concentrations of various organic materials which are expressed for instance as BOD
- Phenols, suspended solids, cyanide, grease, oil, heavy metals, other toxic substances

- Limit on pH
- Limit on the variations in quantity of waste water e.g. maximum instantaneous flow must be no more than 10 % larger than mean daily flow.

Recommended discharge limits for industrial effluents entering public sewers in Kenya /9/:

1.	pH	6 - 9,5
2.	Sulphide	$\leq$ 10 mg/l as S
3.	Sulphate	$\leq$ 100 mg/l as SO^{-2}
4.	Cyanide	$\leq$ 10 mg/l as CN^{-}
5.	Ammonia	$\leq$ 100 mg/l as NH_3
6.	Grease and oil	$\leq$ 100 mg/l (grease and oil dissolved in methylated spirits)
7.	Total dissolved solids	$\leq$ 3000 mg/l as NaCl
8.	Heavy metals (any metal with atomic weight greater than 50 excluding Fe, Mn, Zn)	$\leq$ 25 mg/l combined
9.	Temperature	$\leq$ 43 °C (110 °F)
10.	BOD_5	Acceptable limit will be stated in agreement
11.	Suspended solids	No limits provided that gritty or inorganic materials such as sand which will settle out in the sewer pipes is discharged
12.	Prohibited substances	

a) Flammable compounds i.e. petrol, kerosine etc.
b) Organic solvents
c) Tars
d) Toxic materials i.e. herbicides, pesticides, arsenic, cadmium or mercury containing compounds etc.

5. ECONOMIC INCENTIVES

5.1 Pollution charges

This is a general term including both effluent charge and user charges. Effluent charges are those charges made on discharges to water bodies. User charges are those charges paid for using collective (municipal) treatment facilities. The common similarity is that the payment is directly tied to the amount of pollutant discharged.

The factors which form the basis of the charge include the following /3/

- suspended solids
- oxidisable matter expressed as BOD or COD
- nitrogenous substances
- inhibiting and toxic substances
- soluble salts.

5.1.1 Need for pollution charges

- The charge provides a continuing incentive to discharger to reduce his waste discharge and serves as a guide to public investment decisions.
- Provides some finance to the regulatory body for effectively enforcing the regulations.
- Provides new financial resources which will enable a programme for investing (even operating) pollution control work.

5.2 Effluent charges

In Central Europe and in the United States of America every discharger of waste water into an aquatic environment (rivers, lakes etc.) must pay a pollution charge. The basis for assessing the charge is the quantity of pollutants discharged. In Netherlands pollution load is expressed in population equivalent (p.e.). The charging formula

$$P = Q \frac{COD + 4,7\ N}{180}$$

where

P = pollution load

COD = chemical oxygen demand (mg/l)

Q = rate of discharge (m^3/day)

N = organic N + NH_4-N content (mg/l)

180 = conversation factor to convert load to p.e.

The standard rate of charge (per p.e) is fixed annually. The government fixed it at 2 guildens (~ 9 Ksh) per p.e in 1971 for discharges into fresh state waters, gradually increasing to 23,50 guildens (~ 100 Ksh) in 1980. For discharge into salt waters the rate was fixed at 2,01 guildens (~ 9 Ksh) per p.e in 1973 increasing to 17,50 guildens (~ 80 Ksh) in 1980 /10/.

5.3 User charges

These are charges for acceptance and treatment of industrial effluent in public sewerage system. It was recommended in 1975, in Kenya, that the basis for charging is the Mogden formula /9/.

$$C = V \frac{Qe}{2Qs} + B \frac{Oe}{Os} + S \frac{Se}{Ss}$$

C = cost (in Ksh)

V = cost/1000 gal of sewer, preliminary and primary treated

$$= \frac{6,50}{1000} \times \frac{\text{Annual running cost of sewers, preliminary and primary treated}}{\text{Total annual running cost of sewerage system plus sewage treatment works}}$$

Qe = maximum flow of industrial effluent

Qs = average flow of industrial effluent in 24 hours

B = cost/1000 gallons for secondary treatment

B (conventional works) = Ksh 6,50 x $\frac{9}{40}$ / 1000 gal

= 1,50 Ksh

B (lagoons) = Ksh 6,50 x $\frac{3}{13}$ / 1000 gal = 1,50 Ksh

Oe = average BOD_5 (mg O_2/l) of industrial effluent

Os = average BOD_5 of domestic sewage

This value was set as equal to 450 mg O_2/l. It was based on BOD_5 determinations in various towns in Kenya, where no industries discharged into the sewage treatment works i.e. Bungoma, Nanyuki and Molo.

S = cost/1000 gal for sludge handling

This figure is applied only to conventional works where sludge handling is a regular operation.

S (conventional) = Ksh 6,50 x $\frac{4}{40}$ / 1000 gal

= 0,60 Ksh

Se = average settleable solids concentration of industrial effluent (ml/l)

Ss = average settleable solids concentration of domestic sewage

This was fixed at 10 mg/l. Since limited data for Kenyan sewage was available, the value for strong U.S domestic sewage was applied.

The value Qs is multiplied by 2 to estimate the peak effluent flow, just as the peak domestic sewage flow is determined. The benefit of flow balancing by the industry is realised through the Qe/Qs ratio. The more constant the discharge flow, the lower the sewer charge to the industry. Balancing also allows for installation of the minimum acceptable diameter sewers from the industry to the treatment works.

The industry also benefits by any pretreatment it undertakes, as seen in the Oe/Os and Se/Ss ratios. All forms of pre-treatment, e.g. screening, sedimentation, aeration etc. will serve to reduce the initial BOD and Ss to some extent.

The lower the average BOD of the effluent into the treatment works the lower the biological treatment capacity that the works must have. In turn, the Oe/Os ratio is reduced and accordingly the charges to the industry are lowered.

In practice, these recommendations were never implemented. In Thika municipality for example, the same charge for domestic waste waters apply for industrial waste waters

1st 10000 gal	Ksh 6,70 per 1000 gal
above 10000 gal	Ksh 8,70 per 1000 gal
minimum charge	Ksh 10/month /11/.

5.4 Pollution fines

In Hungary a pollution fine may be imposed upon any industry, farming operation or community which causes harmful pollution while cases of serious offense, a criminal procedure may be started. The magnitude of the fine depends on the amount of pollutants discharged beyond the specified limits, on the streamflow rate in the recipient flow, on the kind of pollution, on the special requirements to be observed in particular pollution control area and on other interests associated with water quality and public health. Table 3 shows effluent standards according to water categories and the fining rates per quantity exceeded.

Table 3. Effluent standards and fining rates /4/.

Pollutants	Effluent standards according to categories						Fining rate
	I	II	III	IV	V	VI	
	mg/l						Ft/kg
1. COD (dichromate)	50	75	100	100	150	75	1
2. Oil and fat (1)	2	5	10	10	10	10	20
3. pH (2) under	6,5	6,5	5	6	5	6	5
over	8,5	9	9	9	10	9	5
4. Total dissolved salts, natural	1000	1000	2000	1000	-	2000	0,1
technical	1000	1000	2000	1000	-	2000	1,0
5. Sodium equivalent 3 %	-	-	45	45	-	45	2
6. Phenols	0,1	0,1	3	3	3	3	50
7. Total suspended solids	100	100	200	200	500	200	1
8. Tar	0,1	0,1	2	2	2	1	120
9. Ammonium ions (4)	2	5	30	10	30	10	5
10. Total iron	5	5	20	20	20	10	2
11. Total manganese	2	2	5	5	5	5	20
12. Detergents (anionic)	2	2	5	5	5	5	60
13. Sulphides	0,01	0,01	2	2	2	2	100
14. Chlorine (free)	2	2	2	2	2	2	50
15. Fluorides	2	2	10	5	10	10	50
16. Total P (5)	2	2	2	2	-	2	20
17. Nitrate (5)	20	20	50	50	-	50	1
18. Coliform count (6)			10/ml				($0,05 \times 3^n$ Ft x m^3)
19. Cyanide (easily releasable)	0,1	0,2	0,2	0,2	0,2	0,2	5000
20. Total cyanides	2	10	10	10	10	10	50
21. Total Cu	2	5	5	2	5	5	50
22. Total Pb	0,2	1	1	1	1	1	200
23. Total Cr	2	2	5	5	5	5	50
24. $Cr^{(VI)}$	0,5	0,5	1	1	1	1	200
25. Total As	0,1	0,5	1	1	1	0,5	200
26. Total Cd	0,02	0,05	0,2	0,1	0,2	0,1	500

Table 3. Effluent standards and fining rates /4/. (Continued)

Pollutants	Effluent standards according to categories						Fining rate
	I	II	III	IV	V	VI	
	mg/l						Ft/kg
27. Total Hg	0,002	0,01	0,02	0,02	0,02	0,02	10000
28. Total Ni	2	5	5	5	5	5	200
29. Total Zn	5	5	20	20	10	10	50
30. Total Ag	0,05	0,05	0,1	0,1	0,1	0,1	1000
31.	LD 50 % dilution demand x m^3 x 1 ft						

1 Ft ≙ Ksh 0,3

(1) Three times as high for animal or vegetable fats.

(2) Expressed in equivalent quantity of NaOH or HCl.

(3) Sodium, in kg units, in excess of amount balancing 45 equivalent percentage of Ca, Mg and K in water.

(4) Total amount of ammonium-nitrogen expressed as mg N per litre.

(5) In categories I - II always, in categories III - VI only if discharged into standing water.

(6) n is the exponent of the coliform count expressed in normal form, but not more than 4.

5.5 Compulsory construction of waste water treatment facilities

In most developed countries it is obligatory for every industry to arrange for the treatment of their waste water. Whether they are connected to municipal sewerage system with or without pre-treatment or they have to have own treatment facilities.

In Kenya, experience has shown that it is extremely difficult to install water pollution control measures in already functioning industry. Although the industrialist claims that there are no funds for the installation of the required units, it is also technically difficult because of the layout of the machinery which could also be outmoded and not suitable for pollution control.

To avoid this problem, it is extremely necessary to clearly define and incorporate water pollution control measures at the planning stage of every new industry.

The Water Pollution Control section of the Ministry of Water Development has developed a procedure for dealing with new developers. Proposals of industrial venture that are presented to the Ministry of Industry must be referred to the Ministry of Water Development for clearance and matters related to water pollution control. Where the proposed establishment requires water permit, the Water Apportionment Board also refers the developer to the Water Pollution Control section.

5.6 State subsidies

In some countries the state subsidises the investments and running costs for industrial waste water treatment. This may take any form from contributing a certain percentage to waiving taxation on imported equipment and machinery for waste water treatment.

Whereas it may not be possible in Kenya for the state to finance individual enterprises with public finance, it should be quite possible, if not to waive taxation completely, to reduce taxation on imported equipment and machinery.

Another possibility would be to provide soft loans for water pollution control investments.

6. INDUSTRIAL WATER POLLUTION CONTROL TECHNOLOGY WITH REFERENCE TO TANNING INDUSTRY

6.1 Tanning process

The facilities in tannery consist of six process areas:

1) the beam house where hides are cleaned, sorted and prepared for tanning
2) tanning liquor preparation
3) the tan yard where the hides are converted into leather
4) the scrubhouse where cleaning, oiling and filling of leather are accomplished
5) the dry loft where the rough leather is dried
6) the rolling loft where final finishing of the leather is accomplished.

This is best outlined in table 4.

Table 4. Typical process for African dry hides for corrected grain upper leather /13/.

Process	Subprocess	Notes	Time
<u>Soak</u>	Weigh	Calculate estimated soaked weight = basis for lime process (soaked weight may be as dry weight x 2,9)	
	Soak	In pit with several changes of water. Water usage may be up to 400 % on expected soaked weight (over 1100 % on dry weight).	2 days
	Dry drum and washing	According to condition	3 hours
	Green flesh	On machine	

Table 4. Continued

Process	Subprocess	Notes	Time
Lime		200 % water at 28 °C 2,0 % lime 0,5 % glucose 1,5 % sodium sulphide	
		Drum	1 hour
	Add	2,0 % sodium sulphide	
	Drum rotation	At intervals for balance of	24 hours
	Flesh	On machine	
	Round - Trim	Weigh = Basis for delime and tan	
Delime and tan	Wash	Running water for	15 mins
	Delime	70 % water at 25 °C 2 % sodium bisulphite	
	Drum rotation		
	Drain		
	Pickle	70 % water at 25 °C 6 % salt 1,2 % sulphuric acid	
	Drum		1 hour
	Add	0,5 % formic acid	
	Drum		½ hour
	Add	12 % self basifying chrome	
	Drum		6 - 8 hours
		Lay overnight	
	Pile		48 hours
	Samm	Now in "Wet Blue" state	
	Split		
	Shave		
	Weigh	= basis for later process	

Table 4. Continued

Process	Subprocess	Notes	Time
Retan/ Dye	Wash	Twice 300 % water at 30 °C	15 mins
	Neutralize	100 % water at 35 °C 1 % calcium formate	
	Drum		30 mins
	Add	3 % syntan 1 % sulphited oil	
	Drum		15 mins
	Add	4 % mimosa extract	
	Drum		15 mins
	Add	2 % resin	
	Drum		30 mins
	Fat liquor	100 % water at 55 °C 3 % light sulphated cod oil 1 % raw cod oil 2 % filler (soya or other flour)	
	Drum rotation		45 mins
	Add	0,5 % cationic oil	
	Drum rotation		15 mins
	Rinse	Samm - Set - Paste dry	
	Hand condition	Stake - Pole dry - Sort	
		Now in a crust state	
Finish to requirement	Typically	Plate - Buff - Dust - Impregnate - Plate - Rebuff - Dust - Pad coat - Spray coat (twice) - Plate or emboss - Spray top - Board - Measure	
		Now finished shoe upper leather	

6.1.1 Typical water consumption

From soaking to wet blue state	21 litres water per kg limed pelt
To crust state a further	9 litres water per kg limed pelt
i.e. a total of	30 litres water/kg limed pelt

Tanneries however notoriously consume much more and to operate such process, may well consume 45 litres per kg limed pelt (including social use).

Thus a typical Kenyan hide of 5,5 kg dry may consume 650 litres during processing to the crust state /13/.

6.1.2 Source of pollution

The major sources of pollutants are

1) The constituents of the raw hide which are necessarily removed or adapted during the leather making process. These include the hair substances (whole, pulped or dissolved), various non collagenous proteins and natural fats of the hides together, with any curing agents which may be utilized.

2) The chemicals employed in leather production - either present as surplus in their original form or converted into other products.

3) Miscellaneous pollutants arising from housekeeping in tannery e.g. machine washing and other sanitary activities. Trimmings may be present.

6.1.3 Amount of pollutants (theoretical)

A UNIDO/UNEP study suggested that the theoretical minimal amount of pollution which currently is inevitable during production of chrome tanned leathers, employing conventional process, with water consumption of 66 litres/kg salted hide could be /14/

Total solids	10000 mg/l
Suspended solids	2500 mg/l
$KMnO_4$-value	1000 mg/l
BOD_5	900 mg/l
Sulphide	160 mg/l
Chrome	70 mg/l
Chloride	2500 mg/l

If however a similar chemical input was employed with short float techniques, 15 l/kg hide, one could possibly obtain a 4 fold increase in pollutant concentration, i.e. /13/

Suspended solids	10000 mg/l
BOD_5	3600 mg/l.

6.1.4 Solid wastes

In addition to the effluent produced, tanneries also produce large volumes of solid wastes. It is reported that a survey of 50 tanneries suggested the following solid waste production /13/.

Solid wastes as % of wet salted hide	
Trimmings with hair on	1,5
Fleshing after liming	13,5
Splits after liming	4,8
Chrome tan splits x)	6,9
Shavings	6,5
Leather trimmings	4,7
Buffing dust	1,0
Vegetable tanned splits x)	4,9

x) either or

Depending on the level of "house keeping" these solid wastes may be collected and disposed. However, if these solid wastes are allowed to enter the effluent stream, they only introduce unnecessary pollutant load.

6.2 In-plant measures for reducing discharges

The possibility of employing better environmental processing will be determined by the plant and machinery available. In a new tannery it is possible to introduce modern procedures at the design stage. But in old tanneries possibilities exist but may be more difficult to introduce due to unsuitable lay-out of the plant.

Also certain processing techniques may necessitate the presence of a qualified leather chemist with a laboratory at his disposal. This cannot be guaranteed in all Kenyan tanneries.

The possibilities of improving environmental aspected of leather processing are endless. In this paper it will be presented some of the major areas where it is known that significant reduction of pollution is possible or where economic advantage is visible.

It is shown that water consumption may be reduced from 40 to 11 l/kg and lime usage reduced to only 2 % on soaked weight /13/.

6.2.1 Water usage

6.2.1.1 Short floats

Short floats give both water and chemical savings. Higher concentrations of chemicals are used (more than in long floats). In turn more efficient exhaustion and more rapid penetration and processing results. But it should be observed that this increases wear and tear of the drum and better drive mechanisms are necessary. Older factories may not be able to use short floats.

6.2.1.2 Water recycling

Diagramatic representation of a simple recycling proposal is shown in figure 2 /14/.

Figure 2. Modified "Bailey" process

Process	No re-use		With re-use = saving
Soak and wash			
1st wash	300 %	s	
2nd wash	200 %	s	350 %
Lime	100 %	s	100 %
1st wash	150 %	s	
2nd wash	150 %		
Delime and bate	100 %	s	
Wash	100 %		
Pickle and chrome tanning	60 %	s	
Wash	100 %	s	
Neutralization	100 %		
Wash	100 %		
Retanning	50 %	s	
Wash	50 %		
Fat-liquoring and dyeing	50 %	s	
1st wash	50 %	s	
2nd wash	50 %	s	
	1710 %		450 %

Saving	1710 % (17 l/kg)
	- 450 %
Water usage	1260 %
	or about 13 l/kg

s = direct to factory effluent collection system

The proposal suggests that

the wash after bate,
neutralization float,
the wash after neutralization
and wash after retan

are collected in catchpits and used for first and second liquors and washes. Also the second lime wash is recycled to be the float for the depilation operation. Recycling would be much better suited for new tanneries. It is also difficult to recycle if the tannery has many small drums hence different operations may be taking place simultaneously.

6.2.1.3 Batch washing

Batch washing is far more economic than continuous washing. It has been shown that continuous running water rinsing can raise total water consumption to up to 100 l/kg whereas with controlled batch washing 25 l/kg could suffice /14/.

6.2.2 Curing

Kenyan hides and skins are normally sun dried and hence do not use salt for curing. Salt curing brings into the effluent about 150 g salt per kg hide /13/. In Kenya where much of the waste waters should be used for irrigation, this can have deleterious effects on the soil. However, salt cured hides are said to produce better quality leather.

6.2.2.1 Soaking

Soaking reverses the drying process. The duration depends on the level of mechanical action as well as inputs of chemicals. In addition to detergents proteolytic enzymes are used (1 - 2 % enzyme product on dry weight). Initial soaking employs floats of over 1000 % on dry weight /15/.

The pollution load is enormous (blood, dirt, fat and proteins). Water quality requirements for soaking are low hence this is ideal operation for recycling. Also control of water usage should be done.

6.2.3 Improving lime/sulphide dehairing

It is accepted that today traditional lime sulphide yields superior leather, though it is expected that non lime/ sulphide unhairing process will be developed in the future. It is therefore necessary to reduce the pollutant load produced and/or treat the pollutant so produced.

Two major ways of reducing pollutant load in this process are available:

a) minimise amount of lime/sulphide
b) a) plus recycling.

6.2.3.1 Minimisation of lime/sulphide amount

The maximum amount of lime and sulphide is dependent on the efficiency of soaking, quality of hide and skin, temperature of the bath, time and level of mechanical action /13/.

It is therefore essential that tanneries should carry out tests to reduce their inputs to optimum levels.

6.2.3.2 Recycling of lime liquors

In recycling there are three objectives:

I to maximise the efficiency of chemical offered,
II to reduce the pollutants,
III to preserve the pollutants in minimal levels to allow economic treatment.

A level of recycling applicable to large tanneries in Kenya may be:

The used lime liquor is collected, allowed to settle overnight. The supernatant drawn off, analysed and replenished and reused.

6.2.4 Improving pickle and chrome tan

The pollutants consist of unfixed chrome, neutral salts introduced with chrome, salts from pickle and tan baths and residues of any masking and basification together with minute amounts of hide protein.

Where pickling is carried out as a separate process, it is relatively easy to recycle and generate the pickle.

Reduction of chrome in tannery effluent may be achieved by

1. Incresing chrome fixation
2. a) Recycling of liquor
   b) Recycling followed by precipitation of chrome from effluent.

6.2.4.1 Increasing fixation

Increased fixation is favoured by /13/

I Short float
II Increased temperature
III Increased time of tanning
IV Increased basification
V Decrease in neutral salts
VI Optimising certain specific chemicals.

6.2.4.2 Recycling of chrome liquors

Two main systems of recycling of chrome liquors currently practised are a) recycling of chrome liquor floats without precipitation, b) recycling of chrome following precipitation and resobulising. Lime or sodium carbonate can be utilized to precipitate the chrome. The used float is treated with an alkali to precipitate the chrome as a hydroxide. The sludge can then be passed to a filter press and the cake so formed redissolved chrome can be used for split tannage where final properties are not so demanding. One drawback of this system is that the neutral salts would be discharged to the effluent from the filter press (thus there will be no reduction in salinity of effluent).

Under Kenyan conditions, one could assume that high fixation "or liquor recycling" is more suitable. The precipitation process could be suitable as a major recycling process in a large tannery which would justify the plant cost. However, a cruder precipitation system could be installed as a back up unit to remove any chrome effluent pile/wash/neutralize processes.

6.2.5 Post chrome process

This section of processing contains four water utilizing activities which are of minor pollution significance. These processes are:

1) Wash, neutralize, wash
2) Retan, dye, fat, liquor
3) Dry
4) Pigment finish

6.2.5.1 Neutralization

It is only necessary to ensure that no surplus waters are employed. In the washes, some chrome will bleed out of the hide. Relatively short floats are now universally accepted.

6.2.5.2 Retan, dye, fat, liquor

Using short floats and high temperatures ensure maximum fixation. This reduces the amount of pollution load.

6.2.5.3 Drying

Appreciable amounts of warm water are utilised in this process. This should be recycled. Pasting machines use 2 - 3 litres/kg hide for washing the plates. The water can also be recycled. However, small quantities of polysacharides from the paste will enter the effluent.

Colour changes should be minimized in order to be able to maximize the recycling.

6.2.5.4 Pigment finishing

Pigment finishes are sprayed onto dry leather surface and hence should not contaminate the effluent directly. Most pigment effluents will be due to washing of equipment and utensils. These can be disposed of separately into soakage pits where the insoluble colloidal nature of the mixture is unlikely to permeate far or contaminate ground water.

6.3 External effluent treatment technology

6.3.1 Treatment technologies employed in Kenya

Due to the fact that there has been only limited and unco-ordinated pressure to date, to control and minimise effluent pollution levels, none of the tanneries employ "Better

Environmental Process". This is compounded by the fact that most of the existing tanneries are not of recent installation, have grown gradually without any real long term plan thus the plant and machinery are poorly laid out.

This creates major problems in the design of waste water treatment plants. The wrong unit operations are incorporated with excessive costs without obtaining the required removal efficiency.

In new industries, also, the problem persists due to lack of qualified expertise. Some designs are taken straight from the book without consideration of the specific problem.

Table 5 shows types of technologies employed in Kenya /16/.

6.3.2 Treatment technologies available

6.3.2.1 Waste stream separation and pretreatment

The following steps are followed in this type of treatment.

1) Initial wash water screened and clarified, sometimes re-used.
2) Unhairing liquors screened, manganese and air added to oxidize sulfides, flue gas added to neutrize excess alkalinity and clarified. The lime can be removed by settling and reused and sulphides can be expelled by acidification, captured and reused.
3) Fleshings can be used for oil, glue, gelatin or screened and discharged as solid refuse.
4) Bate liquors screened.
5) Pickle liquors can be used as makeup for tanning solutions.
6) Spent chrome liquors screened, pH raised to 9,5 - 11,5 to precipitate chromium hydroxide. Chromium hydroxide either discarded as solid waste or re-dissolved and returned to process. This may represent 25 - 35 % of total chrome into process. Lime can be used to precipitate chromium hydroxide.

Table 5. Technologies employed by Kenyan tanneries. * = Estimate

A Operational

Company/ Location	Annual Production (P) Capacity (C)	Size Cate-gory	Water Usage Currently & Source	Effluent Disposal	Comments
Bata - Limuru Tannery (urban) (urban)	200000 hides (P) 600000 skins (C) Hides mostly finished Skins mostly wet blue (10 M.T. soaked weigth daily)	L	Borehole 600 m^3/day *	Via a series of pits and informal ponds. Said to be: sedimentation tanks, equalisation, facultative lagoon, polishing lagoons. Final discharge in lake/swamp together with municipal waste waters. Ultimate recipient River Tigoni. Flow of river is not known.	System working poorly and not in accordance with Pollution Control Dept. advise. Discharge would appear well above pollutant level authorized. Pond leaking of H_2S noticeable several miles distant. Significantly down-grades local environment.
Bata - Limuru	Leatherboard ? M.T.	-	?	Apparently untreated discharged to swamp as above.	Effluent appears to contain high % of suspended solids.
Bulleys - Thika	300000 hides (P) mostly crust less than 10 % finished	L	River 600/800 m^3/day *	Following a series of horizontal flow sedimentation tanks the effluent is allowed to flow over land down the banks of the river Thika with 1250 m^3/d MQ said to be diluted 300 fold.	System - although only basic primary does appear to be operated with at least regular sludge removal. No data as to effect on river.

Table 5. Technologies employed by Kenyan tanneries. Continued. * = Estimate

Company/ Location	Annual Production (P) Capacity (C)	Size Cate-gory	Water Usage Currently & Source	Effluent Disposal	Comments
Bulleys - Kahawa	3 million skins (C) 1 million skins (P)* mostly to wet blue state	L	200 m^3/d *	Effluent following pre-treatment given "land treatment" prior to discharge into river Kiu. Flow of river is 10 l/s MQ.	Factory due to be closed in near future as site unsuitable for disposal of effluent.
Tannery of Kenya - Athi River (Bulleys Associate) (Semi-Rural)	200000 hides (P) Few splits finished	L	400 m^3/d *	Only recently restarted production. Effluent via 2 small informal pits is pumped to sedimentation section of large lagoon a weir allows entry to main lagoon. This was originally aerobic but the 2 aerators have been stopped and attempts made to obtain anaerobic conditions. Proposed to dispose of effluent by land spray over 20 hectares. Flow of river 50 l/s MQ.	Efficiency of system unproven. Possibly will work initially but ultimately may expect land to clog. Vegetation to die and then seapage towards river may occur. With the low flows in the Athi river disposal of water by evaporation would appear "anti social".

Table 5. Technologies employed by Kenyan tanneries. Continued. * = Estimate

Company/ Location	Annual Production (P) Capacity (C)	Size Category	Water Usage Currently & Source	Effluent Disposal	Comments
Sagana Tannery - Sagana (Semi-rural)	100000 hides (C) 25000 hides (P) mostly completely finished	M	Water abstracted from small stream 50 m^3/d *	Effluent flows through series of interconnecting lagoons (15 day retention at full capacity) then partially diluted with fresh water prior to overflow to Sagana river. Flow of river 8000 l/s MQ.	Currently working at low level. Lagoons mostly dry. Large potential dilution by river ensures minimal impact/ pollution.
Nakuru Chrome Tanners - Nakuru (Urban)	1,5 million skins (P) 2,5 million skins (C) wet blue only	M	Municipal water supply 250 m^3/d	Effluent pumped via a holding pit, equalization pit to a series of 4 sedimentation tanks (1 day retention) then to municipal sewer. (daily total 3600 m^3/d)	Sedimentation pits poorly designed and operated. Appears low efficiency - uncertain effect on municipal ponds but H_2S is noticeable.
Nakuru Tanners - Nakuru (Urban)	10000 hides 25000 skins all finished mostly vegetable	S	Municipal water supply 20 m^3/d	With above.	

Table 5. Technologies employed by Kenyan tanneries. Continued. * = Estimate

Company/ Location	Annual Production (P) Capacity (C)	Size Cate-gory	Water Usage Currently & Source	Effluent Disposal	Comments
Azziz Din Nabibux Nairobi Industrial Area	20000 hides mostly vegetable tanned rejects	S	City water supply N/A	Directly to city sewer (1000 l/s municipal sewer)	- No direct nuisance.
East African Leather Factory Juja Road Nairobi	25000 hides most to crude vegetable sole	S	Borehole 45 m^3/d	Effluent currently employed for irrigation. Series of 3 sedimentation pits installed to be employed when sewer available. Nairobi river flow 1000 l/s.	No discharge to river. No environmental nuisance. (Sedimentation pits need modification to be effective.)
Newmarket Leather Factory - Nairobi	250000 skins wet blue	S	City water supply 30 m^3/d	Effluent passes via a nominal sedimentation/ grease trap to city sewer.	Sedimentation pit wrongly designed. Possible easy conversion.

7) Paste wash water settled and reused or simply discharged.

8) Shaving used for fertilizer or discarded as solid refuse.

9) Colouring, fat liquoring and finishing wastes screened and clarified.

10) Buffing dust removed in dry form (they are highly inflammable) or wet by a fine screen or centrifugal device.

Effect of pH on solubility of trivalent chromium /17/ is shown in figure 3.

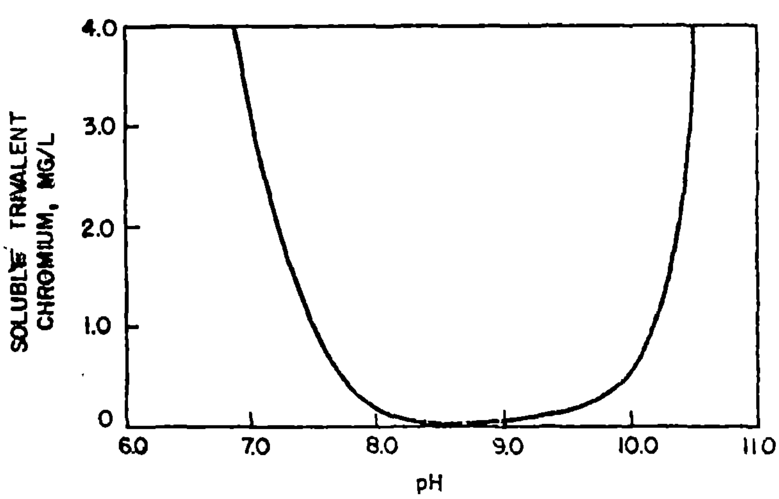


Fig 3. Effect of pH on solubility of trivalent chromium.

6.3.2.2 Final treatment

All waste streams after pretreatment are usually subjected to biological treatment.

a) Aerated lagoons; work well in warm weather: leave high ammonia levels and long detention times are required.

b) Active sludge (conventional); generally not used because of operational problems. Also they have low level of nitrification.

c) Activated sludge (extended aeration); are used in Europe but there is limited experience elsewhere. Long detention time required (2 - 3 days). High sludge age required for complete nitrification.

d) Trickling filters; have been used to a limited extent in the United States of America. Aerated lagoons and activated sludge processes have high high power requirements, often as much as the production processes.

6.3.3 Residual modification technology and reuse

Residues can be modified and reused as follows;

- The fleshing waste recovered from the beamhouse can be used as glue stock. This would provide a minor source of income.
- The waste waters especially from the beamhouse can be used for irrigation if the hides are not salt cured.
- Sludge can be used as fertilizer.
- Trimmings can also be processed into protein supplements for animal feed.

6.4 Effluent disposal by irrigation

Traditionally, irrigation has been used to improve crop yields but in more recent years there has been a growing interest in irrigation as a method of waste water disposal /18/.

The following parameters must be considered before starting irrigation with waste waters; suspended solids, salinity, organic substances, nutrients, inorganic ions, sodium absorption ratio, temperature and bacteriological quality /18/.

Soil scientists have classified the quality of irrigation water according to salinity, relative amounts of sodium, boron, chloride ions, exchangable sodium (ES) and sodium carbonate /19/. These classification schemes obtained are in form of tables and diagrams. Four examples of classification schemes are shown in the following two tables.

Table 6. Standards for irrigation waters /20/.

Water	Conductivity	Salt content	Sodium, Na^+,	Boron
	µS/cm	in	as per cent of (Ca^{++} + Mg^{++} + Na^+ + K^+)	mg/l
1	1000	700	60	0,5
2	1000 - 3000	77 - 3000	60 - 75	0,5 - 2,0
3	3000	2000	75	2,0

Class 1 = Excellent to good, suitable for most plants under most conditions.

Class 2 = Good to injurious, probably harmful to more sensitive crops.

Class 3 = Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant.

Table 7. Evaluation of irrigation water quality /19/.

Evaluation rating	EC, in mS/cm	Na^{+}, as percentage of $Ca^{++}+Mg^{++}+Na^{+}+K^{+}$	SAR	Na_2Co_3 in milli-equivalents per litre	Cl^{-}, in milli-equivalents per litre	Es, in milli-equivalents per litre	Boron, in mg/l
1	0,5	40	3	0,5	3	4	0,5
2	1,0	60	6	1,0	6	8	1,0
3	2,0	70	9	2,0	10	16	2,0
4	3,0	80	12	3,0	15	24	3,0
5	4,0	90	15	4,0	20	32	4,0

Water rated number 1 would be considered excellent for agriculture and water that exceeds the limits for class 5 would generally not be usable for irrigation under any management or drainage condition. Intermediate values are relative to these extremes.

6.5 Selection of plant site

The following points should be considered when selecting a tannery site.

1. Areas where humidity is low and the temperatures are cool. There should not be great thermal variations.
2. Areas where there is availability of clear fresh water and adequate means for disposing of large quantities of abnoxious effluent. A tannery producing 330000 m^2 (3 million sq. ft) of leather a year would require approximately 230 m^3 (50000 g) of process water per day /12/.
3. The site should have easy accessibility.
4. The site should be close to a collecting and distributing point of raw hide.
5. Place where labour is easily available.
6. Proximity to consumption area i.e. where a great deal of shoes, bags etc. are used.

Point number two (2) is very important from water pollution point of view. Thus it should be noted that a site may satisfy all the other requirements but if it does not meet the requirements of environmental protection, it should not be recommended.

7. MONITORING

Monitoring can be defined as the collection of information on a continual basis. Monitoring must therefore provide information about the quality and characteristics of waste water delivered into the system.

The initial step in developing a sound monitoring program is the metering, sampling and analysis of all significant streams leading into a plant, circulating through the plant and leaving the plant. This procedure is basic to any of the following purposes:

1. To meet refulatory agency effluent requirements.
2. To determine equitable charges for joint treatment.
3. To determine adequate treatment process.
4. To plan for water reuse and conservation.
5. To determine production losses, either for the purpose of planning a recovery system or the design of processes which prevent such losses.
6. To determine treatment efficiency and to trouble-shoot any process failures.
7. To design treatment plant expansion /21/.

The control of a waste system will therefore require monitoring beyond that specified by the regulatory agencies, since the regulatory system should be an overview function. Providing a system preventing violations should be the responsibility of the manufacturer. If the in-plant control system is carried out effectively, there will be a minimum of regulatory involvement in plant production operations.

A waste monitoring system should become an integral portion of the manufacturing process and be used as a measure of efficient operation.

7.1 Sampling

The basis of any plant pollution abatement program rests upon information obtained by sampling. Obtaining good results will depend upon certain details. Among these are the following:

1. Ensuring that the sample taken is truly representative of the waste stream.
2. Using proper sampling techniques.
3. Protecting the samples until they are analysed. Obviously, the type of sample and sampling equipment will depend upon
   a) Pollutants to be monitored
   b) Quantity of sample required
   c) Frequency of sampling
   d) Nature of the sampling station
   e) Available resources.

There are six major types of sampling techniques:

1. Grab sample
2. Simple composite
3. Sequential composite
4. Continuous sample
5. Hand proportional composite
6. Automatic proportioned composite.

7.2 Parameters

To minimise the analytical costs and increase the effectiveness of a monitoring program, it is essential to select the proper parameters for measurements.

The parameters must be easy to measure but should give reliable results at the same time. In case where an analytical technique of a parameter is more expensive and there exists correlation with a cheaper analysis, substitution can be approved as the parameter in question can be correctly inferred /22/.

8. LEGAL ASPECTS

When an effluent is to be discharged into a water body, permission is required under the 1951 Water Act /6/. Standards giving the maximum concentrations of potentially harmful substances in the effluent are now incorporated in the agreement when the Water Apportionment Board issue a permit. The standards laid down are based on the assumption that allowable concentrations will not affect the down-stream use of the water. Standards are also considered necessary at the very start of a proposed works so that a goal for the design of the treatment plant can be established.

There is a long history of attempts to control pollution in the United States. The River and Harbour Act was approved on March 3, 1899. Then came the Federal Water Pollution Control Act in 1912 in which the US Public Health Services was authorised to investigate pollution. A series of amendments have since been issued on the same laws so as to accomodate the pressing and increasing needs of water pollution control. These acts had several limitations and subsequently fell into disuse because of several legal battles over the lack of defination of "Navigable Waterways" and the need to establish "environmental impact statements" at each outfall. The current "Federal Water Pollution Control Act Amendments" was established on October 18, 1972 and has been found to be free of most federal limitations. The responsibility for the protection of the environment lies on the Environmental Protection Agency (E.P.A.). Also there is another federal agency with important environmental protection activities i.e. the Council on Environmental Quality /23/.

In the U.K. the latest legislation is the Control of Pollution Act of 1974, for water authority control of effluent dis-charges /24/.

In Kenya, the available legislation for control of water pollution is mainly contained in the Water Act; chapter 372 of the Laws of Kenya /25/. Section 158 reads as follows:
(1) Any person who, by an act or neglect causes any source of water supply, the water from which is used or is likely to be used for human consumption or domestic purposes, or for manufacturing food or drink for human consumption, to be polluted, or to be likely polluted, shall be guilty of an offense.

Provided that nothing in this section shall be construed as prohibiting or restricting (I) any lawful cultivation of land or the watering of stock, which in the opinion of the Minister, does not conflict with the principles of good husbandry. (II) The reasonable use of oil, tar or other substances on any highway or road so long as the authority or person concerned takes all reasonable steps to preventing such oil, tar or other substances or any liquid or matter resulting from the use thereof, from polluting any source of water supply and any question as to what is reasonable use under the provisions of this paragraph shall be determined by the Minister or (III) the disposal of effluents or waste in any area which the Minister may, by order, from time to time specify.

(2) Any person duly authorised under this Act for the purpose may, on producing his authority, if so requested by the owner or occupier thereof, at all reasonable hours enter any land or premises for the purpose of ascertaining whether there is or has been any contravention of the provisions of this section in relation to such source of water supply and section 164 of this Act shall apply to such right of entry.

The rules 71 - 78 of the same Act attempts to describe how and in what manner should the effluents be discharged into the water bodies. Rule 74 is of particular importance because it dwells quite at length on coffee waste water. This may be because in the early 60's and 70's the coffee industry was the biggest polluter of surface waters especially in the pulping season. With more industrialization much more knowledge is therefore required for the various wastes and their treatments.

It has been realised for a long time that comprehensive revisions and considerably tightening of the Water Act is needed as far as pollution is concerned. The Water Apportionment Board has not adequate control over all effluents discharged into the rivers due to difficulties in interpretation and lack of precise formulation of the rules. The weakness lies in the fact that, whereas Section 158 of the Act and Rules 71 - 81 inclusive of the Water (General) Rules gives a norminal control of pollution, any powers exercised under them might be challenged in Courts on the ground that neither in the Act nor in the Rules is laid down a defination of what constitutes "Pollution".

The strenghtening of this position is particularly difficult problem which has from time to time received a good deal of attention without a satisfactory solution being reached as yet.

A major difficulty lies in the fact that a number of Kenya's established and developing industries; coffee, sisal, canneries, tanneries, creameries, meat processing, sugar, textiles. All these produce considerable volumes of highly polluted waste water, and if the Board were to impose suddenly and arbitrarily on say, the coffee industry,a degree of purity in their waste waters approaching that generally acceptable for trade and domestic wastes in other parts of the developed world, there would be a danger of putting these industries out of business. On the other hand, the total water availability in Kenya is so limited that to accept heavy pollution as inevitable and in consequence to withdraw these large volumes of polluted waters completely from further use after they have served their purpose either in coffee or tannery industries would also have serious effect on the economy of the country.

In view of the serious consequences to some industrial interests, it would be advisable to suggest that provision should be made for a period of grace 2 - 3 years within which industries emitting a polluting effluent would be required to make the necessary adjustments in order to comply with the requirements of the Water Apportionment Board.

As mentioned before, there is need of high standards of purity for effluents discharged from treatment works into rivers. The Public Health Act Section 126 authorises the Minister (of Health) to make rules on standards of purity but this has never been accomplished.

The responsibility of the Ministry of Health administrating the Public Health Act and that of Ministry of Water Development under the Water Act have to be clearly defined. As the rules under Section 126 of the Public Health Act mainly cover drainage and latrines for domestic buildings, it appears to be a sound reason to leave the responsibility of main sewers, treatment works, rivers and estuaries to the Ministry of Water Development. Nevertheless, Medical Officers may enter any premises and make any inquiries and take any precautions which is deemed necessary under the Public Health Act and Malaria Prevention Act.

In order to enable the Water Apportionment Board to take steps to prevent water pollution and to make necessary sanctions, the Water Pollution Control Officers have to report to the Board. It will be equally necessary to establish rules which give Ministry of Water Development legal rights to gain control of design, operation and maintenance of waste water treatment plants.

9. LEATHER INDUSTRY IN KENYA

9.1 Introduction

Currently the Kenya leather industry and leather products sector is poorly developed with only 20 % of hides being processed to finished procuct state. In the skin sector the industrialization is even less developed /26/.

In 1981 there were about 7 major tanneries operating. These tanneries employed about 900 people all together. The total sales were about Ksh 6.505.000 and the contribution to GDP was Ksh 32.207 /27/.

The raw hide and skin current exports is Ksh 8.000.000/a. This represents some 25 % of Kenyan exports of crude materials. Kenyan exports of leather is about Ksh 2.000.000. This represents about 10 % of Kenyan exports of manufactured goods.

Data is fragile regarding raw materials available to Kenyan tanners. An estimate from the veterinary depertment (1978/79) /28/ shows the availability of

1,3 - 1,4 million hides
4,0 million sheep and goat skins.

The apparent availability has until recently been much higher due to "unrecorded imports" from neighbouring countries.

Thus up to 2 million hides and 6 million skins have been available to the Kenyan hide and tanning sectors.

9.2 Tannery capacity and production

The actual capacity utilization of Kenyan tanneries has been low in recent years. The output was a reflection of world market demand and with no governmental incentives and relatively high manufacturing costs, large volumes of hides were exported raw even though capacity to process them existed. Currently the imposition of variable export cess and threatened ban on exports of raw hides and skins seems likely to lead to high tannery utilization factors /13/.

In 1977/78 the position was as follows; the domestically available hides were 1,4 million and the skins were 4,0 million. Hides processed in the tanneries were 0,73 million while skins processed were 0,54 million. The tannery capacity was 1,13 million hides and 5,63 million skins. Skins exported as wet blue were 3.165.980. Those exported as crust were negligible while those completely finished and domestically utilized were 123.500.

9.3 Potential effluent

An outline estimate /13/ of total water borne effluents arising out of 100 % processing to leather of all its hides and skins could be

1,4 million hides at average weight of 5,5 kg	= 7700 tons
4,0 million skins at average weight of 0,5 kg	= 2000 tons
Total dry weight	= 9700 tons

This would represent some 24000 tons in fresh state.

Potential pollution produced annually would be

BOD	1440 t/a
SS	3600 t/a.

Water could be consumed with conventional process annually 1,5 million m^3/a (6000 m^3/day). With more appropriate updated process could consume 0,8 million m^3/a (3000 m^3/day).

9.4 The case study

The tanning industry was chosen for this case study on the basis of its potential contribution to the Kenyan economy and also its potential as a major water pollutant.

Three tanneries were chosen, namely

1. Double Diamond Tannery
2. Fur and Wools Tannery
3. Bulley's Tanneries.

Their proximity to Nairobi (they lie within a radius of 40 - 50 km from Nairobi) made them ideal for this kind of study.

These tanneries differ in many respects. Double Diamond is a small tannery while Fur and Wools is medium in size. Bulley's Tanneries is the largest tannery in the country.

Double Diamond disposes its effluent on land through irrigation while Fur and Wools is connected to Thika municipality's sewerage system. Bulley's Tanneries discharge its effluent into Thika river.

Double Diamond is situated 40 km south of Nairobi in Athi River town while Bulley's and Fur and Wools tanneries are situated about 45 km north of Nairobi in Thika municipality.

9.4.1 Sampling

Except for composite raw effluent from Bulley's Tanneries, the rest are all grab samples.

Due to delay in arrival of chemicals there was time-lag between sampling and analysing. Some samples also got destroyed.

9.4.2 Analysis

All determinations were done according to the standard methods /29/. For all tanneries pH, BOD_5, COD chromium (total), conductivity and suspended solids were analysed. For effluent from Double Diamond Tannery, in addition, calcium, sodium, alkalinity and magnesium were analysed. Soil samples were analysed in Finland.

9.5 The Double Diamond Tannery

9.5.1 General

This is a small size tannery by Kenyan standards. It processes 200 dried cattle hides and 3000 dried sheep and goat skins per day.

	Weight/piece hides	(kg) skins
Dry weight	4	0,6
Soak weight	10	1,2
"Normal salt weight"	10	1,2

Since most of the experience regarding pollution emmission from tanneries refers to working up salted raw materials, a fictional "normal salt weight" is used in the calculations. The "normal salt weight" for hides is 2,5 times the dry weight and for skins 2 times the dry weight. Rinsing is done 2 times after dehairing, 1 time after deliming and 2 times after degreasing. 200 % water for each rinse is allowed.

The following table shows water consumption (litres/kg dry weight) /15/.

Table 8. Water consumption (litres/kg dry weight).

Process	Hides		Skins	
	Process water	Rinse water	Process water	Rinse water
Soaking	6,6	-	9,0	-
Dehairing	5,0	10,0	4,1	6,0
Deliming	2,8	5,5	4,1	4,0
Degreasing	-	-	2,2	6,0
Pickle/chromium tanning	1,6	-	2,0	-
Foul water	16,0	15,5	21,4	16,0
	3,5		4,1	
Total	35,0		41,5	

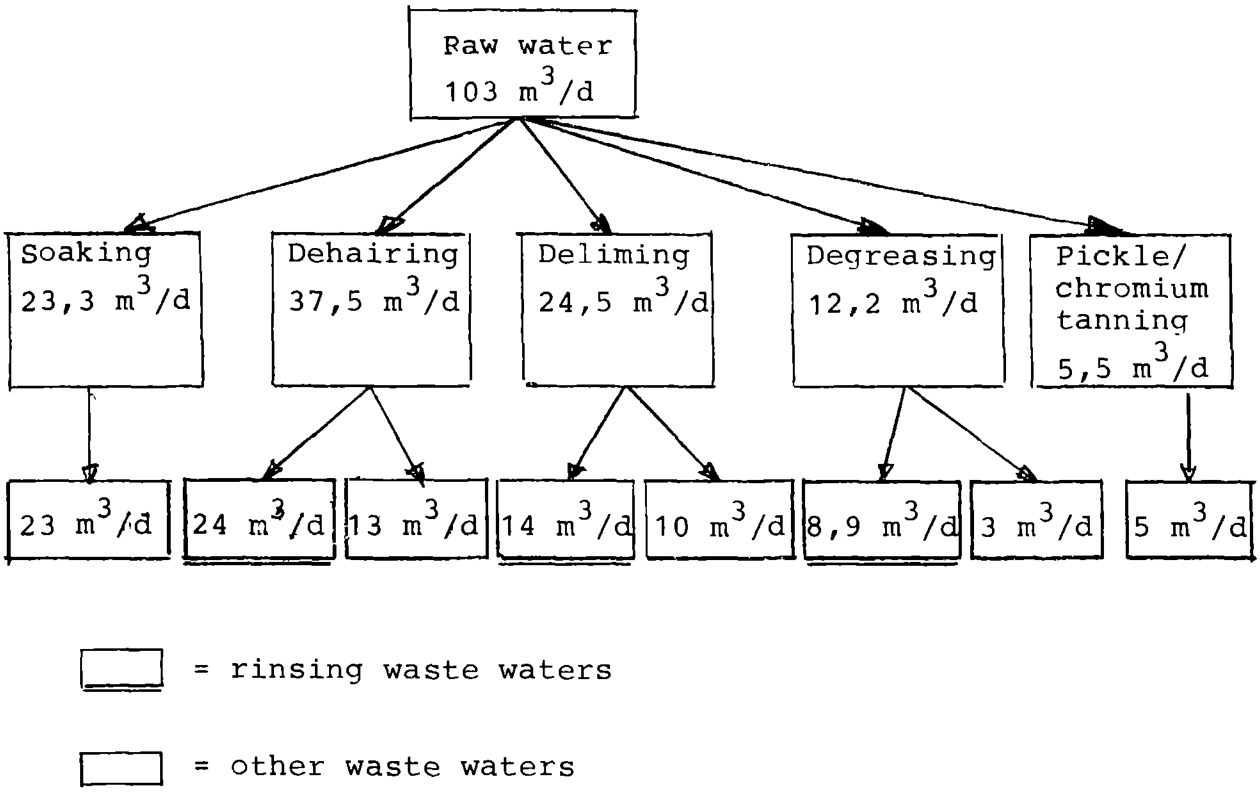
Based on this, the total water consumption has been approximated to be 0,8 x 35 + 1,8 x 41,5 = 103 m^3/day.

Due to bad "house-keeping" the estimated water consumption may be higher.

Typically up to half of the total daily waste water amounts appear within a few hours in the early morning.

9.5.2 Water balance

Water balance is shown in the flow chart figure 4.



Note: losses 2,1 m^3/d in the whole processing.

Fig 4. Water balance for Double Diamond Tannery.

9.5.3 Waste water treatment

The Double Diamond Tannery operates segregated effluent treatment method. The liming and soaking liquors plus the rinsing waste waters are collected and treated separately from tannage liquors.

Sulphide stripping is done with air blowers. The liming and soaking liquors go through sulphide stripping tank before entering an oxidation lagoon. The retention period in the oxidation lagoon is 24 hours. The effluent is then clarified in a sedimentation basin from which it is used directly for irrigation. Sludge is pumped out from the oxidation lagoon and sedimentation tank into sludge drying beds. After drying the sludge is used for fertilizing land.

The tannage liquors are led into a holding tank. Here the detention time is 24 hours. Lime is added in this tank and pH is raised to about 9. Chromium hydroxide is then precipitated. Chromium sludge is then dried. The possibility of recovering chromium is being looked into but upto now nothing is being done with the sludge.

Tannage liquors are pre-used for about two times before chromium precipitation is done. Figure 5 shows waste water treatment arrangements.

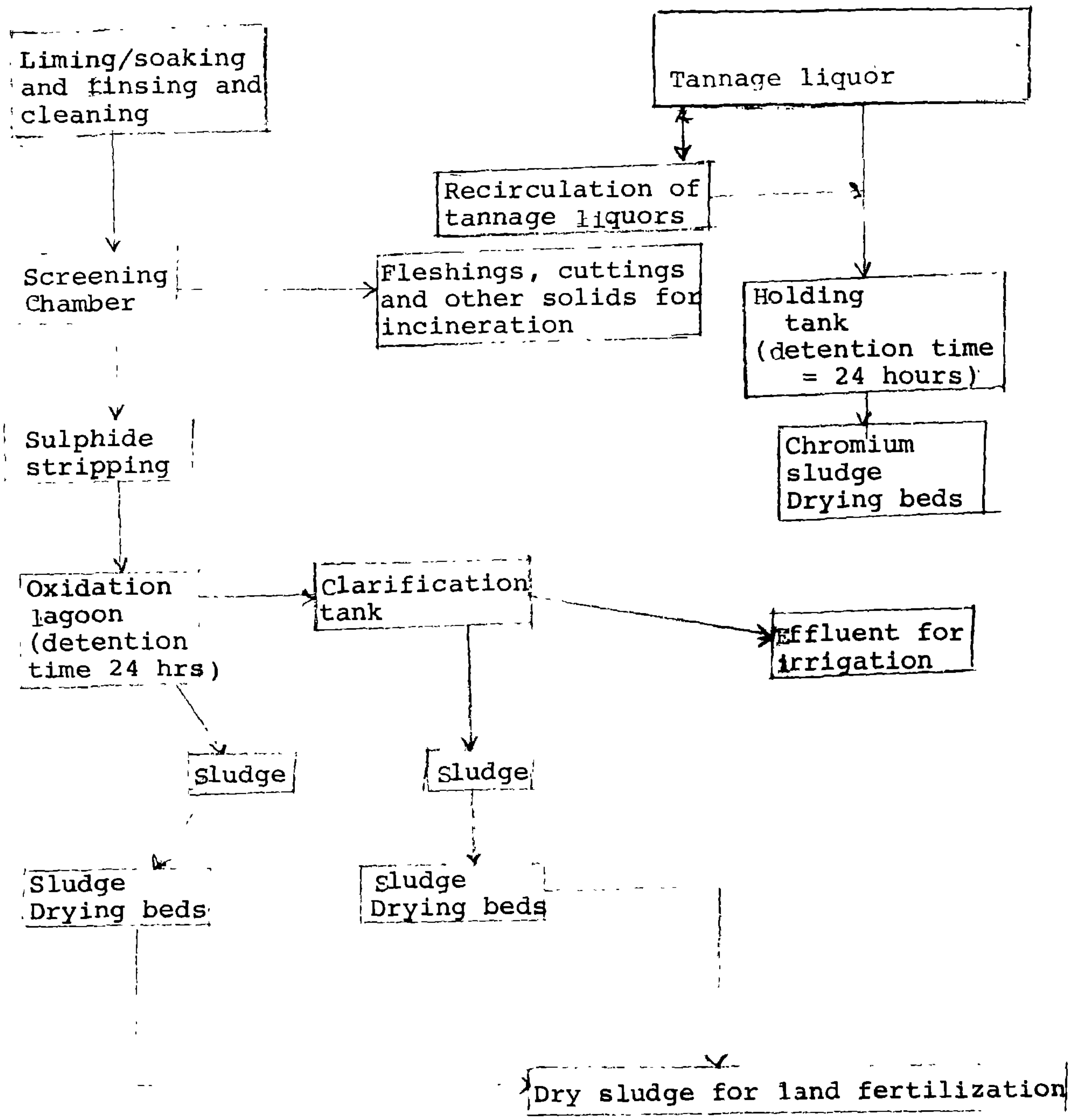


Fig 5. a) Waste water treatment arrangement.

Fig 5. b) Oxidation pond.

Fig 5. c) Treated waste water is disposed on land by spray irrigation.

Fig 5. d) Drying chromium sludge.

9.5.4 Effluent discharge guidelines for Double Diamond Tannery

- BOD_5 should not exceed 20 mg O/l.
- Suspended solids should not exceed 30 mg/l.
- Chromium (total) should not exceed 0,05 mg/l.

Since Double Diamond is not discharging its effluent to Athi river as has been proposed before, these guidelines are therefore obsolete.

9.5.5 Effluent quality

Results for analysis done on treated effluent are given in table 9.

Table 9. Effluent quality after treatment.

Date of Sampling	18.11.83	24.11.83	1.11.83	7.12.83	16.12.83	12.1.84
Sample number	1	2	3	4	5	6
pH	9.4	8.8	8.5	7.3	7.2	8.0
Conductivity µS/cm	7100	6500	6000	10000	6000	4000
COD mg/l	1800	2880	1584	5428	2200	1450
Magnessium mg/l	29	16	24	23	12	22
Sodium mg/l	1000	700	1600	900	1700	900
Calcium mg/l	55	80	120	40	65	51
Total suspended solids mg/l	222	224	201	10004	184	123
Chromium mg/l	1.2	1.7	2.1	2.2	0.6	1.4
Alkalinity $CaCo_3/l$	218	314	185	172	220	200
BOD_5 mgO_2/l	788	820	560	1490	740	510

The main problem associated with irrigation is salinity, which is expressed either as total dissolved solids, TDS in ppm or in electrical conductivity, EC, which is in μS/cm /30/. There are two methods used in measuring salinity 1) by evaporating a given volume of water and weighing the residue and 2) by measuring the electrical conductivity, EC /31/.

From the six grab samples analysed, conductivity ranges from 4000 μS/cm - 10000 μS/cm. From table 6 it is observed that the waste water lies within class 3 and is not good irrigation water for crops except the most tolerant. High sodium content (shown by high sodium absorption ratio) relative to calcium and magnessium will effect the physical properties of soil.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{++} + Mg^{++})}{2}}}$$

Na^{+} = Sodium ions, in milliequivalents per litre
Ca^{++} = Calsium ions, in milliequivalents per litre
Mg^{++} = Magnessium ions, in milliequivalents per litre /19/.

So from the analytical results the sodium absorption ratio calculated ranges from 30 - 70. This ratio exceeds the limits for class 5 and would therefore not be usable for irrigation (table 7).

Water with high sodium content make even sandy soils with good drainage impermeable after prolonged use. But with higher salt content there is a flocculating action that tends to counter-balance the poor physical condition caused by a high sodium concentration in the water /20/.

Soils affected by excess of sodium carbonate or sodium bicarbonate have poor tilth, being very hard with large cracks when dry and very sticky when wet /20/.

9.5.6 Soil analysis

Ten soil samples were analysed. Eight samples were taken from land irrigated with effluent for about 3 months. The other two samples were taken from land which had not been irrigated. Table 10 shows results of analysis.

Conductivity for irrigation water is from 50 - 400 millisiemens/m (= 0,5 - 4,0 mS/cm) /28/.

In the soil conductivity was quite high. Flushing by rain is therefore needed every now and then otherwise the crop will die off. In site numbers 1 and 2 where they have not irrigated recently conductivity was not extremely high. In site number 3 which was also irrigated some time back, conductivity was still very high. Some rain is probably needed before other than salt resistant crops can grow.

High calcium concentrations were observed. In sample number 4 of site 2, surface calcium was 295 g/kg and it means that it is almost clean limestone or a lot of lime has been added on the soil. This sample also shows high magnessium value and low conductivity and chloride. The highest concentration of chromium in the soil was about 100 mg/kg. In Finland when applying sludge on farmlands, the maximum allowable chromium concentration in the sludge is 1000 mg/kg /32/. So chromium seems not to be a problem at this stage. Conductivity values give the best indication of irrigation effects (except for sample number 4 where all salts seem to be precipitated).

However, irrigation should not only be considered as a method to improve crop yields but also as a method of waste water disposal.

Table 10. Soil analysis results.

Site No.	Sample No.	Depth	pH	Conductivity (millisiemens/m)	Cr (mg/kg dry solids)	Ca (g/kg)	Na (mg/kg)	Mg (g/kg of dry solids)	K (g/kg dry solids)	Cl (g/kg dry solids)
1	1	10 cm	8,1	55	10,0	40,4	760	7,5	6,7	1,48
1	2	50 cm	8,4	32	13,4	2,9	1180	6,4	7,9	0,37
1	3	100 cm	8,3	65	33,6	33,6	1640	6,9	8,5	2,04
2	4	surface	9,2	18	15,2	295,0	1320	17,4	5,0	0,09
3	5	surface	8,2	214	46,8	27,2	4980	4,9	6,0	2,73
3	6	10 cm	8,5	190	96,8	24,6	6600	10,8	7,8	4,12
3	7	50 cm	8,2	53	19,6	25,8	2140	6,4	6,3	1,36
4	8	surface	9,4	68	17,4	150,0	4160	15,0	6,9	1,22
5	9	surface	8,5	16	18,2	2,6	540	6,4	7,3	0,10
5	10	surface	8,4	15	14,8	4,6	376	5,8	6,0	0,07

NB: Sample numbers 9 and 10 from site No. 5 were chosen from land which was not irrigated.

The soil and the vegetation are then used as a treatment system either to prevent waste water from reaching the recipient or to remove organic pollutants by soil filtration and microbiological decomposition prior to entry into the recipient.

Normal removal efficiencies in irrigation with waste water from the pulp and paper industry are given in table 11 /18/.

Table 11. Normal removal efficiencies for pollutants in irrigation with waste water.

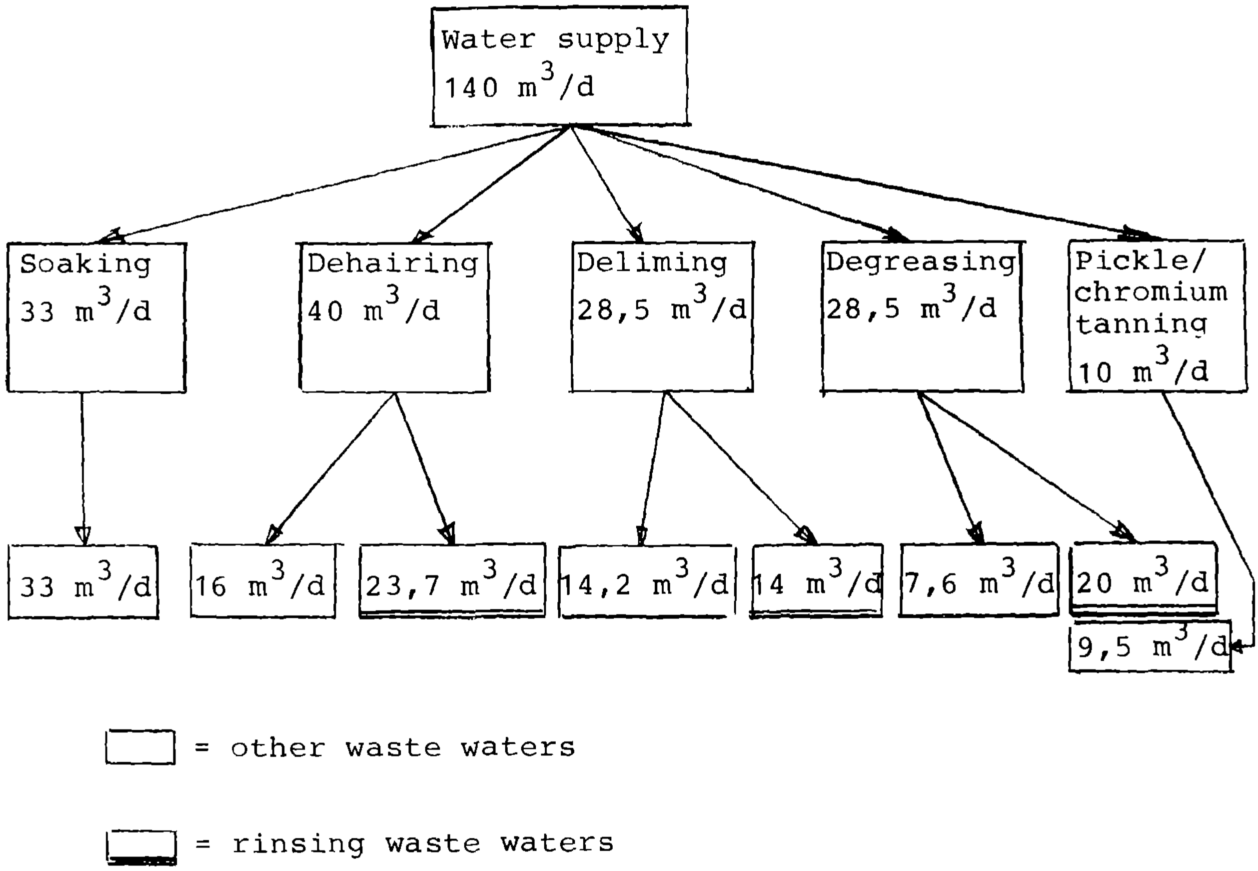
Parameters	Removal efficiency %
BOD	95 - 99
Suspended solids	99
Nitrogen	70 - 90
Phosphorous	80 - 99
Trace metals	95 - 99
Viruses and bacteria	99

This shows that depending on topography, type of soil and other factors, land treatment can be efficient in pollutants removal.

9.6 Fur and Wool Tannery

9.6.1 General

This is a medium sized tannery by Kenyan conditions. It processes 5000 dried sheep and goat skins/day. The processing is similar to that mentioned in Double Diamond Tannery (for skins).



Note: 2 m^3/d losses in factory processes.

Fig 6. Water balance for Fur and Wool Tannery

9.6.2 Water use

<u>Phase 1</u>

Factory process	140 m^3/d
General cleaning	15 m^3/d
Domestic use	5 m^3/d
Total	160 m^3/d

Ultimate requirements

Factory process	520 m^3/d
General cleaning	50 m^3/d
Domestic use	20 m^3/d
Total	590 m^3/d

This factory discharges effluent into the municipal sewerage system. The effluent is discharged after pretreatment.

9.6.3 Water balance

Water balance is shown by the flow chart figure 6.

9.6.4 Waste water treatment

The treatment technology is based on waste-stream separation and pretreatment.

a) Beam house liquors together with rinsing waters are collected and after screening passed through sulphide stripping chamber where air is added. The liquor is then passed into an oxidation tank with detention time of 24 hours.

The liquor then passes into a clarification tank after which it joins the waste water stream from the tannage and then the combined pretreated effluent is pumped into the sewer system. Sludge is pumped into sludge drying beds and used for fertilising the land after drying.

Suttings, shavings and fleshings are collected after screening and dried, after which they are incinerated.

b) Pickling and tannage liquors are collected and after screening led into a sedimentation tank. Facility exists for dosing lime to raise the pH but it is rarely utilized hence precipitation of chromium hydroxide is not very effective. After 24 hours detention time the effluent joins the beamhouse effluent and the combined effluent is then pumped into the municipal sewerage system.

Chromium sludge is then removed and taken away to the municipality's dumping site.

Figure 7 shows waste water treatment arrangement.

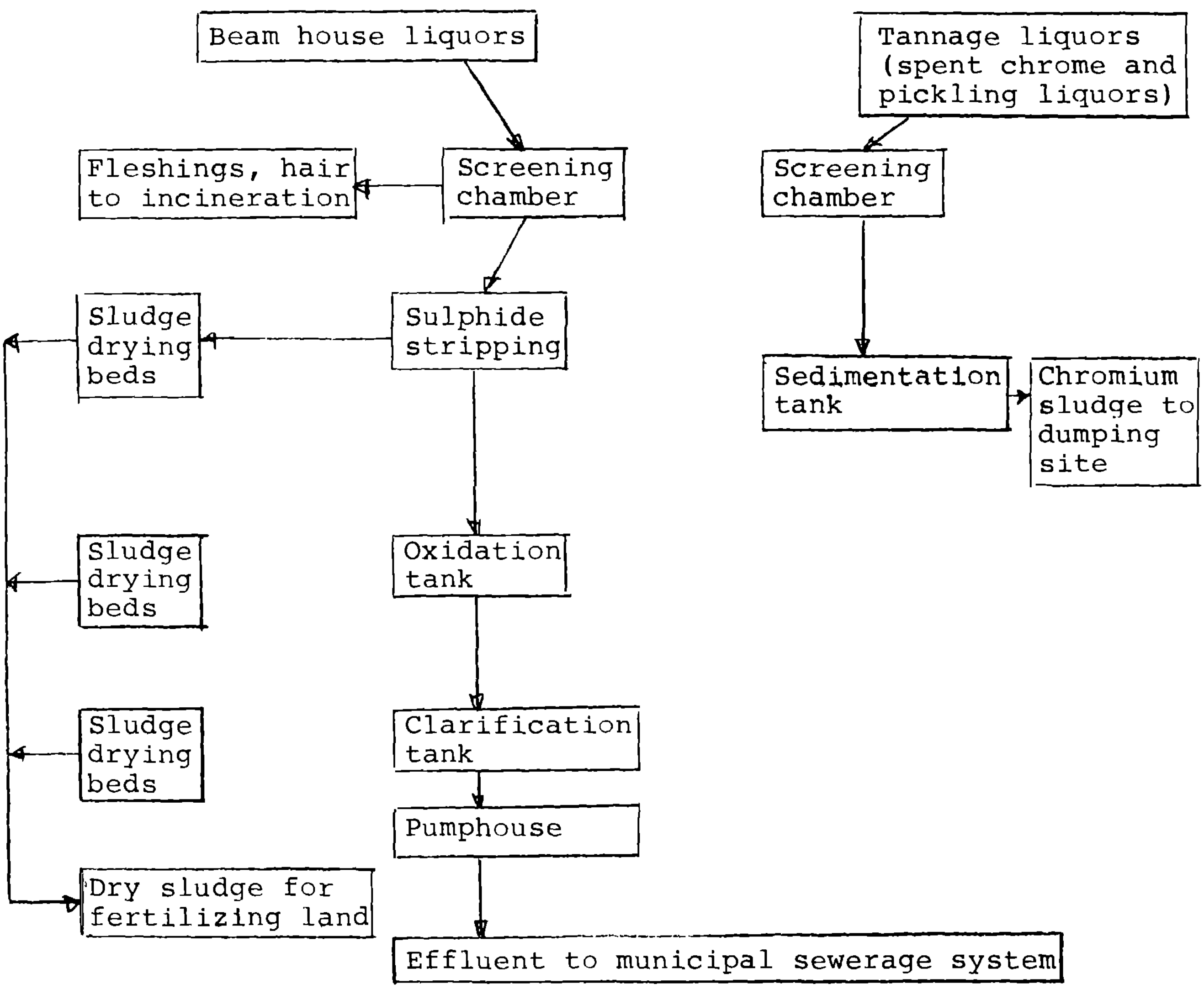


Fig 7. a) Waste water treatment arrangement.

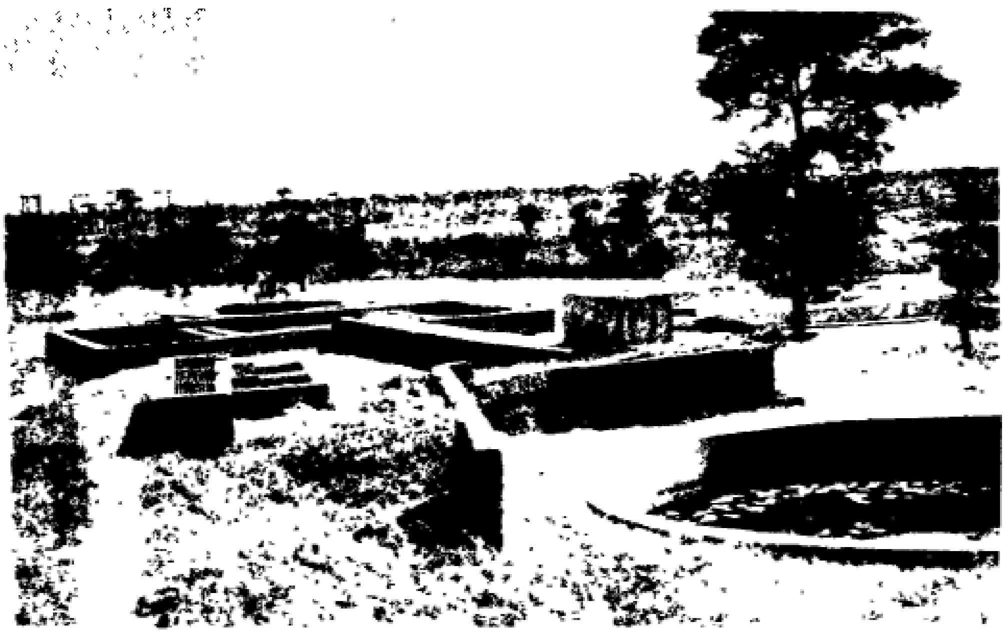


Fig 7. b) Part of the waste water pretreatment facilities.

Fig 7. c) Sludge drying beds.

9.6.5 Effluent guidelines for discharge into Thika municipal sewerage system

Fur and Wools must have segregated flows so that

a) Effectively remove chrome from both effluent and sludge (trace only allowable) by high fixation or precipitation means.

b) Effectively remove 95 % minimum of sulphides from their effluent and sludge (by oxidation or other means of sulphides stripping or avoidance).

c) Install effective sludge drying beds and means of sludge disposal in order to reduce pollution of ground water.

d) In addition to a), b) and c) above, ensure an effective sedimentation to remove at least 60 % of the initial suspended solids and bring also a reduction of 25 % to 30 % BOD_5.

Effluent quality is shown in table 12.

Table 12. Effluent quality before discharge into Thika municipal sewerage system.

Date of sampling:	10.11.83	17.11.83	23.11.83	30.11.83	6.12.83	16.12.83	6.1.84
Sample No:	1	2	3	4	5	6	7
pH	6.8	7.2	8.0	7.8	7.0	8.5	8.5
BOD_5 mgO_2/l	800	720	840	780	918	670	650
COD mgO_2/l	1762	1600	1900	1700	2100	1400	1430
Chromium mg/l	28	34	18	39	20	1.3	6.7
Total suspended solids mg/l	102	620	315	225	174	650	435
Conductivity µS/cm	1600	6100	4000	3200	2100	7800	6000

From the seven grab samples analysed the pH ranges from 6,8 - 8,5, BOD_5 from 650 - 918 mgO_2/l, chromium 1,3 - 39 mg/l. From the conditions of agreement it should be noted that only trace of chromium is allowed. Concentration in the pre-treated effluent is therefore too high and is not acceptable for discharge into the municipal sewer. Reduction of chromium is minimal due to lack of pH adjustment with, for instance, lime. Chromium hydroxide is effectively precipitated within pH range 8,5 - 9,5 /17/. Facility for dosing lime exists but is rarely, if ever, used.

Investigations done at Thika municipal treatment plant during November 1983 showed that

$$Q_{Design} = 4890\ m^3/day$$

$$Q_{Average} = 4900\ m^3/day.$$

This indicates that design hydraulic loading has already been reached. This means that no more industries or domestic discharge should be connected. This is very important for Fur and Wools tannery if they are planning any expansion in their production. Considerations regarding pollution and hydraulic loadings against the capacity and efficiency of the existing municipal treatment plant should be carefully made. This will influence any decision to be made on the type of pre-treatment and reduction achievement to be desired.

Fur and Wools has been operating irregularly. Due to inadequate equalization, effluent discharge into the sewer system has been intermittent and not uniform. This may cause pollution and/or hydraulic shocks to the sewerage system.

Real water consumption has followed quite closely the calculated consumption for conventional tannery. No attempts have been made to save water and hence the waste water amounts are quite large.

On the whole, in-plant measures for reducing quality of discharges have not been implemented.

It should also be noted that whereas in 1972 Mogden's formula was recommended as the basis for calculating the sewerage charges for industries whose effluent is connected to municipal facilities, this was never implemented. Therefore, Fur and Wools tannery pay charges according to only hydraulic loading regardless of whether the effluent is stronger than domestic waste water.

9.7 Bulley's Tanneries

9.7.1 General

Bulley's Tanneries is the biggest tannery in Kenya. The history of the company dates back to 1942 when it was started as a small company to utilize the wattle back produced in the area. Since then the company has changed its process to chrome-tanning.

9.7.2 Water consumption

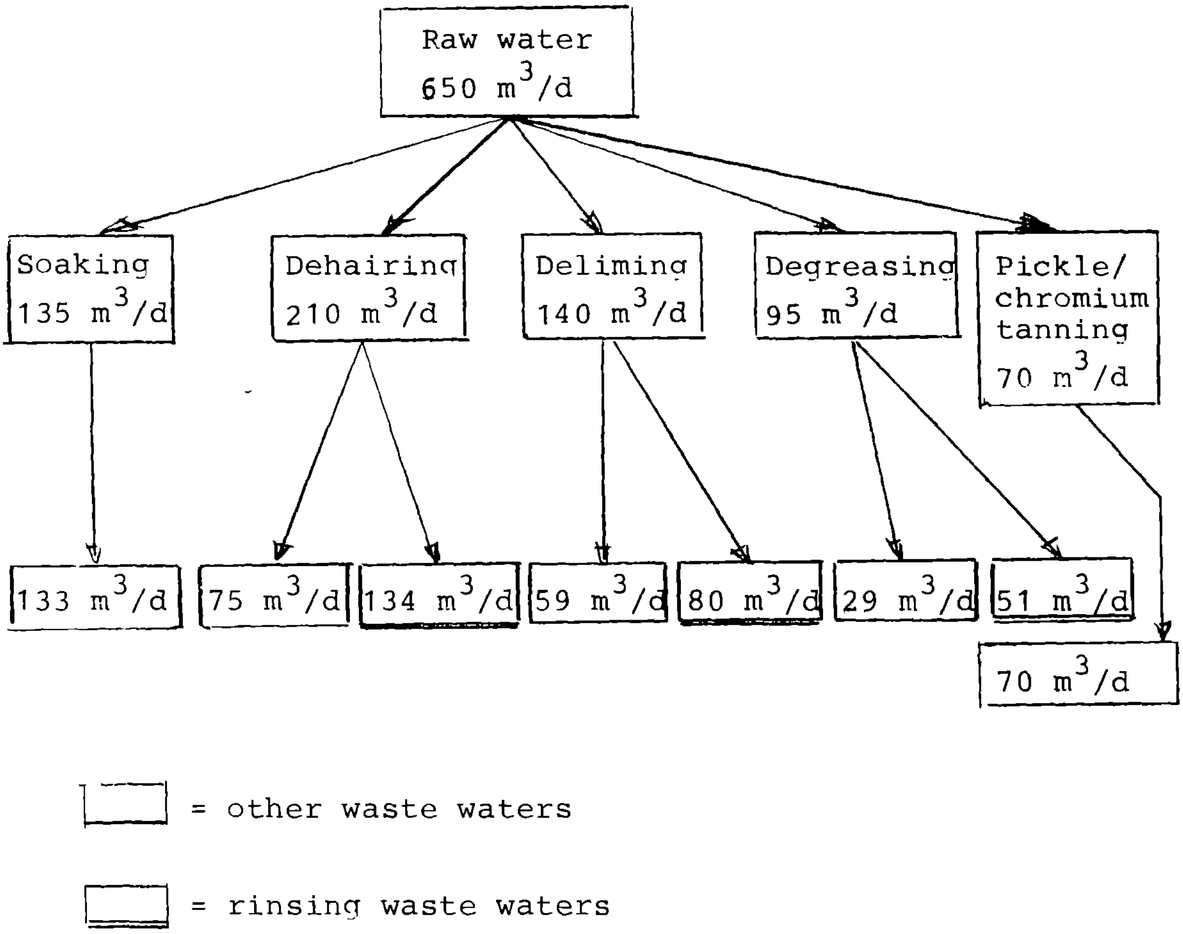
Water for industrial use is 155540 m^3/year or about 650 m^3/day.

It processes about 300 tons of raw hide and 185 tons of raw skins.

The water for industrial purposes is taken from Thika river while water for social use is taken from the municipality's water supply.

9.7.3 Water balance

Water balance is shown in figure 8.



Note: 19 m^3/d losses in the whole process.

Fig 8. Water balance for Bulley's Tanneries.

9.7.4 Waste water treatment

Like the other two tanneries, Bulley's segregates tanning and beamhouse liquors and treats them separately. Beamhouse liquors from the old tannery are conveyed to oxidation lagoons 1 and 2 (as shown in figure 9) where they combine with beamhouse liquors from the new tannery after screening. The detention time is 12 hours after which the waste waters pass to oxidation lagoons 1 and 4 where after aeration and detention time of 12 hours pass into a clarification basin. After detention time of 12 hours the effluent is discharged into Thika river.

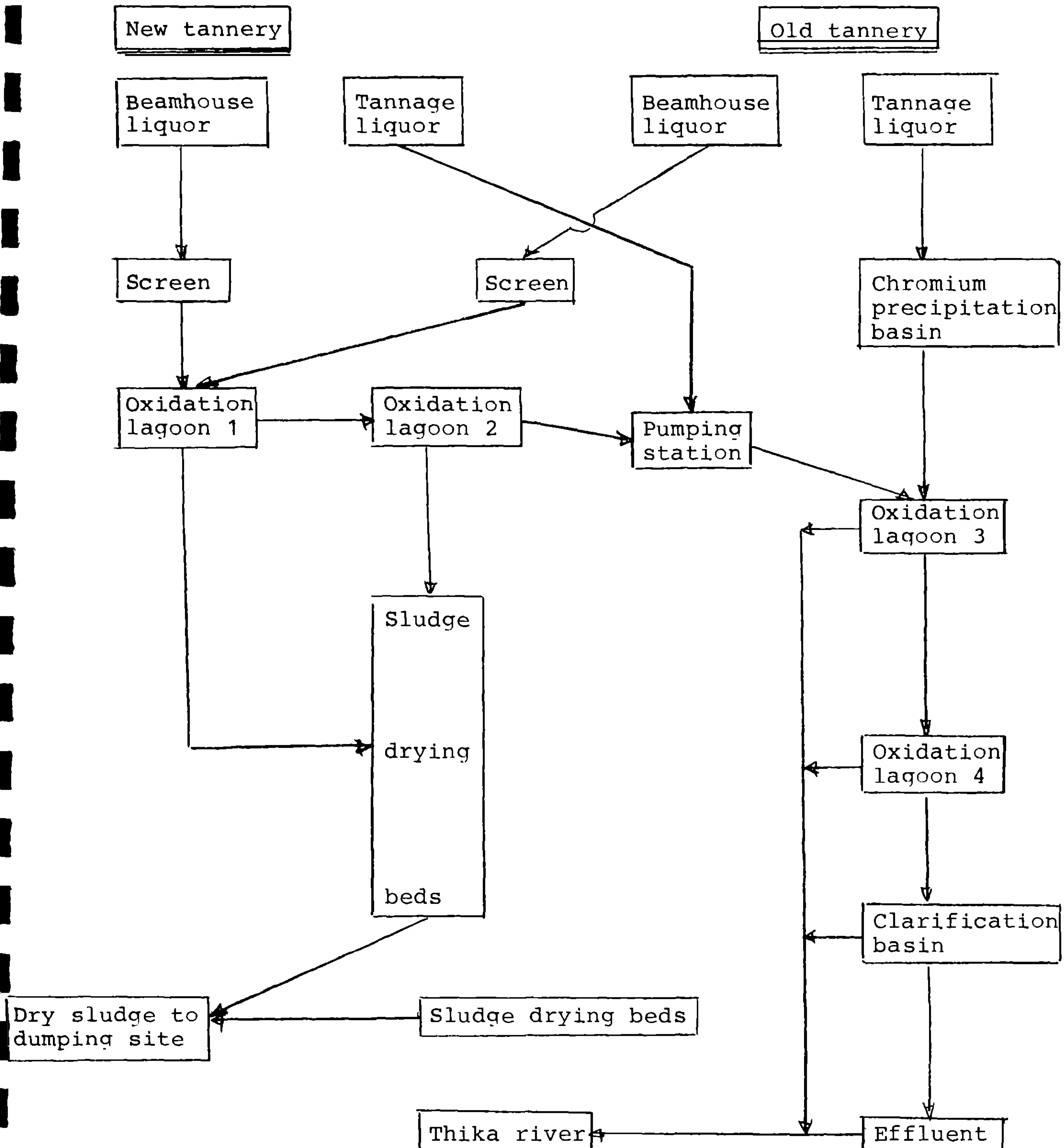


Fig 9. a) Waste water treatment arrangement.

The chromium liquors are separated and chromium liquors eventually get into oxidation lagoon number 3 and continue with the rest of the process. The pH of chromium liquors is not raised and precipitation of chromium hydroxide is therefore quite slow. Beamhouse sludge is pumped and dried at the sludge drying beds. It can be used for fertilizing land. Chromium sludge is dumped at the municipal dumping site.

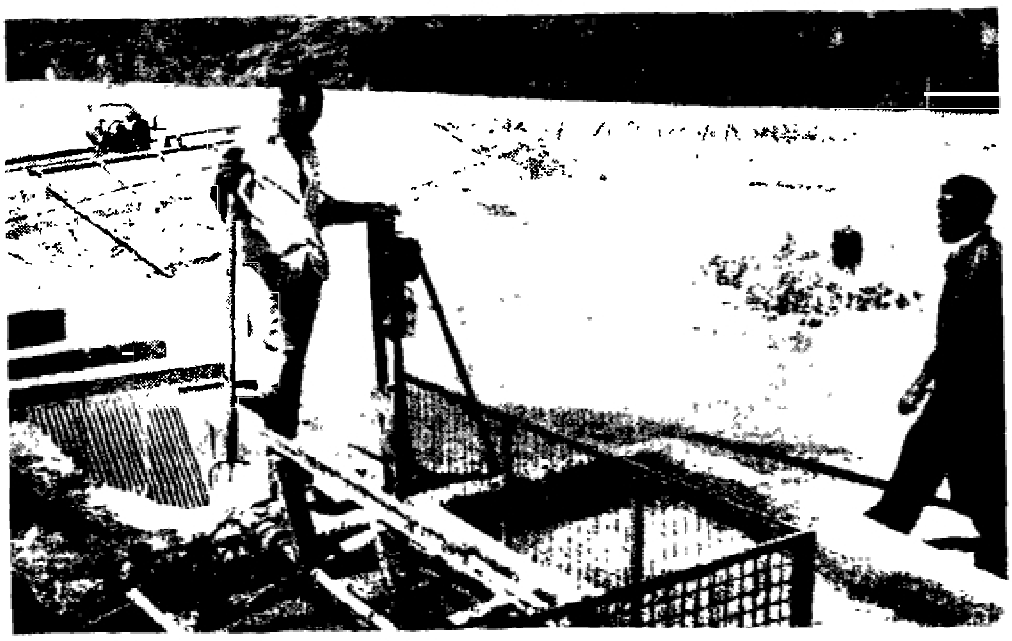


Fig 9. b) Bar screens and mechanical screen.

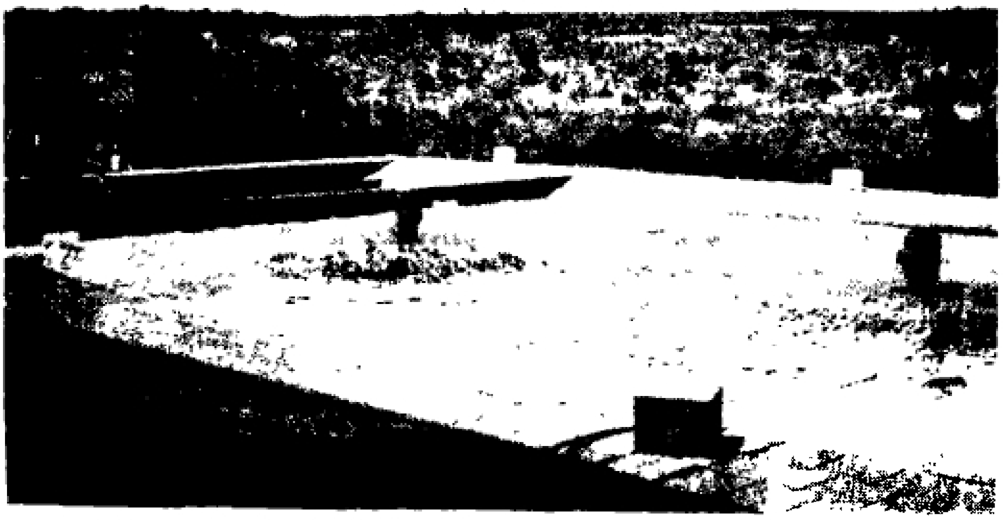


Fig 9. c) Oxidation lagoon and at the far end, desludging the clarification basin.

Fig 9. d) Sludge drying beds.

Fig 9. e) Chromium precipitation facility.

9.7.5 Effluent standards for discharge into Thika river

Bulley's Tanneries must discharge effluent quality of:

1.	BOD_5 not exceeding	20 mg/l
2.	Suspended solids not exceeding	30 mg/l
3.	Oxygen absorbed from N/80 potassium permanganate in 4 hours at 27 °C not exceeding	15 mg/l
4.	Free ammonia not exceeding	5 mg/l
5.	pH to be with the range of	6 - 9
6.	Chromium not exceeding	0,05 mg/l
7.	Other heavy metals not exceeding	1,0 mg/l
8.	Cyanide not exceeding	0,05 mg/l
9.	Phenols not exceeding	0,02 mg/l
10.	Organic chlorines not exceeding	0,001 mg/l
11.	Oil	no trace
12.	Flow measuring devices to be installed at single final outlet.	

Effluent quality

Table 13 shows quality of raw effluent while table 14 gives quality of treated effluent before discharge into Thika river.

Table 13. Bulley's Tanneries analysis results.
Raw effluent (combined).

Sample No.	1	2	3	4	5
Date of Sampling	17.11.83	23.11.83	30.11.83	6.12.83	16.12.83
Parameter					
pH	9.0	8.5	8.2	8.6	7.2
Conductivity μS/cm	5500	7500	8100	14000	10000
BOD_5 mg/l	1800	2600	2400	1550	1490
COD mg/l	8210	4500	4600	3856	5428
Chromium mg/l	26.2	86	93	11.2	84
Total suspended solids mg/l	780	3000	2900	2360	1004
Alkalinity mg $CaCo_3$/l	-	5000	4600	3712	173
Total dissolved solids mg/l	4500	9600	11,000	8400	6000

Table 14. Bulley's Tanneries analysis results.
Final effluent.

	Sample number	1	2	3	4	5
	Date of sampling	17.11.83	23.11.83	30.11.83	6.12.83	16.12.83
Parameter						
pH		8.4	8.3	7.8	7.0	8.5
Conductivity µS/cm		18000	13000	7000	9000	9000
BOD_5 mgO_2/l		723	551	570	460	788
COD mg/l		1461	1422	1090	1548	2570
Total suspended solids mg/l		422	373	117.0	453	222
Alkalinity $mgCaCo_3/l$		2644	373	220	120	1178
Total dissolved solids mg/l		10000	7800	5000	5800	5400
Chromium mg/l		24.5	3.5	1.25	12.5	32

BOD_5 reduction of about 65 - 70 % is achieved. Suspended solids reduction is about 85 %. However, discharge limits provided allow that BOD_5 should not exceed 20 mgO_2/l. The lowest value of BOD_5 observed was 460 mgO_2/l. This is beyond the limits provided. The upperlimit for suspended solids is 30 mg/l. The lowest observed value is 117 mg/l. It is also higher than the upperlimit allowed.

Chromium concentration should not exceed 0,05 mg/l. Observed chromium ranges from 1,25 - 35 mg/l. The effluent guidelines have been exceeded by far.

9.7.6 Thika river

Thika river flow at measuring station RGS 4CC5 (which is situated after the confluence with Chania river) is listed in table 15.

Table 15. Thika river flow at measuring station RGS 4CC5.

Year	Maximum (m^3/s)	Minimum (m^3/s)
1967	79,0	1,07
1968	316,31	2,55
1969	72,8	3,08
1970	82,7	0,77
1971	85,2	0,73
1972	61,2	4,33
1973	29,45	2,88
1974	22,6	4,58
1975	48,7	0,467
1976	175,0	0,467
1977	175,0	4,98
1978	175,0	9,85
1979	101,3	5,749
1980	95,1	1,65

River water quality 50 m upstream the discharge point of Bulley's Tannery is listed in table 16.

Table 16. River water quality 50 m upstream of discharge point.

Sample Number	1	2	3	4	5
Date of sampling	17.11.83	23.11.83	30.11.83	6.12.83	16.12.83
Parameter					
pH	7.1	7.1	6.5	6.3	6.0
Conductivity µS/cm	87	95	90	110	200
BOD_5 mgO_2/l	10	6.2	25	42	119
COD mg/l	16.1	10.4	78	218	446
Total suspended solids mg/l	45	48	60	70	85
Alkalinity $mgCaCo_3/l$	6	8	10	9	10
Total dissolved solids mg/l	50	62	75	108	120
Chromium mg/l	0.0	0.0	0.0	0.0	0.0

Thika river water quality 100 m downstream of the discharge point of Bulley's Tannery is listed in table 17.

Table 17. River water quality 100 m downstream of discharge point.

	Sample number 1	2	3	4	5
	Date of sampling 17.11.83	23.11.83	30.11.83	6.12.83	16.12.83
Parameter					
pH	7.3	7.3	7.6	7.1	6.8
Conductivity μS/cm	119	135	1250	810	928
BOD_5 mgO_2/l	16.2	10.2	155	213	190.5
COD mg/l	27.2	23.0	339	704	513
Chromium mg/l	2.3	2.4	0.0	1.1	0.1
Total suspended solids mg/l	82	76	128	224	292
Alkalinity $mgCaCo_3/l$	12	15	21	82	213
Total dissolved solids mg/l	72	78	614	515	600

Minimum dry weather flow records within 14 years duration (1967 - 1980) was 0,467 m^3/s.

Bulley's Tanneries discharge between 0,01 - 0,02 m^3/s.

The available dilution is about 25 times.

Thika river is already a polluted river even before receiving discharge from Bulley's Tanneries. BOD_5 ranges from 6,2 - 119 mgO_2/l, COD from 10,4 to 446 mg/l, suspended solids from 45 - 85 mg/l. Chromium was not detected 50 metres upstream of outfall from Bulley's Tanneries. pH is within 6,0 - 7,1.

Thika river originates from the Aberdare ranges and is joined by Chania river before it gets into Thika town. This river passes through intensively cultivated land where food crops such as maize, beans, potatoes, bananas and vegetables are grown. It also passes through one of the most important coffee growing areas in the country. Thus, pollution from the coffee factories and also non-point pollution from surface runoff and erosion have rendered the river almost unusable for domestic water supply.

10. CONCLUSION

Though effluent discharge standards have been issued for every tannery, they are very rarely kept. For example

- Bulley's Tanneries is allowed to discharge an effluent of "20/30" quality. In all samples analysed the lowest values observed are BOD_5 460 mgO_2/l and 117 mg/l suspended solids. Lowest chromium value is 1,25 mg/l while the highest allowable limit is 0,05 mg/l.

The waste water treatment plant was designed to achieve effluent quality of 20 mgO_2/l BOD and 30 mg/l suspended solids. There must be something wrong with any or all of the following:

a) the design
b) the operation
c) the maintenance.

In all tanneries the effluent contains more chromium although the waste streams have been separated, i.e. tanning liquors and beamhouse liquors, the pH is not raised high enough to precipitate chromium hydroxide. Facilities for dosing lime are present and except for Double Diamond Tannery, they are not used. This is partly due to negligence by the tannery management or may be due to ignorance or due to the unavailability of lime when needed. Effluent flow from Fur and Wool Tannery is not uniform.

Sometimes there is no flow at all. This is because the plant does not operate as regularly as had been planned. Inadequate equalization also may result in irregular flow. This may cause both pollution and hydraulic shock to the municipal sewerage system.

Though recommendations had been made as far back as 1972 for charging industrial effluent according to Mogden formula, Fur and Wools still pay according to their hydraulic loading regardless of whether the trade effluent is stronger than domestic waste.

Double Diamond Tannery recycles chromium liquor and is looking for ways of recovering and reusing the chromium.

Conventional methods of processing are used in all industries and except for the recycling of chromium in Double Diamond, no in-plant measures have been implemented to cut down on water consumption and also to reduce both quality and quantity of pollutants.

Waste water from Double Diamond has high salinity and sodium absorption ratio. This water is therefore not suitable for crops except the most tolerant ones. However, irrigation can be a means of waste water purification and disposal.

However, it should be noted that a more conclusive study should be made. Some parameters could not be determined within this short period due to breakdown of equipment in the water laboratory.

These parameters include sulphide and the nutrients nitrogen and phosphorous.

Highest allowable limit of sulphide, $S^{=}$, has already been given in the discharge guidelines for Fur and Wool tanneries. This is important because acid producing bacteria under aerobic conditions convert the weak acid H_2S to strong sulphuric acid, H_2SO_4. Sulphuric acid chemically attacks pipes if susceptible to corrosion.

Nutrients, nitrogen, N, and phosphorous, P, would have provided information on eutrophication. Thika river is a tributary of Tana river which has a series of hydropower dams. Eutrophication could be a major threat downstream.

11. RECOMMENDATIONS

In Kenya a classification of the quality of surface waters in relation to use should be made and ambient water quality standards should be established to safeguard all uses of waters. However, variations in surface water quality have to be accepted and allowed for in the classification of the quality of rivers and streams.

The selection of effluent quality conditions must begin with the selection of river quality objectives and should follow through the steps of assessing the permissible in a particular maximum rate of effluent discharge.

The effluent discharge permits should contain limits both given in concentrations (mg/l) and average loading (kg/d). The maximum permissible concentration should be related to the maximum rate of discharge of an industrial discharge.

Enforcing a system of charges will provide the necessary incentive to industries to reduce the amount of pollutants. Industries should pay pollution charges if they are discharging to surface water. This can be assessed according to the strength of the discharges. Effluent charges must also be paid when industries are connected to municipal sewerage system. These will be calculated on the strength of the effluent as compared to normal domestic waste waters.

If an industry exceeds its allowed quantity of pollutants in its permit of discharge, a fine should be imposed. The amount of fine should be calculated on the basis of the exceeded amount. The excess amount will therefore be termed as illegal discharge and a crime will have been committed.

Technologies exist for reducing pollution load in the plant and also externally by waste water treatment. It will therefore be the responsibility of the industry to choose the best but economically practicable technology. On the other hand, the industry does not have expertise in waste water engineering and would therefore not be able to choose wisely. There is therefore need for close liason between the industry and the water pollution control authority. The problem then arises because the water pollution control authority is a watch dog and would not want to hold itself responsible if problems arise. Thus the only solution is to appoint qualified consultants under the direction of the water pollution control authority.

If the objective of both the industry and pollution control authority is to reduce pollution in our waters, then there should be free flow of ideas. Industry should then show concern and get ready to handle more responsibility than it is doing nowadays.

Waste water treatment installations do not make profit for industry. They only provide us with a better environment which we cannot very easily convert into material gains. It should be with this thinking that the Central Government should interfere. Make it more cheaper for the industry so that it does not loose its profits. Most of the machinery in these installations are imported. It would be part of the goodwill by the Government to reduce taxation on the machineries, equipment and chemicals which are to be used for pollution control work.

To effectively enforce a water pollution control programme there should be a thorough monitoring programme. A monitoring programme can only be meaningful if it produces useful information on which decisions can be made. There would be no reason to establish a monitoring network and when information is obtained it is just stored. Maybe at a later date, somebody may notice the information but it is usually too late to take action. Monitoring is an expensive venture and a passive programme should not be allowed. Data collected should be immediately studied so that the right decision can be made. It should be pointed out that the choice of parameters to be monitored should be as accurate as possible. The parameters must be easy to measure yet accurate in showing the true situation. They must also be cheap.

The money collected from discharge charges and fines could be used in financing a monitoring programme or any other pollution control work.

The responsibility of operating a monitoring network should not be left to the water pollution control authority alone. Industries should now take a more active role bearing in mind the benefit they can obtain from operating in a good healthy environment. This would attract labour. A good monitoring system by the industry would act as a trouble-shooter and would provide information on the efficiency of processing. This information can be used by the industry to modify processes that have low efficiency.

The Kenyan Law governing Water Pollution Control is absolete. It lacks clarity and precision. With increasing population and industrial development, all competing for diminishing water resources, there is bound to be a lot of conflict. This is now the best time for Kenya to formulate a legal system which will accommodate all the different legitimate uses of the water resources and at the same time reducing the areas of conflict. The legal system developed should contain effluent guidelines which are proper for Kenyan conditions, taking into account hydrological, climatic, sociological, technical and financial situation of the country. At the same time with clear and precise law and regulation governing water pollution, the enforcing officers will stop getting frustrated.

As constraints on water resources continue increasing and the needs change due to raising standards of living, the user requires more rigid standards. Effluent guidelines should therefore be dynamic and should change with changing demands. Effluent guidelines should therefore be reviewed maybe every one or two years depending on the rate of increasing demands.

Lastly experience gained by other countries in water pollution control work should be used to the fullest advantage. Kenya, at this time, should not engage in high level research but should borrow and try to adapt foreign technologies to suite Kenyan conditions.

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