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Assistance to the National Africa Leather and Footwear Industry Scheme (NALFIS)

Cleaner Technology Options for Implementation in selected tanneries in Uganda

US/UGA/96/300

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FINAL REPORT

ABRIDGED VERSION

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0. ABSTRACT

The main contents of this report are the recommendations for the selected tanneries, Leather Industries Uganda (LIU) in Jinja and the Bassajja Tannery in Mbarara (compare progress report 05/97), concerning the implementation of clean technology methods and the wastewater treatment systems (pre-, primary and secondary treatment).

The aim was the preparation of recommendations for the selected tanneries, to reach environmental standards as assumed necessary in chapter 6.4.4. (assumptions on necessary final effluent quality) of the submitted progress report (IWGA, 05/97), based on this progress report, information gathered by the Department of Civil Engineering, Makerere University (DCE), concerning cost and availability of necessary components and effluent quality and quantity of the selected tanneries and assumptions on basic conditions (chapter 3.).

Summarised the following recommendations are given:

For Leather Industries Uganda the optimisation of the chrome reduction in the final effluent and sludge by precipitation and reuse of chrome and the optimisation of the primary sedimentation by installing a new and appropriate sedimentation tank is recommended. As far as necessary the implementation of different equipment instead of the presently used has been recommended.

Concerning the reuse of chrome it has to be considered that at a low production of hides, as it is presently the case, it is not economically profitable.

For the Bassajja Tannery the implementation of a chrome precipitation unit for the reduction of chrome contaminated sewage sludge is recommended. Additionally the existing pre- and primary treatment system has to be reconstructed for proper sulphide oxidation, sedimentation and if necessary flocculation.

Due to the insufficient design of the secondary treatment system (lagoon) and the insufficient area available the combination of a high loaded trickling filter with a

constructed wetland is recommended. Main reasons for this decision were requirements of maintenance for these systems.

At both tanneries the treatment of sludge is considered insufficient and for the present situation the implementation of static thickeners combined with sludge beds (or in the case of LIU, reconstruction of the existing beds) is recommended. The only solution for the future increased production of sludge is the installation of a press at both tanneries due to the lack of available area.

Taking into account all considerations which are the basis for this report, it is recommended to be careful in increasing the capacity of the tanneries. Especially in the case of the Bassajja Tannery additional costs (press, secondary treatment, ...) will have to be considered.

1. INTRODUCTION

This report is submitted to UNIDO as a final report on phase I on the basis of the work carried out by the Department for Sanitary Engineering and Water Pollution Control, Institute for Water Provision, Water Ecology and Waste Management, Universität für Bodenkultur, Vienna under the contract No. 97/032P for the project US/UGA/96/300, mainly on the basis of the submitted flash report and the progress report on phase I and additional information gathered by the DCE, subcontractor to the IWGA.

Main contents are the recommendations for the selected tanneries, Leather Industries Uganda (LIU) in Jinja and the Bassajja Tannery in Mbarara, concerning the implementation of clean technology methods and the wastewater treatment systems (pre-, primary and secondary treatment).

Because of demands from UNIDO concerning the length of the report in the following an abridged version of the report is given. It has been prepared on the basis of comments from Mr. Magne Nestvold (UNIDO Consultant). For detailed information it is referred to the original (long) version (o.v., Annex - 15.).

2. SUMMARY OF ACTIVITIES

The main points were gathering of information by the Department of Civil Engineering, Makerere University (DCE), concerning

- cost and availability of necessary components for pollution reduction
- effluent quality and quantity of the selected tanneries,

and the preparation of recommendations for the selected tanneries, to reach environmental standards as assumed necessary.

Schemes of the existing constructions and equipment at the tanneries and recommended new constructions and equipment are connected to the report (o.v.) in the annexes.

3. ASSUMPTIONS FOR THE FINAL REPORT

For the preparation of the recommendations for the selected tanneries the basic conditions must be limited. Therefore the following assumptions (partly including the constraints) additional to assumptions in the progress report have to be met.

- Quality and quantity of the tannery effluent / split flows are sufficiently described by chemical analyses and information available from the tannery operator, by chemical analyses carried out by the DCE under this contract and by comparison with literature values
- The increase in production as planned by the tannery owners requires many preconditions with a high degree of uncertainty, therefore the moment for this increase will not be before 5 to 10 years ⇒ it is not required or even possible or sensitive to design all parts of the treatment system for the planned future capacity but the treatment system is designed for the actual resp. built in capacity. Nevertheless possibilities for extension are considered.
- The existing resources, especially existing equipment and installations for effluent treatment, should be used as best as possible ⇒ therefore the solution can not be ideal compared to a solution where design of all parts from the very beginning is possible (compare progress report 5.2, page 20 - Masaka tannery)

It is emphasised that these assumptions are based on the actual authors information and knowledge and can therefore differ due to additional information received. At least these preconditions must be checked before starting the implementation as all of them represent elements of uncertainty in the recommendations.

4. WASTEWATER QUALITY AND QUANTITY

Mainly three sources for quality and quantity of effluents - total and split flows - have been used to prepare this report:

⇨ historic data from the tanneries

⇨ chemical analyses carried out by the DCE

⇨ literature values.

5. RECOMMENDATIONS - GENERAL

5.1. Flow measurement

For the design of any part of the treatment system information on the amount of wastewater is required. Therefore it is necessary to measure the flow of water discharged in the various steps of the process. Besides it is important for plant operation control to know the load for the treatment stages. Only with this information evidence on the efficiency of the treatment system is possible.

5.2. Sewer system

For the pretreatment of various split flows as well as for the implementation of recycling systems the separation of these flows is required.

5.3. Pretreatment

5.3.1. Screening

To reduce operational problems in the following treatment steps and for the filtration of liquors before recycling usually screening to remove coarse solids is applied.

Design criteria are minimum and maximum flow rate, thickness of the bar and width of the space between the bars.

Concerning the design parameters for both tanneries only assumptions can be met within this project.

The maximum possible flow at LIU can be calculated to

$$q = \frac{20}{5 \cdot 60} = 0,07 m^3 / s,$$

and at the Bassajja tannery to

$$q = \frac{10}{5 \cdot 60} = 0{,}035 m^3 / s \,.$$

5.3.1.1. Recommendations

As at both tanneries the sewer channels are partly open for the drainage of surface water, primarily the installation of a manually cleaned medium to coarse screen (space between bars 20 to 50mm) is recommended to prevent clogging or damage of further mechanical equipment (e.g. fine screen, pumps).

5.3.2. Sulphide elimination

5.3.2.1. General

To reduce the concentration of sulphide in the tannery effluent basically two possibilities exist: the precipitation as unsolved sulphide and the oxidation to sulphur resp. thiosulphate. Usually the oxidation with air under the presence of manganese sulphate as catalyst is preferred.

The required oxygen supply for complete oxidation is 0,5 kg O_2 / kg S^{--} (depending on the product, this is depending on the pH value). For a sufficient elimination an oxidation time of 1 to 2 hours is necessary. An amount of 0.1 to 0.5 g/l $MnSO_4$ will be the best option.

5.3.2.2. Recommendations

In both cases according to the problems connected with the precipitation of sulphide oxidation with air is recommended.

5.3.3. Chrome Precipitation

5.3.3.1. General

5.3.3.1.1. Chrome in tannery effluents

Chrome is mainly produced as waste from the chrome tanning process. Sources are besides wash waters after tanning / retanning (25% of total chrome offer incl. retanning), liquors draining from wet blue in pile (0,3% of total chrome offer incl. retanning) and liquor wrung out of the leather in the sammying machine (1,5% of total chrome offer incl. retanning).

5.3.3.1.2. Methods for the reduction of the chrome concentration

Various possibilities for the reduction of chrome in tanning effluents exist. Two different types can be separated, the implementation of „clean technologies" in the tanning process (e.g. direct recycling of tanning floats, high exhaustion tanning) and the so called „end-of-pipe" treatment of split flows or the total effluent.

5.3.3.2. Recommendations

Both selected tanneries use chrome in the tanning process. The reduction of the chrome concentration in the effluents therefore is necessary.

5.4. Flocculation

It is considered necessary to use flocculation with chemicals for the effluents of the selected tanneries to meet the required purification capacity. As the consumption of chemicals is rather expensive it is recommended to check the necessity (legal situation) first before building an appropriate system.

6. PRIMARY SEDIMENTATION

Before discharging pre-treated tannery effluent to a sewer system or to a secondary treatment plant reduction of suspended solids is necessary.

7. SLUDGE TREATMENT

7.1. Utilisation of sludge

The aim of wastewater treatment is the reduction of the pollution discharge into the recipient to an acceptable limit. Elimination of wastewater constituents is possible by transformation into gas (CO_2, N, NH_3, H_2S, ...), mechanical means (screening, sedimentation) and incorporation in and transformation to biomass. Therefore by cleaning wastewater, solid waste (= sludge) is produced.

Usually the simplest and most ecological way to use the sludge is agricultural application. But only sludge with low contents of toxic substances is allowed to use. Special standards have to be met.

Usually the concentration of chrome is the main problem in sewage sludge from tanneries. With an assumed average use of 6 to 8% of BCS (Basic Chrome Sulphate) and a sludge production (without secondary treatment) of 150kg/t the following concentration in the resulting sludge can be calculated:

$$c_{PS} = \frac{70kgBCS \cdot 0{,}25 \cdot 0{,}30}{150kg} \cdot \frac{104}{152} = 0{,}024 g / g$$

From this can be seen that by using no special treatment the content of chrome in the sludge would be much to high for agricultural use.

7.2. Treatment of sludge

To achieve a low water content (with respect to transport costs) further treatment is necessary. After sedimentation an average water content for primary sludge of 95 % can be achieved. To reduce the water content further static thickeners or reduction by mechanical means (e.g. filter press) or drainage/evaporation (e.g. sludge drying beds) is necessary. It is recommended not to implement sludge dewatering by mechanical means. As long as there is sufficient space, which is the case at both tanneries, at least for the actual situation, it is recommended to use sludge beds.

8. CHROME RECOVERY

8.1. General

According to 5.3.3.1.2 the reduction of chrome in the final effluent is possible by precipitation. As this is only a transformation of the problem from water to the soil further steps are necessary. According to 5.3.3 principally the reuse of the precipitated chrome is necessary. Therefore in the following the feasibility of chrome recovery is investigated. These chapters have been prepared by K.H. Munz (Tannery expert) for the IWGA (the full version is given in the original report, annex to this report).

9. REQUIRED EQUIPMENT

For practical realisation of the recommendations given in this report partly reconstruction of the existing treatment systems and additional equipment is required.

Therefore in the long version of this report and in chapter 12.6 and 13.6 those parts are listed, which are necessary to achieve a satisfying solution considering the basic conditions given in the progress report (05/97) and in chapter 3.

10. COSTS

The prepared list of costs is based on chapter 9. As far as possible equipment available in Uganda (Information gathered by the DCE) has been considered. For equipment that is not available in Uganda prices of various European products were used. For special equipment used for cost estimation references are given in annex 3 of the long version of the final report.

It is emphasised that if equipment of a certain company is recommended, this serves as an example to demonstrate the technical requirements and for cost estimation only. It is the decision of the client which product to use as long as it meets the technical requirements according to the recommendations.

Additionally the information on locally available equipment prepared by the DCE can naturally not be complete. Therefore it is possible that certain products are yet available in Uganda.

Summarised for the preparation of the costs equipment available in Uganda has been used as far as possible and for other products specific examples of European companies were. In the long version (Annex) an estimation of costs for required equipment as well as civil works as far as construction or reconstruction of concrete buildings is concerned is given. No estimation has been done on civil works concerning the installation of the technical equipment (incl. electrical installation). Additionally the costs of technical equipment do not include cost for transportation to the location.

Concerning the costs for pumps a reserve of 100% is considered necessary for all pumps but is not included in Table 8 and Table 12.

Operation costs, including electrical energy for pumps and blowers and chemicals, are shown in Table 1.

Costs for the reuse of chrome are not included (compare chapter 14) on the contrary to 12.5.3. It has to be considered that costs for the precipitation of chrome containing effluents are included in both estimations (equipment and chemicals).

For plant control and to meet legal possible requirements equipment to carry out simple chemical analyses is necessary. As legal requirements are not known only a rough estimated total is given.

Summarised in 12.7 and 13.7 the total investment costs for the selected tanneries are shown according to the recommendations given in this report, assuming the implementation of all recommendations.

Costs for operation						
LIU						
pumps		[kW]	[h/d]	[kWh/d]	[$/unit]	[$/a]
	chrome liquor storage tank	1,9	0,5	0,95	0,11	38,14
	sludge	2,6	1,3	3,38	0,11	135,71
	equalisation tank	3,8	16	60,8	0,11	2441,12
	to NWSC	unknown - assumed like equalisation tank				2441,12
blowers		[kW]	[h/d]	[kWh/d]	[$/unit]	[$/a]
	equalisation tank	8	24	192	0,11	7708,80
mixer		[kW]	[h/d]	[kWh/d]	[$/unit]	[$/a]
	chrome precipitation	2,06	24	49,44	0,11	1985,02
chemicals				[kg/d]	[$/unit]	[$/a]
	$MnSO_4$			2	0,20	124,80
	MgO			20	0,16	998,40
	H_2SO_4			compare chapter 11		
total						***15873,11***
Bassajja						
pumps		[kW]	[h/d]	[kWh/d]	[$/unit]	[$/a]
	chrome liquor storage tank	1,9	0,5	0,95	0,11	38,14
	chrome sludge	1,9	1	1,9	0,11	76,29
	to constructed wetland	3,8	6	22,8	0,11	915,42
	to trickling filter	5,4	20	108	0,11	4336,20
	sludge	2,6	0,6	1,56	0,11	62,63
blowers		[kW]	[h/d]	[kWh/d]	[$/unit]	[$/a]
	equalisation tank	5,6	24	134,4	0,11	5396,16
mixer						
	equalisation	4,12	4	16,48	0,11	661,67
	chrome precipitation	2,06	24	49,44	0,11	1985,02
chemicals				[kg/d]	[$/unit]	[$/a]
	$MnSO_4$			6	0,20	374,40
	lime			27	0,15	1263,60
	H_3PO_4 (60%)			16	0,40	1971,84
total						***15109,53***

Table 1: Cost estimation - summary operation costs

11. LIST OF PRIORITIES

Taking into account the costs given in chapter 10. it is possible that the implementation of all recommendations is not possible presently. This will especially be the case if the tannery owners have to pay for the implementation by themselves, which is considered a good option, as for future extensions it is necessary to calculate the cost of the „use of nature" in the product.

Considering this fact a recommended list of priorities for implementation is given in the long version of this report. Table 9 and Table 13 show the costs for the implementation of the recommendations in regard to the priorities defined in this list.

12. RECOMMENDATIONS - LIU

12.1. Flow measurement

The Table 2 shows recommended measurements of flow rate, the reason for the measurement and the measuring device.

measurement	purpose	device
LIU		
total amount of waste water discharged to NWSC	environmental standards, condition from NWSC	pump capacity + time
maximum flow rate to the primary sedimentation tank	operation, search of errors	pump capacity

Table 2: Measurement of flow, purpose and device

12.2. Sewer system

At LIU at the moment the separation in time of different discharged liquors is possible by a manually operated bypass unit.

To achieve a sufficient elimination capacity for chrome, the collection of the main chrome containing liquors is required. To increase the efficiency of the chrome elimination / recovery unit it is recommended to separate at least sammying liquors and chrome containing liquors from finishing from other effluents.

For the separation of tanning effluents the bypass unit is considered appropriate. Nevertheless to prevent leakage the shutoff devices must be replaced.

12.3. Pretreatment

12.3.1. Screening

At LIU a screen (20mm) can be situated at the outflow of the collection tank in front of the bypass unit. The existing screen should be replaced by a bar screen angled 50 to 60.

For the recycling of the chrome containing split flow further purification concerning solids is required. Therefore the installation of a fine screen (2mm) is recommended.

The design criteria is the flow rate, which can be calculated from the required pump capacity to

$$q_p = \frac{8m^3}{0,5h} = 16m^3/h \Rightarrow 4,45l/s.$$

12.3.2. Sulphide oxidation

At LIU the oxidation of sulphide is already carried out. The equalisation tank is used. The mixing of the equalisation tank as well as the supply with oxygen is carried out by pressurised aeration.

The total amount of air supply possible at the moment is calculated from the capacity of the blower:

12.75 m³/h • 24 = 306 m³/d

The necessary oxygen supply is calculated to

$$\frac{17.5\ kgO_2/day}{(3\ m \bullet 9\ g\ O_{2(Tcorr)}\ /\ (m^3 \bullet m_t)\ /\ m^3\ O_2)} = 650m^3/day,$$

the average hydraulic retention time to

$$\frac{550m^3}{100m^3/d} = 55days.$$

While the hydraulic retention time is sufficient for sulphide oxidation, the capacity of the installed blower is too small. Therefore either the repair of the second blower or, considering that the capacity is at the limit, the installation of a new air supply system is necessary. Information on the air diffusers is not available. It can be assumed that an exchange might be necessary.

Because of the size of the aeration / equalisation tank no compensation for peak inflows is necessary.

The dosage of manganese sulphate as catalyst at the moment is carried out manually by gravitation while discharging. For controlling the quantity of catalyst added, a dosing pump is the best solution.

A concentration of 20 mg/l of $MnSO_4$ is used for the calculation. The minimum concentration in the specific cases must be found out by trials.

The necessary amount of $MnSO_4$ can be calculated to

$100m^3 / d \bullet 0{,}02kg / m^3 = 2kg / d$.

According to the information received from LIU an increase in production to an average of 750 hides per day is planned. The hydraulic retention time for sulphide oxidation would still be sufficient, but the installed blower capacity is too small.

Therefore it is recommended, if the air supply system is replaced by a new one, more smaller blowers or at least additional blowers as soon as they are needed should be installed.

12.3.3. Chrome precipitation

At LIU at the moment (compare progress report, 05/97) wastewater from the tanning drums is separated manually by a bypass unit and chrome is precipitated with lime.

With precipitation a concentration of ~ 10 mg/l chrome can be achieved in the split flow. This results in an average concentration of

$$\frac{10mg / l \cdot 7{,}5m^3 / 5t(chrome - liquor)}{92{,}5m^3 / 5t(totaleffluent)} = 0{,}8mg / l$$

for the total effluent.

Considering the existing plant and the intermittent discharge of chrome water the treatment in a batch is the appropriate method.

Basically this system is applied at LIU.

According to the work scheme from LIU (see Annex 9, progress report) chrome containing effluent from the tanning drums is discharged once a day, while water from the sammying machine is discharged more or less continuously during the working hours of the tannery.

The average quantity of water containing excessive chrome (tanning incl. washing; 50% + 100%) is approximately

$$1{,}5m^3H_2O / 1000kg \times 250h_{ides} / d \times 20kg / h_{ide} = 7{,}5\ m^3 / d\ .$$

The theoretical hydraulic retention time is calculated based on the volume of the reaction tank to

$$\frac{4m \cdot 5m \cdot 1{,}5m}{7{,}5m^3 / d} = 4d\ .$$

At the moment this tank is operated continuously as it is constantly filled to the upper level.

To use the existing constructions the changeover to a discontinually operated system is the best option.

As the collection of „all" chrome containing waters - including the more or less continuously discharging sammying machine - is required and a 4 to 5 hours phase without discharge can not be assured (especially in future) the separation of storage and reaction is recommended.

Summarised the existing precipitation tank can be used as a storage tank for chrome containing liquors and as soon as a certain water level is reached the water is pumped together with alkali to a reaction tank.

Additional to the existing constructions a new reaction tank will be necessary. A volume of 10 m^3 (=7,5m^3+reserve) is sufficient for the actual amount of chrome water (one cycle - precipitation, separation - per day).

Nevertheless possible changes in future have to be considered.

The theoretically required amount of alkali depends on the pH-value of the split flow and on the amount of Cr^{3+} in the solution. It can be calculated from the concentrations of hydrogen (pH= -log [cH^+]) and chrome [Cr^{3+}].

The actual required amount of alkali has to be found out during operation by keeping a pH-value of ~7,5 (or possibly higher, if the results are not satisfying).

According to 12.3.3 for the present situation a storage tank with $10m^3$ is recommended. Depending on the actual sedimentation time required and future increase either more batches per day or an additional tank may be necessary.

The volume of the existing precipitation tank (used for storage - compare12.3.3) is sufficient for storage.

12.3.4. Flocculation

A) Primary sedimentation

For LIU the required purification efficiency concerning suspended solids is defined by demands from NWSC. Therefore at the moment the implementation of flocculation before sedimentation is not considered necessary.

b) Chrome precipitation

For the planned future capacity more cycles - precipitation, sedimentation - will be necessary without changing the volume of the reaction tank. As described this is possible if operation over 24 hours can be assured and as long as the given sedimentation time is sufficient. Otherwise the adding of flocculants together with the precipitant could be necessary.

12.4. Primary sedimentation

After pre-treatment at LIU a sedimentation tank is located to reduce the concentration of solids in the effluent before discharging to the sewer.

The surface of the tank is approximately *30,25m²*, and the height *1,5 m*.

The effluent is pumped continuously from the equalisation tank to the sedimentation tank by two pumps (only one is working at the moment).

Assuming a uniform flow over 8h per day ($\Rightarrow$ working hours of the tannery) to the sedimentation tank the calculated values for design parameters are within the common ranges. Nevertheless at the time of the visit, as mentioned in the progress report, this sedimentation tank was obviously overloaded (sludge in the outlet trough). Reason for this difference between calculations and appearance could be

⇔ efficiency of the sedimentation tank

⇔ insufficient sludge withdrawal

⇔ higher pump capacity.

The design of the existing sedimentation tank is not ideal. Additional problems can occur because of insufficient sludge withdrawal device.

Due to these problems the construction of a new sedimentation tank is recommended. With respect to the relatively small quantity of waste water the application of a circular vertical flow tank with sludge collection by gravity (Dortmund type) is recommended.

Main parameter for the design of this sedimentation tank is the hydraulic surface loading.

The sedimentation tank should be designed for the future requirements, therefore the maximum daily hydraulic load is 300 m³.

The required capacity of the pump from the equalisation tank to the sedimentation tank can be calculated to

$$\frac{300m^3/d}{16h/d} = 18{,}75m^3/h.$$

The required surface can be calculated to

$$A = \frac{Q}{q_a} = \frac{18m^3/h}{1m/h} = 18m^2.$$

The average hydraulic retention time is

$$\frac{27{,}5m^3}{18{,}75m^3/h} = 1{,}5h.$$

With a circular outflow trough (free overfall) the effluent is collected and discharged to the pump station. The sludge can be withdrawn from the sludge hopper and discharged to the sludge treatment.

The presently produced amount of sludge is calculated to

$0{,}15kgS_{ludge}/kgH_{ide} \cdot 5000kgH/d = 750kgS/d$ or

$8000 mgS / l \cdot 100 m^3 / d = 800 kgS / d$.

With an average water content of 95% an amount of 15m³/d must be withdrawn. This requires a high frequency in sludge withdrawal due to the limited storage capacity of the sedimentation tank unless a system similar to an Emscher tank for combined sedimentation and sludge storage is built. A combination sedimentation + storage is recommended. Because of the required height for an Emscher tank (approximately 8,6m depth of water) and the connected problems with the construction works (groundwaterlevel) it is recommended to separate sedimentation and sludge storage.

12.4.1. Sludge treatment

12.4.1.1. Utilisation of sludge

As mentioned in 7.1 the best possibility to prevent contamination of the sludge is the reduction of chrome in the effluent of the tannery. At LIU presently this is achieved by separation of the main chrome containing split flows and separate treatment in a precipitation unit.

The sludge produced at LIU by primary sedimentation after separate chrome elimination should have a sufficiently low content of chrome for save agricultural use.

12.4.1.2. Treatment of sludge

As explained in chapter 12.4 for storage of sludge a tank is required to reduce the intervals for sludge withdrawal from the sedimentation tank and increase the efficiency of separation and decrease the water content of the sludge. This tank can be used to reduce the water content further, before discharging the sludge to the drying beds.

The required size can be calculated to

surface O=15m²; height of cylindrical part =2,25 m; volume = 52,7m³

The supernatant is discharged to the pump station, while the sludge is discharged to sludge beds by a pump. At LIU presently 8 beds exist, for two the separate discharge of chrome sludge is possible.

The height of the sludge layer is limited to 0,20 - 0,30 m.
The capacity of natural systems to reach a water content of 75% considering periods for sludge removal is between 120 to 220 kg DS/m².a. Precondition is the separation of the sludge water by drainage.

With an actual value of 230t of sludge per year (750kg/d.6d/w.52w) the required area can be calculated to

$$\frac{230000kg/a}{150kg/m^2/a} = 1500m^2.$$

Additional reduction of the water content by evaporation is not calculated.

The available surface at LIU is

$8 \cdot 150m^2 = 1200m^2$ (information obtained from LIU).

Taking into account that the assumed values for sludge production are rather high (0,15kg/kg) and considering increased efficiency due to evaporation, the available area will be sufficient for the actual situation.

For future increase in production either additional area is required, or the installation of a press is necessary. Another possibility to cope with a slight increased amount of sludge is the discharge to the beds up to a height of ~1,0 m, although possibilities for drainage of the water must be built.

As mentioned before the main task of sludge beds is drainage of the sludge water. As far as information was available from LIU the existing beds are built without a drainage system at the bottom. If this information is correct the installation of such a system is necessary, to reach a sufficient capacity.

The drained water can be discharged by gravity to the pump station and led to the municipal treatment plant.

12.5. Chrome Recovery

12.5.1. Chrome Tannage

In traditional chrome tanning it has been observed that generally 60 - 80 % chromium applied in the form of basic chrome sulphate is absorbed by the hides and skins under process and the balance is discharged as waste with the effluent. In common procedures 6 - 10 % of tannin (i.e. 1,5 - 2,5 % Cr_2O_3), related to the pelt weight, are offered, and so 0,3 - 1,0 % Cr_2O_3 will be discharged.

It has also to be stated clearly that with no technical measure a complete uptake of the offered chrome tannin can be achieved. It is also evident that the fixation of chrome tannins is not completed. Therefore small amounts of chrome tannin will be resolved in the subsequent processes and so lead to a certain chrome loading in all effluents from retanning, dyeing and fat liquoring processes.

Depending on the applied procedure and the utilized drums, for discharged floats following figures for not bounded can be expected:

Origin of float	Float relation (%, related to...)	% of not bounded tannin (%)	chrome concentration (g Cr_2O_3/l)
end float of tannage	50 - 100 pelt weight	10 - 30	2 - 6
end float of washing	100 - 150 pelt weight	5 - 10	0,5 - 2,5
end float of wet finishing processes*	500 - 1000 shaved weight	1 - 5	0,05 - 0,5

*....including retannage, dyeing and fat liquoring processes as well as all washing floats

Table 3: Chrome concentration in discharged floats

12.5.2. Chrome Recycling in Ugandan Tanneries

As stated in the reports of several experts, at the moment it will only be possible to implement this procedure in *Leather Industry of Uganda (LIU)*, Jinja. Although the capacity of this tannery would be 750 hides and 1 500 skins per day, the tannery processes only about 300 (mainly green) hides per day into wet blue and finished leather.

Furthermore, as the tannin is added in powdered form (the necessary water to dissolve the chrome tannin will come from the wet pelt), a maximum of 50 % float relation can be expected at the end of the tannin process. It is assumed that this end float will contain 6 g/l Cr_2O_3, while the wash water (100 %) will contain another 2 g/l Cr_2O_3. So, related to 1 000 kg pelt (i.e. about 1 300 kg raw hide) 1,5 m^3 chrome - contaminated float with an average chrome-content of 3,3 g/l Cr_2O_3. will arise. Related to the offered amount of chrome tannin, the exhaustion will be 66 %.

12.5.3. Assumptions for LIU

Three different chrome contents of the combined effluents (end float of tannage + wash water) are assumed:

- 3 g/l Cr_2O_3
- 5 g/l Cr_2O_3
- 7 g/l Cr_2O_3

According to UNIDOs *„Technical Package Information"* (RAJAMANI, 1994) , for the precipitation of chrome 2 kg, 2,5 kg and 3 kg MgO are necessary per 1 m^3 combined liquor (1 kg MgO costs about 0,20 US $). For resolving the precipitated chromium hydroxide, 3 l, 4 l and 5 l concen-trated sulphuric acid (H_2SO_4, 1 l = 2 kg costs about 0,40 US $) will be required.

As the common basic chrome sulphate (BCS) contains about 25 % Cr_2O_3, 1 kg Cr_2O_3 will be equal to 4 kg of tannin (costs per kg will be about US $ 0,70). In the following comparison, calculations for 1 m^3 combined effluents (chrome - contents as given above) in regard of chemical costs and recovered chrome tannin are made:

Cr_2O_3 - content of effluent	required MgO for precipitation	required H_2SO_4 for resolving	recovered Cr_2O_3 (x 4 = BCS)	total costs in US $
3 kg/ m3 Cr2O3	2 kg = 0,40 US $	3 l = 1,20 US $	3 kg=12 kg BCS = 8,40 US $	+ 6,80 US $
5 kg/ m3 Cr2O3	2,5 kg=0,50 US $	4 l = 1,60 US $	5 kg=20 kg BCS = 14,00 US $	+ 11,90 US $
7 kg/ m3 Cr2O3	3 kg = 0,60 US $	5 l = 2,00 US $	7 kg= 28 kg BCS = 19,60 US $	+ 17,00 US $

Table 4: Chemical costs and recovered tannin

It is evident that LIU does not always work with full capacity. Therefore 4 work-in-rates are assumed:

- 250 hides per day
- 500 hides per day
- 750 hides per day
- 1 000 hides per day (as target for the future).

250 hides = 5 000 kg raw hide weight = 4 500 kg pelt weight

500 hides = 10 000 kg raw hide weight = 9 000 kg pelt weight

750 hides = 15 000 kg raw hide weight = 13 500 kg pelt weight

1 000 hides = 20 000 kg raw hide weight = 18 000 kg pelt weight

Hides per day (pelt weight)	Volume of chrome-containing effluents	kg of recovered BCS (chrome content of effluent)		
		3 g/l Cr2O3	5 g/l Cr2O3	7 g/l Cr2O3
250 (= 4 500 kg)	6 750 l	81 kg =45,90 US $*	135 kg = 80,33 US $*	189 kg =114,75 US $*
500(= 9 000 kg)	13 500 l	162 kg =91,80 US $*	270 kg =160,65 US $*	378 kg =229,50 US $*
750(= 13 500 kg)	20 250 l	243 kg = 137,70 US $*	405 kg =240,98 US $*	567 kg = 344,25 US $*
1 000(= 18 000 kg)	27 000 l	324 kg =183,60 US $*	540 kg =321,30 US $*	756 kg =459,00 US $*

*....net profit (chemical costs for precipitation are included)

Table 5: Recovered BCS

Related to one year (250 work days), following results are obtained (net profit is given again):

Hides per year (pelt weight)	Volume of chrome-containing effluents	tons of recovered BCS (chrome content of effluent)		
		3 g/l Cr2O3	5 g/l Cr2O3	7 g/l Cr2O3
62 500(= 1 125 t)	1 687,5 m3	20,25 t =11 475,00 US $	33,75 t = 20 082,50 US $	47,25 t kg =28 687,50 US $
125 000(= 2 250 t)	3 375 m3	40,50 t =22 950,00 US $	67,50 t =40 162,50 US $	94,50 t =57 375,00 US $
187 500(= 3 375 t)	5 062,5 m3	60,75 t = 34 425 US $	101,25 t =60 245,00 US $	141,75 t = 86 062,50 US $
250 000(= 4 500 t)	6 750 m3	81,00 t =45 900,00 US $	135 t =80 325,00 US $	189 t =114 750,00 US$

Table 6: Recovered BCS per year

In order to consider the feasibility, following assumptions are made (all costs from TECHPACK/ UNIDO/ RePO):

Capital costs for the implementation: 60 000,- US $

If implementation costs will be financed by a revolving funds or bank loans, also interests and depreciation have to be taken into consideration:

Yearly operation and maintenance costs: .... 5 000,- US $

Yearly financing costs (15 % of 60 000,-) .... 9 000,- US $

Yearly depreciation (15 % of 60 000,-) .... 9 000,- US $

Total costs per year .... 23 000,- US $

Although the yearly cost figures are only estimated, for the feasibility following calculation can be carried out:

Hides per day (hides per year)	**Saving due to chrome recovery minus total yearly costs** (chrome content of effluent)		
	3 g/l Cr2O3	5 g/l Cr2O3	7 g/l Cr2O3
250 (62 500)	- 11 525,- US $	- 2 917,50 US $	+ 5 687,50 US $
500 (125 000)	- 50,- US $	+ 17 162,50 US $	+ 34 375,- US $
750 (187 500)	+ 11 425,- US $	+ 37 245,- US $	+ 63 062,50 US $
1 000 (250 000)	+ 22 900,- US $	+ 57 325,- US $	+ 91 750,- US $

Table 7: Savings due to chrome recovery

12.5.4. Conclusions

⇨ It is evident that at the moment for all Ugandan (chrome) tanneries the recycling and reuse of spent tanning liquors can be the only clean technology, worth to be taken into consideration.

⇨ However, also for chrome recycling a certain tanning capacity will be required in order to make the implementation feasible.

⇨ For LIU (Leather Industry of Uganda), it is to assume that due to the applied tanning procedure the combined chrome-burdened effluents (tanning rest float and wash water) will contain between 3 to 5 g/l Cr_2O_3.

⇨ Therefore, with the current capacity of 250 - 300 hides per day, a profit due to savings by recovered chrome tannin hardly can be predicted.

⇨ Only when the tannery works with (nearly) full capacity (i.e. 750 hides per day), the implementation of a chrome recycling plant will be feasible.

⇨ As for the present study no analytic data were available, all given results can only be considered as estimated predictions, based on the expert´s experience.

⇨ Therefore, it is strongly recommended that prior to any implementation a longer analytic monitoring in regard of discharged volumes and chrome contents will be carried out. Only with exact datas, an exact evaluation on the feasibility of chrome recycling can be given.

⇨ Furthermore, based on the monitoring datas, exact dimensions for the required tanks, screens, pumps and pipelines can be determined.

12.6. Required equipment

12.6.1. Flow measurement

A) Meter for pump - operating hours (for plant control)

12.6.2. Sewer System

A) Piping from sammying machine to chrome precipitaion unit PVC DN200, ~50m, I>0,5%

B) Two gate valves width/height of channel 30/50 cm; stainless steel

12.6.3. Primary sedimentation

Sedimentation tank

A) Vertical flow tank (Dortmund type); surface = 18 m^2; Ø 5,3 m; volume = 27,5 m^3

B) Circular inflow cone Ø 0,50 m; h=1,50 m; stainless steel

C) Circular outflow trough Ø 4,90 m (inside); stainless steel

D) Piping for sludge to thickener PVC DN 150; ~5m; I>1%

E) Piping for supernatant to collecting manhole PVC DN 200; ~15m

F) Collecting manhole DN 800; h=1,20 m

12.6.4. Sulphide oxidation

Oxidation tank

A) Blowers (Q_L=100m³/h (mixing+aeration) * 3 (incl. 100% reserve) - actual situation)

B) Aerators (if necessary)

C) Air distribution system (future capacity); DN 80 ~ 60m (circular distribution line); DN 100 ~ 10m (supply from blowers); 1" PE ~150m (aerators)

D) Valves DN 100

E) Miscellaneous (installation material for blowers)

F) Dosing pump ($MnSO_4$); 2 kg/d (80%$MnSO_4$; 25% solution) ⇒ 5 l/d; total time of discharge approximately 1,5 h/d ⇒ *0,05 l/min*

G) PE-Pipe for $MnSO_4$-solution; ½"; ~ 5 m

H) Storage tank for $MnSO_4$-solution; PE-tank - e.g. 140l (store for one week - future demand) incl. manual mixer

Pump to sedimentation tank

A) Pumps (Q=18,75 m³/h = 5,2 l/s; h_{man}~ 3,0m) - 100% reserve; installed in existing pump house

B) 4 valves DN 100

C) Miscellaneous (installation material of pumps)

D) Piping to pumps PVC DN 100; ~10m

E) Piping to sedimentation tank (via old sedimentation tank) PVC DN 100; ~15m

F) Control of pump - float operated switch

12.6.5. Chrome precipitation

Storage tank

A) Pump to reaction tank (4,2 l/s; h_{man}~6,0m)

B) Piping to reaction tank (PVC DN 100, ~5m)

C) Gate valve for overflow to equalisation tank; for pipe DN 150; stainless steel

Reaction tank

A) Cone-shaped tank (Ø 3,80m, angel of sidewalls 60°, volume 10m³)

B) Mixer

C) pH-meter

D) Piping for supernatant to equalisation tank (PVC DN 150; ~10m)

E) Piping for sludge to resolution tank (PVC DN 150; ~5m)

F) Two valves DN 150

Storage tank for MgO

A) e.g. V=250 l

12.6.6. Sludge treatment

Sludge storage tank / thickener

A) Cylindrical tank with sludge hopper (angel of sidewalls 60°)

B) Surface O=15m² (Ø 4,50m)

C) Height of cylindrical part =2,25 m

D) Volume = 52,7m³

E) Circular outflow trough ($Ø_i$ 3,80m)

F) Piping for supernatant to collection tank PVC DN 200 ~25m (I ≥ 1%)

G) Piping for sludge to distribution tank PVC DN 200 ~15m;1 valve DN 200

Distribution tank / pump station

A) Rectangular manhole 1,5/1,0/2,50 m

B) Pump for sludge to sludge beds (Q=2,6l/s; $h_{v\text{-}max}$=0,23m; h_{geo}≈1,70m - 100% reserve)

C) Piping for sludge to sludge beds PVC DN 100 ~130m

D) 15 valves DN 100

Sludge beds

A) Sealing (8*150m²=1200m² + sidewalls=400m²) - PE-layer or clay 2*20 cm (=640m³)

B) Drainage layer (from top to bottom): sand (0-10mm) = 240 m³ (20cm); fine gravel (18-25mm) = 120 m³(10cm); coarse gravel (50-100mm) = 220 m³ (av. 18cm)

C) Drainage pipe PVC DN 100; ~120m

D) Piping for drained water to collection tank PVC DN 150 ~ 20m; PVC DN 200 ~ 60m

E) 4 manholes DN 800, h=1,20m

Collection tank

A) Manhole DN 800, h=1,50m

B) Piping to pump station, PVC DN 200; ~10 m

12.6.7. Screen

Bar screen:

A) Angle 60° ⇒ length ~ 1000 mm (height of channel 500 mm)

B) Space between bars ~ 20 mm

C) Bar width corresponding static requirements (15mm)

D) Screen chamber (width = 600 mm)

E) By-pass channel (350/500mm) + two gate valves

F) Platform for collection of solids (board 2m/(channel width + 2.0,5 m))

G) Rake for cleaning of the screen

Static grid:

A) Capacity Q=16m³/h

B) Possible type - Annex 3

C) By pass pipe (L~3m) incl. two valves DN80, one valve DN150

12.7. Costs

	Investment for buildings and tecnical equipment [US$]	Operation costs per year (energy, chemicals) [US$/a]	costs for maintenance (~2% of investment per year) [US$/a]
Leather Industries Uganda	129.800,00	15870,00	2600,00

Table 8: Cost estimation - summary

12.8. Priorities

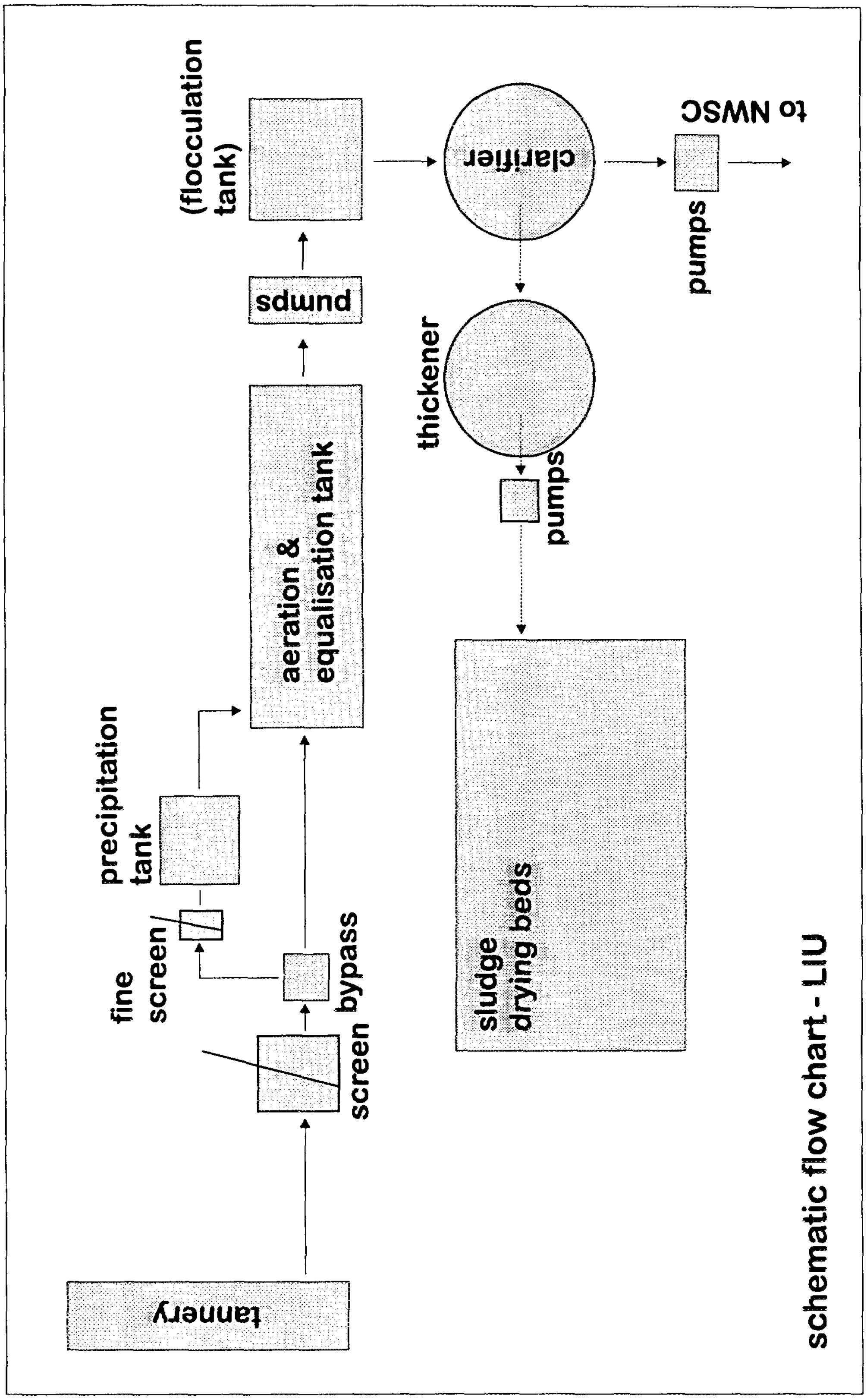
LIU

Priorities	*1*	*2*	*3*	*4*	*5*
Costs	17210	24805	67980	18060	1750

Priorities	*1*	*1+2*	*1+2+3*	*1+2+3+4*	*1+2+3+4+5*
Costs	17200	42000	110000	128100	129800

Table 9: Costs for the implementation in regard to the priority

12.9. Schematic flow chart



13. RECOMMENDATIONS - BASSAJJA TANNERY

13.1. Flow measurement

The Table 10 shows recommended measurements of flow rate, the reason for the measurement and the measuring device.

measurement	purpose	device
BASAJJA		
total amount of waste water discharged (future recommendation)	standards	venturi channel + float
total amount of waste water discharged to secondary treatment	operation, search of errors	pump capacity + time
maximum flow rate to the primary sedimentation tank	operation, search of errors	pump capacity

Table 10: Measurement of flow, purpose and device

13.2. Sewer system

At the Bassajja tannery at the moment due to a lack of specific split flow treatment no separation of any liquors is possible.

For the future chrome containing streams have to be separated for split flow treatment. As only production to wet blue is planned it is recommended to use to drain effluents from the sammying machine and the tanning drums directly to the storage tank and to install a bypass unit (gate valve) to be able to separate chrome containing water from the tanning process from other. The „chrome-free" supernatant from the reaction tank has to be pumped into the channel below the bypass unit.

13.3. Pretreatment

13.3.1. Screening

At the Bassajja tannery immediately outside the building a tank, originally planned for sedimentation, exists. As the size is insufficient for sedimentation it could be converted to a screen chamber.

For chrome precipitation no pretreatment (screening) is required as long as it is not planned to reuse the precipitated chrome sludge.

If the recycling of chrome after precipitation shall be carried out in future a solution similar to LIU is recommended. For the design again the flow rate is the required criteria:

$$q_p = \frac{10m^3}{0,5h} = 20m^3/h \Rightarrow 5,56l/s.$$

Because of intermittent discharge the recommendations are sufficient for future requirements. Only the intervals between two loadings as well as the cleaning intervals will change.

13.3.2. Sulphide oxidation

The tannery in Mbarara started operation at the end of May.

Therefore it is necessary to use average values (literature) for the dimensioning of the treatment of sulphide containing effluents.

The total volume of the aerated tanks is

$$2 streets \bullet 4 \tan ks \bullet (\sim 3m \cdot \sim 4m \cdot \sim 1,5m) = 144m^3.$$

The actual capacity in Mbarara is 3000 goat / sheep skins per day.

Using a water consumption of 35 m^3/t, the hydraulic retention time in the eight aerated tanks is calculated to approximately

$$\frac{144m^3}{300m^3/d} = 0,48 \Rightarrow 11,5h,$$

which is sufficient for catalytic sulphide oxidation.

By an average of 3000 skins per day a total load of 39 kg of sulphide is discharged to the treatment plant.

During the retention time in the eight aerated tanks this load will have to be reduced by aeration.

The required oxygen supply for complete sulphide oxidation is calculated to

$$\frac{19.5\ kgO_2 / day}{(3\ m \bullet 9\ g\ O_{2(Tcorr)}\ /\ (m^3 \bullet m_t)\ /\ m^3\ O_2)} = 720 m^3 / day$$

This value has to be compared with the actual value of the blowers if obtained from the tannery. If these are not available the oxygenation capacity of the aeration system has to be tested.

For proper oxidation of sulphide the addition of approximately 20 mg/l $MnSO_4$ will be necessary. The total amount of $MnSO_4$ necessary at the moment is

$300 m^3 / d \bullet 0{,}02 kg / m^3 = 6 kg / d$.

As mentioned, the actual planned production is 200 hides or 3000 skins. For the future an increase in production of 300 % is planned.

This increase would lead to a retention time in the aeration tanks of

$11{,}5/3 = 3{,}8\ h$,

which is still sufficient for catalytic sulphide oxidation. Nevertheless it is doubted that the installed blower capacity is sufficient for this situation.

13.3.3. Chrome precipitation

At the Bassajja tannery at the moment no chrome precipitation is carried out. To reach the required values elimination of chrome is necessary.

The calculation is based on an average value of 9 m^3 of chrome containing water per day (⇒100%). This amount is discharged intermittently over the whole day. As mentioned two batch cycles - precipitation, sedimentation, separation - should be possible per day. Therefore for the actual situation a tank with approximately 5 m^3, assuming the existence of a storage tank, is sufficient.

As described in the progress report opposite the tanning drums (approximately 2,5m) three tanks with a volume of

$\sim 2m \cdot 4m \cdot 1{,}5m = 12 m^3$

each, could be used for chrome precipitation. The separation of the chrome containing effluent can be carried out easily with gate valves and a new channel to the existing tanks.

For the actual situation the storage of the daily chrome containing effluent is possible in one of these tanks, and the precipitation in one cycle in a second one.

If reuse of the precipitated chrome is required, MgO is the best solution to rise the pH-value. Usually it is added as a powder, therefore difficulties in finding out the required dosage can occur.

Recycling of the produced sludge is not recommended, as at the moment many other problems should be given priority to.

For the future an increase in production of 300 % is planned. The required reaction volume for precipitation, assuming two cycles per day can be calculated to

$$300\% \cdot 9m^3/d/2 = 13{,}5m^3/d.$$

The volume of the existing tanks will be reduced to $10m^3$ each, because of necessary changes at the bottom (sludge withdrawal), which is still sufficient, if two of the three existing tanks are used for precipitation.

The maximum required storage volume can be calculated to

$$300\% \cdot 9m^3/d - 2 \cdot 10m^3 = 7m^3.$$

The third tank left opposite the tanning drums is capable of serving this purpose.

13.3.4. Flocculation

a) Primary sedimentation

As it is planned to use a natural system, preferably a constructed wetland, for biological secondary treatment the extensive elimination of suspended solids from the effluent is necessary to prevent clogging problems.

The simplest way is to control the effluent quality of the sedimentation tank and the addition of flocculants *if required*.

b) Chrome Precipitation

compare 12.3.4 b)

13.4. Primary sedimentation

At the existing treatment plant 2 x 2 tanks (H x L x W = 1,5 x 3 x 4) shall be used for sedimentation.

As the water is discharged by gravity into the treatment plant, hydraulic shock loadings will pass through the aerated tanks slightly softened to the sedimentation tanks.

Considering the high probability of short circuits due to the arrangement of inlet and outlet of the tanks and the unfavourable width:length ratio (1,3) these tanks can not be expected to eliminate suspended solids sufficiently. An additional problem is the sludge withdrawal. At the moment there is no chance to withdraw any sludge from the tanks.

The sedimentation tank should be designed for the future requirements, that means a maximum daily hydraulic load of 900 m^3. Due to retention in the aeration tanks the peak is softened but nevertheless high fluctuations of the flow to the sedimentation tank can be expected.

The average continuous discharge value to the sedimentation tank can be calculated to

$$\frac{900 m^3/d}{24 h/d} = 37{,}5 m^3/h .$$

Compared to the calculated maximum possible value of 64,8 m^3/h the ratio maximum : average is 1,7. Therefore it is recommended to use either a pump to the sedimentation tank or a flow constriction when discharging by gravity. Because of cost for electricity and available natural slope the installation of a pipe for flow constriction may be considered as an appropriate solution.

With an inflow pipe to the sedimentation tank with a diameter of 80mm (length = 5m) and by using the entire volume of the last four tanks for storage the maximum flow can be calculated to *15,3l/s* (k_b=1,5mm).

This flow requires a surface area of

$$A = \frac{Q}{q_a} = \frac{55 m^3/h}{1 m/h} = 55 m^2 .$$

Using a slope of the tank walls of 60° the depth of the tank is more than 8m. Therefore the application of two Dortmund tanks is recommended.

For the distribution of the wastewater in two sedimentation units a distribution box is required to assure uniform flow to both tanks.

With a circular outflow trough (free overfall) the effluent is collected and discharged directly to the secondary treatment. From the sludge hopper the sludge can be withdrawn and discharged to the sludge treatment.

The produced amount of sludge is calculated to

$$0{,}15 kgS / kgH \cdot 9000 kgH / d = 1.350 kgS / d\ .$$

This results in the same problems described for LIU. Again it is recommended to separate sedimentation and sludge storage.

13.5. Secondary Treatment System

Tannery effluent treated according to the recommendations given will match the requirements for discharge to a sewer system. If it is necessary to discharge directly into a natural water body, which is the case at the Bassajja tannery in Mbarara, further treatment is required. As explained in the progress report (05/97) due to various reasons (operation cost, lack of trained personnel, ...) for the tannery in Mbarara the application of a natural system as a secondary treatment is recommended, if possible.

The requirements for the purification efficiency are given in Table 11:

Parameter	after pre- and primary treatment	after secondary treament
COD	~2000	200/90%
BOD_5	~1000	80
Cr^{3+}	~3	0,5
S^{-}	~5	0,5
SS	<500	30
TKN	~500	η_{ges}>50%
P	<<	-

Table 11: Secondary treatment - required purification efficiency

As can be seen from Table 11 the content of phosphorus is very low. Microorganisms in conventional biological treatment systems need at least a BOD_5 : P ratio of 100:1. Therefore when treating only tannery effluent dosage of phosphorous according to the organic loading (BOD_5) is necessary.

The required amount of phosphorous can be calculated from the BOD_5-load to

$1\% \cdot 300 kg/d = 3 kgP/d$.

13.5.1. Constructed Wetland

13.5.1.1. General

Out of various reasons (compare o.v.) a constructed wetland was chosen as secondary treatment stage after pre- and primary treatment.

Constructed wetlands are designed and man-made systems which are aimed at simulating the treatment processes observed in natural water bodies and water saturated soils. The treatment mechanisms are complex and include aerobic degradation (organic matter), sedimentation and filtration (suspended solids), matrix adsorption and plant uptake (metals) among others.

Among the different systems the vertical, subsurface flow constructed wetland is the most appropiate system to treat high polluted wastewaters with relatively small place requirements. Such systems have been in operation for several years in Europe.

13.5.1.2. Design

1) wastewater quality and quantity:

The design parameters including expected effluent concentrations after pre- and primary treatment (= inlet concentrations of the constructed wetland system) are given in Table 6 (o.v.) as well as the required effluent concentrations after the constructed wetland.

The inlet concentrations are very high (COD, BOD_5, SS), so that a subsurface vertical flow constructed wetland with intermittent loading is the only appropriate system and is therefore chosen as secondary treatment step for the Bassajja Tannery.

Because of the very low concentration of phosphorous in the tannery wastewater, a dosage of phosphorous is necessary.

2) storage tank for intermittent loading:

Due to the pre- and primary treatment the flow rate of the wastewater will be rather constant. However, the beds of the constructed wetland have to be loaded intermittently. Therefore a storage tank is required, out of which two pumps feed the beds 6 times per day.

3) area of beds:

The dimensioning of the required area is based on the most common used design model for constructed wetlands, the first order k-C* areal model.

The background concentration (BOD_5) chosen for calculation amounts to 10 mg/l for BOD_5. Due to the higher performance of vertical flow systems a k- value of 0,13 m/d is chosen for calculation of the Bassajja constructed wetland.

The factor k is temperature dependent, the required bed area is therefore about

4000 m^2.

Beside this calculation the high inlet concentrations have to be taken into consideration, because of soil clogging of the substrate matrix of the constructed wetland.

Out of these considerations the maximum load for prevention of clogging should not exceed 30 to 35 $gBOD_5/m^2/d$ in warm climates. This would lead to an area of 10.000 m^2.

This required area is obviously too much for the available space at Bassajja Tannery.

This leads to the need of an additional treatment step after the pre- and primary treatment which reduces the inlet concentrations into the constructed wetland to:

BOD_5: 300 mg/l; SS: 100 mg/l

On the basis of these concentrations the required area for the constructed wetland amounts to:

$$A = \frac{300}{0,2}[\ln(300-10)-\ln(80-10)] = 2130m^2$$

The already excavated pit for a former planned wastewater lagoon amounts to ~720 m². This pit could be used as one bed of the treatment plant. 3 additional beds like this one have to be built, giving a total area of 2880 m² of all four beds.

The BOD_5 load therefore is:

$$L = \frac{0,3 \times 300.000}{2880} = 31,25g\ /\ m^2\ /\ d$$

which is well within the above given limits.

4) treatment concept:

The constructed wetland consists of 4 beds, each 60m long and 12m wide (720m²). The beds are loaded intermittently (6 times a day) by two pumps. One loading period lasts for half an hour and one resting period lasts for 3,5 hours.

Furthermore the beds are fed alternating which means that just 3 beds are fed parallel while the 4th bed is resting. This situation is changed every week. Therefore, for each bed a period of 3 weeks of feeding is followed by a one week period of resting.

The beds are planted with common reed (*Phragmites australis*) or a similar macrophyte. The macrophytes stabilise the surface of the beds, provide good conditions for filtration, prevent the beds from clogging and provide a huge surface area for attached microorganisms within the rootzone.

13.5.2. High loaded trickling filter for partial purification

13.5.2.1. General

As calculated in 13.5.1 the use of a constructed wetland for entire purification to the required values requires an area which is, according to the authors knowledge, not available. Therefore it is recommended to use the available area (~2200m²) for a constructed wetland but to reduce the organic load by a high loaded biological system before discharging to the constructed wetland. The required purification efficiency for this system is approximately 70%. Due to the reasons which led to the decision on the use of natural systems - operation and maintenance - a trickling filter is recommended although the costs for construction will be higher.

For industrial wastewater with high concentrations of organic compounds (BOD_5) and suspended solids the use of plastic sprinkler packages is advantageous against common slag or lava.

13.5.2.2. Design

Using plastic material with a specific surface of 150 m²/m³ according to Annex 3/11 (o.v.) the trickling filter can be designed to:

required volume $V = \frac{1 \cdot 300}{1,5} = 200m^3$

As the contact time is independent from the area:height ratio it is recommended to build the filter rather low to minimise the costs. A height of 4 m is suggested; this results in a diameter of 8 m.

The surface is calculated to

$O=50m^2$.

With a minimum hydraulic surface load of $q_f=1,2$ m/h, a required backflow of

$$q_b = 50m^2 \cdot 1,2m/h - {}^{300m^3/d}\!\!\diagup_{20h/d} = 45m^3/h = 12,5l/s$$

is calculated.

For the distribution of the water on the surface a rotary distributor is necessary.

By the implementation of a high loaded biological system an increase in the production of sludge must be considered.

An additional sedimentation tank is necessary which can be designed according to the primary sedimentation unit.

The total amount of sludge produced (incl. primary sedimentation) is increased by the implementation of this trickling filter to 10-15%.

13.5.3. Sludge treatment

13.5.3.1. Utilisation of sludge

Presently all the sludge produced at the Bassajja tannery shows chrome concentrations in the range of the values calculated in 7.1. Therefore the only possibility at the moment is landfill. It is recommended to introduce precipitation of chrome by split flow treatment and separation of the produced sludge as a short term solution to facilitate at least agricultural use of all other produced sludge and to reduce the amount of sludge that has to be dumped. For a long term solution it is recommended to recycle the precipitated sludge and further minimise the amount of contaminated sludge.

13.5.3.2. Treatment of sludge

At the Bassajja tannery presently no possibilities for further treatment of sludge exist, although due to the high water content and the resulting high volume it is necessary to treat the sludge. It is recommended to use natural systems - sludge beds - to reduce the water content. For the same reasons as for LIU after sedimentation a storage tank for sludge is recommended. If used for sludge thickening the required volume can be calculated to (actual situation)

surface O=33m^2; height of cylindrical part =2,25 m; volume = 91,2m^3

After thickening the sludge is discharged intermittently to the sludge drying beds while the supernatant as well as the drainage water from the beds are fed by gravity into a collection tank.

The required area of the sludge drying beds (amount of sludge = 1650.5.52=430000kg/a) can be assumed with

$$\frac{430000kg}{150kg/m^2} = 2800m^2.$$

As far as it is known to the author this area is available at the Bassajja tannery. If this is not the case and at least for increased capacity (as planned) a mechanical system has to be considered. For the actual situation the reduction of the water content using natural systems is recommended.

13.6. Required equipment

13.6.1. Flow measurement

A) Meter for pump - operating hours (for plant control)

13.6.2. Sewer System

A) Channel from tanning drums to storage tank; concrete 30/50 cm; 5m

B) Two gate valves width/height of channel 30/50 cm; stainless steel

13.6.3. Primary sedimentation

*Reconstruction of the last 2*2 existing tanks + collecting tank*

A) Four passages at bottom level at least 100/50cm (utilisation of total volume for equalisation)

B) Mixer (prevention of sedimentation)

Distribution box

A) Concrete tank (inside 2,40/1,00/1,00)

B) Two weirs h=0,40 (concrete) + adjustable metal weirs on top ⇒ total height ~ 0,50 m

C) Two gate valves; stainless steel

Sedimentation tank

A) Vertical flow tank (Dortmund type); surface = 27,5 m^2; Ø 6,40 m; volume = 51 m^3

B) Circular inflow cone Ø 0,50 m; h=1,50 m; stainless steel

C) Circular outflow trough Ø 6,00 m (inside) ; stainless steel

D) Piping for water to distribution box PVC DN 80, L=5,0 m (flow constriction)

E) Piping to sedimentation tank PVC DN 150, ~ 8 m

F) Piping for sludge to thickener PVC DN 150; ~20m; I>1%

G) Valve DN 150

H) Piping for supernatant to collecting manhole PVC DN 200; ~ 8m

I) Collecting manhole DN 800; h=1,20 m

J) Piping to pump tank (trickling filter) PVC DN 200; ~ 15 m

13.6.4. Sulphide oxidation

Oxidation tanks

A) Blowers (if necessary); 160 m^3/h (mixing+aeration) - 2 blowers á 80 m^3/h + reserve 80 m^3/h

B) Aerators (if necessary)

C) Dosing pump ($MnSO_4$); 6 kg/d (80% $MnSO_4$; 25% solution) ⇒ 30 l/d; total time of discharge approximately 1,5 h/d ⇒ *0,35 l/min*

D) PE-Pipe for $MnSO_4$-solution; ½"; ~ 5 m

E) Storage tank for $MnSO_4$-solution; PE-tank - e.g. 250 l (store for one week - future demand) incl. manual mixer

13.6.5. Chrome precipitation

Storage tank

A) Pump to reaction tank (5 l/s; h_{man}~2,0m)

B) Piping to reaction tank (PVC DN 100, ~5m)

C) Valve DN 100

Reaction tank

A) Reconstruction of bottom of existing tank, angel of walls 60°

B) Mixer

C) pH-meter

D) Pump for sludge to drying beds/recycling unit and supernatant to existing sewer (Q=3,5l/s, h_{man}=2,0m)

E) Piping to pump (PVC DN 80, ~6m)

F) Piping for supernatant to existing sewer (PVC DN 100; ~10m)

G) Piping for sludge to drying beds (PVC DN 100; ~50m)

H) Two valves DN 100 + valve DN 100 (connection to sludge distribution piping)

Storage tank for lime / Mgo

A) Dosing pump for lime (Q=1,55; h_{man}=0,10m)

B) Pipe to reaction tank (∅ ½", ~2m)

13.6.6. Sludge treatment

Sludge storage tank / thickener

A) Cylindrical tank with sludge hopper (angel of sidewalls 60°)

B) Surface O=27m² (∅ 5,90m)

C) Height of cylindrical part =2,40 m

D) Volume = 91m³

E) Circular outflow trough (∅ 5,20m)

F) Piping for supernatant to collection tank PVC DN 200 ~2m (I ≥ 1%)

G) Piping for sludge to distribution tank PVC DN 200 ~5m; 1 valve DN 200

Distribution tank / pump station

A) Rectangular manhole 1,5/1,0/2,50 m

B) Pump for sludge to sludge beds (Q=4,7l/s; $h_{v\text{-}max}$=0,98m; h_{geo}≈5,00m - 100% reserve)

C) Piping for sludge to sludge beds PVC DN 100 ~120m

D) 18 valves DN 100

Sludge beds

A) Sealing (9*250m²=2250m²) - PE-layer or clay 2*20 cm (=900m³)

B) Concrete sidewalls h=0,50m; d=0,20m

C) Drainage layer (from top to bottom): sand (0-10mm) = 500 m³ (20cm); fine gravel (18-25mm) = 225 m³(10cm); coarse gravel (50-100mm) = 405 m³ (av. 18cm)

D) Drainage pipe PVC DN 100; ~225m

E) Piping for drained water to collection tank PVC DN 150 ~ 40m; PVC DN 200 ~ 60m

F) 8 manholes DN 800, h=1,20m

Collection tank

A) V = 300m³/d / 6/d = 50 m³

B) Feed to constructed wetland (discharge interval ~3,5h): 2 pumps á

$$\frac{100m^3/h}{3 fields \cdot 2 pumps \cdot 3{,}6 \frac{l/s}{m^3/h}} = 4{,}6 l/s$$

13.6.7. Screen

Bar screen:

A) Angle 60° ⇒ length ~ 1000 mm (height of channel 500 mm)

B) Space between bars ~ 20 mm

C) Bar width corresponding static requirements (15mm)

D) Screen chamber (width 550 mm)

E) Rake for cleaning of screen

F) By-pass channel (350/500mm) + two gate valves

Static grid:

A) Capacity Q=20m³/h

B) Possible type - Annex 3

C) By pass pipe (L~3m) incl. two valves DN80, one valve DN150

13.6.8. Secondary treatment

Trickling filter

A) Construction (concrete tank, Ø 8m, H=5,0m; tank for discharge + tank for pumps)

B) Pumps 2 x 8,5l/s; H_{man}~10m

C) Rotary distributor Ø 7,5m; 17 l/s

D) Piping

E) Plastic sprinkler package

Sedimentation tank

A) Vertical flow tank (Dortmund type); surface = 27,5 m²; Ø 6,40 m; volume = 51 m³

B) Circular inflow cone Ø 0,50 m; h=1,50 m; stainless steel

C) Circular outflow trough Ø 6,00 m (inside) ; stainless steel

D) Piping for water to sedimentation tank PVC DN 150, L ~ 8 m

E) Piping for sludge to thickener PVC DN 150; ~15m; I>1%

F) Piping for supernatant to collection tank PVC DN 200; ~ 8m

Constructed wetland

Layers

Succession of layers according to Fig. 17:

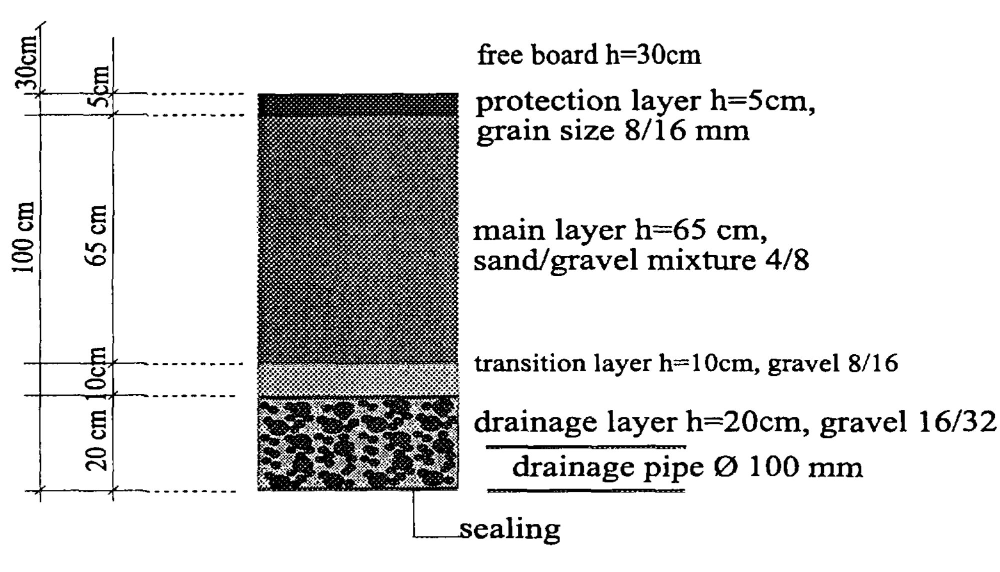


Fig. 1: Succession of layers of the constructed wetland beds

The main layer has to fulfil the following two criteria:

- Hydraulic conductivity high, k_f value 10^{-3} - 10^{-4} m/s
- $U = \frac{d_{60}}{d_{10}} \leq 4$

A) Sealing: PE or PVC liner with a minimum thickness of 1mm (to prevent rodents and roots to break through the liner) - 2900m²

B) Sand - beyond the sealing; 5cm; 144m³

C) Gravel - protection and transition layer; 8/16mm; 5+10cm; 432m³

D) Sand / gravel - main layer; 16/32mm; 65 cm; 1870 m³

E) Gravel - drainage layer; 16/32mm; 20 cm; 576 m³

Distribution system

The distribution system is made out of plastic pipes (DN 50). There are 5 pipes per bed (each 60m long) at a distance of 2,4m from each other. Every 2m there are holes at the bottom of the pipes, which means that each hole supports 4,8m² bed surface with wastewater. The pipes have a slope of at least 0,5%. Beyond the holes are plates (40cm x 40cm) at the surface of the bed to prevent from erosion. The diameter of theses holes has to ensure the even distribution of the water over the whole area. This can be achieved by variation of the diameter of the holes in direction of the flow. This can be checked during the installation.

A) Pipes to the distribution system PVC DN 150; L ~ 150 m

B) Distribution pipes PVC DN 50; L ~1200 m

C) Concrete plates 40/40 cm; 600 pieces

Drainage system

Within the drainage layer are perforated drainage pipes with a diameter of 100 mm. There should be 3 drainage pipes per bed at a distance of 4m from each other which collect the water at the bottom of the bed. The bottom of the drainage layer should have a slope of 0,5% (as well of course the drainage pipes), but there should not be a slope at the top of the drainage layer and at the top of the bed at all. The drainage pipes end in an outlet chamber at the end of each bed where it is possible to measure the outflow and to take effluent samples. Between the 4 outlet chambers are collection pipes and the collected water flows to the river.

A) Drainage pipes PVC DN 100; L ~ 720 m

B) Outlet chambers concrete DN 800; H=1,50m

Control of the feeding

The wastewater is pumped out of the storage tank by two pumps (capacity ~ 10 l/s) every four hours which means 16,7m³/feeding/bed. Which bed is fed by the pumps is controlled by automatic valves. In the storage tanks is a minimum and maximum alarm (float) to prevent the pumps from running without water resp. the storage tank from overfilling. A time switch controls the pumps.

A) Storage tank

B) Pumps

C) Float switch

D) Time switch

E) 4 automatic valves DN 100

F) Control unit for valves (time switch)

13.7. Costs

	Investment for buildings and tecnical equipment [US$]	Operation costs per year (energy, chemicals) [US$/a]	costs for maintenance (~2% of investment per year) [US$/a]
Bassajja Tannery	352.300,00	15110,00	7050,00

Table 12: Cost estimation - summary

13.8. Priorities

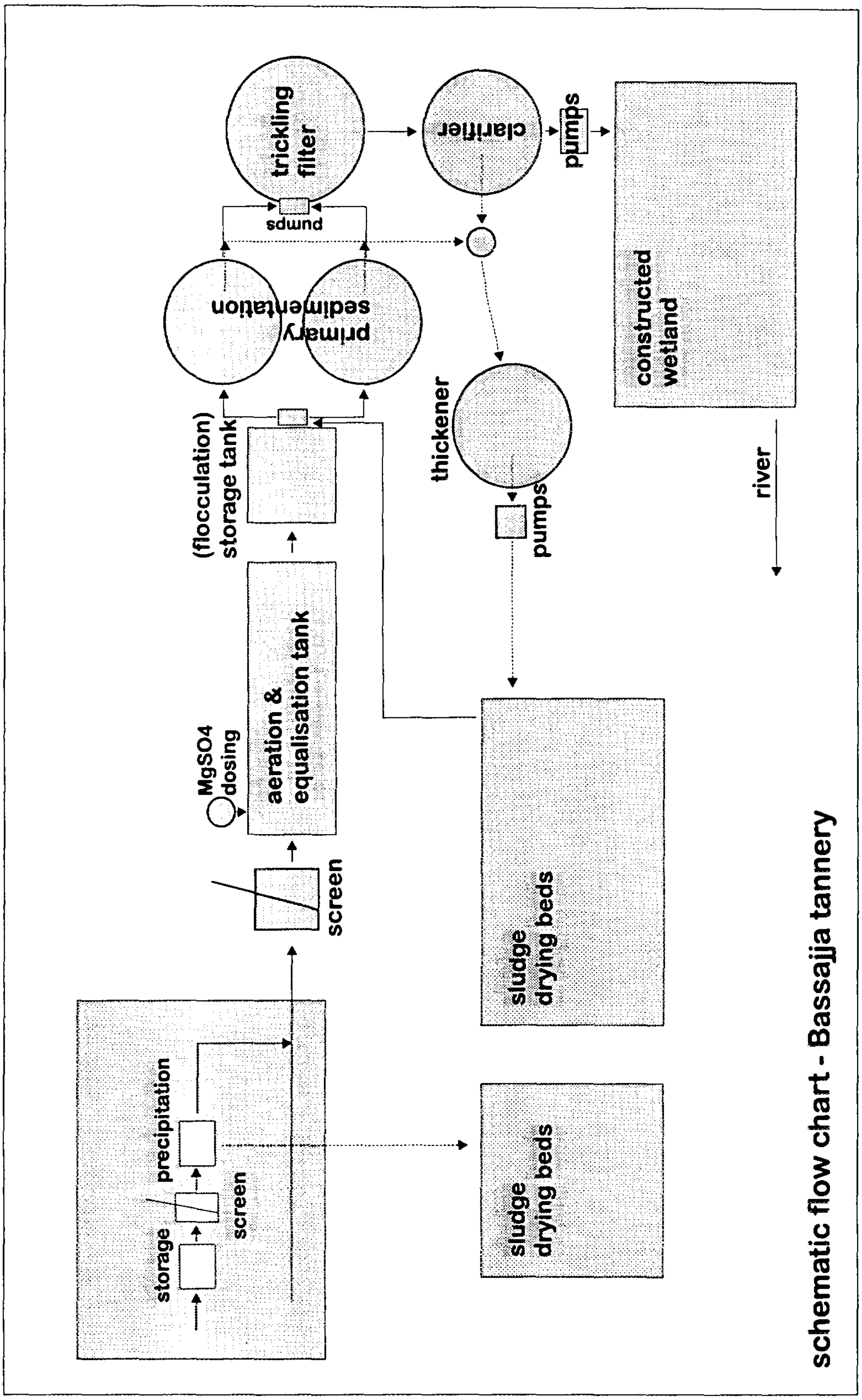
Bassajja

Priorities	*1*	*2*	*3*	*4*	*5*
Costs	282635	42520	16820	6800	3500

Priorities	*1*	*1+2*	*1+2+3*	*1+2+3+4*	*1+2+3+4+5*
Costs	282600	325200	342000	348800	352300

Table 13: Costs for the implementation in regard to the priority

13.9. Schematic flow chart



14. SUMMARY AND CONCLUSIONS

The main contents of this report are the recommendations for the selected tanneries, Leather Industries Uganda (LIU) in Jinja and the Bassajja Tannery in Mbarara (compare progress report 05/97), concerning the implementation of clean technology methods and the wastewater treatment systems (pre-, primary and secondary treatment).

The aim was the preparation of recommendations, to reach environmental standards as assumed necessary in chapter 6.4.4. (assumptions on necessary final effluent quality) of the submitted progress report (IWGA, 05/97). These recommendations are based on the progress report, information gathered by the Department of Civil Engineering, Makerere University (DCE), concerning cost and availability of necessary components and effluent quality and quantity of the selected tanneries.

All recommendations are based on the assumptions in chapter 3. Therefore before implementation it is necessary to check the correctness of these assumptions (especially wastewater quality and quantity).

According to the assumptions the recommendations for the effluent treatment are mainly for the actual situation (only some parts are designed for the future situation). It is necessary to consider this fact when increasing the capacity of the tannery.

Roughly the following recommendations are given:

Leather Industries Uganda

⇨ implementation of a rough screen for the total effluent

⇨ reconstruction of the chrome precipitation unit

⇨ reconstruction of the existing aeration system for the oxidation / equalisation tank

⇨ construction of a sedimentation tank (Dortmund type)

⇨ construction of a static thickener for sludge treatment

⇨ reconstruction of the sludge beds (if necessary)

⇨ Installation of necessary mechanical equipment

Bassajja Tannery

⇨ construction of a chrome precipitation unit using three existing unused pits

⇨ implementation of a rough screen for the total effluent

⇨ reconstruction of the existing aeration system for the oxidation / equalisation tank (as far as necessary)

⇨ construction of a sedimentation tank (Dortmund type)

⇨ construction of a high loaded trickling filter for partial purification

⇨ construction of a constructed wetland system for final purification

⇨ construction of a static thickener for sludge treatment

⇨ construction of sludge beds

⇨ installation of necessary mechanical equipment

Besides for plant control and possibly legal requirements it is necessary to check various chemical parameters and flow rates. As presently no legal requirements exist in Uganda and the recommendations are based on as simple equipment as possible not much equipment for control is required. Nevertheless especially considering future increase in production the expenditure for control must not be underestimated.

As mentioned in the progress report (05/97) plant control is considered very important for optimising the treatment system. Therefore for the actual implemented treatment plant it is necessary to check possibilities and necessities for control according to the actual requirements (e.g. legal situation).

Concerning the implementation of clean technologies according to K.H. Munz (tannery expert, subcontractor to the IWGA) the only feasible technology is the recycling of chrome after precipitation. According to 12.5.2 it is not economically feasible at the moment due to the low production of hides. Nevertheless it is considered very important to reduce the amount of chrome containing sludge. From an environmental point of view it is recommended to implement this technology at least at LIU.

Concerning the environmental point of view it is emphasised that the recommended treatment systems are minimal requirements. To achieve higher standards (e.g. sludge quality, nutrient removal) additional investment is necessary.

Besides these technical aspects the practical implementation in the tanneries is very important. Due to the lack of any legal requirements presently interest from the tanneries will probably be low (due to rather high costs without short-term benefit) concerning construction *and* operation. Nevertheless it is considered very important for a sustainable success of this project that the implementation is financed by the tanneries themselves. On the one hand this would be a sign of interest in environmental aspects and on the other hand it is necessary to calculate costs for effluent treatment in the product to allow future extensions of the treatment plant. Based on these considerations a list of priorities has been prepared for the various recommendations (chapter 11.). So it is possible to keep costs rather low and implement the treatment system stepwise. These steps can be kept when increasing the tanneries capacity. This procedure is considered advantageous especially for the future compared with single high investment. Nevertheless the increasing of the tannery's capacity has to correspond with the treatment situation. This means that before increasing the capacity the treatment system has to meet with the requirements prepared in this report.

15. ANNEX: FINAL REPORT - LONG VERSION (INCL. REMAINING ANNEXES)

Due to demands from UNIDO this report is a brief summary of the recommendations prepared under this contract. In the following the original version of the report is given. For detailed information on the recommendations and to be able to understand decisions on various recommendations the unabridged version is considered necessary.

The unabridged version is added as an external supplement to this report.