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22013
(1 of 2)

INTEGRATION

Project No. US/CPR/97/022

Study on Safe Disposal of Tannery Sludge In The People's Republic of China

Final Report

Volume I: Main Report

Juli 1998

for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, Vienna

UNIDO

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The final report includes two volumes: Volume I: Main Report
Volume II: Annexes

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Abbreviations

BIMSCH V 90	Bundesimissionsschutzverordnung V 90 (governmental imission regulation V 90)
BOD	Biochemical oxygen demand
Cd	Cadmium
Cr	Chromium
ds	dry substance
EC	European Community
EPA	Environmental Protection Agency (USA)
EPB	Environmental Protection Bureau (China)
EWC	European Water Council
FBR	Fluidized bed reactor (incineration plant)
ha	1 hectare = 10,000 m^2
yr	year
kg	kilo gram
kJ	kilo Joule = 2.78 10^{-4} kWh
kWh	kilo Watt hour = 3.6 MJ
l.s.	lump sum
mg	milligram = 10^{-3} kg
MHF	Multiple hearth furnace (incineration plant)
MJ	Mega Joule = 0.278 kWh
NCW	Near Coastal Water
Nm^3	standard cubic meter
Pb	Lead
pe	population equivalent
ppm	parts per million
PTE	Potential toxic elements
RMB	Ren Min Bi: Chinese Currency 1 RMB = 0,12 US$
STW	Standard treatment works
TA Luft	Technische Anleitung Luft (Technical Standard Manual for Air)
tds	tons of dry solids
TM	registered Trade Mark
TS	Trockensubstanz (dry matter)
Zn	Zinc

0 EXECUTIVE SUMMARY

1 Introduction

1.1 General

Disposal of sludge attracts increasing attention throughout the world. The main reasons are

- The increasing amounts of sludge due to the growing number of treatment facilities and improved technologies applied
- The efforts undertaken in order to protect natural resources such as soil and groundwater leading to higher standards for final disposal sites
- The political efforts to promote re-utilisation of sludge instead of final disposal
- The fast increasing cost for common landfill disposal practices due to political pressure, limited suitable areas for the erection of landfill sites, and the growing public sensibility towards this subject.

For a major part of the industry sludge is becoming an increasingly problem for the future. The quantity will increase due to stricter effluent standards and in addition considerable higher quality standards will be required for common disposal options. And last but not least the growing political force to promote reuse options will lead to much higher cost for sludge handling thus creating an economic pressure. Landfill as one of the major recent options will be prohibited for organic substances within the next few years in at least some European countries. The consequences are remarkable. The whole disposal sector is currently dominated by landfill, and agriculture application whereby incineration has an increasing share. But taking into account that agricultural application will not increase very much due to consumer problems and incineration is limited due to high cost and acceptance problems the chances for alternative technologies for either volume reduction or product generation must be seen as being excellent.

1.2 Tannery sludge characteristics

Leather production is a process creating considerable quantities of waste water and solid wastes. Per ton of cattle raw hide, about 150 kg of sludge (ds) are produced on average.

Composition
The composition of tannery sludge does not differ very much from that of municipal sources. Compared with sludge resulting from common municipal waste water, (which usually is a mixture of domestic and industrial waste water) tannery sludge contains slightly higher amounts of nitrogen, is lower in terms of phosphorous, potassium, and heavy metal concentration except chromium and contains higher concentrations of calcium. In addition, oil and grease, as well as chloride concentrations, are usually higher in tannery effluents. Thus, all common handling methods may be applied to tannery sludge in general. But there is no single "**optimal solution**" for the disposal of tannery sludge. Each technology described has its own advantages and disadvantages and has to be adopted to the respective specific site conditions.

Clean technology

Tanning process technology, collection, separation, pre-treatment and final effluent treatment influence the amount, composition, and physical/chemical characteristics of the sludge and may exclude or hamper the application of one or the other option. Main factors to be controlled are water content, chemical contents as chromium and salts, nitrogen, and sulfide. Main limiting factors are:

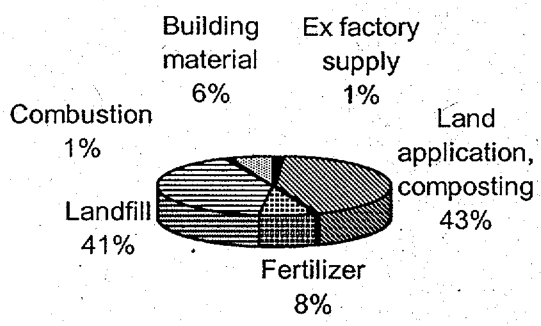
Limiting Factor	Impacts on	Measures required
Chromium	land application Composting Lime fertiliser Combustion	separate treatment recycling, precipitation pre-treatment
Lower concentration of organic solids	all processes using the calorific value of sludge	adding of organic material de-watering
Low values of potassium and phosphorous.	all processes where sludge is used as fertiliser.	selection of crops

Consequently an environmental friendly and clean production is a pre-requisite for the selection and establishing of an optimal sludge disposal route at a sustain and low cost level.

2 Current situation in China

Although governmental regulations force the tanneries to treat their waste water and respective standards have been set, only about 10% of the tanneries currently meet the standards. About 76% have effluent treatment or at least part-effluent treatment facilities at their disposal. Sludge treatment does not receive much attention in Chinese tanneries. The majority of the factories simply dispose sludge at any convenient site. However, it was a surprising result, that a number of treatment processes and technologies have been already used or at least tested, either at full scale or at least at a trial scale (Figure 0-1).

Figure 0-1: Treatment methods used



Source: compare Annex 1

Legislation

Environmental legislation in China has improved remarkably during the last few years. Main emphasis was hereby laid upon the protection of water. Consequently, regulations concerning tanneries deal mainly with waste water standards. There are no special regulations concerning the utilisation and/or treatment of sludge. For land application and/or utilisation of sludge as fertiliser or soil conditioner the "Chinese Control Standards for Pollutants in Sludge for Agricultural Use" can be applied. The standard includes a maximum chromium content for sludge to be applied on agricultural soil of 1,000 mg/kg ds for medium basic soils, and 600 mg/kg ds for basic soils which is somehow similar to the standards applied in the EU Member States. No standards for maximum concentration or maximum application rates exist.

Future Prospects

The fast changing market conditions, rising awareness of the population concerning environmental issues and the economic forces will further strengthen the political pressure on the Chinese tanneries to adopt methods for cleaner production, waste minimisation or re-utilisation. The CLIA and the tanneries already recognise this future challenge and draw much more attention on related aspects in the field of cleaner production and sludge handling. CLIA recently founded an environmental department in Shanghai which deals with possibilities for further re-utilisation and /or further treatment of tannery sludge.

3 Sludge handling options

3.1 Legal aspects

No special regulations exist for tannery sludge. Its valuation as toxic or non-toxic depends solely on its chromium and other heavy metal concentrations. In case heavy metal limits can be achieved, tannery sludge can be handled like any ordinary municipal sludge. In general, few countries have legislation or quality standards which specifically apply to sludge disposal. These issues are mostly covered by national waste legislation. Only when the sludge is for agricultural use are there specific national regulations. The USA has established a comprehensive legislation covering all aspects of sludge use and disposal.

In future it is likely that legal measures will be taken by an increasing number of countries to limit amounts of organic wastes which are disposed of in landfills. The purpose of this is to increase the use of recyclable waste and to reduce emissions from landfills (mainly groundwater contamination and air pollution).

3.2 Technical options

There are only limited experiences available of possible processing routes of tannery sludge. Main reasons are among others, that many tanneries run pre-treatment facilities only thus limiting the quantity of sludge occurring in the factory itself. In this case final treatment is done by a municipal effluent treatment plant. Another reason is that landfill was the cheapest and easiest disposal option in the past and there was simply no necessity for any alternative. As mentioned above the situation will change dramatically in future. Also the tanning industry has to identify and develop other options including minimisation through suitable process technologies.

There are two basic approaches in the handling of sludge. One is directed towards **reuse**, the other towards **disposal**. The **reuse** approach is based upon recycling of sludge so that nutrients, organic and/or other materials contained in the sludge are beneficially reused. The **disposal** philosophy considers the sludge as a waste material.

The most important reuse options are

- Energy recovery
- Nutrient recovery and
- Product transformation

Sludge handling routes are compiled and evaluated in Table 0-1 with respect to investments, O&M cost, qualification of personnel, product quality, environmental impacts, and general process experiences.

Table 0-1: Valuation of sludge processing methods

Process	Investment	M&O cost	Qualification of Manpower	volume reduction (ds)	product quality	environ mental impacts	Process experiences
Marine disposal	Low	Low	Low	100%	Non	High	Well proven
Landfill	moderate	Moderate	low – moderate	Non	Non	Moderate	Well proven
Land application	Very low	very low	low – moderate	100%	Good	Low	Well proven
Combustion	Very high	very high	very high	98.5%	Toxic ash	Moderate – high	Well proven
Drying	High	Moderate	Moderate	95%	Good	Low – moderate	Well proven
Composting	Low	Moderate – high	Low	65%	Very good	Low	Little production
Pyrolysis	Very high	High	High	98%	Very good	Moderate – high	Laboratory test; 2 pilot plants
Land reclamation	Low	Low	Low	100%	Non	Low – moderate	Well proven
Lime fertiliser	Low	Low	Low	100%	Very good	Low	Tested, proven
Brick Kilns	moderate	Low	Low	100%	Very good	Low	Tested, some production
Asphalt	High	Moderate	Moderate	100%	Very good	Moderate	Tested; pilot plant
Cement	High	Moderate	Moderate	100%	Very good	Moderate	Tested; production
Light weight. Aggregates	High	Moderate	Moderate	100%	Good	Moderate	Tested; pilot plants
Energy (fuel)	moderate-high	Moderate	Moderate	100%	Very good	Moderate	Well proven
Biometha-nization	Low-moderate	Moderate	Moderate	35%	Very good	Moderate	Tested; pilot plant
Underground Disposal	Low-moderate	Very low	low	100%	non	Dependi ng on site (x)	Tested

Source: Own estimations

Remarks:

Investment cost: The valuation is based on very general figures because exact figures could not be obtained for all methods described

Volume reduction: Is calculated on the basis of raw sludge with 5% ds

Combustion: Initial/final water content 5%/0%. Reduction of 98.5% means evaporation of 95% water and 3.5% of organic solids (70% of 5% ds). Remains 1.5% as ash and a small amount of filter dust

Sludge composition: The assessments are valid for an average tannery sludge as described in chapter III/1.1.

(x): depends an geological, hydrological conditions

With regard to tannery sludge the following experiences are available:

- **marine disposal:** No special experiences with tannery sludge are reported.
- **landfill:** Landfill is one of the main disposal options. In Germany about 90% of the tannery sludge is disposed off at landfill sites. Main reasons are cost and easy handling. The situation will remarkably change within the next few years towards a drastic reduction of landfill and an increasing re-utilisation.
- **land application:** A considerable number of studies and field research have been carried out in this subject. Summarised tannery sludge can be used as fertiliser in general. Rather scientific than philosophical is the discussion on chromium. This is also reflected by the tremendous differences in chromium standards applied in different countries. However, land application requires sound monitoring and control.
- **combustion/energy recovery:** Combustion of tannery sludge is carried out in a number of tanneries especially in developing countries. It is considered as a fuel substitution thus reducing production cost. In developed countries it is not common due to high cost (pre-drying, mixing, pelletisation) and necessary measures for pollution control.
- **composting:** About 10% of the sludge from German tanneries is used in agriculture; mostly after composting. Experiences are also reported from United States.
- **pyrolysis:** No semi-industrial experiences are available yet. First plants are under operation for municipal waste and mixtures of sludge and solid wastes.
- **land reclamation:** No experiences with tannery sludge are known; but no restrictions are to be seen.
- **lime fertiliser:** No experiences with tannery sludge are reported.
- **brick kilns:** Trials with tannery sludge have been carried out in India indicating the technical suitability but problems in marketing
- **asphalt:** No special experiences with tannery sludge available, but no restrictions can be seen.
- **cement:** Tests have been carried out In Lhasa (Tibet), indicating that the quality of the cement was not influenced by adding of sludge and chromium containing solids (fleshings, trimmings). No special experiences at an industrial scale with tannery sludge are reported; but no restrictions can be seen.
- **light weight aggregates:** First tests at an semi-industrial stage have been carried out successfully in Germany and Italy. A plant is under construction in Italy.
- **biomethanisation:** Tests at an industrial scale have been carried out successfully in France. Further plants are under construction respectively in planning
- **cement stones:** Except the first very preliminary tests carried out in Nanjing, no special experiences with tannery sludge are available; experiences in utilisation of effluent treatment sludge for the production of cement stones are reported from Brasilia.

3.3 Economics

Sludge handling and disposal is an expensive part of effluent treatment. Therefor, the identification of low cost treatment solutions including the whole process chain is a highly required priority. Cost estimations for various handling routes indicate that:

- All technical processes requiring machinery and equipment are expensive because of the low production capacity of the majority of the Chinese tanneries. The oversized equipment is reflected by considerably high capital cost.
- Costs for truck hauling depend on volume and distance. Costs can be considerably reduced by using de-watering processes.
- Land application is the cheapest method of sludge disposal, because ideally only transport costs have to be borne by the factory.
- Costs for land-filling and composting are close together, whereby composting is cheaper when transport cost from the factory to the dumping site is taken into consideration. Furthermore additional revenues could be achieved with the composted material.
- Treatment paths with incineration are the most expensive.

4 Recommendations

4.1 Technical aspects

The current situation and the potential changes in the near future leads to the following assumptions:

⇒ From the technical point of view most of the new technologies described in chapter III and compiled in Table 0-1 can be applied by the Chinese tanneries.

⇒ The methods introduced must take care of possible secondary emissions. Examples are air pollution by heating processes and soil contamination by land application.

⇒ Due to the high investments, the qualified staff required, and the high volumes necessary, incineration is in general not suitable for Chinese tanneries.

⇒ Solutions have to be adopted to the different sizes, production and treatment technologies of the tanneries.

Due to the diverse structure of the Chinese tanneries with a wide range of sludge volumes and sludge properties, the different tanning processes and effluent treatment technologies, and last but not least due to the different regional/local frame conditions, a set of possible solutions covering different conditions are recommended. Consequently, in contrast to the original plan to identify one single technology and to establish a demonstration plant it is recommended to carry out practical full-scale tests for the selected technologies. The results should be compiled and disseminated; tanneries ready for adoption should be supported at least by providing technical advice. Promising technologies for the treatment of **tannery sludge** are summarised as follows:

- **Reuse techniques**
  - ⇒ **land application on agricultural or forestry land**. Chromium and nitrate concentration are the limiting factors.
  - ⇒ **land reclamation:** Derelict land refers, in general, to areas without an established soil cover such as colliery waste, shale tips, mine waste, China clay waste tips, sand dunes and the sides of embankments and cuttings, or pits filled with overburden from open-cast coal mining or with urban refuse and then covered with a layer of soil.

- **Product development**
  Sludge may be processed to produce a stable final product which may be sold as a commercial product.
  - ⇒ **composting:** composting receives increasing attention due to its specific advantages, such as low capital cost and easy management and the production of a marketable product. Limiting factors are chromium and organic contents.
  - ⇒ **Calcinisation:** This technology creates a sand-like final product in which heavy metals are stabilised. Disadvantages are the high cost (comparable to incineration cost).
  - ⇒ **Brick kilns:** Utilisation in brick kilns makes use of the energy content as well as of the physical characteristics of the sludge solids. Changes of process flow are required due to necessary control of oxidation of chromium. Marketing aspects have to be considered.
  - ⇒ **Cement stone:** Another promising technology is the utilisation of sludge in cement stone production. First experiences are reported from Brasilia using municipal and industrial sludge. Preliminary experiences with tannery sludge are available with Nanjing tannery where first tests have been carried out. Utilisation of sludge in cement stone production increases the insulation capacities and reduces production cost. Application is simple and does not need prior drying and big equipment. Influences on physical parameters as well as risk of chromium leaching require further investigations.
  - ⇒ **Asphalt:** Utilisation in asphalt mixing harnesses the energy content of the sludge, while at the same time hazardous contents are fixed in the residuals which are used as filler in the asphalt. Main disadvantages are the varying transport distances.
  - ⇒ **Light weight aggregates:** The production of light weight aggregates has been already successfully tested with tannery sludge and river sediments with high metal loads in Germany. High investments limit the application to tannery cities or the few large tanneries in China.
  - ⇒ **Lime fertiliser:** Lime fertiliser (Ca contents > 40%) is a valuable fertiliser or soil conditioner especially on acidic soils. The process is easy and requires only little additional equipment and manpower. The technology requires chromium pre-treatment.

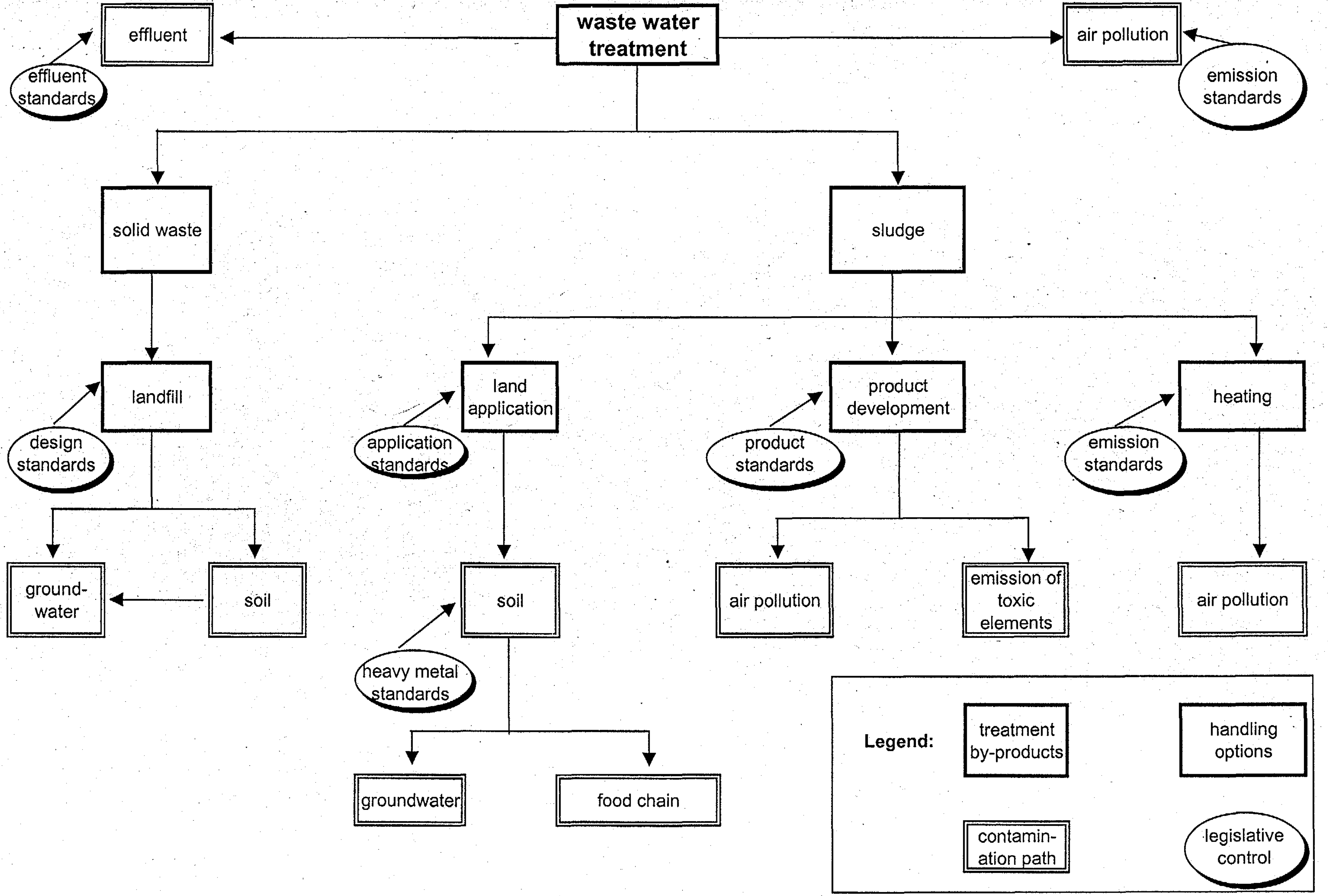
- **Energy/resource recovery**
  Energy and resource recovery are attractive because they make use of the energy content of the sludge. Due to its relatively high calorific value, sludge has the potential as a low grade fuel for use in energy recovery schemes. Because of the high capital cost and sophisticated technology required, most of the energy recovery processes appear not to be applicable for single tanneries.
  ⇒ Utilisation of sludge in **boiler houses** is one method which might be applicable. However, high investment for pre-drying is required. In addition, air pollution control is necessary.
  ⇒ **Methanization** of tannery wastes and sludge is another possibility which has already been tested with tannery sludge. The results appear promising but no further plant practising this method is known. It is reported that a pilot plant for tannery sludge and –waste will be erected in South India in the near future. Satisfactory amortisation times can be achieved from a daily capacity of 5 tons upwards.

- **Disposal Techniques**
  Disposal options include application to sanitary landfill, incineration, and underground disposal:
  ⇒ **Sanitary landfill** of sludge, separately or with municipal solid waste can be an acceptable means of ultimate sludge disposal. It should be applied only if reuse or other utilisation is impossible. The geology, hydrology and hydro-geology of the landfill sites must be carefully investigated. Landfill technique, when applied, depends on the water content of sludge, and the characteristics of the landfill area.
  ⇒ **Incineration** is considered as an ultimate sludge disposal technique even though the produced ash must still disposed of. Incineration is a capital intensive method, requiring skilled labour, and huge amounts of sludge which are normally not available in a single tannery. Moreover, measures for air pollution control and safe disposal of ashes is required.
  ⇒ **Underground disposal:** Disposal of toxic and hazardous waste material in underground caverns-, and abandoned mines has fairly widespread acceptance.

4.2 Legal aspects

Handling of sludge should be guided and regulated by the Chinese Government through appropriate legislative measures and by encouraging tanneries in developing of new treatment paths.

Governmental regulations are required especially in the field of sludge handling and final disposal. Recently the tanneries are forced to operate effluent treatment facilities but are left alone with the increasing quantities of sludge resulting from these. This policy leads finally to a transformation of environmental pollution from the water to the solid side only, with almost no positive effect although considerable efforts and investments are undertaken.


waste water treatment
effluent
effluent standards
air pollution
emission standards
solid waste
sludge
landfill
design standards
land application
application standards
product development
product standards
heating
emission standards
ground-water
soil
soil
heavy metal standards
air pollution
emission of toxic elements
air pollution
groundwater
food chain
Legend:
treatment by-products
handling options
contamin-ation path
legislative control

The concerned regulations should therefor consider all by-products and possible secondary pollution created during the treatment process. A principle flow-chart of contamination paths and possibilities of legislative control is presented in Figure 0-2.

Regulations could include the following sectors:

- standards for land fill sites including site selection, design and operation
- standards for the characterisation of sludge as toxic or non-toxic waste including appropriate recommendations for handling of toxic sludge.
- standards for air pollution (emission control) applicable to boiler houses and other plants utilising sludge (e.g. brick kilns).

With respect to the governmental policy to strengthen the introduction of ISO 14 000 and ISO 9 000 for all exporting industries and due to the high export rate of the tanning industry it might be worthwhile to discuss the introduction of waste handling manuals which are anyhow part of the International Standards mentioned above.

Finally the Government may support the utilisation of tannery sludge by introducing financial and other subsidies. One positive example is the tax free status of products made by using waste or recycling material. Other possibilities might be

- direct financial support for environmental investments
- higher depreciation rates for environmental investments
- substitution of higher production cost due to environmental sound sludge handling.

5 Project proposals

As already described before, the diverse structure of the Chinese tanneries leads to a wide range of sludge volumes and sludge properties. Thus, a set of possible solutions covering different conditions are recommended.

5.1 Co-Drying

Drying is generally a solution for a cluster of tanneries (e.g. tanning cities) or for bigger single tanneries. Instead of running own drying plants possibilities for co-drying should be investigated, thus limiting financial burden and work load for the tannery itself. For Da Chang it seems to be one of the favourable solutions. The dried residuals can be used for various purposes or dumped at an ordinary landfill site.

Advantages

- In case of co-drying: low to moderate capital and operational cost
- No additional work load for the tannery (except transportation of sludge)
- High volume reduction (up to 95% ds)

Disadvantages:

- Problems may occur with the utilisation of the residuals

Limiting factors:

- Lime → influences pumping

Working Program:

The test program proposed includes

- analyses of tannery sludge (especially organic contents, heavy metals); 5 times
- running of full scale tests with a mixture of (tannery sludge / own sludge) 1:2; 1:3; 1:4; 1:5, in order to identify optimal mixtures
- running of additional full scale test with optimal mixture
- analyses of final product after each run including chromium content and -eluation
- summarising the results in a final report.

5.2 Cement stone production

Advantages:

- low capital and operational cost (only de-watering required)
- easy to handle
- no qualified staff required
- additional measures limited to de-watering
- applicable to all tanneries

Disadvantages:

- brick factories have to be convinced
- economic feasibility declines with increasing transport distances
- physical characteristics are not proofed
- colour may be influenced

Limiting factors:

- leaching of chromium has to be controlled

Working program:

- manufacturing of stones with sludge ratios of 5%, 10%, 15% and 20%
- execution of standard tests according to Chinese standard regulations, evaluation and interpretation of results
- analyses of elutriation of chromium of bare and plastered stones
- construction of test wall to investigate long-term stability of chromium fixation
- execution of composting test
- evaluation and interpretation of results
- applying for certification according to national regulations
- final report.

5.3 Composting

Advantages:

- low to moderate capital and operational cost
- volume reduction to 65% water content at reasonable cost basis
- easy to handle
- no qualified staff required
- starting at a low cost level possible by using static pile methods and available equipment
- marketable product might offer additional sources of income
- monitoring and process control can be carried out by own laboratory

Disadvantages:

- process and product control required which have to be introduced
- proper process know-how required
- applicable to sludge resulting from tanneries with chromium pre-treatment only

Limiting factors:

- chromium → toxicity
- C:N ratio → requires organic material (source of carbon)
- potassium, phosphorous → influence on marketing
- vegetable tanning agents → hampers destruction of organic material

Working Program:

Xian was selected for the testing of composting for the following reasons:

- more than 20 years lasting experience in utilisation of tannery sludge in agriculture
- the program could be easy monitored by the Xian Institute of North-West Light Industry
- the user groups are strongly interested in the continuation of the sludge utilisation.

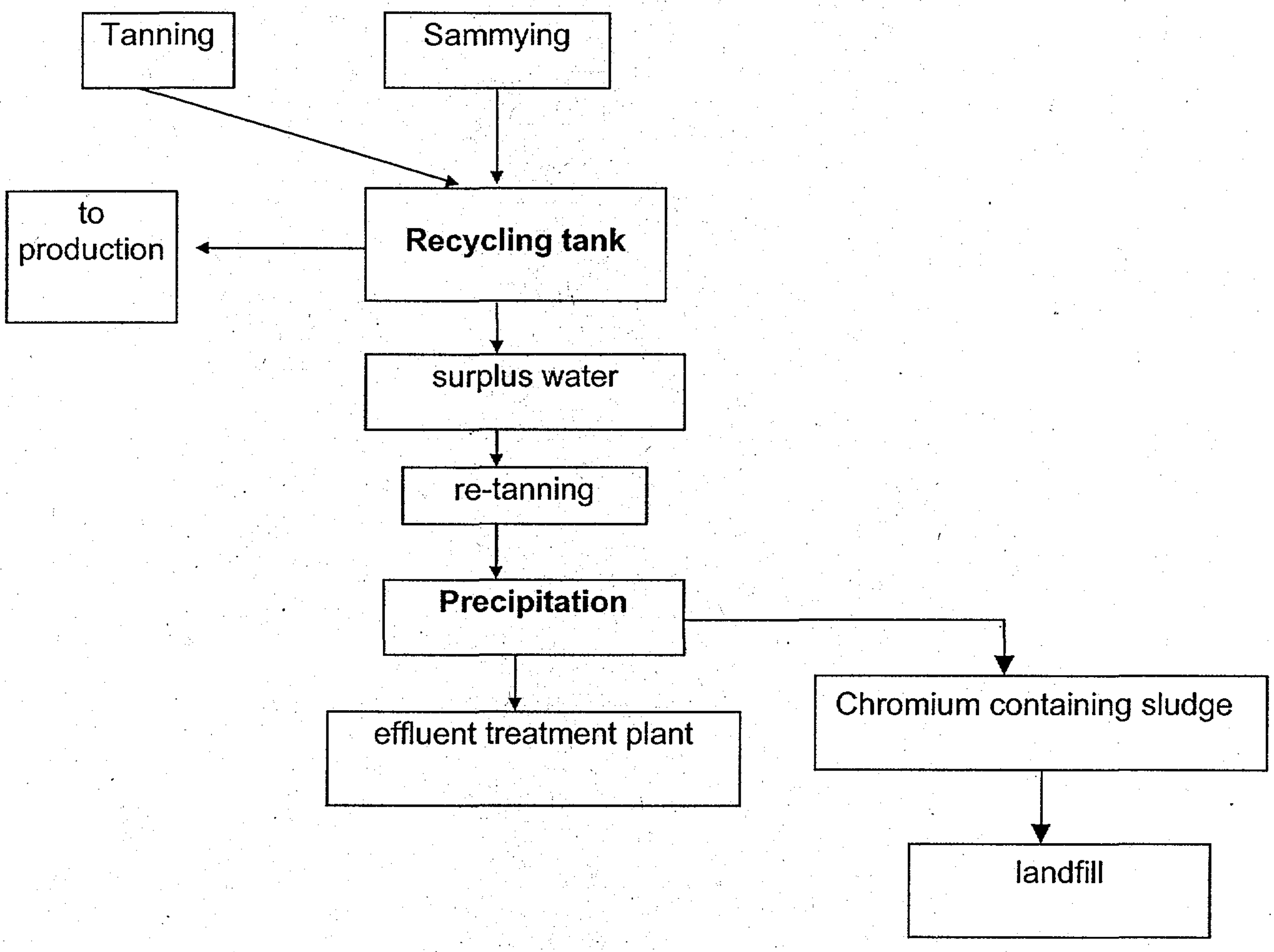
Main limiting factor is the chromium concentration which has to be below the national standards. The chromium problem was discussed at the very beginning by using the experiences gained during the study tour to Germany. The current chromium content of the sludge in Xian tannery is about 20,000 mg/kg ds, thus exceeding the national standards 20 fold. Main reasons are

- only part of the chromium containing water is collected separately
- the direct recycling system generates chromium containing surplus water (about 15%) which flows directly to the effluent treatment plant.

Consequently the modification of the existing waste water collection system and pre-treatment was discussed (Figure 0-3):

1. Concentration of chromium containing processes and total separation of waste water streams
2. Separate treatment of the chromium containing surplus water by the introduction of a precipitation step after the chrome recycling tank prior to the effluent treatment plant. The sludge produced there which is of very little volume, can be dumped at an appropriate dumping site or reused within the production process.

Figure 0-3: Flow chart of chromium separation



Further Steps

The working program concentrates on two issues:

- **Finishing of separate chromium containing waste water collection system**
  - ⇒ execution of precipitation tests at laboratory level
  - ⇒ design of system
  - ⇒ cost estimation, tendering, purchase of equipment
  - ⇒ construction
  - ⇒ reporting

- **Execution of composting tests**
  - ⇒ execution of chromium analyses of fields already manured by using sludge for some times
  - ⇒ selection and design of composting site
  - ⇒ cost estimation, tendering, purchase of equipment, construction
  - ⇒ execution of composting tests
  - ⇒ analysis and tests of compost performance and quality
  - ⇒ applying for certification
  - ⇒ final reporting.

Analysis and research on the chromium up-take by plants and the general field of toxicology is not included, because sufficient international research has been done during the past. The results indicate that if certain thresholds are met, there are no negative impacts on crops and human beings to be expected. The existing standard of 1,000 mg/kg Cr in sludge used for agriculture is in conformity with international standards and guarantees the exclusion of negative impacts.

5.4 Lime fertiliser

Advantages

- low to moderate capital and operational cost
- easy to handle
- no qualified staff required
- starting at a low cost level is possible
- good market arguments
- utilisation of other lime wastes is possible

Disadvantages:

- market concept has to be established
- certification as fertiliser or soil conditioner might be necessary
- applicable to sludge resulting from tanneries with chromium pre-treatment only

Limiting factors:

- chromium → toxicity
- potassium, phosphorous → influence on marketing

Working Program:

Sludge can be used as lime fertiliser in case chromium standards can be met and in case Ca-content is higher than 40% ds. It is recommended that general tests at laboratory scale should be carried out by the Xian Institute. The working program includes:

- preparation of Ca-fertiliser using different kinds of lime
- analysis of performance, nutrient contents
- reporting.

I SUMMARY

1 Background

The project "Safe Disposal of Tannery Sludge" aims to support the Chinese Government in identification, demonstration and dissemination of possible solutions for the treatment of tannery sludge and its safe disposal. The objective of the whole project is to provide a practical, viable and cost-effective solution for safe disposal of tannery sludge resulting from tanneries at Da Chang (Shanghai), Nanjing and/or Xian, including recommendations to the Chinese Government on legislative measures to promote and sustain the selected solution.

2 Sludge handling

2.1 Introduction

There are only limited experiences available of possible disposal routes of tannery sludge. Main reasons are among others, that many tanneries run pre-treatment facilities only whereas final treatment is done in a municipal sewage plant and that over a long period landfill was the easiest and cheapest solution. However, taking into account that tannery sludge differs little from sewage sludge, most of the technologies applied there can be used for tannery sludge, too. Thus in the following chapters methods already used for tannery sludge and methods well proven for municipal sludge or mixtures of both are discussed.

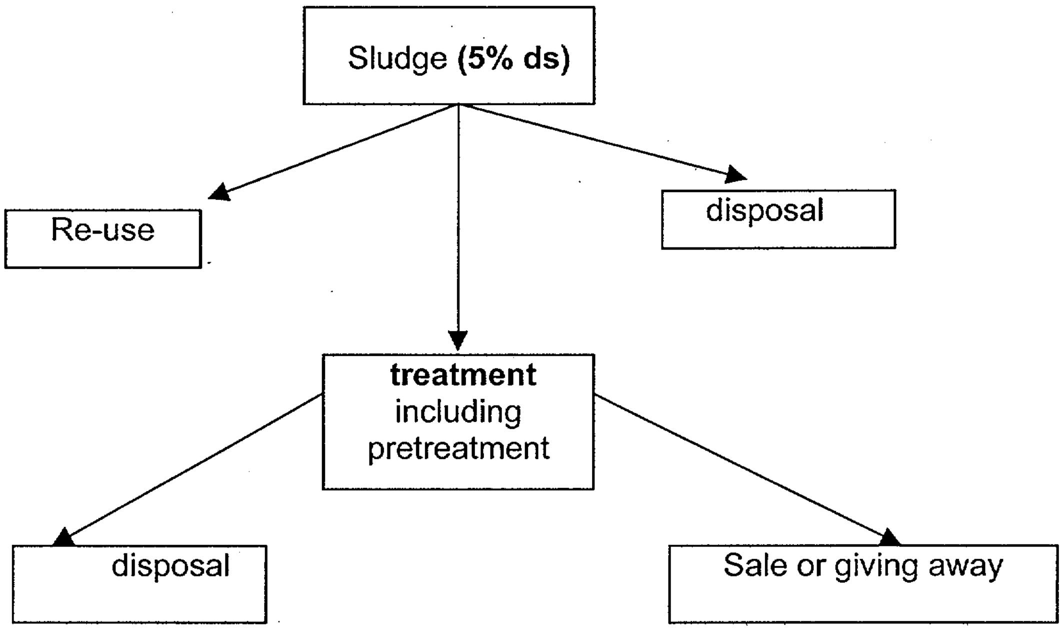
Disposal or treatment of tannery sludge cannot substitute adequate measures for reduction of waste and toxic substances during the production process especially when taking into consideration that sludge handling and disposal is an expensive part of waste water treatment. High concentrations of substances often hamper or simply exclude sensible sludge disposal routes. Consequently, the main emphasis should be placed on the reduction of sludge volumes produced. The remaining sludge should be suitable for further utilisation without any additional treatment, or at least treatment should be possible and economically feasible. Both require adoption and sometimes even changes to existing technologies and processes, taking into account not only an optimal product quality but also possibilities and associated cost for further utilisation or handling of wastes including sludge. Consequently, the identification of low cost treatment solutions is a high priority.

Sludge can be
- disposed off
- directly used
- treated to improve disposal and/or utilisation properties.

Treatment processes may include

- volume reduction
- improvement of contents and/or properties
- processing to other products.

Figure I/2-1: Sludge handling paths



Source: own compilation

2.2 Sludge characteristics

Compared with sludge resulting from common municipal waste water, (as a mixture of domestic and industrial waste water) tannery sludge contains higher amounts of nitrogen, is lower in terms of phosphorous, potassium, and heavy metal concentration except chromium and contains higher concentrations of calcium. In addition, oil and grease, as well as chloride concentrations, are usually higher in tannery effluents.

Table I/2-1: Characteristic differences between tannery and municipal sludge

	Unit	Tannery sludge	Municipal sludge
Total nitrogen	% ds	3 - 6	2 – 5
Oil & grease	% ds	4 - 11	Low
Calcium	% ds	8 - 12 (up to 30)	1 – 2
Chloride	% ds	1 – 3	Low
Organic matter	% ds	40 - 60	56 – 80
Potassium	% ds	Very low	0.1 - 0.5
Phosphorous	mg/kg ds	5 - 7	10 000 - 25 000
Chromium	mg/kg ds	8 000 - 20 000 (1) 500 - 8 000 (2)	400 (3)

Remarks: (1): without pre-treatment
(2): with chromium precipitation
(3): common value

2.3 Sludge processing

There are two basic approaches in sludge processing. One is directed towards **reuse**, the other towards **disposal**. The **reuse** approach is based upon recycling of sludge so that nutrients, organic and/or other materials contained in the sludge are beneficially reused. The **disposal** philosophy considers the sludge as a waste material and, therefore, such systems generally incorporate treatment techniques to provide for maximum reductions in the volume of sludge to be disposed. The organic solids which make up 40 - 60 percent of the solids in a typical tannery sludge are also a potential source of **energy**. Each disposal option requires certain sludge conditions and contents. Main factors to be controlled are water content, chemical contents as chromium and salts, nitrogen, and sulfide.

The most important reuse options are

- **energy recovery** includes all technologies using the energy content of the sludge mainly in form of thermal energy
- **final disposal** includes all kinds of final disposal either in special dumping sites or in form of land reclamation
- **nutrient recovery** includes all kinds of agricultural utilisation including direct field application, composting, production of fertiliser.
- **product transformation** into other products as bricks, light weight aggregates, etc. requires specific preparation steps and sludge characteristics which have to be developed for every single technology.

Processing of sludge involves one or more of the following pre-treatment processes:

- **Thickening**
  Thickening refers to the separation of some of the free water from the solid particles of sludge, the purpose of which is to reduce the volume of sludge to be stabilised, de-watered or disposed of. Due to the high quantity of lime, gravity thickening is seen as the most appropriate solution for tannery sludge. Beside flotation and centrifugation are common alternative methods for sludge thickening.

- **Stabilisation**
  Some form of stabilisation is generally recommended for all sludge treatment and disposal options, primarily because of odour problems associated with the processing of raw sludge. Major types of stabilisation processes are **anaerobic** and **aerobic** digestion, **chemical** treatment and **heat** treatment.
- **Conditioning**
  In addition to free water between sludge particles, sludge also contains bound water. Conditioning is designed to alter the nature of the sludge to an extent that releasing of all free water and some of the bound and intraparticle water becomes possible. Conditioning is mainly carried out by adding appropriate chemicals which can be either inorganic compounds containing aluminum or iron and calcium, or organic polyelectrolytes.
- **De-watering**
  During sludge de-watering any remaining free interparticle water together with some of the intraparticle water is removed from liquid sludge so as to change their physical form from liquids to semi-solids. De-watering devices include **drying beds, lagoons, centrifuges, filter presses and belt filters.**

  Drying beds and **sludge lagoons** are generally used only for smaller sludge amounts because of the relatively large land area requirements. De-watered sludge from such facilities is generally either disposed of onto agricultural lands or into sanitary landfills.

  Plate and frame filter presses receive high acceptance within the tanning industry due to their high efficiency. The major disadvantages of the filter press over the vacuum filter are the semi-batch mode of operation and frequent requirement for operator attention during cake removal. The greatest advantage of the filter press is its ability to de-water up to a 50% ds, made possible by operating pressures up to 16 bar. Under normal operation tannery sludge with about 35% ds is achieved.

  The **belt filters** have been relatively recently introduced into the sludge de-watering field but are gaining rapidly in popularity because of their simplicity in operation and low power requirement. Solid cakes similar to or somewhat higher than those from the vacuum filter are achieved.

Main limiting factors for the introduction of sludge processing techniques to tannery sludge can be seen in:

- concentration of **chromium**
  ⇒ has **impacts** on
  - land application
  - composting
  - lime fertiliser
  - combustion

  ⇒ requires **additional measures** in
  - combustion
  - brick kiln
  - land fill

⇒ can be **controlled** by
  * separate treatment of chromium containing waste water
  * recycling, precipitation, pre-treatment.

- concentration of **organic solids** (55-60% instead of 56-80% for municipal sludge)
  ⇒ has **impacts** on
    * all processes using the calorific value of the sludge
  ⇒ requires **additional measures** in
    * all processes (auxiliary fuel, further de-watering)
  ⇒ can be **controlled** by
    * adding of other solid dry organic wastes
    * further de-watering.

- low values of **potassium and phosphorous**
  ⇒ has **impacts** on
    * all processes where sludge is used as fertiliser
  ⇒ requires **additional measures** in
    * application where higher values are required (crop demand)
  ⇒ can be **controlled** by
    * selection of crops.

In Table I/2-2 all treatment technologies described are compiled and evaluated with respect to:

- investments
- O&M cost
- qualification of personnel
- product quality
- environmental impacts
- process experiences.

Table I/2-2: Evaluation of sludge treatment methods

Process	Investment	M&O cost	Qualification of Manpower	volume reduction (ds)	product quality	environ mental impacts	Process experiences with tannery sludge
Marine disposal	Low	Low	Low	100%	Non	High	Well proven
Landfill	Moderate	Moderate	low – moderate	Non	Non	Moderate	Well proven
Land application	Very low	very low	low – moderate	100%	Good	Low	Well proven
Combustion	Very high	very high	very high	98.5%	Toxic ash	Moderate – high	Well proven
Drying	High	Moderate	Moderate	95%	Good	Low – moderate	Well proven
Composting	Low	Moderate – high	Low	65%	Very good	Low	Little production
Pyrolysis	Very high	High	High	98%	Very good	Moderate – high	Laboratory test; 2 pilot plants
Land reclamation	Low	Low	Low	100%	Non	Low – moderate	Well proven
Lime fertiliser	Low	Low	Low	100%	Very good	Low	Tested, proven
Brick Kilns	Moderate	Low	Low	100%	Very good	Low	Tested, some production
Asphalt	High	Moderate	Moderate	100%	Very good	Moderate	Tested; pilot plant
Cement	High	Moderate	Moderate	100%	Very good	Moderate	Tested; production
Light weight. Aggregates	High	Moderate	Moderate	100%	Good	Moderate	Tested; pilot plants
Energy (fuel)	Moderate-high	Moderate	Moderate	100%	Very good	Moderate	Well proven
Biometha-nization	Low-moderate	Moderate	Moderate	35%	Very good	Moderate	Tested; pilot plant
Underground Disposal	Low-moderate	Very low	low	100%	non	Dependi ng on site (x)	Tested

Source: Own estimations

Remarks:

Investment cost: The valuation is based on very general figures because exact figures could not be obtained for all methods described

Volume reduction: Is calculated on the basis of raw sludge with 5% ds

Combustion: Initial/final water content 5%/0%. Reduction of 98.5% means evaporation of 95% water and 3.5% of organic solids (70% of 5% ds). Remains 1.5% as ash and a small amount of filter dust

Sludge composition: The assessments are valid for an average tannery sludge as described in chapter III/1.1.

(x): depends an geological, hydrological conditions

With respect to tannery sludge the following experiences are available:

- **marine disposal:** No special experiences with tannery sludge are reported.
- **landfill:** Landfill is one of the main disposal options. In Germany about 90% of the tannery sludge is disposed off at landfill sites. Main reasons are cost and easy handling. The situation will remarkably change within the next few years towards a drastic reduction of landfill and an increasing re-utilisation.
- **land application:** A considerable number of studies and field research have been carried out in this subject. Summarised, tannery sludge can be used as fertiliser in general. Rather scientific than philosophical is the discussion on chromium. This is also reflected by the tremendous differences in chromium standards applied in different countries. However, land application requires sound monitoring and control.
- **combustion/energy recovery:** Combustion of tannery sludge is carried out in a number of tanneries especially in developing countries. It is considered as a fuel substitution thus reducing production cost. In developed countries it is not common due to high cost (pre-drying, mixing, pelletisation) and necessary measures for pollution control.
- **composting:** About 10% of the sludge from German tanneries is used in agriculture; mostly after composting. Experiences are also reported from United States.
- **pyrolysis:** No semi-industrial experiences are available yet. First plants are under operation for municipal waste and mixtures of sludge and solid wastes.
- **land reclamation:** No experiences with tannery sludge are known; but no restrictions are to be seen.
- **lime fertiliser:** No experiences with tannery sludge are reported.
- **brick kilns:** Trials with tannery sludge have been carried out in India indicating the technical suitability but problems in marketing
- **asphalt:** No special experiences with tannery sludge available, but no restrictions can be seen.
- **cement:** Tests have been carried out In Lhasa (Tibet), indicating that the quality of the cement was not influenced by adding of sludge and chromium containing solids (fleshings, trimmings). No special experiences at an industrial scale with tannery sludge are reported; but no restrictions can be seen.
- **light weight aggregates:** First tests at an semi-industrial stage have been carried out successfully in Germany and Italy. A plant is under construction in Italy.
- **biomethanisation:** Tests at an industrial scale have been carried out successfully in France. Further plants are under construction respectively in planning
- **cement stones:** Except the first very preliminary tests carried out in Nanjing, no special experiences with tannery sludge are available; experiences in utilisation of effluent treatment sludge for the production of cement stones are reported from Brasilia.

2.4 Economic aspects

Cost estimates have been established for 4 different annual sludge production rates of 500, 5 000, and 50 000 t per year (at 5% ds). Annual production rates ranging from between 500 to 50,000 tons of sludge (at 5% ds) reflects the current range of production of Chinese tanneries considering various sizes and raw materials (compare Annex 1). The annual rate of 100,000 t (at 5% ds) of sludge was chosen in order to provide indicative cost for treatment facilities operated jointly by a number of tanneries (e.g. for tanning centres). From Table I/2-3 the following brief conclusions may be drawn:

- none of the technical processes are economically suitable for the small production capacities of group I (production of 500 tons of sludge per year at 5% ds). The oversized equipment is reflected by considerably high capital cost. For these group, either the technological processes have to be adjusted or special solutions fitting with the local framework conditions have to be designed.
- The same is valid for the next group (annual sludge production of 5,000 t at 5% ds), whereby the cost for low mechanised solutions (e.g. hauling, composting, landfill) are already considerably lower.
- Full advantage of the equipment is taken in case annual sludge production achieves 50,000 tons at 5% ds. Any further increase has little or no influence on the cost per dry ton.
- Incineration is by far the most expensive method of sludge treatment. Real capital cost will be even higher taking into account necessary devices and equipment for pollution control.
- Costs for truck hauling depend on volume and distance. Costs can be considerably reduced by using de-watering processes. The distance impacts on the cost only where equipment is fully utilised (greater distances means more equipment) or where volumes exceed 50.000 t/yr (due to the same reason).
- Landfill is the cheapest method of sludge treatment, close to composting. Also, here costs vary widely with the solid concentration of sludge, which determines the land requirements and disposal work.
- Composting is one of the cheapest methods for sludge treatment requiring nevertheless, de-watering and final disposal measures.

Table I/2-3: Summary of cost estimation (in US$/tds)

			Annual sludge production in tons (at 5% ds)			
Process	solid content in (%)	solid content out (%)	500	5 000	50 000	100 000
• Belt press de-watering	5	20	210	37	9	8
• Centrifuge de-watering	5	25	353	51	11	10
• plate press de-watering	5	35	390	75	15	15
• multiple hearth incineration	35	98.5	462	186	20	20
• fluidised bed incineration	35	98.5	434	103	51	44
• windrow composting	35	65	132	19	6	5
• aerated static pile method	35	65	102	16	6	6
• liquid sludge truck hauling (20 km round trip)	5	5	158 (x)	32	13	14
• liquid sludge truck hauling (30 km round trip)	5	5	165 (x)	39	16	17
• liquid sludge truck hauling (50 km round trip)	5	5	178 (x)	52	21	22
• de-watered sludge truck hauling (20 km round trip)	35	35	27 (x)	6	1.6	1.6
• de-watered sludge truck hauling (30 km round trip)	35	35	28 (x)	7	1.8	2.0
• de-watered sludge truck hauling (50 km round trip)	35	35	30 (x)	9	2.2	2.8
• landfill	5		595	94	34	24
• landfill	20		149	24	8	6
• landfill	35		74	12	4	3

Source: compare Annex 3

Remarks: (x): Cost might be lower in case transport is done by a contractor

2.5 Legislation

In general, few countries have legislation or quality standards which specifically apply to sludge disposal. Mostly these issues are covered by national waste legislation. Only when the sludge is for agricultural use are there specific national regulations. The USA has established a comprehensive legislation covering all aspects of sludge use and disposal.

No special regulations exist for tannery sludge in the industrialized countries. Its valuation as toxic or non-toxic depends solely on its chromium and other heavy metal contents. Where heavy metal limits can be achieved, tannery sludge can be handled like any ordinary municipal sludge. Heavy metal limits including chromium limits are compiled in Table I/2-4 for selected countries.

2.5.1 Sludge use in agriculture

All the countries reviewed have set limits on the rate of addition of sludge to agricultural land by one or more of the following methods:

- limits on the rates of **addition** of potentially toxic elements in terms of kg per ha and year. For EU Member States these are set at or below the limits values given in Annex 1 C of the Sludge in Agriculture Directive (compare Annex 6). In the USA, annual loading rates are only obligatory where the concentrations of PTEs in the sludge exceed the „clean„ limit values and where the sludge is sold or given away in bath or container. This is also valid for chromium.
- limits on the rate of **application** of sludge dry solids in terms of t ds per ha and year. These are used in conjunction with the sludge concentration limits, from which may be derived maximum rates of addition of PTEs.
- limits on the rates of **addition** of nutrients.

Only a few countries have set explicit limits on nitrogen and/or phosphorus, although all countries state that sludge should be applied according to no more than crop nutrient requirements.

2.5.2 Sludge disposal to landfill

Few countries have specific legislation for the disposal of sludge in landfills: most include sludge within general waste legislation. The exception to this is the USA which has integrated legislation covering all aspects of sludge recycling and disposal. Currently, sludge is disposed of in both urban (non-hazardous) and toxic (hazardous) landfills, although policies vary between countries with regard to which type of landfill should be used and whether sludge should be deemed hazardous. The European Standards Committee, CEN 292, is currently considering appropriate characterisation and compliance tests for land-filled wastes.

In the USA, no eluate test is required but limit values have been placed on certain PTEs in sludge and are set according to risk including also chromium. More stringent limits are set where landfills have no liner or leachate collection system and are close to housing.

Most European countries require, in practice if not statute, that sludge should be de-watered before landfilling. Minimum dry solids contents of 30-35% are common to meet physical stability requirements and are now much more readily achievable with current de-watering technology.

It is likely that legal measures will be taken by an increasing number of countries to limit amounts of organic wastes which are disposed of in landfills. The purpose of this is to increase the use of recyclable waste and to reduce emissions from landfills (high strength leachates to groundwater and methane to the atmosphere). The approaches adopted by different countries vary, for example:
tax on land-filled wastes (e.g. Denmark);

- source separate collection of domestic wastes and the production of compost (e.g. Germany, The Netherlands);
- pre-treatment to avoid reactive processes in, and emissions from, landfills (dry tomb approach). Restriction would be placed on the organic matter content of land-filled

wastes (e.g. Germany and France propose to introduce limits of 5-10% in the future);

- co-disposal or joint disposal of sludge with domestic refuse (the wet reactor approach to achieve rapid stabilisation adopted in most countries).

2.5.3 Incineration of sludge

There are no specific regulations in any European country for the incineration of sludge. This is usually covered by general legislation on waste incineration.

Table I/2-4: Comparison of sludge re-use standards for chromium for selected countries

Parameter	Denmark	France	Germany	Netherland	Belgium	Norway	Sweden	Switzerl.	Engl.&Wales	USA
Maximum permissable soil concentration (mg/kg	100	150	100	100*	150				600	No limit
Maximum permissible sludge concentration (mg/kg) ds	100	1 000	900	500	500	200	150	1 000		No limit
Suggested annual loading limit for Cr (kg/ha/yr)		6.0	2.0	1.0	2.0	0.4	1.0	2.5		No limit
Maximum recommended metal loading (kg/ha)		360	210	100		4			1 000	
Maximum sludge solids loading (t/ha)			167	200		20	5 in 5 years			
Suggested maximum annual sludge solids application /t/ha)	1.5	3.0	1.7	2 (arable) 1 (grass)		2	1	2.5		
Minimal application period (yrs)	20		100	100		10	5		30	
Minimal soil pH		6.0							6.5 (arable-) 6.0 grassland)	

* : varies according to clay content, e.g. 50 + (2*%clay) = max. permissible soil Cr concentration

Source: Williams (1988), revised

3 Current situation in China

China's leather industry is the biggest industry sector within the Council of Light Industry (the former Ministry of Light Industry). The sector incorporates more than 20,000 enterprises, of which some 2,000 are tanneries.

Although governmental regulations force the tanneries to treat their waste water and respective standards have been set, only about 10% of the tanneries currently meet the standards. Moreover, not all tanneries have effluent treatment facilities at their disposal. Effluent treatment plants in operation are available in 61% of the tanneries only. 16% have part-effluent-treatment facilities and 23% (mainly located in north and north-west China) have no effluent treatment facilities.

3.1 Waste water and sludge production

The figures presented in the following are derived from a report elaborated by the North-West Institute of Light Industry, Xian. Average waste water and sludge production for various raw products are compiled in Table I/3-1. Amounts of waste water by far exceed the international standards.

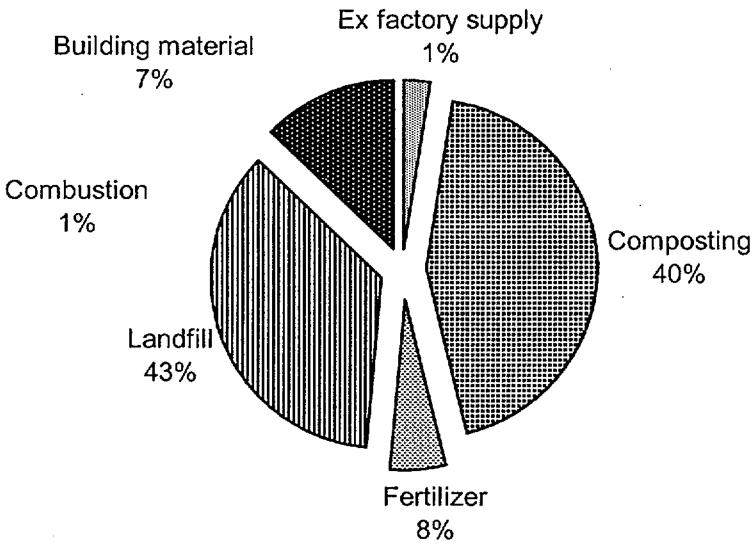
Table I/3-1: Average waste water and sludge production

Production	Annual average waste water		Annual average sludge volume (40% ds)
	10,000 t	per ton of raw hide/skin	(t/10,000t waste water)
Pig	3	43	19
Sheep, Goats	1	172	8
Cattle	2	59	16

Source: Annex 1, the figures are presented uncommented as result from the survey (compare Annex 1).

Sludge treatment does not receive much attention in Chinese tanneries. The majority of the factories simply dispose sludge at any convenient site. However, it was a surprising result, that a number of treatment processes and technologies have been used already or at least tested, either at full scale or at least at a trial scale (Figure I/3-1).

Figure I/3-1: Treatment methods used



Source: compare Annex 1

3.2 Legislation

Environmental legislation in China has improved remarkably during the last few years. Main emphasis was hereby laid upon the protection of water. Consequently, regulations concerning tanneries deal mainly with waste water standards. Up to now, little emphasis has been laid on the solid waste disposal and the sludge treatment aspects. There are no special rules for the utilisation and/or treatment of sludge.

For land application and/or utilisation of sludge as fertiliser or soil conditioner the Chinese control standards for pollutants in sludge for agricultural use can be applied. The standard includes a maximum chromium content for sludge to be applied on agricultural soil of 1,000 mg/kg ds for medium basic soils, and 600 mg/kg ds for basic soils which is somehow similar to the standards applied in the EU Member States. No standards for maximum concentration or maximum application rates exist.

4 Recommendations

4.1 Legal aspects

Handling of sludge should be guided and regulated by the Chinese Government through appropriate legislative measures and by encouraging tanneries in developing of new treatment paths.

Governmental regulations are required especially in the field of sludge handling and final disposal. Recently the tanneries are forced to operate effluent treatment facilities but are left alone with the increasing quantities of sludge resulting from these. This policy leads finally to a transformation of environmental pollution from the water to the solid side only, with almost no positive effect although considerable efforts and investments are undertaken.

The concerned regulations should therefor consider all by-products and possible secondary pollution created during the treatment process. A principle flow-chart of contamination paths and possibilities of legislative control is presented in Figure I/4-1.

Regulations could include the following sectors:

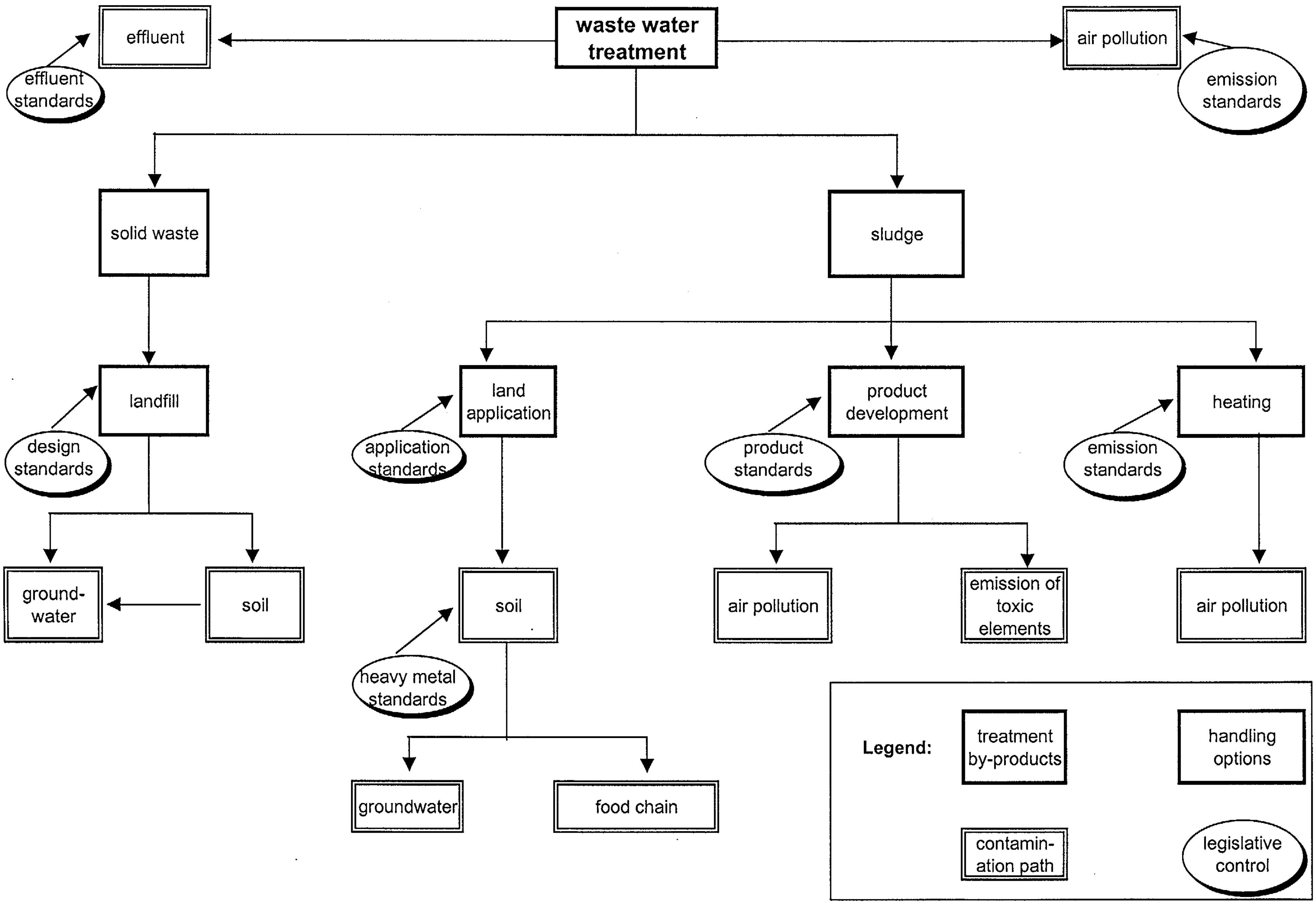
- standards for land fill sites including site selection, design and operation
- standards for the characterisation of sludge as toxic or non-toxic waste including appropriate recommendations for handling of toxic sludge.
- standards for air pollution (emission control) applicable to boiler houses and other plants utilising sludge (e.g. brick kilns).

With respect to the governmental policy to strengthen the introduction of ISO 14 000 and ISO 9 000 for all exporting industries and due to the high export rate of the tanning industry it might be worthwhile to discuss the introduction of waste handling manuals which are anyhow part of the International Standards mentioned above.

Finally the Government may support the utilisation of tannery sludge by introducing financial and other subsidies. One positive example is the tax free status of products made by using waste or recycling material. Other possibilities might be

- direct financial support for environmental investments
- higher depreciation rates for environmental investments
- substitution of higher production cost due to environmental sound sludge handling.

Figure I/4-1: Legislative control of waste water treatment



4.2 Technical aspects

A sludge management system should consider the following criteria:
- cost efficient
- easy to handle
- low to moderate O&M cost whereby manpower requirements in state-owned tanneries are of minor importance
- technical applicability to processes and production
- little additional working load
- additional treatment measures should be left outside the factory to a maximum extent. Firstly, sludge treatment is not a traditional field of activity, with the consequence that tannery labor is not very familiar with. Secondly, the tannery is mainly interested in dispose of the sludge, which may effect the quality of the treatment and of the sludge accordingly. Thirdly the acceptance of new methods will increase with less cost for the factory.
- the new system should aim to demonstrate appropriate sludge management solutions matching with international standards and policies
- low environmental impacts.

Promising technologies for the treatment of tannery sludge are summarised as follows:
- **Reuse techniques**
  - ⇒ **land application on agricultural or forestry land**. Chromium and nitrate concentration are the limiting factors which should be monitored.
  - ⇒ **land reclamation.** Derelict land refers, in general to areas without an established soil cover such as colliery waste, shale tips, mine waste, China clay waste tips, sand dunes, and the sides of embankments and cuttings, or pits filled with overburden from open-cast coal mining or with urban refuse and then covered with a layer of soil.

- **Product development**
  - ⇒ **brick kilns:** Utilisation in brick kilns makes use of the energy content as well as of the physical characteristics of the sludge solids. Mobility of chromium requires process changes and dark colour may hamper marketing. **Asphalt:** Utilisation in asphalt mixing harnesses the energy content of the sludge, while at the same time hazardous contents are fixed in the residuals which are used as filler in the asphalt. Main limiting factor are the varying transport distances.
  - ⇒ **light weight aggregates:** The production of light weight aggregates has been already successfully tested with tannery sludge and river sediments with high metal loads in Germany. High investments limit the application to tannery cities or the few large tanneries in China.
  - ⇒ **lime fertiliser:** The utilisation of sludge as lime fertiliser or soil conditioner is another concept applicable to tanneries. It is produced by simple mixing of lime with sludge. Lime fertiliser (Ca contents > 40%) is a valuable fertiliser or soil conditioner especially on acidic soils. The technology is applicable to sludge from tanneries with chromium pre-treatment only.
  - ⇒ **composting:** composting receives increasing attention due to its specific advantages, such as low capital cost and easy management and the production of a marketable product. The processes are well developed since the beginning of the 1970th. Negative impressions resulted mainly from marketing problems. For tannery sludge, additional organic bulk material is necessary.

Composting includes the biodegradation of organic material under the presence of oxygen. The composting process is primarily facilitated by a high concentration of biodegradable organic material in the compost matrix and an active microbial population. Secondary enhancers of microbial activity include moisture, inorganic nutrients, and oxygen. Under these favorable conditions microbial metabolism is released in the form of heat. Increased temperature serves to further increase the metabolism rate up to approx. 60°C at which point the pasteurization process begins.

The requirements of the compost process are:

- A proper C/N ratio of about 30:1 should be provided
- The mixture should have water contents of about 50-69%
- The mixture should be sufficiently porous to allow for adequate aeration
- The mixture should be arranged in a way to allow for sufficient heat retention to attain thermophilic temperatures in the range of 55-65°C
- The waste should contain a readily available carboneous substrate.

Main limiting factors are chromium content and C:N ratio which requires mixing with bulk material.

⇒ **Cement stone production:** An alternative solution to the utilisation of sludge in brick kilns is the production of cement stones. Main problem here is malodour due to biodegradation processes. Utilisation of sludge in cement stone production increases the insulation capacities and reduces production cost. Application is simple and does not need prior drying and large scale equipment. First experiences are reported from Brasilia using municipal and industrial sludge. Main limiting factors are market acceptance, malodour and risk of leaching of chromium. Influences on physical parameters require further investigations.

⇒ **Co-Drying:** Drying is generally a solution for a cluster of tanneries (e.g. tanning cities) or for bigger single tanneries where co-drying is possible. For Da Chang it appears to be one of the favourable solutions. Co-drying includes all possible forms of technologies suitable for tannery sludge as described in Chapter III. Low investments and operation cost are the main advantages of this process. Limiting factor is lime (mainly added during stabilisation) which might influence pumping ability.

- **Energy/resource recovery**

  Energy and resource recovery are attractive because they make use of the energy content of the sludge.

  ⇒ Utilisation of sludge in **boiler houses** seems to be one methodology which might be applicable. However, high investment for drying and pelletization is required.

  ⇒ **Methanization** of tannery wastes and sludge is another possibility which has already been tested with tannery sludge.

- **Disposal techniques**

  ⇒ **Sanitary landfill** of sludge, separately or with municipal solid waste can be an acceptable mean of ultimate sludge disposal. It should be applied only if reuse or other utilisation is impossible.

  ⇒ **Underground disposal:** Disposal of toxic and hazardous waste material in underground caverns, abandoned mines, as well as through deep well injection, has fairly widespread acceptance.

From an economical point of view cheapest treatment methods are landfilling and composting whereby composting produces a marketable product. Highest cost treatment methods are thermal processes such as drying and incineration.

In almost all countries main emphasis is laid on reuse or utilisation of sludge due to the set objectives to

- protect natural resources
- protect the environment, and
- reduce CO_2-emission.

4.3 Project proposals

Due to the diverse structure of the Chinese tanneries with a wide range of sludge volumes and sludge properties, the different tanning processes and effluent treatment technologies-, and, last but not least, the different regional/local frame conditions, a set of possible solutions covering different conditions are recommended. Consequently, in contrast to the original plan to identify one single technology and to establish a demonstration plant it is recommended to carry out practical full-scale tests for the selected technologies. During the execution of the test program it will become clear whether the respective technology is really applicable with respect to frame conditions (production, tanning technology, regional/local situation) and whether a demonstration plant is necessary for further demonstration and dissemination. The results should be compiled and disseminated; tanneries ready for adoption should be supported by providing technical advice at least. Finally it has to be pointed out, that **„the attractive solution"** for the disposal of tannery sludge does not exist. Each technology described has its own advantages and disadvantages and has to be adopted to the respective specific site conditions.

The technologies proposed for further consideration include the main treatment paths (land application, thermal treatment, product utilisation). The test program presented includes all project sites and takes into consideration specific advantageous local frame conditions as already available basic experiences, existing hardware, and interested user groups.

The following project sites have been chosen (the treatment technologies proposed are described lateron):

- **Da Chang, Shanghai** for co-drying (activities started in the field of utilisation in fertiliser factory and co-composting should be continued)
- **Nanjing** for production of cement stones and
- **Xian** for composting and lime fertiliser.

For the overall monitoring and coordination of the programme the **Xian Institute of North-West Light Industry** was chosen.

4.3.1 Co-Drying

Drying is generally a solution for a cluster of tanneries (e.g. tanning cities) or for bigger single tanneries. Co-drying in already existing drying plants is preferred due to very low investments and work load for the tannery itself. For Da Chang it seems to be one of the favourable solutions. Co-drying includes all possible forms of technologies suitable for tannery sludge as described in Chapter III.

Advantages

- Low to moderate capital and operational cost
- No additional work load for the tannery (except transportation of sludge)
- Very high volume reduction

Disadvantages:

- Dependence on outside owner and operator of the drying plant
- Problems may occur with the utilization of the residuals

Limiting factors:

- Lime → influences pumping

Working Program:

The test program proposed includes

- analysis of tannery sludge (especially organic contents, heavy metals); 5 times
- running of full scale tests with a mixture of (tannery sludge / own sludge) 1:2; 1:3; 1:4; 1:5, in order to identify optimal mixtures
- running of additional full scale test with optimal mixture
- analysis of final product after each run including chromium content and -eluation
- summarising the results in a final report.

Table I/4-1: Cost Calculation Co-Drying

Item	Unit	Unit Cost (RMB)	Quantity	Total Cost (RMB)
Sludge handling (transport, unloading, mixing, manual feeding) including drying for 5 test runs	no	12,000	5	60,000
Analyses of final products	no	3,000	5	15,000
Analyses of tannery sludge	no	3,000	5	15,000
Miscellaneous	l.s.	10,000	1	10,000
Transport of residuals	tons	200	50	10,000
TOTAL				**110,000**

4.3.2 Cement stone production

Sludge is mixed with cement, sand, slag from boiler houses, and water, compacted and formed to stones.

Advantages:

- low capital and operational cost (no drying but only dewatering required)
- easy to handle
- no qualified staff required
- additional measures limited to dewatering
- applicable to all tanneries

Disadvantages:

- factories have to be convinced
- economic feasibility declines with increasing transport distances
- physical characteristics are not proofed
- colour may be influenced

Limiting factors:

- risk of leaching has to be controlled

Working program:

- manufacturing of stones with different sludge ratios of 5%, 10%, 15% and 20%
- execution of standard tests, evaluation and interpretation of results
- analysis of elutriation of chromium out of bare and plastered stones
- construction of test wall to investigate long-term stability of chromium fixation
- execution of composting test
- evaluation and interpretation of results
- applying for certification according to national regulations
- final report.

Apart from the general questions of marketing and cost advantages further investigations and trials should consider the following aspects:

- fixation of chromium (chemical elutriation and mechanical removability of chromium from the surface)
- malodour
- physical characteristics which have to meet the national standards
- long-term stability of chromium fixation.

Table I/4-2: Cost Calculation Cement Stone Production

Item	Unit	Unit Cost (RMB)	Quantity	Total Cost (RMB)
Stone manufacturing: 50 stones per mixture; final mixture 300 stones (PDX 24)	no	4	500	2,000
Elutriation equipment	no	30,000	1	30,000
Standard test fees	no	3,000	15	45,000
Certification fee	no	10,000	1	10,000
Transport of sludge	l.s.	3,000	1	3,000
Miscellaneous	l.s.	15,000	1	15,000
TOTAL				**105,000**

Remarks: Cost for analyses and testing are included in sub-contract Xian Institute
PDX 24: Factory's standards specification number (compare chapter V/2.1.7, page 107)

4.3.3 Composting

Advantages:

- low to moderate capital and operational cost
- volume reduction to 65% ds at reasonable cost basis
- easy to handle
- no qualified staff required
- starting at a low cost level possible by using static pile methods and available equipment
- marketable product might offer additional sources of income
- monitoring and process control can be carried out by own laboratory

Disadvantages:

- process and product control required which have to be introduced
- proper process know-how required
- applicable to sludge resulting from tanneries with chromium pre-treatment only in most cases additional sources of carbon are required.

Limiting factors:

- chromium → toxicity
- C:N ratio → requires organic material (source of carbon)
- potassium, phosphorous → influence on marketing
- vegetable tanning agents → hampers destruction of organic material

Working Program:

Xian was selected for the testing of composting due to the following reasons:

- more than 20 years lasting experience in utilisation of tannery sludge in agriculture
- the program could be easy monitored by the Xian Institute of North-West Light Industry
- the user groups are strongly interested in the continuation of the sludge utilisation.

Main limiting factor is the chromium concentration which has to be below the national standards. The chromium problem was discussed at the very beginning by using the experiences gained during the study tour to Germany. The current chromium content of the sludge in Xian tannery is about 20,000 mg/kg ds, thus exceeding the national standards 20 fold. Main reasons are

- only part of the chromium containing water is collected separately
- the direct recycling system generates chromium containing excess float (about 15%) which flows directly to the effluent treatment plant.

Consequently the modification of the existing waste water collection system and pre-treatment was discussed (Figure I/4-2):

1. Concentration of chromium containing processes and total separation of waste water streams
2. Separate treatment of the chromium containing surplus water by the introduction of a precipitation step after the chrome recycling tank prior to the effluent treatment plant. The sludge produced there which is of very little volume, can be dumped at an appropriate dumping site or reused within the production process.

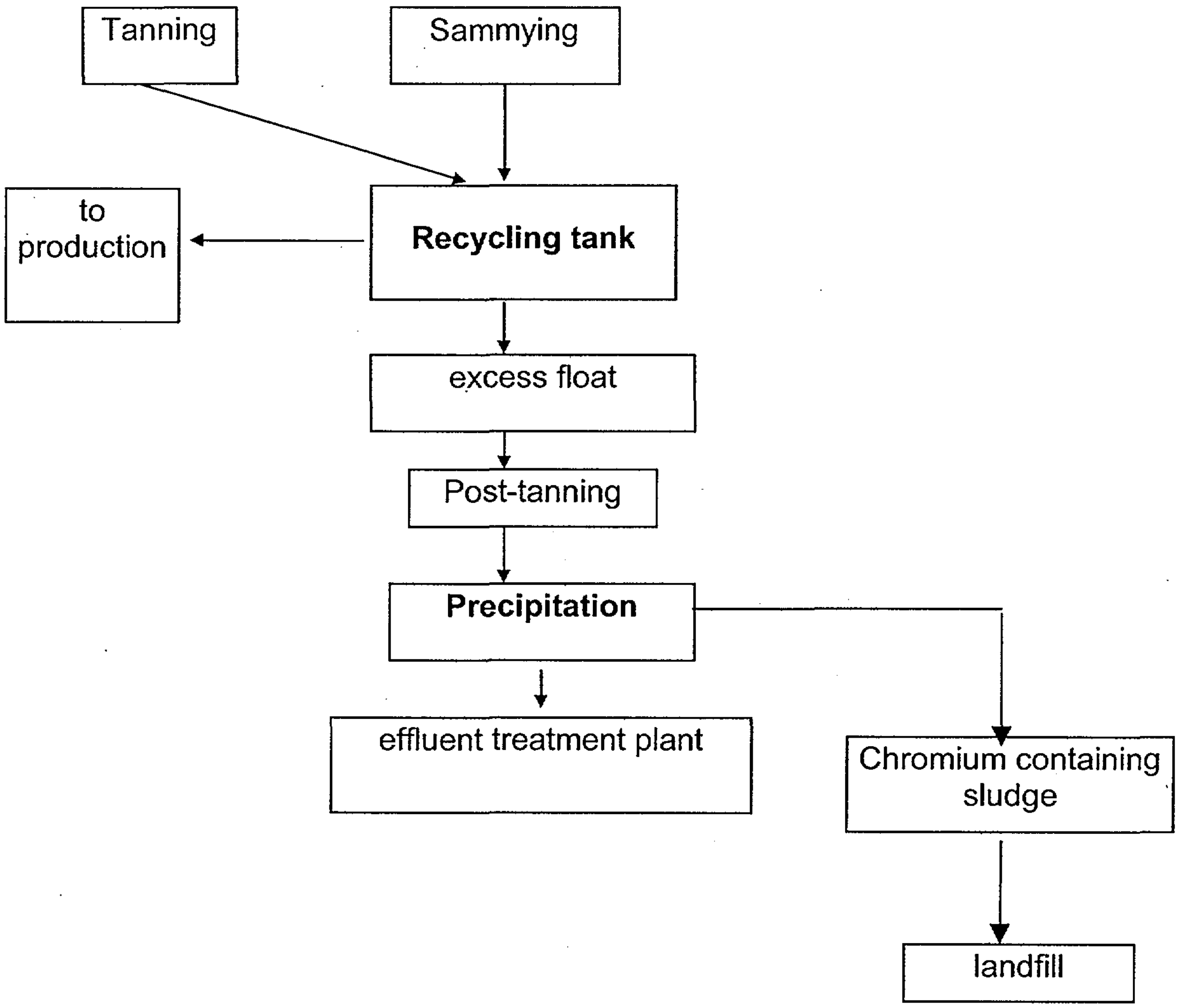
Further steps

The working program concentrates on two issues:

- **Finishing of separate chromium containing waste water collection system**
  - ⇒ execution of precipitation tests at laboratory level
  - ⇒ design of system
  - ⇒ cost estimation, tendering, purchase of equipment
  - ⇒ construction
  - ⇒ reporting

- **Execution of composting tests**
  - ⇒ execution of chromium analyses of fields already manured by using sludge for some times
  - ⇒ selection and design of composting site
  - ⇒ cost estimation, tendering, purchase of equipment, construction
  - ⇒ execution of composting tests
  - ⇒ analysis and tests of compost performance and quality
  - ⇒ applying for certification
  - ⇒ final reporting.

Figure I/4-2: Flow chart of chromium separation



Analysis and research on the chromium up-take by plants and the general field of toxicology is not included, because sufficient international research has been done in the past. The results indicate that where certain thresholds are met, there are no negative impacts on crops and human beings to be expected. The existing standard of 1,000 mg/kg Cr in sludge used for agriculture is in conformity with international standards and guarantees the exclusion of negative impacts.

Table I/4-3: Cost Calculation Composting

Item	Unit	Unit Cost (RMB)	Quantity	Total Cost (RMB)
Sub-contract:				
- compost test programme	l.s.	195,000	1	195,000
- auxiliary staff	l.s.	25,000	1	25,000
- management staff	l.s.	3,000	1	3,000
Equipment:				
- lime-fertiliser and composting	l.s.	35,000	1	35,000
- chrome reduction	l.s.	355,000	1	355,000
TOTAL				**578,000**

4.3.4 Lime fertiliser

The utilization of sludge as lime fertilizer or soil conditioner is another concept applicable to tanneries. It is produced by simple mixing of lime with sludge.

Advantages

- low to moderate capital and operational cost
- easy to handle
- no qualified staff required
- starting at a low cost level possible
- good market arguments
- utilisation of other lime wastes possible

Disadvantages:

- market concept has to be established
- certification as fertiliser or soil conditioner might be necessary
- applicable to sludge resulting from tanneries with chromium pre-treatment only

Limiting factors:

- chromium → toxicity
- potassium, phosphorous → influence on marketing

Working Program:

Sludge can be used as lime fertiliser where chromium standards can be met and where Ca-content is higher than 40% ds. It is recommended that general tests at laboratory scale only should be carried out by the Xian Institute. The cost are included in their monitoring programme.

The working program includes:

- preparation of Ca-fertiliser using different kinds of lime
- analysis of performance, nutrient contents
- reporting.

II INTRODUCTION

1 Leather sector

Disposal of sludge attracts increasing attention throughout the world. The main reasons are

- The increasing amounts of sludge due to the growing number of treatment facilities and improved technologies applied
- The efforts undertaken in order to protect natural resources such as soil and groundwater leading to higher standards for final disposal sites
- The political efforts to promote re-utilisation of sludge instead of final disposal
- The fast increasing cost for common landfill disposal practices due to political pressure, limited suitable areas for the erection of landfill sites, and the growing public sensibility towards this subject.

For a major part of the industry sludge is becoming an increasingly problem for the future. The quantity will increase due to stricter effluent standards and in addition considerable higher quality standards will be required for common disposal options. And last but not least the growing political force to promote reuse options will lead to much higher cost for sludge handling thus creating an economic pressure. Landfill as one of the major recent options will be prohibited for organic substances within the next few years in at least some European countries. The consequences are remarkable. The whole disposal sector is currently dominated by landfill, and agriculture application whereby incineration has an increasing share. But taking into account that agricultural application will not increase very much due to consumer problems and incineration is limited due to high cost and acceptance problems the chances for alternative technologies for either volume reduction or product generation must be seen as being excellent.

The leather sector is the most important sector in China with regard to exports, amounting to US$ 8.45 billion in 1995. The major exports in 1995 were shoes (US$ 4 billion), leather suitcases (US$ 2.3 billion) and leather garments. China's main leather export markets are Australia, Japan, Germany, Italy, and the USA.

Leather sales in the domestic market in 1995 have dropped by 10-15%. Local consumption of finished leather products declined due to the problems of inflation (which was at a rate of 15-20% in 1995) and the Government's policy of slowing the overheated economy.

Leather production is a process creating considerable quantities of waste water and solid wastes. Per ton of cattle raw hide, about 30 - 50 m^3 of waste water and 150 kg of sludge (ds) are produced on average.

The standards for effluent from industrial activities are applicable nationwide and enforced by the respective regional authorities. Legislation standards concerning disposal of industrial solid waste and sludge are under preparation.

Due to the serious pollution problems generated by tanneries, those which are located in densely populated urban areas are instructed by the Government to take appropriate action to move their factories to areas located outside of cities, mainly to new established industrial sites. At the new sites, modern tanneries are being built with waste water treatment plants and some are also being equipped with chrome recycling units.

2 Scope of work

2.1 Project goals and outputs

The project "Safe Disposal of Tannery Sludge" aims to support the Chinese Government in identification, demonstration and dissemination of possible solutions for the treatment of sludge and its safe disposal resulting from tanneries. The objective of the whole project is to provide practical, viable and cost-effective solutions for safe disposal of tannery sludge resulting from tanneries at Da Chang (Shanghai), Nanjing and/or Xian, including recommendations to the Chinese Government on legislative measures to promote and sustain the solution selected.

The direct counterpart organisation is the China Leather Industry Association (CLIA), Beijing. The North-West Light Industry Institute, Xian provides technical support and the CLIRI in Beijing will be able to play a useful role in disseminating the results obtained through the project.

The project consists of two stages. In stage I, the main emphasis is on reviewing the current situation in China and also that of industrialised countries with respect to sludge treatment. The findings shall eventually lead to recommendations and proposals for sludge management systems appropriate for the specific Chinese frame conditions. During Stage II, the recommendations shall be demonstrated at demonstration sites to be selected.

- **The expected output for Stage I is**
  A comprehensive study on Safe Disposal of Tannery Sludge with detailed comparisons of technical and cost parameters of most used and /or promising methods for the safe disposal of tannery solid wastes and sludge. The methods studied in detail are: landfill, land application (spreading of sludge as soil conditioner under controlled conditions), composting and incineration and other volume reduction and/or chrome immobilisation systems. The study will also contain a basic, preliminary design for a pilot plant to test and demonstrate the selected option.

- **Stage II**
  ⇒ **Expected Output**
  In conformity with the conclusions and recommendations of the Study "Safe Disposal of Tannery Sludge" and subsequent discussions in the field with representatives of tanneries, institutes, environmental authorities and other counterparts concerned, the following tasks will be undertaken:
  i) a detailed design will be prepared

  ii) a pilot plant to test and demonstrate the alternative selected will be set up.

2.2 Activities

According to the work plan proposed in the TOR, the whole project is divided into three steps within the two stages mentioned above:

- **First Step (Stage I)**
  Desk and field research for the collection and consolidation of data (including conducting a study tour) resulting in a comprehensive comparative review of various sludge disposal methods, with emphasis on composting, including a comparison of typical investment and operational cost.

  The comprehensive desk research will cope with the technologies, as mentioned in the output of Stage I, on an equal basis without prejudgement. It will include:
  ⇒ a technical review of relevant technologies
  ⇒ a description of reference projects
  ⇒ practical experiences with system operation available so far
  ⇒ a financial breakdown including investment and operation cost based on local Chinese price units.

  The Chinese legal and organisational situation and development aspects are reviewed in the field of
  ⇒ industrial/tannery sludge and waste disposal
  ⇒ landfill and land application of ETP-sludge
  ⇒ cost for waste disposal, land
  ⇒ existing methods and technologies and their individual cost.

- **Second Step (Stage I)**
  Preparation of a programme "Safe Disposal of Tannery Sludge": this will focus on basic design, equipment specification, cost estimates, with a detailed work plan of testing, monitoring activities and training. In between the two steps, a review of the study will be done both in Vienna (at UNIDO headquarters) and in China.

- **Third Step (Stage II)**
  Preparation of a detailed design and cost estimation and provide on-the-spot guidance in installation, start-up and the operations of the pilot plant.

2.3 Execution of Work

The work commenced end of August 1997 and included:

- comprehensive literature research
- contacting relevant institutions, enterprises, and treatment plants
- organisation and supervision of a questionnaire dealing with the current situation of Chinese tanneries in the field of waste water and sludge treatment
- at least 2 trips to China for a discussion with the China North-West Light Industry in Xian and the UNIDO office in Beijing.
- preparation of draft report.

III SLUDGE TREATMENT

1 Introduction

Choosing the correct and appropriate treatment method depends not only on economic factors but also on the contents of the sludge. Contents of tannery waste water and the resulting sludge vary according to the process technology applied and the type of tanning.

In order to avoid misinterpretation the words pre-treatment, clean technology and treatment are used in the study as follows.

Pre-treatment: Technological process used for removal of substances from waste water prior final treatment in a ETP.

Clean technology: Production process producing low or less contaminated quantities of waste including waste water.

Treatment: Elimination of certain substances in waste water or sludge in an effluent treatment plant.

1.1 Composition of tannery effluent and sludge

- **Waste water**

  Typical pollution values for tannery waste water are presented in Table III/1-1 and Table III/1-2. In Table III/1-1 typical pollution values for untreated waste water are compiled, whereas Table III/1-2 reflects the performance which might be expected through different methods of pre-treatment, and treatment primary and biological of tannery effluent, and an indication of the quantities of solids generated.

  The volume of water may vary considerably from tannery to tannery. The amount of sulphide and the presence or absence of significant quantities of chromium varies depending upon the pre-treatment systems applied. By using a primary settling system, sludge may be obtained which is directly proportional to the amount of hides processed. Assuming a removal of approximately 75 to 80 percent of suspended solids in primary treatment, the total amount of sludge on a dry basis will be approximately 6 to 8 percent of the weight of the hides processed.

Table III/1-1: **Typical pollution values related to conventional tannery process**

Values per ton of raw hide in m3 or kg	Water m^3/t	COD kg/t	BOD5 kg/t	SS kg/t	Cr_3 + kg/t	S-kg/t	NTK kg/t	Cl- kg/t	SO_4-kg/t
BOVINE SALTED RAW HIDE PROCESS									
Beamhouse (soaking to bating)	7/25	120/160	40/60	70/120		4/9	9/14	120/150	5/20
Tanning operations	1/3	10/20	3/7	5/10	2/5		0/1	20/60	30/50
Post tanning	4/8	15/40	5/15	10/20	1/2		1/2	5/10	10/40
Finishing	0/1	0/10	0/4	0/5					
TOTAL	**12/37**	**145/230**	**48/86**	**85/155**	**3/7**	**4/9**	**10/17**	**145/220**	**45/110**
PIG SKINS									
Beamhouse	23/49	120/272	46/98	62/110		3/7	11/17	107/197	4/15
Tanning operations	2/5	10/18	3/6	4/8	2/4		0/1	20/37	26/45
Dyeing operations	5/10	10/25	3/9	8/15	1/2		1/2	3/6	10/40
Finishing	2/5	0/5	0/2	0/2					
TOTAL	**32/69**	**140/320**	**52/115**	**70/135**	**3/6**	**3/7**	**12/20**	**130/240**	**40/100**

Bovine hides = goat skins by weight

Values per skin in litre or gram	Water l/skin	COD g/skin	BOD5 g/skin	SS g/skin	Cr_3+g/skin	S-g/skin	NTK g/skin	Cl- g/skin	SO_4- g/skin
SHEEPSKINS (wet-salted)									
Beamhouse	65/150	250/600	100/260	150/300		6/20	15/30	150/300	5/15
Degreasing – Tanning	30/70	50/300	20/100	15/30	8/12		4/10	40/200	30/70
Post tanning	15/35	30/100	15/35	10/20	1/3		2/4	20/40	10/40
Finishing	0/10	0/5	0/2	0/2					
TOTAL	**110/265**	**330/1005**	**135/397**	**175/352**	**9/15**	**6/20**	**21/44**	**210/540**	**45/125**

Bovine hides = goat skins
Source: World Leather, 11/1996
It is important to note that all values relate to processing under conditions of good practice, and the ranges reflect variations In raw materials and processes. Taking into account the increasing importance of water conservation, it must be pointed out That this practice leads to higher pollution levels in terms of concentration. For this reason, the IUE commission requests that The regulating authorities limit discharges in terms of mass rather than concentration.

- **Sludge**

  Sludge from a given tannery with proper equalisation is quite consistent. The volume of the sludge at the clarifier depends on two factors; the amount and concentration of solids.

  The weight of solids expected can be calculated from the composition of the waste stream entering the clarifier. The solids that will settle in the clarifier are in the order of 75% to 80% of the TSS of the influent. The COD is partly suspended solids, but with proper coagulation, a large portion of the soluble organic matter will also settle. All soluble substances under the condition of coagulation will remain in the solution.

Table III/1-2: Typical performance for tannery waste water treatment

Parameter	COD		BOD5		SS		Chromium		Sulfide		N (Kjeldahl)		Sludges production
% or mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	kg DS/ton raw hide
PRETREATMENT													
Grease removal (dissolved air flotation)	20-40												
Sulfide oxidation (liming and rinsing liquors)	10									10			
Chromium precipitation								5-10					
PRIMARY TREATMENT													
Mixing + Sedimentation	25-35		25-35		50-70			20-30			25-35		80
Mixing + Chemical treatment + sedimentation	50-65		50-65		80-90			2-5		2-10	40-50		150 - 200
Mixing + Chemical treatment + flotation	55-75		55-75		80-95			2-5		2-5	40-50		150 - 200
BIOLOGICAL TREATMENT													
Primary or chemical + Extended aeration	85-95	200-400	90-97	20-60	90-98	20-50		<1		<1	50	150	130 - 150
Primary or chemical + Extended aeration with nitrif. and denitrification	85-95	200-400	90-97	20-60	90-98	20-50		<1		<1	80-90	30-60	130 - 150
Primary or chemical + Aerated facultative lagooning	80-90	300-500	85-95	60-100	85-90	80-120		<1		<1	50	80	100 - 140
Anaerobic treatment (lagoon or UASB* with 66% domestic sewage)	65-75	500-700	60-70	150-200	50-80	100-200		<2	0		20-30		60 - 100

Source: World Leather, 11/96

The above data represents typical values for tannery waste water treatment efficiency for conventional process liquors for production of finished leather from raw material.

* Upward anaerobic sludge blanket.

The coagulated waste stream entering the clarifier contains about 152 - 193 kg of settleable solids in about 40 m³ of solution, which is equal to a concentration of about 3 - 6 g/l. Table III/1-3 presents analyses of the sludge from three different tanneries. Tannery A works hides through chrome tanning only. In this tannery, the fresh and cured hides are unhaired by a hair burn system and chrome tanned. The wastes are screened and then go through primary settling. The primary sludge, after de-watering on a filter press, gives the analyses indicated. The sulphide liquors used in this tannery are not recycled, but the chrome tanning solutions are.

Tannery B works cattle-hides in hide processors. The concentrated sulphide solutions are recycled by means of the Indronova System, and the sludge is obtained only from this recycling.

Tannery C is a cattle-hide tannery operating with a paddle system for unhairing. The wastes from the hair burn system go through a primary settling without pH adjustment. There is no de-watering of the sludge from the clarifier. The primary settling system also receives the wastes from bate, pickle, tan, colour, and fatliquoring operations.

Table III/1-3: Composition of sludge originating from different tannery processes

	Tannery A[1]		Tannery B[2]		Tannery C[3]	
	wet	Ds	wet	ds	wet	ds
Total Solids, %	48.5	-	34.6	-	12.2	-
Total Nitrogen, %	2.6	5.5	1.5	4.2	.4	3.3
Ammonia Nitrogen, %	0.19	0.39	.05	.1	.07	.6
Oil & Grease, %	2.0	4.2	3.9	11.2	1.2	10.2
Calcium, %	5.7	11.7	3.3	9.6	1.1	8.7
Chloride, %	0.6	1.2	3.15	9.1	.39	3.2
Ash, %	20.0	41.3	16.8	47.7	5.4	44.3
PH	7.0		>12.		6.7	
Chromium, %	0.66	1.36	<.005	-	0.2	1.9
Cadmium, ppm	4.5	9.28	5.3	15.3	4.7	38.5
Zinc, ppm	11.0	22.68	21.1	61.1	17.5	143.1
Lead, ppm	7.5	15.46	35.2	101.8	39.4	323.1

[1] Blueside tannery with filter press: Cattle-hides, both fresh and cured, processed through chrome tanning in hide processors. Effluent treated by preliminary screening, primary settling; sludge dewatered by filter press

[2] Side leather tannery: Cattle-hides (salt cured) unhaired in hide processors with hair burn system; unhairing solutions recycled using an Indronova sludge removal system sludge as it comes from the Indronova system with no de-watering. Chromium containing waste water is separately treated and recycled.

[3] Complete side leather tannery: Cattlehides (salt cured) unhaired in paddles in hair burn system; combined effluents from chrome tan, color, and fatliquoring given preliminary screening, primary settling, no sludge de-watering

[5] Ammonia may have been lost while air drying Source: Thorstens. (1979)

Quantitative chromium precipitation as carried out, for instance, in the Da Chang tannery reduces chromium content to about 4 mg/l, about 500 mg/kg ds respectively (WEN, 1996).

1.2 Municipal waste water sludge

The average nutrient content of sludge depends on the treatment process applied but can be generalised as being:

- nitrogen (N) 2 - 5 %
- Phosphorous (P) 1 - 2.5 %
- Potassium (as K) 0.1 - 0.5 %

at dry weight.

Heavy metal concentration depends, to a large extent, on the industrial portion of waste water received and on the type of industry connected to the system. However, ranges and typical values are (DAVIS, R., 1987):

	Range (ppm)	Common Value (ppm)	Domestic Sludge (ppm)
Cd	2 - 1 500	20	5
Cu	200 - 8 000	650	380
Zn	600 - 20 000	1 500	515
Pb	50 - 3 600	400	120
Cr	40 - 14 000	400	50

1.3 Conclusions

Compared with sludge resulting from common municipal waste water, (as a mixture of domestic and industrial waste water) tannery sludge contains higher amounts of nitrogen, is lower in terms of phosphorous, potassium, and heavy metal concentration except chromium and contains higher concentrations of calcium (Table III/1-4). Chromium contents can be in the range of common values in case pre-treatment is carried out. In addition, oil and grease, as well as chloride concentrations, are usually higher in tannery effluents.

Table III/1-4: Characteristic differences between tannery and municipal sludge

	Unit	Tannery sludge	Municipal sludge
Total nitrogen	% ds	3 - 6	2 – 5
Oil & grease	% ds	4 - 11	Low
Calcium	% ds	8 - 12 (up to 30)	1 – 2
Chloride	% ds	1 – 3	Low
Organic matter	% ds	40 - 60	56 – 80
Potassium	% ds	Very low	0.1 - 0.5
Phosphorous	mg/kg ds	5 - 7	10 000 - 25 000
Chromium	mg/kg ds	8 000 - 20 000 (1) 500 - 8 000 (2)	400 (3)

Remarks: (1): without pre-treatment
(2): with chromium precipitation
(3): common value

Summarising, all common treatment processes may be applied to tannery sludges in general. Tanning process technology, pre-treatment of waste water streams, and final waste water treatment influence the composition and the physical characteristics of the sludge and may exclude or hamper the application of one or the other treatment. For example, waste water from vegetable tanning does not contain any chromium but may contain a considerable percentage of bark liquor which is not very bio-degradable and this, in turn, limits its application in agriculture or as compost raw material.

2 Legislation for the disposal and recycling of sludge in the European Union and other selected countries

The are no special regulations concerning tannery sludge. This subject is covered by regulations dealing with sludge from effluent treatment plants. An outline of these regulations is presented in the following chapter.

The recycling and disposal of sludge is, in general, covered by two types of legislation:

- dedicated sludge legislation; for example legislation related to sludge applied to agricultural land;
- general waste legislation, for example legislation related to incineration and landfilling.

Almost all EU Member States have national legislation of these types, much of which is influenced by developments on an European level.

2.1 European Union legislation

Three types of European Union legislation have had an impact on sludge disposal:

- **legislation that has led to an increased amount of sludge being produced and consequently requiring disposal.**
  Early EC legislation - the Bathing Water Directive 76/160/EEC - required the introduction of treatment of discharges into designated bathing waters. More recently, the Urban Waste Water Treatment Directive (91/271/EEC) has placed minimum treatment requirements on most discharges and, when fully implemented, this will substantially increase the amount of sludge requiring disposal in the European Union: The Directive also bans the marine disposal of sludge from the end of 1998;

- **Other legislative developments which have served to reduce the options available for the disposal of sludge on land.**
  The „Sludge in Agriculture„ Directive (86/268/EEC) places controls on the heavy metal contents of sludge and soils when sludge is applied to agricultural land, whilst the Nitrates Directive (91/676/EEC) restricts the introduction of sludge into areas prone to eutrophication or nitrate pollution;

- In addition EU waste legislation is in a state of flux at present, with proposed legislation on hazardous waste disposal, hazardous waste incineration and landfilling all having a potential impact on sludge disposal routes.

2.1.1 The Urban Waste Water Treatment Directive

The Urban Waste Treatment Directive (91/271/EEC) requires that all communities, above a certain size, (measured in terms of population equivalents - pe) install adequate collection, treatment and disposal systems to cope with the urban wastewater generated. The Directive also requires that the disposal of sludge at sea is phased out by the end of 1998.

2.1.2 The „Sludge in Agriculture„ Directive

The Directive (86/278/EEC) on the Protection of the Environment, and in particular of the soil, when sludge is used in agriculture (the „Sludge in Agriculture„ Directive) was adopted with the dual intention of:

- protecting humans, animals, plants and the environment from the potential harmful effects that could arise from the uncontrolled application of sludge to land; and
- to promote the beneficial use of sludge on such land.

Control of sludge application to agricultural land is based upon the identification of certain heavy metals (zinc, cadmium, copper, nickel, lead and mercury) as potentially toxic elements (PTEs). The Directive contains three annexes stipulating the limit values for concentrations of PTEs to be observed which covers the following:
- soil;
- sludge for use in agriculture; and
- amounts which may be applied annually to agricultural land, based on a ten year average.

An amendment to the Directive was proposed in 1988 establishing limit values for chromium. The proposed limits were 100-200 mg/kg for concentrations of heavy metals in soil, 1,000 – 1,750 mg/kg as for concentrations in sludge and 4.5 kg/ha and year for an annual average application rate to agricultural land, respectively. The proposed amendment has recently been removed from the legislative process.

The Directive takes a two-pronged approach to the control of the application of sludge to agricultural land:

1. by considering the **PTE content** of the soil nominated to receive sludge. If the concentration of any one of the PTEs in the soil exceeds the maximum limit stipulated in the National Legislation, used to implement the requirements of the Directive, then sludge application will not be allowed;

2. by regulating the **application of sludge to land** to ensure that the accumulation of heavy metals after sludge application does not exceed the limits laid down in legislation. In turn, regulation of the application of sludge to agricultural land by the Member States can be carried out by only one of two methods:

   - by placing upper limits on the quantity of sludge that can be applied per unit area of land each year whilst observing the limits for the heavy metal content of sludge stipulated in the Directive;

- by applying the limit values for heavy metals that may be applied to the soil per unit of area and unit of time (kg/ha and year) as stipulated in the Directive.

The Directive allows Member States to vary the limit values used to control the input of sludge in order to take into account the pH value of the local soil. Soils of pH 6 or below are likely to increase the mobility and availability of some heavy metals, and Member States should take this into account when setting national limits. Higher values by up to 50% may be permitted in soils permanently above pH 7.

2.1.3 Nitrates Directive

In recent years there has been a growing awareness of the contribution that diffuse sources are making to the pollution of the aquatic environment. By their very nature these sources are inherently difficult to control. In general, controls enacted to reduce pollution from diffuse sources have been based upon minimising the presence of certain dangerous substances in product formulations before they are applied or used in the environment. However, the Council of Ministers recently adopted a Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC).

The nitrates Directive seeks to reduce diffuse pollution to surface and ground-water, caused by the use and storage of inorganic fertiliser and manure on land. It complements, to a certain extent, the Urban Waste Water Treatment Directive (91/276/EEC). Both seek to reduce the presence of nitrates in the aquatic environment, the former from diffuse sources, the latter from specific sources. Nitrate pollution is believed to adversely affect the quality of drinking water and contribute to the problem of eutrophication.

In addition, a code of good agricultural practice must be implemented in order to provide a minimum level of protection for all waters, not just those designated as vulnerable zones.

2.1.4 Hazardous Waste Directive

The Hazardous Waste Directive (91/689/EEC) was adopted in 1991 with full implementation planned for December 1993. However, practical implementation is only possible when a list of hazardous waste has been drawn up. Problems with the preparation of this list has resulted in a delay in the implementation of the Directive . In the meantime, the existing Directive on Toxic and Dangerous Waste (78/319/EEC) will remain in force. Sludge from treatment plants, untreated or unsuitable for use in agriculture, is listed in Annex I of Directive 91/689/EEC.

2.1.5 Landfill Directive

The provisions of the Directive on Landfilling are being finalised. The Directive will stipulate minimum technical and administrative requirements for the operation of landfills, in particular for the disposal of hazardous waste. The co-disposal of sludge with domestic waste will continue to be allowed, although co-disposal with hazardous waste will have to be phased out within five years of adoption of the Directive.

Hazardous waste can be classified by using an eluate test which is being considered by a European Standards committee, CEN 292, and it is likely that the European Commission will adopt their recommendations.

2.1.6 Proposed Hazardous Waste Incineration Directive

The Council of Ministers has reached a common position on a proposed Hazardous Waste Incineration Directive, however, it cannot be adopted until it has completed a second reading in the European Parliament. If adopted, the Directive would require the prevention, or where this is not possible, the reduction in polluting emissions from hazardous waste incinerators.

Sludge is explicitly exempt, provided its constituents do not make it hazardous. What this means in practice is unclear. Although the present text of the Directive requires the definition of hazardous waste to be based on that stipulated in the Hazardous Waste Directive (91/689/EEC), it will probably not be until the Hazardous Waste List is finalised that the type of wastes covered by its provisions will become clear.

2.2 Summary of sewage sludge legislation

In general, few countries have legislation or quality standards which specifically apply to sludge disposal on landfill or sludge incineration and subsequent ash disposal. Mostly these issues are covered by national waste legislation. Only when the sludge is for agricultural use are there specific national regulations, which in the case of EC Member States, have arisen through the implementation of the Sludge in Agriculture Directive. However, many countries had specific measures for sludge before 1989 when the Directive was to be implemented. It is likely that the Nordic countries will bring their sludge legislation in line with the Sludge in Agriculture Directive. Only in the USA is there comprehensive legislation covering all aspects of sludge use and disposal. Few countries have attempted to develop integrated waste legislation, or to set common quality and environmental standards for the recycling of organic wastes.

There is a clear need to develop an integrated approach to such wastes if the accepted hierarchy of waste management - minimisation, recycling, incineration and landfilling - is to be uniformly and fully implemented. It is quite notable that the legislation governing the use of sludge is the most detailed and restrictive of any covering the use of waste on land. This has not necessarily been disadvantageous as far as sludge is concerned. In fact, it has focused attention on the need or the potential for improving the quality of sludge and its use in agriculture, and provided a more secure framework for the supplier and recipient of sludge.

2.2.1 Sludge use in agriculture

All EC Member States have adopted the Sludge in Agriculture Directive 86/278/EEC. A number of countries also have separate measures which govern the addition of nutrients to agricultural land to reduce losses of nitrogen and/or phosphorus to surface or ground-water. Whilst most controls on the use of sludge and fertiliser adopt the principle that sludge application rates must not exceed crop nutrient requirements, several countries set limits below optimum crop response and restrict timing of applications to reduce further risks of nutrient leaching.

The ultimate environmental constraint, on the sustainability of the use of sludge in agriculture, is the accumulation of heavy metals in the soil in order to protect plant, animal and human health. All EU Member States have set maximum concentrations for at least the six elements in the Sludge in Agriculture Directive, and several have set statutory or advisory limits for chromium as well as selenium, arsenic, fluoride and molybdenum. A number of Member States have set dual limits according to soil texture (Flanders) or soil pH (Germany, Spain and UK). In general lower limits are set for sandy and acidic soils, although in Germany and the UK the different limits only apply to certain heavy metals (Cd and Zn in Germany, and Zn, Cu and Ni in the UK). The Netherlands has developed formulae for each contaminant based on soil organic matter and clay content, factors which influence the bio-availability of the PTEs. For other Member States, the limits are generally set for the most sensitive conditions, usually for soils at pH 5, the lowest soil pH value permitted for sludge use on land. Several Member States permit soil concentrations to be increased by up to 50% in soils which are permanently above pH 7 (>5% calcium carbonate). The most stringent approach to soil protection is being implemented by the Dutch: by the year 2000 the input of heavy metals and other contaminants from all sources including sludge, must not exceed crop off-take. This will have the effect of discouraging any future use of sludge in agriculture.

Several countries outside the European Union have not set soil limits, notably Norway and the USA, although it is likely that soil limits will be set by all Nordic countries in order to bring their environmental legislation in line with the European Union. Heavy metal accumulation is controlled in these countries purely through constraints on sludge quality and application rate.

All countries reviewed have set sludge quality limits for heavy metals and other potential toxic elements, and in some instances, organic contaminants. For most Member States these are set in accordance with Annex 1 B of the Sludge in Agriculture Directive, with the exception of the UK which adopted the permitted alternative approach to controlling rate of application of heavy metals. Unlike soil limits, many Member States have set sludge heavy metal limits well below the lower values given in Annex 1 B, with the exception of zinc and copper.

Of the European non-member States, maximum limit concentrations of all six heavy metals in sludge are set at, or below the Directive values and are broadly comparable with the limits set by Member States. In the USA, the setting of limit values has been derived by risk assessment and this considered the range of concentrations of heavy metals occurring in sludge and the acceptable cumulative loading of heavy metals on land. Two standards are set in the USA: „clean„ sludge can be used without restraint in the most sensitive of outlets (domestic gardens etc.) and has limit values generally within the ranges of Sludge in the Agriculture Directive. Under most circumstances, the „ceiling„ sludge limits would apply and these are, with the exception of lead, much higher than the upper limits in the Directive.

In October 1995 the EPA formally withdrew all chromium limits applicable to wastewater treatment sludge used either in agricultural or non-agricultural land application. Following a successful Court challenge by Leather Industries of America (LIA), these limits had been remanded to the Agency for further review in 1994, but the final outcome remained uncertain. In their final ruling, the EPA stipulated that chromium in sludge is predominantly trivalent and concluded that they could find no risk basis for the establishment of sludge chromium limits. However, in December 1995, the EPA published what could be a highly precedent-setting proposal to establish risk-based pollutant thresholds. These would be used to determine whether an industrial waste is to be classified as hazardous - known as the Hazardous Waste Identification Rule. Despite almost two decades of progress towards valence-specific chromium regulation, this rule proposes to establish a 10 mg/kg threshold for total chromium, based entirely on risk associated with Cr(VI). Once again, LIA is taking an adversarial role and is challenging the proposal. Meanwhile the US industry remains committed to the environmental compatibility of chrome tanning and to the development of appropriate valence-specific regulations.

All the countries reviewed have set limits on the rate of addition of sludge to agricultural land by one or more of the following methods:

- limits on the rates of **addition** of potentially toxic elements in terms of kg/ha and year. For EU Member States these are set at or below the limits values given in Annex 1 C of the Sludge in Agriculture Directive, and are based on average annual additions over ten year periods. These limits are used independently of the sludge concentration limits, and is the approach adopted by the UK. In the USA, annual loading rates are only obligatory where the concentrations of PTEs in the sludge exceed the „clean„ limit values and where the sludge is sold or given away in bath or container. For instance, this would apply to sludge compost used in domestic gardens where the producer has to stipulate the rate of application based on the most limiting PTE;

- limit on the rate of **application** of sludge dry solids in terms of tds ha/year. These are used in conjunction with the sludge concentration limits, from which may be derived maximum rates of addition of PTEs. These are given as average annual additions, but the period over which they apply varies between countries from annually to ten years. This approach has been adopted by most Member States and the Nordic countries.

- limits on the rates of **addition** of nutrients. Only a few countries have set explicit limits on nitrogen and/or phosphorus, although all countries state that sludge should be applied according to no more than crop nutrient requirements. Some countries have specified maximum annual (fixed or average) rates of nutrient addition: others have fixed limits for phosphorus in relation to heavy metal concentrations in the sludge (e.g. Denmark), which is probably the most conservative approach. Several countries, notably Denmark, the Netherlands and the Flanders region of Belgium have set progressively lower limits for phosphorus addition in the future to reduce phosphorus enrichment of soils.

In reality there is a decreasing amount of sludge for which the application rates would be limited due to their heavy metal contents. This is due to the general and significant reductions in pollutants concentrations achieved in sludge in recent years. However heavy metals will ultimately restrict sludge use on land through increasing soil concentrations to limits values, unless sludge PTE concentrations can be reduced to below soil limit values in the future, which is unlikely for certain elements such as zinc and copper.

2.2.2 Sludge disposal to landfill

Few countries have specific legislation for the disposal of sludge in landfills: most include sludge within general waste legislation. The exception to this is the USA which has integrated legislation covering all aspects of sludge recycling and disposal.

Currently, sludge is disposed of in both urban (non-hazardous) and toxic (hazardous) landfills, although policies vary between countries with regard to which type of landfill should be used and whether sludge should be deemed hazardous. Currently, Italy requires an eluate test of the sludge to be carried out and, if above certain values, the sludge must be disposed of in a toxic waste landfill. The European Standards Committee, CEN 292, is currently considering appropriate characterisation and compliance tests for land-filled wastes. It is considered unlikely that most forms of sludge would be deemed hazardous by the Directive if adopted in its current form, but the final outcome is not clear due to the clash of landfill philosophies in different countries (dry tomb vs. wet reactor approaches, mono-, co- or joint disposal etc.).

In the USA, no eluate test is required but limit values have been placed on certain PTEs in sludge and are set according to risk. More stringent limits are set where landfills have no liner or leachate collection system and are close to housing. However, these limits only apply to mono-fills and not co-disposal with domestic solid wastes.

Most European countries require, in practice if not statute, that sludge should be de-watered before landfilling. Minimum dry solids contents of 30-35% are common to meet physical stability requirements and are much more readily achievable now with current de-watering technology. A few countries require that the sludge should also be stabilised. No other quality limits are currently applied, although the quantity of sludge which may be co-disposed with domestic solid wastes is often limited to no more than 10%.

It is likely that legal measures will be taken by an increasing number of countries to limit amounts of organic wastes which are disposed of in landfills. The purpose of this is to increase the use of recyclable waste and to reduce emissions from landfills (high strength leachates to groundwater and methane to the atmosphere). The approaches adopted by different countries varies, for example:

- tax on land-filled wastes (e.g. Denmark);
- source separate collection of domestic wastes and the production of compost (e.g. Germany, The Netherlands);
- pre-treatment to avoid reactive processes in, and emissions from landfills (dry tomb approach). Restriction would be placed on the organic matter content of land-filled wastes (e.g. Germany and France propose to introduce limits of 5-10% in the future);
- co-disposal or joint disposal of sludge with domestic refuse (the wet reactor approach to achieve rapid stabilisation adopted in most countries).

Depending on how widely such measures are adopted, they will have the effect of increasing the use of techniques that reduce moisture and volume (e.g. thermal drying) and reduce organic matter content (e.g. thermal destruction). The effect will be to increase the amounts of sludge recycled to land or incinerated, which follows European Commission policy on the hierarchy of waste management.

In most countries, the ash from sludge incineration is disposed of in hazardous wastes landfills, although some make the distinction between clinker and flue gas cleaning residues, and depends on the composition of the ash or an eluate test. It is not yet clear how sludge ash will be considered under EC legislation and which criteria will be used to define whether an ash is hazardous or not.

2.2.3 Incineration of sludge

There are no specific regulations in any European country for the incineration of sludge: this is usually covered by general legislation on waste incineration. No standards are set for sludge quality in Europe, although in the USA, as part of their integrated standards for sludge use and disposal, quality standards are set for sludge when incinerated on its own, but not for co-incineration with solid waste when other general regulations apply.

For efficient and cost-effective incineration, there are some basic operational sludge quality requirements, such as sufficiently high dry solids content to achieve auto-thermal operation, and this is often a key factor in the satisfactory operation of incinerators to achieve sufficiently high temperatures to meet flue gas emission standards. Such standards have been set by several countries, and adopted by others, to avoid discharge of heavy metals (mercury), organic pollutants (dioxins), dust and odour, and are only achievable by advanced gas cleaning technologies (precipitators, scrubbers etc.).

3 Sludge disposal in selected European Countries

3.1 Denmark

Of the total 130,000 tds disposed in 1987, 38% was utilised in agriculture (with a small amount being composted with other wastes before use), 30% land-filled (27% co-disposal 3% mono-disposal), 27% incinerated, with minor quantities going to forestry (0,4%) and dedicated land (3,5%). In 1992, the quantity of sludge being used in agriculture had almost doubled to 54% of sludge production, due not only to the increase in sludge produced, but also to the decline in sludge disposal to landfill. This decline is expected to continue in the future as a result of the tax imposed on land-filled wastes.

3.2 France

Most sludge in France is recycled into agriculture: about 500,000 tds/year or 60% of that produced. The other two major outlets are landfill and incineration, each accounting for about 20% (176,000 tds/year) of the sludge. It is difficult to provide a more detailed account since it is likely that some sludge is disposed of in an uncontrolled way. Nevertheless, it is clear that there are strong regional variations, with the proportion used in agriculture ranging from 36% in Rhin/Meuse to 93% in Artois/Picardie. Sludge is not disposed of into the sea, and there is only limited experience of using sludge in other outlets, such as forestry and land reclamation. For land application monitoring programmes including regular analyses of soil and sludge are required. The results are reported to the authorities concerned.

3.3 Germany

Providing accurate estimates of quantities of sludge being disposed of into the different outlets has been difficult in Germany. As may be expected, there is a long-term underlying trend in the old FRG of increasing quantity of sludge for disposal with an overall increase between 1987 and 1990 from 2.25 to 2.5 million tds/year. The quantity of sludge disposed of in the former GDR has been estimated to be about 232, 000 tds/year in 1990.

In the former FRG, it is estimated that the majority of sludge is disposed of to landfill (55%), with 25% being used in agriculture, 15% incinerated and only 5% going to other outlets (mostly compost production but also export). The use of incineration has increased in recent years from 279,000 to 375,000 tds/year, and includes co-incineration of sludge with domestic refuse as well as incineration of sludge alone.

Information on disposal practices in the former GDR is sparse. It is understood that most sludge was used in agriculture, but since reunification and more significantly since the implementation of the 1992 Sludge Ordinance in the former GDR, this has declined with much more sludge being disposed of into landfill.

Almost all Federal States rely heavily on landfill disposal, but agriculture remains a key outlet for many. For Germany as a whole, more than half of the sludge is disposed of into landfill, with agriculture as the second most important outlet, and incineration and "other„ outlets accounting for only about 10-20% of the sludge. The overall picture is confused by the proportion of sludge given as being disposed of to "other„ outlets: it is probably because much of this is currently compost, which is effectively recycled to land through agricultural, horticultural and domestic use.

3.4 Netherlands

Half of the sludge produced in the Netherlands was disposed of in landfill and 46% was recycled to agriculture and compost/black soil production. Only 3% was incinerated. Of the 85,000 tds used directly in agriculture, most (93%) was spread on arable land and only 7% on pasture. Generally, sludge from the smaller STWs tended to be used in agriculture whereas sludge from the larger STWs predominantly went to landfill or compost/black soil production.

3.5 United Kingdom

The principal outlet is recycling to agricultural land accounting for 42% of sludge nationally, with sea disposal (30%) being the other major outlet. All of the other outlets, namely dedicated land (as defined in 86/278/EEC), landfill, incineration, beneficial use (forestry, land reclamation etc.) and storage, are only minor outlets at the national level (but very significant at the local level). However, there are some large regional differences, particularly in Scotland, where currently 76% of the sludge is disposed of into sea. This situation contrasts strongly with most other Member States which rely more heavily on landfill and incineration.

3.6 Conclusions

The quantities of sludge recycled or disposed of into different outlets in the European Union are summarised in Table III/3-1. These show that overall, almost equal quantities of sludge went into agriculture and landfill -2.37 and 2.60 million tds/year respectively (37% and 40%). Incineration accounts for only 11% of current sludge production, but in actual quantity incinerated, this has increased by 38 % compared with 1984. Currently, only 6% of sludge is disposed of to surface waters, mostly to the sea. However, in real terms, this outlet has declined by 6% compared with 10 years ago, and will cease to be used from the end of 1998.

Table III/3-1: sludge recycling and disposal in the EEC – tds/year

Member State	Agriculture	Landfill	Incineration	Sea	Other beneficial Outlets	Other disposal outlets	Total
Belgium	17 411 (29)	32 288 (55)	8 835 (15)	0	663 (1)	0	59 200
Denmark	92 500 (54)	34 300 (20)	40 000 (24)	0	500 (<1)	3 000 (2)	170 300
France	500 000 (69)	176 000 (20)	176 000 (20)	0	0	0	852 000
Germany	728 300 (27)	1 463 000 (54)	367 400 (14)	0	0	122 500 (5)	2 681 200
Greece	4 820 (10)	43 380 (90)	0	0	0	0	48 200
Ireland	4 518 (12)	16 568 (45)	0	12 760 (35)	0	2 836 (8)	36 700
Italy	269 000 (33)	449 000 (85)	17 000 (<1)	0	0	81 000 (10)	816 000
Luxembourg	946 (12)	6 930 (88)	0	0	0	0	7 900
Netherlands	84 683 (26)	161 919 (50)	11 230 (3)	0	64 869 (20)	178 (<1)	322 900
Portugal	7 500 (30)	15 000 (60)	0	0	0	2 500 (10)	25 000
Spain	175 000 (50)	122 500 (35)	17 500 (5)	35 000 (10)	0	0	350 000
United Kingdom	490 000 (44)	88 000 (8)	77 000 (7)	334 000 (30)	68 000 (6)	50 000 (5)	1 107 000
Total(3)	2 374 600 (37)	2 608 800 (40)	715 000 (11)	381 800 (6)	134 100 (2)	262 000 (4)	6 476 400
1984	*2 008 000 (36)*	*2 452 000 (44)*	*518 000 (9)*	*408 000 (7)*	*49 000 (1)*	*128 200 (2)*	*5 563 200*

Source: Hall, Dalimier (1994)
Remarks: ( ) = percentage

There are a number of other minor outlets, and these are given in the above table as „other beneficial„ or "other disposal„ outlets, and collectively account for only 6% of current sludge production for the European Union as a whole, although the reliability of these data is questionable. Compared to 1984, these two groupings of outlets appear to have grown considerably by 173% and 113% respectively, perhaps indicating an increased use of recycling outlets such as in land reclamation and forestry.

3.7 Future sludge disposal

No Member State has yet quantified the amounts of sludge to be disposed of or recycled to different outlets in the future. However, policies and trends were identified or estimated for all countries.

Despite the fact that landfill is currently the most widely used disposal outlet, almost all countries recognise that this outlet will not be sustainable at current or projected levels in the future. This is mainly due to increasing competition for landfill space, higher cost, more stringent environmental standards and the implementation of policies to promote recycling. Most Member States have formal or practical limits on the physical nature of sludge to be landfilled. Many operators see thermal drying as a means to overcome such restrictions, but this may be only a short-term solution in those Member States which have introduced measures (or are due to phase in restriction) to limit the amount of organic matter deposited in landfills. Such restrictions are considered necessary to promote the recycling of organic wastes (particularly domestic refuse) wherever possible, and to limit methane and leachate emissions from landfill sites. Consequently, in the future, in Germany, Denmark and France and possibly a few other Member States, will sludge be acceptable in landfills as incinerator ash.

The majority, but significantly not all Member States, recognises **agricultural** land as the major beneficial outlet for sludge, in the medium and/or long term. Concerns over real and perceived risks from the heavy metals and organic contaminants in sludge, and caution over the addition of nitrogen and phosphorus-rich manure to land, will continue to be a major factor in limiting the use of sludge. However the quality of sludge throughout Europe has improved remarkably, even since the Sludge in Agriculture Directive was first proposed and probably far more so than current perceptions suggest. As a result, it is recognised in a number of Member States that the amount of sludge used in agriculture could be increased, possible substantially, by appropriate promotion and adoption of quality assured operational practices and also by the development of sludge products, such as compost.

Incineration of sludge is currently a relatively minor method of sludge disposal. Although it is a strict treatment method to reduce sludge volume (since there is still the residual ash to dispose of), sludge incineration has a beneficial aspect as modern energy-efficient incinerator designs are capable of operating at least autothermically, and are often able to produce surplus and usable heat and power. Almost all Member

States anticipate substantially increasing their sludge incineration capacity in the future to cope with the increased sludge production from large STWs and to deal with sludge previously disposed of in landfill. In some countries, notably the Netherlands and to some extent Germany, sludge currently used in agriculture will be incinerated since agricultural use has become untenable in the Netherlands and regarded by many as increasingly difficult in Germany.

There are a number of other **minor sludge disposal routes** (dedicated sites, storage etc.) and **recycling outlets** (land reclamation, forestry, composting etc.), and these will certainly play an increasing role in sludge management strategies in some countries. However, unless there is a significant technological development (such as creating or recovering products or resources from sludge), these outlets will remain minor, although important on a local level. For the purposes of evaluating the future pattern of sludge disposal and use, the quantities used in these minor outlets have been added, as appropriate, to that used in agriculture. This is done in order to give the total amount of sludge recycled, and added to the quantity land-filled and disposed of at sea, to give a total amount of sludge that is disposed of (i.e. not recycled).

From 1984 to 1992, overall sludge quantities increased but the proportions going to the three principal outlets did not change much, with most sludge being disposed of, and only a small quantity incinerated. By the year 2000, it is expected that the proportions, as well as the quantities, will have changed considerably with a significant increase in incineration and a decrease in sludge disposed. These trends should continue further to 2005 with landfill becoming the smallest outlet (17%), recycling, predominating (45%) but with incineration closing at 38%.

These forecasts are strongly influenced by Germany, which will produce up to 38% of sludge in the European Union in 2005, and the strong decline in sludge disposal to landfill, is mainly due to the anticipated implementation of the German policy to restrict the landfilling of organic matter-rich wastes.

4 Current situation in China

Information with regard to the current situation of Chinese leather production has been collected from various sources:

- Governmental institutions on both a national and provincial level
  ⇒ legal situation
  ⇒ treatment practices
  ⇒ further plans.

- Environment protection bureaux at provincial and city level
  ⇒ monitoring systems executed
  ⇒ fees and fines
  ⇒ operation of central treatment facilities (landfill sites, incinerators, etc.)

- Leather industry and related associations
  ⇒ production
  ⇒ treatment facilities
  ⇒ ways of treatment.

In addition, a questionnaire was elaborated and carried out in co-operation with the Northwest Institute of Light Industry in Xian (the English version of the original report is compiled in Annex 1). The following chapters are mainly based on these sources. For the estimation and interpretation of quantitative data the results of the questionnaire of the Light Industry Institute in Xian have been used, taking other information into account. The questionnaire was based on a statistical sampling, thus the data obtained are somehow representative for the sector.

4.1 Background

China's leather industry is the biggest industry sector within the Committee of Light Industry (the former Ministry of Light Industry). The sector incorporates more than 20,000 enterprises, of which some 2,000 are tanneries. Total production in 1995 was estimated to be in the order of 40 mill pieces of sheep and goat skins, 10 mill cattle hides and 70 mill pig skins.

Taking the production of 1995 and the average water consumption, the generated waste water amounted to about 60 Mio m^3. The corresponding sludge volume was estimated at being about 150,000 tds.

The leather sector is the most important sector in China with regard to exports, amounting to US$ 8.45 billion in 1995. The major exports in 1995 were shoes (US$ 4 billion), leather suitcases (US$ 2.3 billion) and leather garments. China's main leather export markets are Australia, Japan, Germany, Italy, and the USA.

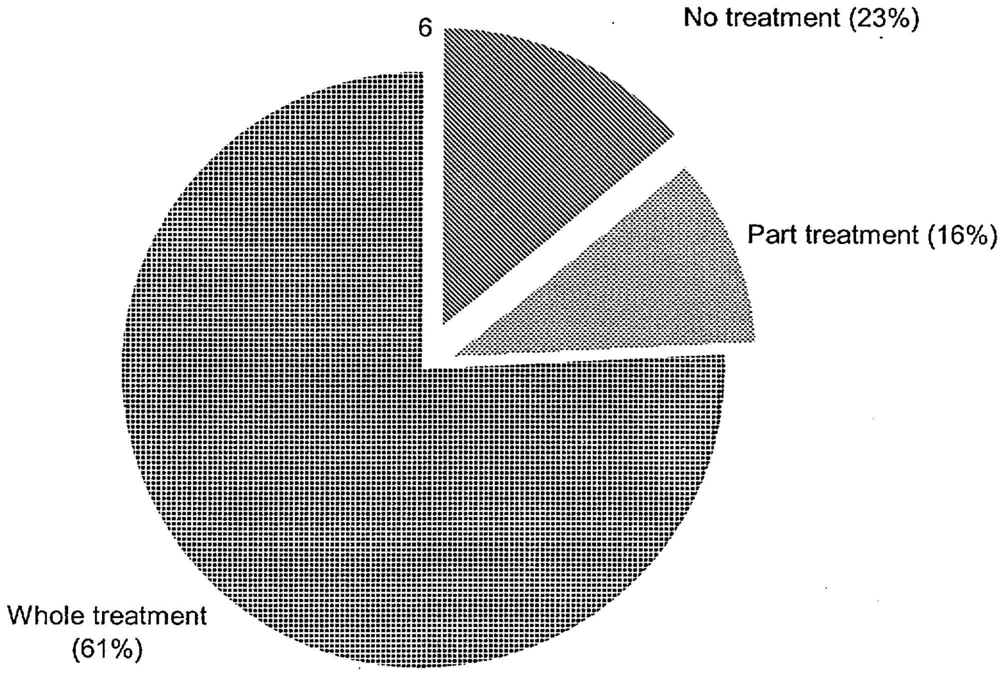
Leather sales in the domestic market in 1995 have dropped by 10-15%. Local consumption of finished leather products declined due to the problems of inflation (which was at a rate of 15-20% in 1995) and the Government's policy of slowing the overheated economy.

Leather production is a process creating considerable quantities of waste water and solid wastes. Per ton of cattle raw hide, about 30 - 50 m³ of waste water and 150 kg of sludge (ds) are produced on average. The standards for effluent from industrial activities are applicable nationwide and enforced by the respective regional authorities. Legislation standards concerning disposal of industrial solid waste and sludge are under preparation.

Due to the serious pollution problems generated by tanneries, those which are located in densely populated urban areas are instructed by the Government to take appropriate action to move their factories to areas located outside of cities, mainly to new established industrial sites. At the new sites, modern tanneries are being built with waste water treatment plants and some are also being equipped with chrome recycling units.

Although governmental regulations force the tanneries to treat their waste water and respective standards have been set, only about 10% of the tanneries currently meet the standards. Moreover, not all tanneries have treatment facilities at their disposal (Figure III/4-1).

Figure III/4-1: Waste water treatment facilities

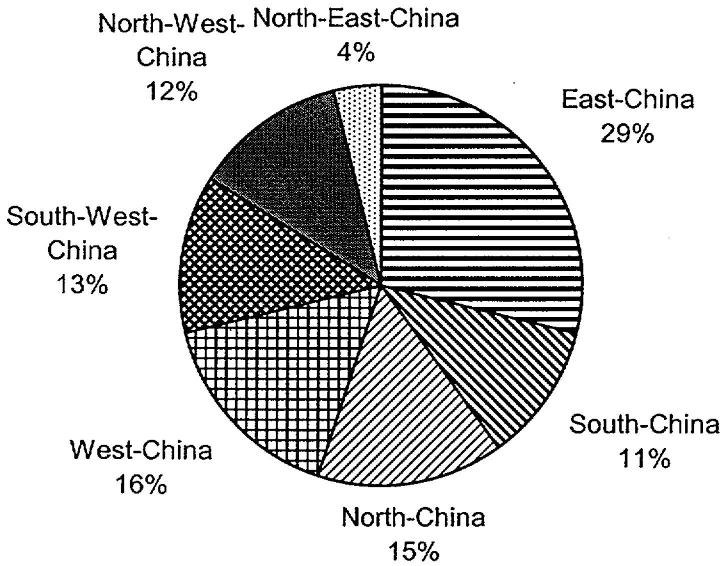


Source: compare Annex 1

Effluent treatment plants in operation are available in 61% of the tanneries only. 16% have part-effluent-treatment facilities and 23% (mainly located in north and north-west China have no effluent treatment facilities.

The majority of the tanneries are located in east and south China (Figure III/4-2) which is due to better infrastructure, easy access to foreign markets, and various traditional reasons.

Figure III/4-2: Regional distribution of tanneries



Source: compare Annex 1

4.2 Waste water and sludge production

Average waste water and sludge production for various raw products are compiled in Table III/4-1. Amounts of waste water exceed by far the international standards.

Table III/4-1: Average waste water and sludge production

Production	Average waste water		Annual average sludge volume (40% ds)
	10,000 t/month	per ton of raw hide	(t/10,000t waste water)
Pig	3	43	19
Sheep, Goat	1	172	8
Cattle	2	59	16

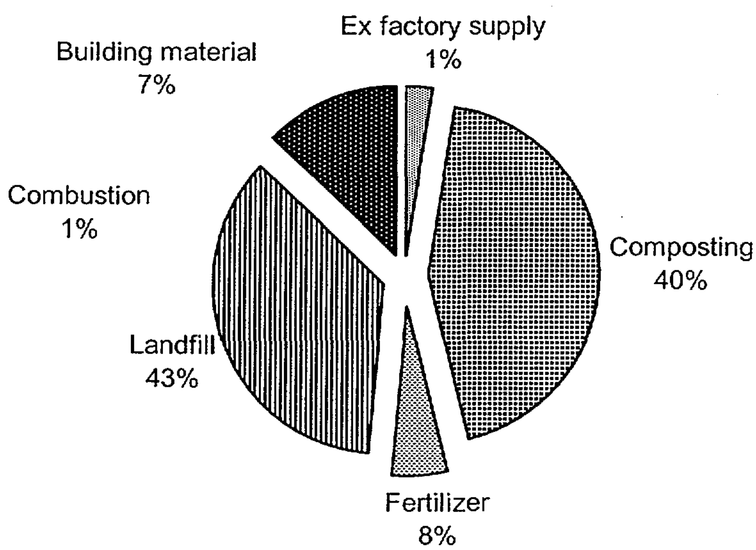
Source: Annex 1
Remarks: The figures are presented uncommented as results of the survey registered in Annex 1.

4.2.1 Sludge treatment

Sludge treatment does not receive much attention in Chinese tanneries. The majority of the factories simply dispose sludge at any convenient site, which may be a river bank, bare land, unprotected dug holes, or municipal dumping sites.

However, it was a surprising result that a number of treatment processes and technologies are already used, either at full scale or at least at a trial scale (Figure III/4-3).

Figure III/4-3: Treatment methods used



Source: compare Annex 1

A short summary of the methods is presented below.

4.2.1.1 De-watering, Thickening, Conditioning

Not much emphasis is laid on the de-watering process which is a pre-condition for most further treatment steps. This may be also the main reason why the currently used methods are unsatisfactory and do not often fulfil the requirements of the user.

Sludge is removed from the sedimentation tanks to sand filter beds or mechanically dewatered after stabilisation and thickening using chemical additives. In factories where no additional space for sludge drying beds is available the sludge is simply stored beside the treatment basins.

As a direct result, de-watering is poor, inhomogeneous, and creates bad odours. The sludge is de-watered to a solid content of maximum 10% which is insufficient for most of the common treatment methods.

4.2.1.2 Temporary storage

Temporary storage of sludge on the factory site is a very common practice. It is often the result of lack of any other treatment possibility (or necessity). The most notable disadvantages are:

- malodour
- percolation of chromium and other nutrients containing water into the ground and groundwater
- no final solution; sludge has to be handled another time.

> A technically sound temporary storage site was designed by UNIDO in Da Chang tannery as a demonstration site. The site is surrounded by reinforced concrete walls. Percolation is prevented by liners and a clay layer of about 0.6 m thickness. Percolation water is drained to a filtration well. Due to the shallow groundwater level and the absence of a solid bedrock and natural clay layers, (the underground consists of unconsolidated sediments of gravel, stones, sand and clay) the hydro-geological conditions for the erection of a landfill are not optimal.

4.2.1.3 Landfill

Landfill is carried out by about 50% of the questioned factories. Landfill sites are mostly unprotected against percolation of drainage water, precipitation and surface flooding. They consist mainly of holes dug by the factory (inside or outside) or farmers, which are then filled. In some cases, sludge is mixed with refuse and dumped at municipal landfill sites. Due to the absence of any proper design of landfill sites, the operation, and the proper handling of toxic substances, currently operated landfill sites cannot be considered as environmentally sound solutions of the sludge problem.

4.2.1.4 Utilisation as fertiliser

De-watered sludge is used by local farmers as a soil conditioner and/or fertiliser. The unrestricted and uncontrolled land application seems risky due to a number of reasons:

- possible contamination of crops by pathogenic germs especially when using as top fertiliser in rice and vegetable production as reported
- possible enrichment of chromium in soils
- possible contamination of groundwater by infiltrating heavy metals and nutrients.

Another method is reported to be used in Harbin. There, sludge is used without prior treatment in plant nurseries as pot soils. Tests have been successfully finished under the monitoring of the provincial agricultural department.

4.2.1.5 Composting

Most farmers mix the sludge with manure or crop stalks and pile them at the field site, thus using a simple static pile system for composting. The resulting compost is used after about half a year. The adding of crop stalks as a bulking agent improves the C:N ratio, but has only a limited effect on the porosity of the sludge. Thus, composting effects may be not optimal. On the other hand, the system is easy to handle, creates no additional cost, and the final product has its well known advantages.

The sludge of Xian tannery was and is still used in Fan Chun Chian village, located about 0.5 hrs away from Xian city. The area is slightly undulated with medium to heavy soils of neutral characteristic. Straw is used for melioration in order to improve porosity. The soil lacks P, N and K. Cost for inorganic fertiliser are mentioned as being 1 RMB/kg for 46% NH_4-fertilizer and 2.2 RMB/kg for a 14%P/16%NH_4 fertiliser.

Main products are vegetables and fruits. Fruit trees (mainly apples) are grown in the community near by. The average per capita income is about 1,100 RMB/year.

The villagers use sludge from the tannery since 1976. From 1976 until 1981 the whole sludge was used on all fields. Since the privatisation of the fields in 1981 sludge is used by those farmers who can afford transport. Farmers have to hire a lorry for transportation because tractors are not allowed to enter Xian city since 1996.

The sludge is used as fertiliser for vegetables (cucumbers, tomatoes, water melons) and for rice production and is described as slow active with excellent fertiliser characteristics:

- Nutrients are released slowly over the whole growing period,
- remarkable higher production rates have been reported (up to 100%)
- the sugar content of water melons are remarkable higher than compared with water melons grown without sludge
- common root diseases of tomatoes and cucumbers which have to be treated by using $CuSO_4$ could not be detected in sludge fertilised fields.

Sludge is stored along the fields until the sludge cakes are easy to grind. It is applicated either by distributing the ground sludge on the fields prior to ploughing or direct to the plants after mixing with soil.

The existing application method and soil monitoring is not acceptable and not in conformity with international and/or national standards.

4.2.1.6 Incineration

Only very few tanneries use sludge as a fuel substitute. The sludge is mixed with coal and burned in the boiler house. Neither the ash nor the air emissions are subject to further treatment. The main problems may be seen as:

- no treatment or safe disposal of secondary wastes
- no air pollution control
- sludge with about 90% water content requires a remarkable amount of energy for water evaporation only. It is doubtful whether energy could be saved
- the wet sludge cannot be properly pelletized, combustion is not homogenous
- mechanical problems (fixing of sludge at conveyor belts, etc.)

4.2.1.7 Utilisation as construction materials

Sludge is used as filler both within the gravel layer of roads, and in brick production. In both cases sludge is mixed with ashes from the boiler house. The chromium containing sludge is also used as colour agent in tile production. Another treatment path includes mixing of sludge with clay for clay stone production.

Tests with stone production have been carried out by Nanjing tannery in co-operation with a local cement stone manufacturer.

The **Pukon Taihau Walls Building Material Factory** in Nanjing produces cement stones for light walls with sizes of

PDX-24	390 * 240 * 190mm
PDX-19	390 * 190 * 190mm
PDX-12	390 * 120 * 190mm
PDX-9	390 * 90 * 190mm.

The factory's capacity is about 15,000 m^3 of stones per annum. Main ingredients are slag and ash from boiler houses and power plants, sand/gravel and cement. The stones have to pass the national standard (DB 32/155-1996; Standard for cement - coal-ash - light bricks) twice a year. The standard includes
- size stability,
- appearance,
- strength,

- freezing resistance,
- specific weight,
- water absorption capacity,
- water tightness.

The main advantage for the Factory in using sludge in the production is the reduction of production cost by substitution of ash by sludge (ash costs around 20-30 RMB/t). In addition the municipality propagates the utilisation of industrial waste by offering a tax free status.

In co-operation with the Nanjing tannery cement stones with sludge have been produced. The mixture used was

coal ash	250 kg	55%
sludge	30 kg (at 30% ds)	7%
slag	86 kg	18%
stones	30 kg	7%
cement	60 kg	13%
Total	**456 kg**	**100%**

The produced stones showed the following characteristics (compared with normal stones):
- appearance more smooth
- residuals (e.g. hairs) visible
- odour (during production and drying)
- colour: no difference.
- physical tests haven't been carried out yet.

The sludge substitutes part of the ash within the stone matrix. Due to its smaller grain size the following impacts on the physical characteristics may be expected:
- higher density with associated higher specific weight
- higher strength due to more compacted matrix
- negative influence on insulation characteristics (lower heat resistivity)

Due to the low temperature process and the always alkali milieu there is no risk of six-valent chromium generation during production. Direct contact with the stones after construction is more or less prevented due to the plastered surfaces. In addition the stones are mainly used in a dry environment (indoor and plastered or tiled) thus excluding the risk of chromium eluation.

Apart from the general questions of marketing and cost advantages further investigations and trials should consider the following aspects:
- fixation of chromium (chemical elutriation and mechanical removability of chromium from the surface)
- odour
- physical characteristics which have to meet the national standards
- long-term stability of chromium fixation.

Odour is created by the continuation of the biodegradation of the organic sludge contents. All organic components which are not stabilised within the cement matrix will continue the degradation process, thus producing malodour.

4.2.1.8 Methanisation of Sludge

Methanisation of sludge was tested on a laboratory scale in Xian 3513 factory. First results obtained were reported as being positive. It is unclear why the test was stopped.

4.2.1.9 Drying

Drying is done in special fluidised-bed dryers. It leads to a stable final product of light weight aggregates with 95% dry solids. The residuals can be used for production of light weight stones and bricks, for insulation, in road construction, and land filling. In principle the combustion in power or boiler houses (heating value 3.7 – 5.3 MJ) is also possible, but might create problems in air pollution. Drying is carried out under nearly oxygen free condition at a low temperature (80°C), thus preventing generation of six-valent chromium.

For single tanneries with a normal production scale the investment is too high and the sludge volumes are too low to run such a plant economically. Even for Da Chang the smallest size of a drying plant exceeds by far the daily sludge production. On the other hand, this technology may be of interest for tanning cities or in case the tannery can share with other user groups.

The Petrochemical Plant in Zinyang installed one drying plant (designed and supplied by a German supplier) for the sludge treatment. The Factory runs its own effluent treatment plant with a capacity of 140,000 m^3/day and an associated sludge production of 50 tons (at 20% ds).

The capacity of the drying plant is 200 tons per day; the investment was 56 Mio. RMB. Due to the big gap between the plant's capacity and the actual sludge production the plant is interested in receiving sludge from outside in order to achieve better utilisation and lower operational cost.

4.3 Legislation

Environmental legislation in China has remarkably improved during the last few years. Main emphasis was hereby laid upon the protection of water. Laws and regulations with respect to environmental protection have been issued during the last years. Consequently, regulations concerning tanneries deal mainly with waste water standards. Up to now, little emphasis has been laid on the solid waste disposal and the sludge treatment aspects.

Table III/4-2: Effluent standards for tanneries - China

CHINA Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C		35
Conductivity µs/cm		
Suspended solids mg/l	200	500
Settable solids ml/l		10
BOD_5 mg 0_2/l	150	500
COD mg/l	300	500
Sulphide mg S^{2-}/l	1	10
Chrome (III) mg/l	1.5	2.0
Chrome (VI) mg/l		0.5
Chrome total mg/l	1.5	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		100
Phenols mg/l		5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

Source: Annex 4

Important acts and laws are:

- Prevention and Control Law for Water Pollution
- Hua He Basin Prevention and Control of Water Pollution
- Integrated Wastewater Discharge Standards
- Effluent Standards for Pollutants from Leather Industry .

The national regulations are tightened by provincial regulations. For instance the City of Shanghai established its own standards for tannery effluent which are partly more strict than the national ones (Table III/4-3).

Table III/4-3: Tannery effluent standards of Shanghai City

Item	Unit	Shanghai Municipality	National Standard
COD	mg/l	100	300
BOD	mg/l	60	60
Sulphide	mg/l	1	1
Chromium	mg/l	0.5	1.5
Ammonia-Nitrogen	mg/l	15	---
Grease	mg/l	10	10
Turbidity		50	50
pH		6-9	6-9

There are no special rules for the utilisation and/or treatment of sludge. Besides the water pollution regulations mentioned above, sludge is to some extent also included in the regulations concerning solid waste treatment. The most important are:

- Legal provisions for preventing ocean pollution by wastes
- prevention and control of water pollution.

For land application and/or utilisation of sludge as fertiliser or soil conditioner the Chinese control standards for pollutants in sludge for agricultural use can be applied (compare Annex 6). The standard includes a maximum chromium content of agricultural soil of 1,000 mg/kg ds which is similar to the standards applied in the EU Member States.

4.4 Conclusions

The understanding that environmental protection is an essential part of industrial development became common sense in China during the last few years. However, environmental protection is only supported by the Government as long as it does not hamper industrial development. Thus, the enforcement of environmental laws or regulations and the tightening of the industry to fulfil their obligations, is duly bound on the understanding of local/regional decision-makers. Consequently, the exceptions are the rule at least in remote areas or in areas with comparably lower industrial growth rates.

Generally, sludge does not receive much attention. However, big differences appear within the industrial sector. Old, state-owned enterprises with unchanged management and sufficient space on their huge factory sites, and with well established relationships, do not feel much pressure to change their traditional way. On the other hand, there are factories, located in modern, industrialised zones, where land is expensive, administration in terms of control and penalties is functioning, and which may produce, at least partly, for export. These tanneries now face increasing pressure to change their traditional way of disposal of sludge, solid wastes and other refuses. This is also due the growing awareness of the population and the declining social acceptance of matters affecting themselves.

Nevertheless, the number of existing treatment paths in use indicate that efforts are being undertaken to overcome certain problems resulting from the sludge handling. On the other hand, the results indicate clearly that neither existing know-how nor available experience is sufficient for the introduction of sound sludge management systems. None of the treatment methods reported work on an optimal or sub-optimal basis. Some of the processes will even create negative impacts.

5 Technological aspects

5.1 General

There are only limited experiences of possible disposal or processing routes of tannery sludge available. Main reasons are among others, that many tanneries run pre-treatment facilities only, thus limiting the quantities of sludge occurrence, whereas final treatment is done in a municipal sewage plant and that over a long period landfill was the easiest and cheapest solution. Consequently the problem of sludge handling was transferred from the tannery to the municipal effluent treatment plant. The sludge characteristics in these plants reflect the mixture of all waste water received thus balancing the typical characteristics of tannery effluents. The low cost for landfill lower the attraction of other solutions and hampers the readiness of tanners and engineers to search for alternatives.

However, taking into account that tannery sludge differs little from sewage sludge, most of the technologies applied there can be adapted to tannery sludge, too. Thus in the following, methods already used for tannery sludge and methods well proven for municipal sludge or mixtures of both are discussed.

5.2 Sludge requirements for disposal options

There are two basically different approaches in the handling and processing of sludge. One is directed towards **reuse**, the other towards **disposal**. The **reuse** approach is based upon recycling sludge so that nutrients, organic and/or other materials contained in the sludge are beneficially reused. The goal of sludge treatment in this case is to make the sludge compatible with the proposed reuse system. If land utilisation is being considered for ultimate disposal for example, prior treatment should be such as to conserve its nutrient value and organic matter content and to make it aesthetically and environmentally acceptable.

The choice between reuse and disposal approaches must be based upon a thorough evaluation of the many factors associated with each of the processes involved. In the current age of resource depletion and energy shortages, however, reuse and resource recovery should receive priority, if either can be feasibly included in the sludge management scheme.

Each disposal option requires certain sludge conditions and contents. Main factors to be controlled are

- Water content
- Chemical contents influencing the physical characteristics
- Concentration of toxic/harmful substances.

The most important disposal options may be compiled in the four categories of energy recovery, final disposal, nutrient recovery and product conversion.

- **Energy recovery**
  includes all technologies using the energy content of the sludge mainly in form of thermal energy.
  - ➢ Water content at maximum 60 – 65%, better pre-drying to 5% water content.
    - ❖ De-watering to about 20 – 35% ds
    - ❖ Drying to about 95 % ds
  - ➢ Stabilisation with lime may create problems during drying
  - ➢ Concentration of toxic/harmful substances influence measures on emission control and final disposal/utilisation of residuals

- **Landfill**
  Includes all kinds of final disposal either in special dumping sites or in form of land reclamation
  - ➢ Eluation of toxic/harmful substances (mainly heavy metals) influences design of landfill site
  - ➢ Odour problems to be minimised by proper planning and operation
  - ➢ Water content should be lower than 70% due to physical stabilisation of site.

- **Nutrient Recovery**
  Includes all kinds of agricultural utilisation including direct field application, composting, production of fertiliser.
  - ➢ Limited by chromium contents. National standards can be met only in case chromium containing waste water is treated separately
  - ➢ Water content should be less than 70%. Liming may improve fertiliser characteristics
  - ➢ Liquid application limited by salinity
  - ➢ Monitoring and control, system to be established
  - ➢ Chemicals used for stabilisation/thickening may influence further application.

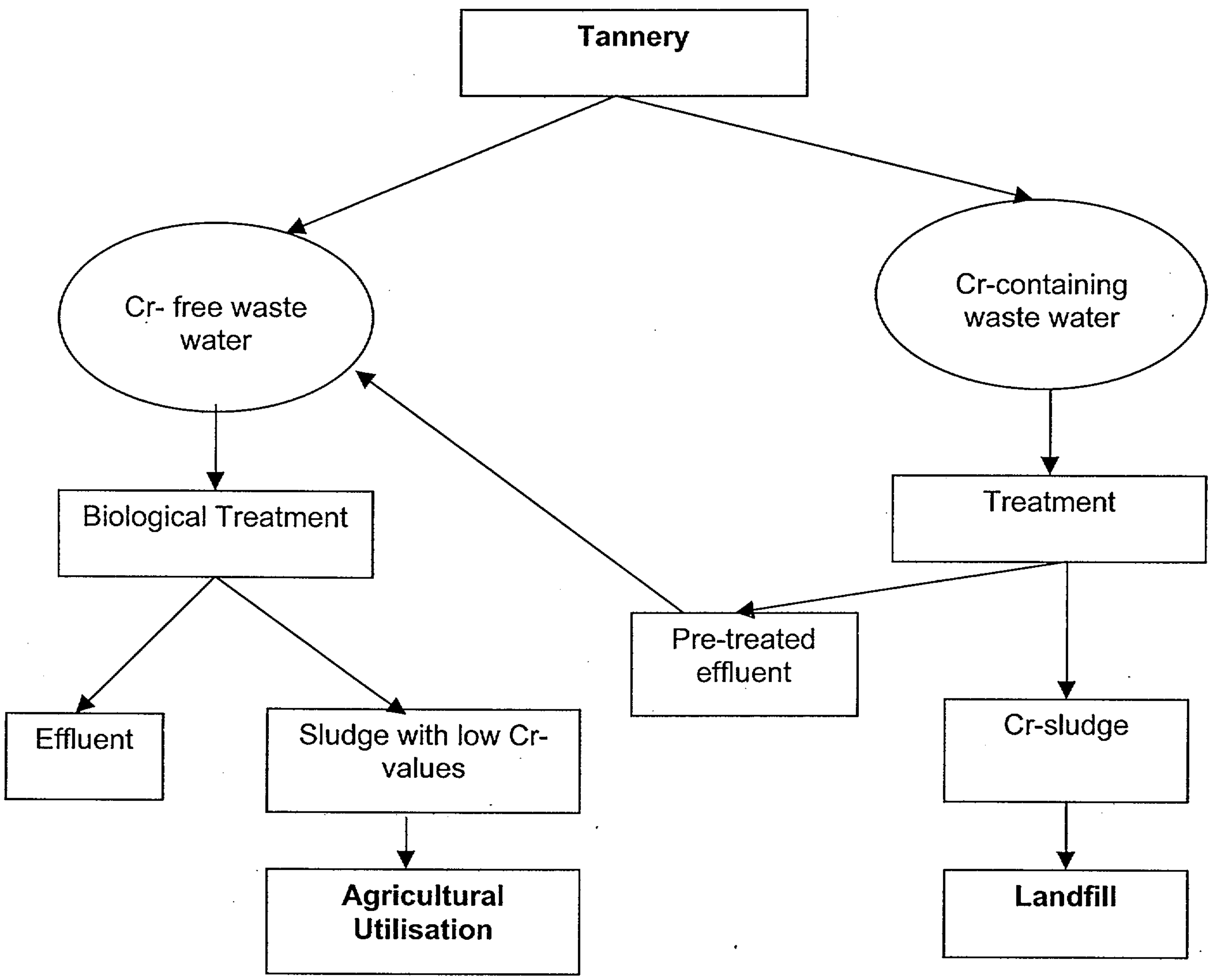
- **Product development**
  Requires specific preparation steps and sludge characteristics which have to be developed for every single technology.

5.3 Processing requirements

No matter what the ultimate sludge treatment method considered, some processing will be required to better prepare the sludge for that particular option. For example, selection of the incineration option presupposes de-watering of the sludge, and de-watering is generally preceded by a conditioning step.

As an example a possible in-house treatment system for waste water sludge to be used in agriculture is presented in Figure III/5-1.

Figure III/5-1: Separation of chromium containing waste water streams



Processing of sludge, prior to ultimate disposal, generally involves one or more of the following unit processes: thickening, stabilisation, conditioning and/or de-watering.

- **Thickening**
  Thickening refers to the separation of some of the free water from the solid particles of sludge, the purpose of which is to reduce the volume of sludge to be stabilised, de-watered or disposed of. Thickening a 2% sludge to 6% solids reduces the volume of sludge to be handled by a factor of more than 5. This reduction can provide significant savings in the cost of dewatering or other downstream processes. Due to the high quantity of lime, gravity thickening is seen as the most appropriate solution for tannery sludge. Beside flotation and centrifugation are common methods for sludge thickening.

- **Stabilisation**
  Some form of stabilisation is generally recommended for all sludge treatment and disposal options, primarily because of odour problems associated with the processing of raw sludge. Major types of stabilisation processes are **anaerobic** and **aerobic** digestion, **chemical** treatment and **heat** treatment.

- **Conditioning**
  In addition to free water between sludge particles, sludge also contains bound water. Conditioning is designed to alter the nature of the sludge to an extent that the release of all the free water and some of the bound and intraparticle water becomes possible. Conditioning is mainly carried out by adding appropriate chemicals which can be either inorganic compounds containing aluminium or iron and calcium, or organic polyelectrolytes.

- **De-watering**
  Sludge de-watering removes remaining free interparticle water together with some of the intraparticle water from liquid sludge so as to change their physical form from liquids to semi-solids.

  De-watering devices include **drying beds, lagoons, centrifuges, filter presses and belt filters. Drying beds** and **sludge lagoons** are generally used only for smaller sludge amounts because of the relatively large land area requirements.

  Plate and frame filter presses receive high acceptance within the tanning industry due to their high efficiency. The major disadvantages of the filter press over the vacuum filter are the semi-batch mode of operation and frequent requirement for operator attention during cake removal. The greatest advantage of the filter press is its ability to de-water up to a 50% ds. Under normal operation tannery sludge with about 35% ds is achieved.

  The **belt filters** have been relatively recently introduced into the sludge de-watering field but are gaining rapidly in popularity because of their simplicity in operation and low power requirement. Solids cakes similar to or somewhat higher than those from the vacuum filter are achieved.

5.4 Treatment and disposal methods

5.4.1 Marine treatment

Marine treatment of sludge is mainly dependent on the availability of coastal borders. At the North Sea only Britain and the Netherlands, both with high coastal population density dispose of sludge at sea. Elsewhere, Ireland, USA, and Spain also use the marine route for sludge disposal. Trends in marine dumping, since the signing of the Oslo Convention, have varied between countries depending on the basic difference in philosophy on the use of the sea. For example, the FRG stopped dumping of sludge completely in 1983. However, marine treatment will be banned throughout the EU by the end of 1998 (compare chapter III/4). With respect to **tannery sludge** or effluent disposal, marine treatment is not an option for a single tannery, but it is applied in conjunction with the disposal of municipal waste water.

In principle, two disposal systems are applied; disposal by out-falls in the coastal area and disposal by vessels off-shore. The management of marine sludge disposal is described for some countries in the following.

- **Great Britain**
  Approximately half of all sewage produced in Scotland and Wales and around 1/4 in England is discharged through out-falls to the sea. In addition, about 30% of the sludge arising from sewage treatment works is disposed of into the sea at licensed disposal grounds.
- **Australia**
  In Australia there is a commonly held view that sewerage authorities should reuse sewage rather than dump it in the ocean. This view, no doubt, derives from the fact that Australia is a dry arid zone. Opposition to ocean disposal comes also from long standing problems of beach pollution caused by sewage discharges. All major cities in Australia make use of ocean waters for direct discharge of sewage effluent.
- **France**
  In France submarine out-falls have been constructed mainly in the Mediterranean. In contrast, along the Atlantic coast the policy has been to construct treatment plants.
- **USA**
  Prior to 1970, marine disposal of sewage and sludge was regulated under the 1899 Rivers and Harbours Act. During this time, water pollution control efforts emphasised water quality-based treatment requirements for municipal and industrial discharges into major river basins and focused on the control of conventional pollutants, BOD in particular.

  Recently, it has been the policy of the EPA
  - ⇒ to protect the oceans from the significant adverse effects of waste disposal. EPA will, therefore, not allow the oceans to be used as a "cheap„ alternative for the disposal of ETP sludge or other wastes;
  - ⇒ to allow ocean disposal of ETP sludge only when there are no practicable, land based alternatives that have less impact on the total environment; and
  - ⇒ in the long run, to encourage environmentally beneficial approaches to ETP sludge management including minimisation and recycling.

- **Environmental Impacts**

The most significant effect arises at the sea bed where sludge particles settle and may include accumulation of carbon, pathogens and other microflora and persistent substances, deoxygenating of sediments and changes in benthic animal communities. There are four aspects of particular interest; the organic content, the microbiological content, nutrient enrichment and the content of persistent materials such as metals.

However, in nearly all marine regions used for sludge disposal, impacts on the eco-system can be observed. In Australia, for example, beach pollution and degradation of sea-grass have been reported.

In the United States evidence is documented for five kinds of major problems:

⇒ widespread toxic contamination of fish and shellfish
⇒ eutrophic conditions and hypoxia over thousands of hectares of coastal waters,
⇒ widespread pathogenic contamination of fish and shellfish as well as thousands of reported cases of gastrointestinal infections of persons consuming pathogen-contaminated fish and shellfish
⇒ loss of, or adverse changes to thousands of hectares of essential marine habitat each year at an increasing rate of loss, and
⇒ loss of living marine resources, such as substantial declines in recreational and commercial fisheries, as well as threatened and endangered birds and animals.

Tannery Sludge

Marine treatment is normally not an option for a single tannery. Marine treatment together with municipal sludge and effluent is applied in UK and in Australia. No further requirements or applied standards are known. In principle, the same problems as with treating of municipal sludge appear: Main problem are the accumulation of heavy metals and the disturbance of very sensitive micro Eco-systems.

5.4.2 Landfill

Land-filling has been traditionally accepted as a viable, albeit difficult disposal method. However, increasing concern about environmental protection and increasing emphasis on the re-utilisation of waste material has led to a steady reduction of landfill in Europe and the United States. In some European countries regulations are already under preparation which will exclude completely untreated sludge from landfill. However, landfill will remain an important disposal option.

With respect to **tannery sludge** landfill is recently the most applied disposal method. For instance in Germany about 90% of the sludge produced by tanneries is dumped in landfills. The design of the sites depends on the classification of the tannery sludge. Main criteria for its classification as harmful or not are the eluate test (mainly in Europe), or certain limit values for toxic elements (e.g. USA).

Landfill sites are restricted to areas where the contamination of ground and surface water is excluded and where the buried wastes are adequately isolated from the environment. Thus, typical areas excluded are:

- flood plains,
- wetlands,
- mountains areas with slopes exceeding 20%
- very flat areas with slopes below 1%.

Landfill sites are difficult to erect in areas with high precipitation rates because it is essential to divert all surface water from the site. Site geology should include a clay soil extending 6 m above bed rock. The cation exchange capacity of the soil should be more than 15 meq/100g and soil permeability should less than 10^{-6} to 10^{-6} m/sec (depending on county). Local aquifers should be isolated. The gradient and quality of the groundwater system should be determined and wells installed to monitor change in groundwater quality.

Co-disposal landfill is a mixing of sludge with solid waste prior to disposal. Most wet sludge is not suitable for sanitary landfill, however under normal conditions a sludge de-watered to at minimum 20% ds can be land-filled. If the solid content is higher than 30%, the material can be added directly into a landfill. Tannery sludge should be de-watered to a minimum of 30 - 35% ds before landfilling in order to meet the physical stability requirements. Spreading with some refuse mixing is preferable to avoid large pockets of sludge in the fill. The sludge can be dumped near to the operating face of the fill, so the operator can mix portions of sludge into the stream of refuse. This ensures a reasonable sludge-refuse mixing. If the solid content is lower than 30% refuse mixing or sludge spreading is mandatory.

Another problem associated with **tannery sludge** is malodour. It can be reduced by proper site selection and proper operation.

Sludge only landfills can be constructed using any of the three basic techniques: trenching, area filling or diking. Trenching can be performed with narrow or wide trenches and area filling can be performed by mounding or layering. The selection of a particular construction technique is determined by site characteristics and sludge moisture content.

Table III/5-1: Sludge and site conditions for landfill

Method	Sludge Moisture Content (%)	Sludge Charac-teristics	Hydrogeology	Ground Slope (%)
Narrow Trench	72 - 85	Unstabilised/ stabilised	deep groundwater and bedrock	<20
Wide Trench	<80	Unstabilised/ stailized	deep groundwater and bedrock	<10
Area Fill Mound	<80	Stabilised	bedrock	suitable for steep terrain as long as level area is prepared for mounding
Area Fill Layer	>85	Unstabilised/ stabilised	bedrock	suitable for medium slopes, but level ground is preferred
Diked Containment	>80	Stabilised	bedrock	suitable for steep terrain as long as a level area is prepared inside dikes
Sludge/Refuse Mixture	>97	Unstabilised	bedrock	<30
Sludge/Soil Mixture	>80	Stabilised	bedrock	<5

Source: Jenkins, J.

The **narrow trenches** are less than 3 m wide and are used for sludge with moisture contents of 85% or less. Final cover of the trench is usually 1 - 1.2 m of earth taken from stockpiles left by the initial trenching. Narrow trench land-filling is particularly well suited for sites with steep slopes. A relatively large amount of land is unusable because the equipment must work from undisturbed earth.

Wide trench landfills use trenches 3 - 12 m wide. This technique is used for sludge with a moisture content below 80% and preferably below 75%, because working equipment must be moved over the filled sludge to spread, compact and cover it. Final cover on wide trenches ranges from 1 to 1.5m and are taken from stockpiled earth, too.

The **area fill** technique is best used with sludge having moisture content lower than 80%. The sludge can either be mounded in individual cells or alternately layered and covered. The layers or mounds are normally covered by 4 to 5m of soil. Normally, for both mounding and layering, the sludge is mixed with soil to enable vehicles to operate on it. Soil mixtures have varying make-ups depending on the type of soil and the moisture content of sludge. Area filling is best suited to areas with fairly levelled terrain. Final cover should be between 1 and 1.5m.

Dike disposal is a modification of the area fill technique. A dike is constructed around a levelled area, filled with sludge and covered with about 1m of soil. Moisture content in the dyke fills should be less than 80%.

General Engineering aspects are compiled in Annex 2.

Tannery Sludge
Landfill of tannery sludge is the most wide-spread treatment used in western countries. For instance in Germany about 90% of tannery sludge is dumped in landfills. Depending on the amount of unfixed chromium, tannery sludge is either considered as being a hazardous waste or a waste which can be dumped at or together with normal household refuses. The design, the monitoring system, and finally the cost of the landfill site are highly influenced by this final treatment category. Stabilisation and de-watering of the sludge to about 30-35% ds prior to dumping is essential in order to reduce odour problems and to meet the physical stability criteria of the landfill site.

Odour problems can be also reduced by proper site selection taking into consideration main wind directions and housing areas and by proper operation (fast mixing, spreading and covering of the sludge).

Landfill sites require in-depth investigations with regard to geology, hydro-geology and hydrology. In areas with high precipitation rates and shallow groundwater levels (e.g. in coastal areas or river plains) site selection will definitively be difficult.

Landfill as an ultimate option should be always considered as second priority after seriously investigating possibilities of reutilization.

5.4.3 Land application

Utilisation on land is usually one of the main disposal options for municipal sludge. Spreading of sludge relatively thin on land means that it is not left to accumulate on site where it might represent a potential source pollution in future.

Sludge contains nutrients and organic matter that can be utilised beneficially for growing crops. The organic matter can maintain the humus content in soils. Due to the presence of lime residues, this sludge can help to neutralise acidity in soils. Main advantages are:
- the changing legislation encouraging the recycling or reuse of waste materials,
- the discontinuation of ocean dumping,
- increased energy cost for incineration,
- the difficulty encountered in locating suitable land fill sites
- the application of stabilised sludge to farmland competes well with other sludge management options
- the nutrient content of sludge makes it a good low-analysis fertiliser for crop production.

Main constraints for the utilisation of **tannery sludge** in agriculture are directed towards chromium. The up-taking and enrichment of chromium by plants and the toxicity of chromium in its various forms has been studied world-wide in recent decades. Reviewing the comprehensive literature the following conclusions can be drawn:

- In contrast to chromium VI the toxicity of chromium III is not justified (it is also an important trace element for human beings). The oral toxicity of chromium III-complexes for rats is about 1,900 - 3,00 mg/kg life weight.
- Chromium III is under normal conditions stable and insoluble and often fixed (absorbed) within organic hums and inorganic clay mineral complexes, or fixed within iron oxide complexes. The solubility has been found very low in 1 or 2 mg per litre under neutral conditions . Chromium VI did not occur due to the reduction capability of the organic complexes. Solubility and transformation can be controlled by liming the soil (a minimum pH value of 6 is recommended) and by observing specific limits based on permissible addition of sludge borne metals on land together with maximum acceptable soil concentrations of elements.
- the application of sludge increases the yield independent of the presence of chromium. Sludge acts as natural slow fertiliser over the whole growing period.

However the rising awareness of the population has led to a steadily increasing pressure on the political decision-makers to establish limit values for chromium application. Most of the limits established to not distinguish between the chromium forms. The uncertainty is also reflected by the wide variation of maximum tolerable values established (compare Table III/5-2). An extreme situation can be found recently in the USA where due to a court decision no chromium standard exists.
It should be pointed out, that chromium standards for agricultural utilisation can be achieved only where separate treatment of chromium containing waste water streams is carried out.

In Germany about 10% of the tannery sludge is used in agriculture either by direct application or after composting.

With respect to chemical contaminants, waste water sludge contains higher concentrations of a variety of potentially toxic elements than do most soils. When sludge is applied to soil, these elements tend to accumulate in the cultivated layer and adding of sludge must be regulated so that soil concentrations of potentially toxic elements never reach levels which could be toxic.

Table III/5-2: Comparison of sludge re-use standards for chromium

Parameter	Denmark	France	Germany	Netherlands	Belgium	Norway	Sweden	Switzerland	Engl.&Wales	USA
Maximum permissible concentration in soil (mg/kg	100	150	100	100*	150				600	No limit
Maximum permissible concentration in sludge (mg/kg) ds	100	1 000	900	500	500	200	150	1 000		No limit
Suggested annual loading limit for Cr (kg/ha/yr)		6.0	2.0	1.0	2.0	0.4	1.0	2.5		No limit
Maximum recommended loading for metal (kg/ha)		360	210	100		4			1 000	
Maximum sludge solids loading (t/ha)			167	200		20	5 in 5 years			
Suggested maximum annual sludge solids application /t/ha)	1.5	3.0	1.7	2 (arable) 1 (grass)		2	1	2.5		
Minimal application period (yrs)	20		100	100		10	5		30	
Minimal soil pH		6.0							6.5 (arable land) 6.0 (grass land)	

* : varies according to clay content, e.g. 50 + (2*%clay) = max. permissible soil Cr concentration

Source: Williams (1988), revised

The development of accumulation of harmful substances in the upper soil layers can be demonstrated in the Braunschweig treatment facility in Germany (Lower Saxonia) where sewage water has been spread on the same land since 1896 by using sprinkler irrigation. The development of main heavy metal loading is compiled in Table III/5-3.

Table III/5-3: Development of heavy metal concentrations in soils

	Under irrig. since 1957 mg/kg ds	under irrig. since 1966 mg/kg ds	German soil standards mg/kg ds	German standard for annual appl. kg/ha and year
Pb	23.7	4.8	100	2.0
Cd	0.9	0.02	3	0.033
Cr	6.0	1.7	100	2.0
Cu	8.8	0.1	100	2.0
Ni	6.0	2.0	50	0.33
Zn	51.5	2.0	300	5.0

Source: Boll, Kayser (1987)

5.4.3.1 Application technologies

Application of sludge can be done in various ways, with and without pre-treatment and processing. Thus, for example, composting, liming, drying are processes where final products are also applied to land. As these methods are described later, the following land application deals with the application of sludge on land only.

Land disposal of wet sludge is done by using spraying, flooding, ridge and furrow, spreading by tank truck and subsurface injection. The quantity of sludge that can be applied to farmland on a yearly basis is generally based on nutrient loading made to supply all or part of the N and P needs. In the long-term, the total quantity of sludge that should be applied to the soil at land application site will be limited by the total metal loading.

Tannery sludge is normally applied on farm area in solid form. Irrigation is not common due to problems caused by odour and salinity. An example of satisfactory disposal of **tannery effluent including sludge** on land has been reported by PARKER (1959). Lagooned waste water from a tannery at Acton, Ontario was disposed of by spray irrigation on 90,000 m^2 and by the ridge and furrow method on another area of 30,000 m^2. The average rate of irrigation has been about 12 mm per day for the ridge and furrow method, the rate for spray irrigation being somewhat higher. The advantage of the ridge and furrow method lies in its ability to handle waste toxic to vegetation. Also, it can be operated for a period somewhat longer than is possible with spray irrigation. The land was cultivated to a depth of 45 cm before cutting furrows with a heavy plough. After commencement of irrigation, the land was subsoiled three or four times in a season. The land was occasionally ploughed deep to a depth of about 1m. Even after the 30-year period during which the ridge and furrow method of irrigation was practised, no problems were encountered.

5.4.3.2 Application of industrial sludge on land

In most of the municipal waste water treatment plants industrial effluents are included to a certain degree. The application of pure industrial sludge on land is reported from Jackson, Michigan, where a low-rate application of sludge was developed and introduced, from Brasilia where **tannery sludge** have been used in fresh and composted condition, and from Canada. The Brasilia investigations indicated that **tannery sludge** can be either raw or composted applied to farmland. No negative impacts of chromium have been observed. Whereas the yield could be increased. Similar results are reported from various tests and research works from different countries.

5.4.3.3 Application of forest land

Sludge disposal on forest land is practised sparingly at the present time but is of considerable interest and is likely to increase in the future. It is perceived by the public to be preferable to application on agricultural land, because very little forest vegetation is included in the human and animal food chain. Experiments conducted in Denmark, France, the Netherlands, and the USA indicate that it generally results in greatly increased tree growth. Draft guidelines for sludge utilisation on forest lands in the USA have recently been prepared. Sludge application rates must be regulated to avoid nitrate-nitrogen contamination of groundwater and long-term application may be detrimental to conifers due to increased soil pH, increased mineralization of the humus ground cover and increased danger of root rot

Tannery Sludge

Land application of tannery sludge is limited by its chromium content and can be applied only in case chromium containing waste water streams are treated separately. Besides, main limitations in Europe are contents of nutrients which should not exceed the annual withdrawing by the vegetation.

Despite the fact that in the United States, where no chromium limits for land application currently exist, most states have their own chromium standards dealing either with maximum soil concentrations or with maximum rates of addition of potentially toxic elements. In Germany, the standard is 900 mg/kg ds of sludge respectively 100 mg/kg ds of soil. The Chinese standard for application of sludge on land is 1,000 mg/kg ds.

However, for example a sludge chromium concentration of about 500 mg/kg ds, an annual application rate of 5 t ds per ha, a specific soil weight of 3,500 t/ha, and a natural concentration of 50 mg/kg ds leads to a threshold of 1,000 mg/kg Chromium (ds) will be reached after 70 years, only.

Extensive field tests have been carried out in various countries with tannery sludge using raw and composted sludge with high chromium contents. The results indicate no negative impacts of chromium and remarkable positive impacts of the sludge on crop growth and yield.

Sludge from tanneries can be hauled and disposed of on cropland by using adjusted agricultural standard equipment. Monitoring of application, sludge and soil characteristics are mandatory.

5.4.4 Thermal processes

Under this sub-chapter important technologies dealing with thermal treatment are briefly described. In general all technologies can be applied to **tannery sludge**. There will be an increasing trend towards the combustion of tannery sludge due to the increasing cost for landfill. For China it seems currently not an economically feasible option to construct own combustion plants. Co-combustion in already existing or newly constructed plants might be feasible.

5.4.4.1 Combustion

High temperature processes have been used for the combustion of wastewater solids from municipal and industrial plants since the early 1900s. Popularity of these processes has fluctuated greatly since their adoption from the industrial combustion field. In the past, combustion of wastewater solids was both practical and inexpensive. Solids were easily de-watered and the fuel required for combustion was cheap and plentiful. In addition air emission standards were virtually non-existent.

In today's environment, waste water solids are more complex and include sludge from secondary and advanced waste treatment processes. This sludge is more difficult to de-water and thereby increases fuel requirements for combustion. Due to environmental concerns with air quality and high costs, the use of high temperature processes for combustion of municipal solids is being scrutinised.

However, recent development in more efficient solids de-watering processes and advances in combustion technologies have renewed the interest in use of high temperature processes for specific applications. Their advantages are summarised as follows:

- maximum volume reduction. Reduced volume and weight of wet sludge cake by approximately 95%, thereby reducing disposal requirements.
- detoxification. Destroys, or reduces toxins that may otherwise create adverse environmental impacts.
- energy recovery. Potentially recovers energy through the combustion of waste products, thereby reducing the overall expenditure of energy
- Waste solids reduced to ash on-site
- Ash represents about 10% by volume of the de-watered sludge at 30% ds
- Combustion destroys all pathogens and can completely oxidise toxic organic
- Combustion renders heavy metals less soluble during sludge oxidation
- Combustion is a long-term disposal means that will fully protect land and water resources
- Properly applied and designed (or upgraded) combustion systems are cost effective
- Air quality concerns can be addressed using state-of-the-art equipment.

Combustion takes advantage of the energy content of sludge. 1 kg of dry substance may have an calorific value of 12 - 19 MJ (about 7 kWh). The heat content of wastewater solids, when dried, is in the range of low-grade (rank) carbonaceous fuels such as peat or lignite coal. The energy usually is gained by the following methods of sludge burning:

- fluidised bed incinerators
- multiple hearth incinerators
- rotary kilns
- kilns together with waste.

However, waste water sludge generally contains higher quantities of volatile matter and lower fixed carbon contents.

Some of the problems associated with combustion are the high costs of pre-treatment (de-watering) and the traditional need for an auxiliary source of fuel to sustain combustion, although adequate de-watering to an excess of 30 to 35% of volatile solids should ensure autogenous combustion. Mixing sludge with other combustible urban wastes is another way of achieving autogenous combustion.

5.4.4.2 Combustion of wet sludge ("Enersludge"-Process)

The combustion of wet sludge was especially designed for industrial sludge. First experiences were gained with **tannery sludge**.

The process of combustion of wet sludge was developed in Canada and Australia under the treatment "Enersludge„ process. The method uses a two-stage reactor, with the main elements comprised of the following:

a. mechanical de-watering of sludge;
b. sludge drying;
c. reaction process;
d. combustion;
e. exhaust gas cleaning.

In the first stage, the sludge is mechanically de-watered to form a cake of about 35% solids. This is then thermally dried using hot gases to form a granular dry product, with a solids content of approximately 95%.

This dry material is then fed into a patented two-stage reactor where it is heated to 450°C in the absence of oxygen, causing breakdown of the carbonaceous component. The gases from this process are cooled in a condenser to remove oils and water for separation by centrifuge, leaving the non condensable gases as a fuel for the operation.

The solid residue remains in the form of a char, for complete combustion with the gas in the combustion/hot gas generator. The heat produced in this combustion stage is sufficient for hot gas drying the in-feed of mechanically de-watered sludge and heating the conversion reactor.

The temperatures attained in the combustion chamber are normally sufficient to oxidise metals to insoluble oxides, generally disposed of as part of the insoluble ash. First tests with tannery sludge showed that, due to the reductive conditions in the conversion reactor, the conversion process will not produce dichromate. Removal of the char before combustion at high temperature, with the volatile, can avoid this potential problem and provides an advantage over conventional incineration, leaving the low volume solids for landfill.

The significant features of the "Enersludge„ process, as compared to direct incineration, are the valorisation of organic under oxygen free conditions, and that the combustion chamber is fed with dry fuels instead of mechanically de-watered sludge. In addition the process maintains the chromium in the three-valent form thus excluding handling problems with the ashes.

The oil produced from the conversion process can be used as boiler fuel and is said to be suitable as a fuel for diesel engines. Ash is low volume and has been used as sand replacement in concrete manufacture. Emissions such as SO_2 are stated to be as low as 50% of that of conventional incineration and Nox can be reduced to nitrogen by injection of ammonia solution into the combustion/hot gas generator. The conversion process also reduces the quantity of exhaust gases generated and the needs for higher levels of air pollution control equipment are greatly reduced.

The minimum economic size for the plant is currently about five tons/day.

5.4.4.3 Sludge calcinization

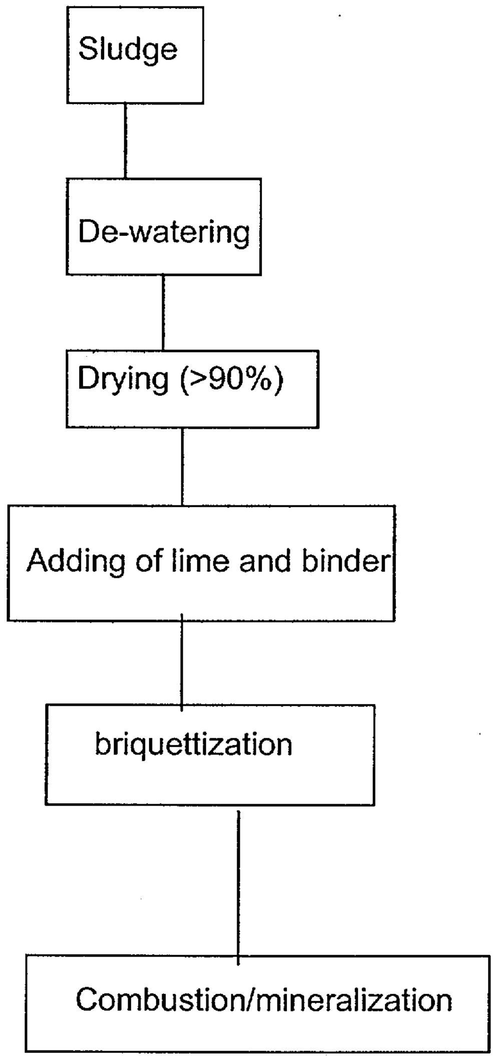
Calcinization is one sub-order of combustion technology. The process includes the drying of sludge and combustion by the adding of lime. The principle flow chart is shown in Figure III/5-2.

The lime has several functions:

- to neutralise the sludge
- it acts as flux thus lowering the melting point
- permits the absorption of heavy metals in mineral complexes.

The mineral residual has sand-like characteristics and can be used as a filling and construction material. The advantage of this process is that all organic pollutants are destroyed, due to the high combustion temperature, and the heavy metals are fixed in mineral complexes.

Figure III/5-2: Calcinisation of sludge - flow chart



Source: own compilations

5.4.4.4 Pyrolysis

The principle of pyrolysis is the chemical destruction of organic matter under the absence of oxygen. Final products are gas, oil, water and residuals. The respective amounts depend on the sludge characteristic and composition and the process concept.

Pyrolysis has the following advantages against combustion:
- low flue gas volume to be cleaned
- production of gas and/or oils with high calorific values to be burned or used for chemical purpose
- enrichment of heavy metals in the pyrolytic residue (coke) which might be treated in special designed incinerators without harm to environment.

The use of coal and wood to produce energy (heat or power) via pyrolysis-gasification processes has been practised since the 18th century. The new generation of gasification technology is directed mainly toward production of medium to high energy gas or production of synthesis gas by using sludge beside traditional fuels. To date, only small-scale, low energy gas biomass gasifiers have been commercialised world-wide.

The process of pyrolyse is divided by temperature in three groups:

- low-temperature-process: <350°C with oil and solid residuals as final products
- medium temperature process: 350 - 850°C with gas as main product
- high temperature process: >850°C

As final products one receives gas, oil, water and residuals, whereby the portions are varying with temperature (Table III/5-4).

Table III/5-4: Pyrolyse technologies

	Unit	University of Tuebingen	waste water technology centre Canada (pilot plant)	University of Hamburg
max. discharge				
- pilot plant 1	kg/h	0.05 - 0.25	1	3
- pilot plant 2	kg/h	5 - 10	40	25 - 30
optimal temperature	°C	280 - 320	450	670 - 760
Duration	Minutes	10 -20	10 - 24	---
Sludge water content	%	10 - 15	4 - 7	1 - 2
final products		Based 10-20% water content	based on ds	Based on organic ds
Oil	% of weight (x)	20 - 27	20.8 - 25.4	27.7 - 1.7
Solid residuals	% of weight	60 - 70	52.5 - 65.6	32.4 - 10.3
Gas	% of weight	approx. 5	10.3 - 14.8	76.8 - 33.7
Water	% of weight	7 - 15	5 - 13.1	15.6 - 0.9
Foreseen utilisation				
Oil		Fatty acids	?	Aromates
Solid residuals		combustion	combustion	disposal
Gas		combustion	combustion	combustion

Source: Kassner (1990)
Remarks: (x): % of weight of final products.

The most promising technology was developed in Germany (University of Tuebingen) using a very simple process to convert sludge to oil and char. The process comprises heating of dried sludge to 280 - 320°C in an oxygen free environment for about 10 - 20 minutes. The yields range from 20 - 27% for oil and 5% of gas. Energy balance calculations indicate that the process is a net energy producer provided that the sludge is mechanically de-watered to about 20% solids. It has been estimated that a net energy production of 10-15 kJ/kg could be demonstrated at full scale. The method has been successfully tested at laboratory scale in Canada.

Due to the lack of experience in full-scale operation an exact cost cannot be given. Optimistic assessments are in the order of 200 US$/tds. Revenues for oil and gas are estimated at being even higher.

Tannery Sludge

Combustion is still one the most expensive ways of sludge treatment. It requires, in addition, a high skilled manpower and know-how. Otherwise, the problem of heavy metal contamination will be transferred from the water to the air and to the solid residuals. Due to the high capital cost, combustion is not a solution recommendable to single tanneries, especially in China where control and monitoring of those plants are not guaranteed to the necessary extent and where appropriate regulations are still lacking.

Co-combustion of tannery wastes and sludge might be a favourable solution in case proper operated plants are available in reasonable distances.

In addition, current research studies funded by the European Commission indicate that the ashes also contain remarkable amounts of 6-valent chromium. Thus, the ashes cannot be used in further processes, but have to be handled as toxic waste. An interesting approach is the recovery of chromium from the ashes which is still under research.

The **"enersludge„** process (compare chapter III/2.6.1) was applied to tannery sludge. A first plant at a full-scale is planned to be erected in Germany. No further information is available yet.

Sludge **calcinization** might be one possibility to use the energy and solid matter content in the sludge. First trials have been carried out in Italy and Germany. Any further investigation should be bound on a market survey with respect to the final product.

Pyrolysis includes relatively new process developments which are based on technologies well known for some time. However, with respect to the increased environmental requirements and the competition of the resulting product with similar products from other sources, a highly sophisticated technology and operational know-how is required, which cannot be easily provided by a tannery. However, tannery sludge seems to be suitable for being processed in a pyrolysis plant.

5.4.5 Sludge drying

Sludge drying as either pre-stage for further processing as combustion or for obtaining a marketable product is increasing in practice, especially in the United States where the sludge is mainly used to produce an improved combustion feed or a fertiliser product. The most marketable dried sludge is in hard pellet form. The value can be enhanced by the addition of nitrogen (N), phosphorous (P), and potassium (K).

Evaporation of sludge water requires a high energy supply. Heating of water from 10°C to 100°C requires 377 kJ/kg energy. Transformation of 100°C hot water into vapour needs another 2.261 kJ/kg. Thus, for evaporation about 6 fold of the energy of heating is required. Some of the energy can be recovered by different technologies but still 1 kWh per kg of water is required for evaporation. Consequently, mechanical de-watering seems to be an imported step in order to reduce energy consumption.

The total energy requirement depends on:
- sludge characteristics
- type of dryer
- starting water content
- final water content
- heat recovery system.

The type of drying must be chosen according to the further processing steps applied. Drying objectives are:

- **Part-Drying:** e.g. at 78% ds It is sufficient for sludge disposal or combustion in Fluid Bed Reactor. The material is not stockable due to biological processes starting after few days.

- **Full-Drying:** At 90-95% ds is only achievable with higher technical and financial efforts. The material obtained can be handled with all existing ways of final disposal as agriculture or direct combustion, also together with refuses. It can be easily stored. A connection to a bio-gas technology seems to be reasonable. Thus, 1/3 to 2/3 of the energy can be covered by the bio-gas plant.

Tannery Sludge

Sludge Drying is only feasible as pre-step for further heat processing (combustion, calcinization) or in case landfill cost can be adequately reduced by lower volumes. For China, the process seems to be too expensive taking into account the lower cost for landfill and the lower restrictions due to land application. It may be an economically feasible solution in case of co-drying; thus using an existing plant on lower cost

Drying, in order to obtain a marketable product, appears also not be competitive.

Experiences with tannery sludge are available with pilot plants in Italy and with first tests in Germany indicating that no special problems are to be expected when dealing with drying of tannery sludge. Lime stabilisation should be avoided because the sludge obtains a stickier characteristic which influences the feeding pumps and the drying efficiency.

5.4.6 Composting

Composting is a process by which organic matter is destroyed by biological activity (biodegradation).
The composting process is primarily facilitated by a high concentration of biodegradable organic material in the compost matrix and an active microbial population. Secondary enhancers of microbial activity include moisture, inorganic nutrients, and oxygen. Under these favourable conditions microbial metabolism is released in the form of heat. Increased temperature serves to further increase the metabolism rate up to approx. 60°C at which point the pasteurisation process begins.

The requirements of the compost process are:
- A proper C/N ratio should be provided. A 30/1 ratio is adequate in most cases
- The mixture should be between 50-69% moisture
- The mixture should be sufficiently porous to allow for adequate aeration
- The mixture should be arranged in a way to allow for sufficient heat retention to attain thermopile temperatures in the range of 55-65°C
- The waste should contain a readily available carboneous substrate.

Composting of sludge leads to a stable product which is sold as fertiliser and soil conditioner. It has received more and more attention during the last years in nearly all industrialised countries. The main reasons for this can be seen in the trend towards re-utilisation of waste, rather than final disposal and in the considerably increasing quantities of sludge to be dealt with.

Composting technologies have been developed specially in the United States and in Europe. One of the major concerns and economic factors involved in the decision to compost is the existence of an adequate market for the final product. Consequently, the main emphasis was on a comprehensive marketing concept including trade marks and quality assurance systems especially, in Germany and the States.

Sale or give-away of bagged or bulk, processed sludge (composted, heat dried, etc.) has been practised in many countries. Frequently, the processed sludge is given a proprietary name such as „Milorganite„, „Philorganic„, „Compro„, etc. and in some cases it is fortified with inorganic fertiliser to enhance its nutrient, particularly nitrogen, content.

Due do its low capital cost, the easy process control, the availability of humus and nutrient contenting soil material for soil improving, and the low level of mechanisation, composting seems to be highly favourable, especially for developing countries.

Utilisation of compost varies with location of the facility, heavy metal content of the compost, and compost uses in the locality. It has been used to build parkland, re-vegetate/re-plant disturbed/mined land, grow food crops, grow horticultural crops, grow nursery crops and used as a top dressing on various crops.

Composting of tannery sludge is performed for about 10% of the tannery sludge produced in Germany. It is applicable in case separation and separate treatment of waste water streams is carried out (which is mandatory due to German regulations).

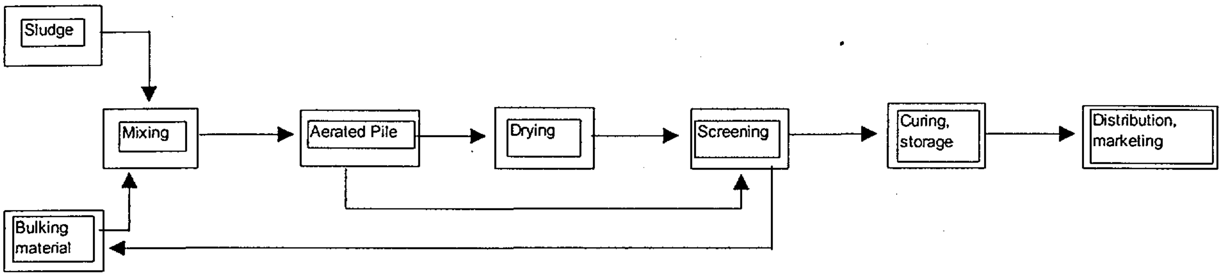
5.4.6.1 Composting technologies

The most basic form of composting technology may be termed as uncontrolled **static pile**. In this process, the mixture to be composted is formed into a pile and essentially left to nature to take its due course.

The next technological level is the **windrow** which is commonly used in waste water sludge composting. The mixture to be composted is formed into one or more long rows. Periodically, the mixture is manually turned to promote aeration and to increase the contact between bio-mass and organic contaminants.

The **aerated static pile** features a built-in aeration system that serves to provide oxygen and also to remove excess heat from the matrix. A typical aeration system consists of a series of perforated pipes that are laid out in a grid form and attached to a mechanical blower. The mixture to be composted is placed on top of the grid. Periodically, the blower is turned on and air is either forced or drawn through the composting mass. In actively composting material, much more air flow is required to remove excess heat than is required to provide adequate oxygen tension. Therefore, it is advantageous to connect the blower to a temperature feedback system that automatically activates the blower when the compost temperature reaches a specified level.

Figure III/5-3: Flow chart of aerated static pile system



Source: Own compilations.

The highest technological level of composting is known as **reactor composting**. In this process, the material to be composted is placed inside a large containment which is equipped with a temperature controlled aeration system. This system provides optimal physical conditions and prevents the material against climatic influences.

The two systems mainly used in North America are the windrow and the aerated pile. Enclosed systems are more common in Europe. In Germany **sludge from tanneries** is composted by using the windrow system, whereas in municipal composting systems also reactor composting is applied.

A variation on sludge composting is employed in the Netherlands to produce "black earth„. Sand or peat is mixed with sludge and the mixture is composted in windrows. The heavy metal content of black earth is regulated and it is recommended for use as a soil replacement, however, research into its hygienic quality is ongoing.

Sludge for composting is generally de-watered to 16 to 30% ds by use of vacuum filters, centrifuges or filter belt press. Thus, in order to meet the biological criteria for aerobic composting, a bulking material is added as required.

- **Sludge characteristics**
  The suitability of sludge for processing into compost depends on the characteristics of the wastewater and on treatment process. The composting process is not sensitive to added chemicals or pH and operation procedures can be adapted to a wide range of sludge solids and sludge stabilisation levels. Heavy metal analyses are needed to assess the marketability of the compost.

  Typically analysis of sludge are presented in Table III/5 - 5.

Table III/5-5: Sludge composting (Blue Plains Washington D.C.)

Component	Dewatered Sludge	dewatered Sludge Compost	Digested Sludge	Digested Sludge Compost
pH	9.5	6.8	6.5	6.8
Water (%)	78	35	76	35
Organic C (%)	31	23	24	13
Total N (%)	3.8	1.6	2.3	0.9
NH_4-N (ppm)	1 540	235	1 210	190
P (%)	1.5	1	2.2	1
K (%)	0.2	0.2	0.2	0.1
Ca (%)	1.4	1.4	2.0	2
Zn (%)	980	770	1 760	1 000
Cu (ppm)	420	300	725	250
Cd (ppm)	10	8	19	9
Cr (ppm)	1 230	230		
Pb (ppm)	425	290	575	320
PCBs (ppm)	2.4	0.17	0.24	0.25
BHC (ppm)	1.22	0.1	0.13	0.05
DDE (ppm)	0.01	0.01		0.008
DDT (ppm)	0.06	0.02		0.06
total coli (100g)	$43*10^8$	in 7 samples found		
fecal coli (100g)	$32*10^7$	in 4 samples found		
fecal strepto (100g)	$33*10^7$	in 3 samples found		
		No salmonella, shigella, yersinia entercolizia in 97 samples		

Source: Willson, G.B. (1983), Nett et al (1983)

Remarks: dewatered sludge: Sludge from ETP only mechanically dewatered
dewatered sludge compost: Compost mode of the sludge described alone
digested sludge: Sludge pre-treated in a digester
digested sludge compost: Compost made of sludge described alone.

- **Site selection**

  The key site requirements are a hard working surface and an ability to convey and treat runoff, leachate and condensation. Leachate can be avoided by proper bed design, and the design of the aeration system. Condensation is produced at the rate of approx. 12.5 l/ton. Thus, the low volumes are not a disposal problem.

- **Mixing**
  The mixing process, including the correct bulking material ratio, is an important and crucial aspect of the process. It is necessary to obtain a homogenous mix. The mix structure should be friable to allow proper aerobic composting.

- **Bulking agents**
  Bulking agents are necessary in order to adjust the C/N ratio to an optimal degree and to improve volumes of water and air pores.

  Numerous bulking agents have been used. Several considerations need to be taken into account when selecting bulking agents especially availability, alternative uses which may effect market prices, reuse efficiency and product enhancement. Sludge which are low in volatile solids, either due to digestion or to the addition of chemicals, may need the bulking agent to provide the necessary carbon.

  Bagasse which was used as bulking agent in Puerto Rico can also be utilised as an energy source. Similarly, rice hulls used in California are a potential energy source. Wood-chips, which are a predominant type of bulking material, are used both for pulp and paper and energy. On the other hand brush chips are a waste product and as with leaves represent a costly disposal problem in many communities. Grass clippings, water hyacinths and plantain skins all of which are wastes have been used experimentally in Puerto Rico. Other bulking materials are saw dust, waste paper, and straw.

  There is a considerable interest in using shredded rubber tires, since this product can be indefinitely recovered and recycled. They can easily be used as a substitute for some of the wood chips (ratio 1:1:1). However, shredded tires in contrast to other bulking materials can increase the heavy metal content of the compost.

- **Stacking**
  Traditionally the aerated composting piles are constructed by front-end loaders. Since the bulk density of the mix or sludge below 1,180 kg/m3 an oversized bucket can be used.

- **Aeration**
  Aeration systems consist of flexible, disposable plastic pipes or rigid plastic and metal pipe laid on the surface or imbedded into the compost pads. Most operations use the flexible pipe. It may also be built into the concrete pad. The blowers are individually designed in order to safe energy and allow more flexibility. The rate of aeration is commonly about 9-15 m^3/hr/dry ton. Oxygen levels between 5 and 15% should be maintained. It is desirable to achieve a 15 to 20% moisture reduction during the composting period in order to obtain a screenable product. Thus, a mixture of drawn and forced aeration achieves both uniform thermophilic temperatures and sufficient drying for easy material

handling. The mix prior to stacking should not exceed 60% moisture as the blocked pores will reduce airflow and aerobic conditions. Reversing the fan from suction to blowing after 10 to 14 days will achieve a dry material which usually can be screened.

- **Screening**
  This process removes the bulking material for reuse as well as produces a uniform attractive product.

A few typical examples for composting of sludge from the United States and from Germany are described below.

5.4.6.2 Forced aeration composting in USA

Blue Plain wastewater treatment plant at Washington D.C. has undertaken a large scale project to compost approximately. 300 tons a day of raw sludge using the forced aeration static pile method.

Sludge is first mixed with wood chips as bulk agent in a ratio of 2:1 by volume. The pile is built to a height of 3m and covered with a 0.5m thick layer of previously composted material. The blowers are controlled by a timer on a 15 minutes on-off-basis. The discharge is directed into a scrubber pile of finished compost, which absorbs any odours. At the end of aeration stage, of at least 21 days, the moisture content is generally in the range of 55-58% moisture. Curing is added for another 30 days. After curing, the material is screened.

The **US department of agriculture at Beltsville Maryland**, in co-operation with the Maryland Environmental Service has developed an aerated pile method for composting of either undigested or digested sludge. The methods transform sludge into usable compost in about 7 weeks, during which time the sludge is stabilised, odours are abated and human pathogenic organism are destroyed.

The **Metropolitan Denver Sewage Disposal District No.1** provides secondary treatment for an average of 6.13 m^3/sec. These treatment operations generate approximately 72 tons dry sludge daily. The district decided to construct and operate a 9 dry ton per day composting demonstration facility. The major features are:
- paved composting and mixing area covers 2.4 ha
- 15 aerated windrows each 76m long
- covered 50m*80m composting area that shelters six windrows
- collection and detention pond for storm water, leachate and condensation.
- truck scale and operations centre, and
- weather station.

Composting of **sludge from tannery** effluent treatment is carried out at Eagle Ottawa plant in Grand Haven, Michigan, USA. The sludge generated in its own treatment plant is high in solids, biodegradable and with acceptably low chrome levels as chrome separation/precipitation is carried out before sending water to waste treatment. With the sludge high in nitrogen, low in chrome and proven as an excellent soil conditioner, an alternative to landfill was possible, and this path has been taken by the company. The settled solids from biological treatment are mixed with the solids from primary clarification, then fed to four recessed plate filter presses for de-watering.

Composting is carried out in a special composting farm. The composting building is a steel and concrete structure 210m long, 25m wide and 14m high. On delivery, the filter cake is mixed with straw and other amendments to give a satisfactory carbon/nitrogen ratio before the process begins. It has been found that the best mix of filter cake to hay, straw or canary grass is in the ratio of 10:1, and manure from the farm's small cattle operation can be added as an inoculator and as a means to adjust the moisture content of the mix.

The composting process takes place in three „windrows", each 100m long, 15m wide and 3m high, with the mixture turned approximately four times a day using a compost turning machine. This is effectively a 3m wide conveyor that travels along the windrow, lifting the mix as it goes trough - over the top of the specially designed machine and turning it over before being re-deposited behind the machine.

This turning is the critical part of the process and, as the windrows are enclosed, the temperature, moisture and odour can be controlled. This produces a uniform and high quality compost in an efficient manner.

With the moisture content of the mix being maintained at approximately 50% by weight, optimum conditions are maintained for aerobic organisms. Sterilisation of seeds and any pathogens takes place in this process as the temperature increases due to bacterial action from 25°C to 60°C.

After 30-45 days, the process is complete and the final product, known as ReTurn™ is removed and stored in bunkers behind the facility. ReTurn has the appearance of potting soil and is applied on the farm by conventional manure spreaders according to crop schedules. In particular it has proved to be a good soil conditioner because it helps to break up clay soils and helps sandy soils to hold water better.

5.4.6.3 Composting in Germany

In Germany, introduction of composting technology started in the 1970s. Today, composting of sludge is a widespread, well introduced method. Development of new technologies, and more importantly, the marketing of the ready product is supported by a national association (ANS; compare Annex 5). As landfill of sludge will be banned by the end of the century, composting will consequently attract even more attention. Composting is mainly carried out by using the reactor process. Hereby sludge, bulking material and recycled compost is mixed and stored in a closed, but aerated reactor. The mixture is moved through the reactor from the top to the bottom within 2 and 4 weeks. Aeration is regulated by temperature; the air is cleaned by using organic air filter.

Special experiences with **tannery waste water** were obtained in the sewage plant of Ferndorf. Before 1990, more than 60% of the total discharge resulted from a couple of tanneries which produced fur and chrome tanned leather. Neither the composition nor the chromium contents have had any negative impact on the quality of the compost.

Composting of **tannery sludge** is also performed in the "Bavaria" Tannery of Donaustauff. After separated treatment of waste water streams with low and high chromium load the sludge from the effluent treatment plant is stabilised by adding of lime and composted by using the windrow system. The chromium cake is disposed of.

Tannery Sludge

Composting is a reasonable alternative for sludge processing. Concerning the chromium content the same remarks and estimations as been done under land application are valid. The only problem to be faced is the availability of the bulking material required in the aerated pile or reactor system which has to be further investigated.

Even if the compost is not marketable, the process of composting can be seen as a low capital requirement and easy to handle process for volume reduction.

Composting is a method which could be best applied by smaller tanneries in co-operation with local farmers or municipalities which can use the compost for land reclamation and/or improvement of park and forest soils.

Experiences have been gained in USA (although their main force was a political one, they showed that composting can be an alternative to any common treatment method), and in Germany where mixtures of tannery sludge and municipal sludge were composted during 20 years.

Intensive field tests in Brasilia showed, that compost from tannery sludge can increase significantly yields of a wide variety of crops without having any negative impact.

5.4.7 Others

5.4.7.1 Land reclamation

Sludge disposal on non-arable land and for land reclamation and waste cover (derelict land) is practised sparingly at the present time, but is likely to increase in the future. For example, it is estimated that 33 000 ha of land in the UK require reclamation, affording a potential outlet for 3.3. million dry tonnes of sludge applied at 100 dry tonnes per ha. A guide for re-vegetation of mined land in the eastern USA using municipal sewage sludge has been prepared. Derelict land refers, in general, to areas without an established soil cover such as colliery waste, shale tips, mine waste, China clay waste tips, sand dunes and the sides of embankments and cuttings, or pits filled with overburden from open-cast coal mining or with urban refuse and then covered with a layer of soil. In most cases, the surface material is severely deficient in organic matter, leading to a lack of water holding capacity and poor soil structure, and it is almost always deficient in nitrogen and phosphorus. The composition of sludge is almost exactly complimentary to the needs of derelict land. It contains large quantities of organic matter, nitrogen, phosphorus (especially in limed sludge) and trace elements. A major advantage of sludge, over most inorganic amendments for land reclamation, is that the nutrients (particularly nitrogen) are released slowly such that one application of sludge may enhance growth for several years. In experiments conducted in Norway, the UK and the USA, reclamation of disturbed lands with sludge has proven much more successful than with inorganic soil amendments. The reclaimed soil may or may not be suitable for the production of food chain crops, depending upon the degree of contamination of the original soil material and the amounts of heavy metal added in sludge.

Tannery Sludge

There are no special restrictions or limitations to tannery sludge.

5.4.7.2 Lime fertiliser

Lime fertiliser or lime containing soil conditioner may have valuable market changes, where they can obtain national certification as fertiliser or soil conditioner and where they can fulfil the respective standards. Especially in tanneries, where lime is used in the tanning process, mixing of lime and sludge would not be a new process to be introduced but could make use of lime remnants from the production without larger investment and operational costs.

The process of adding quick lime to sludge has two targets:. Firstly, the highly exothermic reaction creates temperatures well above 70 to 80°C thus pasteurising the mixture. At the same time, excess water is evaporated, the final solid matter concentration can easily achieved without additional energy. Secondly, the lime improves the quality of the sludge/lime mixture as a fertiliser. Lime fertiliser shall contain a minimum lime-content of 30% to 40% CaO. Other qualitative requirements are concerning grain size and distribution, storage possibilities, and handling.

The dry matter content in the final product can be influenced by:

- adding of dry matter as lime
- the absorption of water by lime ($CaO\ Ca(OH)_2$)
- the evaporation and vaporisation within the exothermic reaction process.

Trials have been made with fresh sludge and stabilised sludge with 21 - 34% ds. During these lime adding until a lime content of 60% (0.4 tp 0.5 kg per kg of sludge) was necessary in order to ease handling of the lime-sludge. With this dose, a partly round, porous material was obtained.

It was also observed that using of quick Ca-lime causes eruptive reactions which could not be controlled. Better results were achieved by using lime of lower reaction time (higher Mg-content)

Tannery Sludge

Improving sludge to a lime containing soil conditioner or fertiliser is one technology which could be best adopted to tanneries. The handling of lime is a common process which his well known in the majority of the Chinese tanneries. Mixing of both sludge and lime requires only little investment and space. The resulting product is dry, easy to handle and to transport, looks humus-like and has no bad odour. Marketing depends mainly on the price for similar soil conditioners or fertilisers.

Attention has to be paid to chromium contents and the potential of transformation of III-valent chromium into VI-valent form.

5.4.7.3 Utilisation in stone production

Utilisation of sludge in brick kilns or in the production of cement stones is one possibility for using the energy content of sludge, to improve the physical conditions of bricks, and to stabilise metal contents. Heavy metals are insolubly fixed within the matrix of the silicate complexes.

Experiences with this method are reported from the States, former Yugoslavia, the Netherlands, India and some East-European countries.

Bricks
One example for industrial utilisation is reported from Subotica (former Yugoslavia). There, sludge at 30% ds is mixed in a 20 - 25% ratio with clay. The main impacts are summarised as follows:

- no changes in production process are necessary
- sludge concentration up to 25% do not influence the quality of the bricks negatively
- the rheological properties are even strengthened in case of non-optimal raw material
- production cost could be lowered by about 10% by using sludge
- no negative impacts due to heavy metals could be observed and are not to be expected due to the stable fixation of metals within the silicate complexes.

Other advantages noted are savings in water and energy and in obtaining a light-weight product with improved water absorption and transfer properties. Further research is recommended on air quality effects, metal and organic emissions and the possibility of occupational hazards for the plant personnel.

Depending on the chromium content utilisation of **tannery sludge** for brick processing is more difficult. Bricks are fired under presence of oxygen in order to achieve the physical standards. Chromium is parallel oxidised to chromium VI which can be leached out. Hence a reduction of chromium during cooling phase is necessary in order to control chromium and to achieve a stable III-valent form. Eluation tests carried out with re-oxidised bricks indicate that no leachable chromium VI is present any more.

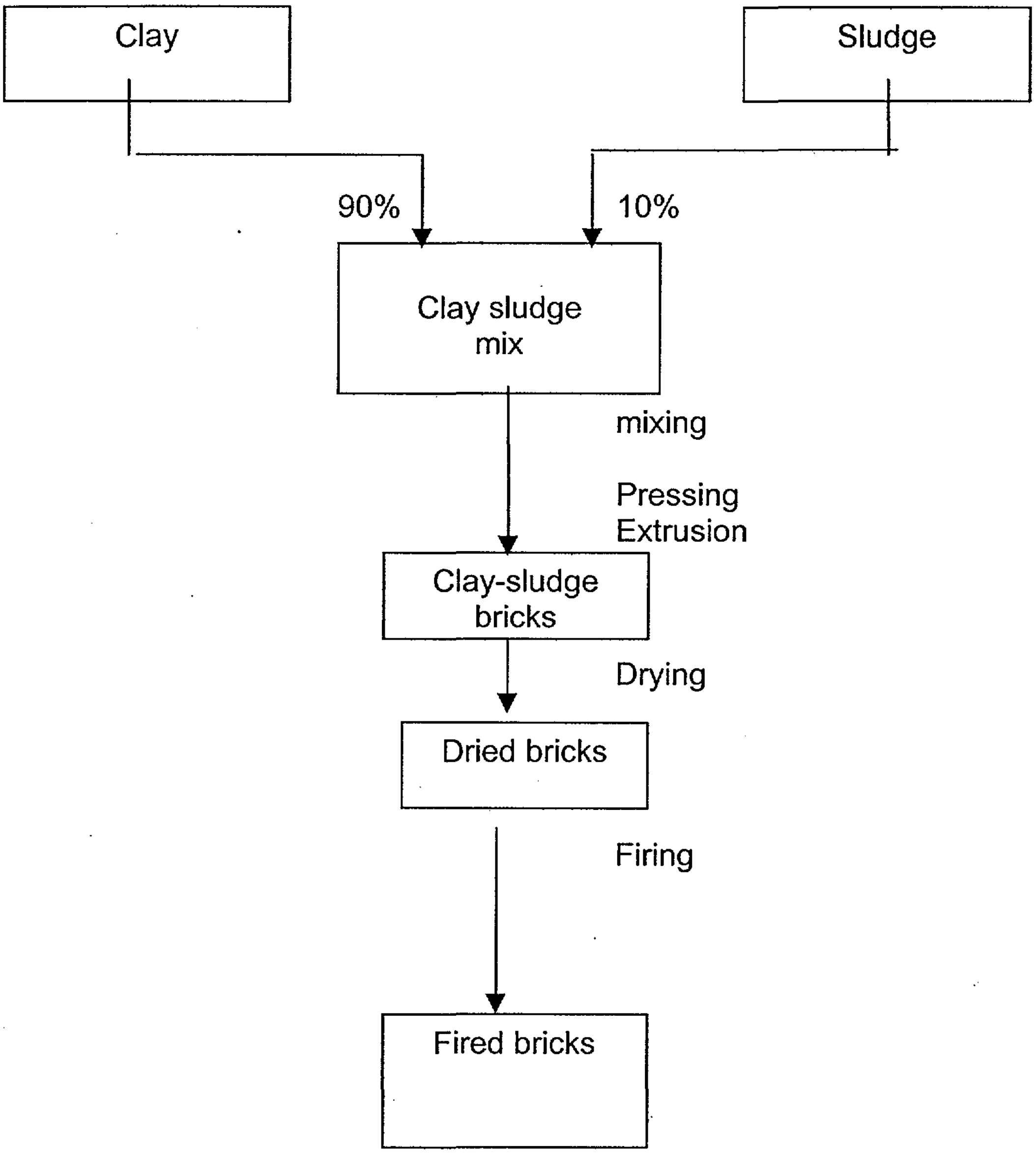
Tests with **tannery sludge** have been carried out in India in 1994 based on the following basic parameter:
- Chrome content: 2 – 3% as Cr at ds
- Maximum portion of sludge: 15%
- Maximum heating temperature: 800 – 950°C
- Cooling procedure: controlled cooling from 900°C to 200°C using a mixture of kerosene and water fed simultaneously
- Number of bricks produced: 500 (100*100*200mm).

The results can be summarised as follows:
- The produced bricks showed a black colour, leading to a low acceptance by the customers
- The little portion of sludge lowers the interest of the brick manufacturer to replace clay by sludge (low cost advantages)
- The kilns including mixing device and temperature control (for heating and cooling) have to be modified
- Chromium is reported to be fixed in the non-leachable Cr-III form

- Compressive strength: above 80 kg/cm²
- Water absorption rate: 15 –20%
- Density: greater than 1,700 kg/m³.

A principle process flow-chart is provided in Figure III/5-4.

Figure III/5-4: Principle flow chart of brick processing with tannery sludge



Cement stones

Another possibility for re-use of **tannery sludge** is its utilisation in cement stone production. Preliminary tests have been carried in Nanjing (P.R. China). Sludge is used to substitute slag from boiler houses. In contrast to fired bricks, cement stones are not heated. The filling material (slag, sand, gravel is mixed with cement and water. The cement acts as binding material after mineralization. Due to the always neutral to alcalic milieu chromium is fixed within the cement mineral structure in III-valent form. The stones produced showed a smoother surface. No physical or chemical tests have been carried out yet. One disadvantage is malodour occurring during production and drying resulting from the unstabilised organic matrix of the sludge. Malodour might be prevented by degradation of the organic matrix prior to stone processing, which can be either done by usual stabilisation methods or by composting as a cheap and easy to handle method.

Tannery Sludge

Using sludge as fuel and bulking material in brick processing is a promising process. First trails have been also carried out in China (Nanjing tannery).

In processing of fired brick the reduction of chromium VI to chromium III has to be controlled. Attention should be paid on possible chromium-VI emission during firing and cooling an on the long-term stability of chromium within the bricks. This concerns also the construction period where masons are in close contact with stones.

The black colour of the brick might hamper the marketing.

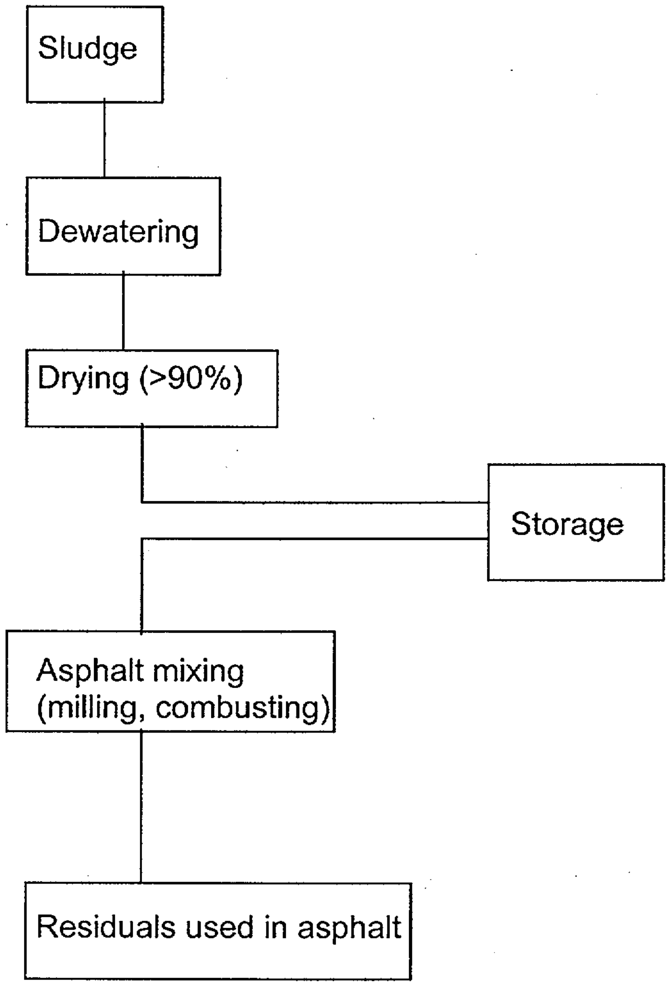
Another interesting possibility is the utilisation of tannery sludge for cement stone production. Due to the low temperatures no oxidation of chromium-III is to be expected and chromium is insolubly fixed within the cement matrix.

Problematic is the malodour produced by the ongoing degradation process of the organic sludge components. It can be avoided by prior stabilisation and degradation of the biomass.

5.4.7.4 Asphalt

Dried sludge can be used in the production of asphalt. The dried sludge acts as fuel whereby the residuals are used as bulking material in the asphalt itself. The process was developed in Germany (Alfeld) and is applied there and in Switzerland. According to information obtained from the company, no negative impacts on the asphalt quality are to be expected. Emissions of heavy metals, dioxin and furane are also not causing problems nor during drying nor during utilisation. It was told that the company erected a asphalt mixing plant in the area of Beijing. No further information could be obtained. The principle flow chart of the system is shown in Figure III/5-5.

Figure III/5-5: Sludge use in asphalt production - flow chart



Source: Own compilations

The sludge must be de-watered and dried down to a water content of less than 10% for which any of the common methods can be used. The dried sludge is milled to a grain size < 0.09 mm and than combusted in a solid fuel furnace. As auxiliary fuel diesel or gas is used in a quantity of about 10% of the total heating capacity.

Approximately, 27.5 kg of sludge granulate with about 90% ds are required per ton of asphalt. This is equivalent 6 kg of diesel. In addition about 0.6 kg diesel are required per ton of asphalt for the auxiliary burner.

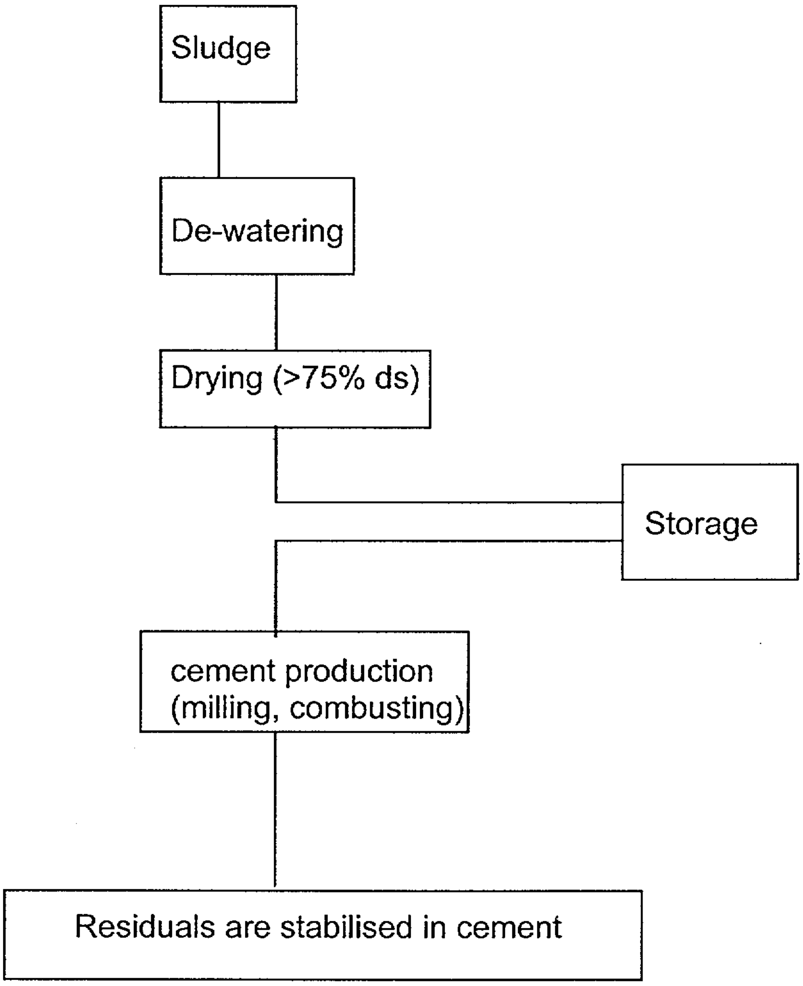
Tannery Sludge

Utilisation of sludge in asphalt might be also one economical solution, in case the mixing plant is located nearby. In addition, the sludge has to be pre-dried which increases the capital cost. There are no further limitations to tannery sludge.

5.4.7.5 Cement production

The principle flow chart of this process is shown in Figure III/5-6.

Figure III/5-6: Sludge use in cement production - flow chart



Source: Own compilations

The sludge must be dry to about 75 to 95% ds. Theoretically, utilisation of only de-watered sludge is possible, but would create an non optimal process. The dried granulate is milled and can be used in both primary and secondary burner. The residuals are fixed within the cement. The maximum portion of sludge not causing any negative impact on the cement quality and not requiring chances in process technology is 5%.

The heavy metals are water-insoluble fixed within the cement due its alkali milieu. Problems may occur with mercury and chlorine in case the volume is higher than 0.2 to 0.5% which is normally not .

The main problem for the utilisation of sludge in cement factories is the negligible advantage for the cement factory. The 5% of sludge has only marginal impacts on the cost structure. Consequently, the cement factories are not very interested in the utilisation of sludge.

Tannery Sludge

The utilisation of tannery sludge in cement production is limited by its water and chlorine content. The water content can be controlled and regulated according to demand, but the chlorine might damage the refractory bricks of the kiln and might influence the cement quality. Utilisation of tannery sludge is applicable in cement factories where chlorine deficits exist.

Chromium is not a limiting factor at all, because cement already contains a significant portion of chromium.

Another important problem is the concern of the cement producers with regard to the product quality and the low economic advantages

5.4.7.6 Production of light weight aggregates

There are several possibilities in utilisation of sludge in the production of light additives for insulation, mixing to concrete, etc. Main objective is the substitution of fuel which is added as carbon source to improve the exposion of the day by producing CO_2 during the treating process.

In **Brasilia (Sao Paulo)** anaerobe stabilised sludge is de-watered to about 30% ds and then dried to 40 to 54% ds. The main process includes:

- mixing with recycled sinter to about 55% ds
- pelletization
- drying to about 85 to 90% ds
- sintering by about 1,400 °C
- screening

The product has the following characteristics:
- grain size: 2,4 - 10 mm
- specific gravity 0,57 g/cm³
- elutriationable contents 1,3%

In **Japan** ashes from sludge incineration have been mixed with bulking agent (refuses from alcohol production), pelletized and dried. The pellets are combusted by 1 000 - 1 150°C in a jet furnace. The resulting light weight aggregate has a specific weight of 1.3 to 1.6 kg/cm³ which is a slightly lower than the specific weight of conventional produced aggregates. The strength is also slightly lower.

In **Germany,** a process was developed by ZÜBLIN AG to manufacture light weight aggregates from high contaminated river sediments (Neckar river). The process was successfully tested. The process includes the following steps:

- excavation of sediments from river
- screening
- de-watering
- mixing with additives (clay, etc)
- drying
- pelletization.

The erection of the plant finally failed on insufficient amounts of sediments available.

The process also was adopted to tannery sludge and included the following process steps:

- mixing with clay (1:1 ds)
- drying at 75% ds
- milling
- storage
- pelletization
- backed by 1,200°C (rotary kiln).

Trials were carried out with Italian **tannery sludge**, indicating that the process can achieve satisfactory results. Replacement of fuel by tannery sludge mixed with clay supports the expansion of the clay thus achieving better qualities at a lower cost level. Chromium is fixed in a stable matrix. An industrial plant is going to be erected in Santa Croce Sull' Arno in 1998/99.

Tannery Sludge

The process has been already successfully tested with tannery sludge and might be applicable in China with its growing demand on lightweight aggregates in construction. Due to the high investments required, market surveys are recommended.

5.4.7.7 Energy production

- **Heat Production**

Dried sludge can be used for energy production especially in coal burners. As a precondition, the sludge has been dried to about 90% TS. Some heating values are listed in Table III/5-6.

Table III/5-6: Caloric values of selected materials

Fuel	Heating value (kJ/kg)
Sludge: organic dried solids	21,000
Sludge: total dried solids, not stabilised	14,700
Sludge: total dried solids, stabilised	10,900
Sludge: 90%ds	9,000 - 13,000
Lignite coal	7.300 - 20,000
Pit coal	32,000
Diesel	38,000
Natural gas	41,400 kJ/Nm³
Sludge gas	24,000 kJ/Nm³
Timber	15,500
Turf	13,700

Source: Kassner, W. & Schmucker, A. (1990)

The process is used in the heat power station of Munich North. There about 3-3.5% of sludge is used after de-watering to about 25% ds.

The process includes the following main steps:
⇒ transport of raw sludge to the power station
⇒ de-watering by centrifuge to 25% ds
⇒ drying to 90 - 95% ds
⇒ grinding
⇒ combustion with pit coal (5,5% sludge, 94,5% pit coal).

The experiences show a slightly higher ash volume.

- **Biomethanization**

Solids undergo enzymatic hydrolysis by complex combinations of bacteria, producing NH3, short chain fatty acids, acetic acid, carbon dioxide, hydrogen, and in a next step methane gas. This effect is well developed and utilised in thousands of bio-gas plants throughout the world and especially in China.

As Chromium does not decrease gas production up to concentrations over 1,000 mg/l (100g/kg ds), therefore, the fermentation of solids (including sludge but also trimmings, fleshings) may be a suitable process for reduction of waste and at the same time lowering production cost of tanneries.

A demonstration plant was erected in France (Rozon tannery at Saint-Symphorien sur Coise) based on a daily capacity of 5 tons of slated fresh hides which creates the following wastes:

- ⇒ fleshings: 1,5 m^3 at 20% ds
- ⇒ trimmings: 0,5 m^3 at 20% ds
- ⇒ primary sludge from the settling tank 7,0 m^3 at 50 g/l.

The energy balance of the system shows a surplus of 2,807,800 Kcal/week which is equal 278 litre of diesel or 284 l of crude oil.

Investment cost and accompanying rate of return for different tannery sizes are compiled in Table III/5-7.

Table III/5-7: Bio-methanization of tannery waste - economic features

Item	Unit	Size			
Tannery size	Tons	5	10	20	40
Investment	US $	193,000	228,000	281,000	386,000
Operators	No/week	53	53	53	53
Revenues from gas	US$/week	108	215	430	860
Savings from waste disposal	US$/week	125	251	502	1,004
Total	US$/week	178	413	879	1,811
Pay-back period	**Years**	**23**	**11.7**	**6.8**	**4.5**

Remarks: crude oil: 175 U$/ton; waste disposal: 175 U$/ton
Source: ALOY, M. (1989)

Tannery Sludge

Utilisation of sludge in production of energy can be carried out within the tannery (boiler-house). Better results are to be achieved with pre-drying and mixing during the drying process with coal-powder. One problematic area is the emission control and air filtration.

Bio-methanization of tannery wastes including sludge was tested in France with optimistic results.

5.4.8 Environmental impacts

For a few of the examples of process technologies described above, an assessment of the environmental impacts are given below (Table III/5-8). The air pollution impacts ascribed to land application, composting and landfill include the vehicular emissions associated with the hauling operations, as well as the particulate and odour that may arise during and after field application.

Table III/5-8: Environmental impacts of various sludge disposal options

Impact Categories	Incineration	Land Application	Composting	Stabilisation and Landfill	Ocean Disposal
Air Pollution					
Odour	---	moderate	moderate	low	---
Particulate	low	?	?	very low	---
CO,NOx	low-medium	varies	varies	varies	very low
Heavy metals	low ?	?	?	---	---
Water pollution					
surface water	---	varies	varies	---	---
groundwater	very low	varies	varies	---	---
Land use	very low	moderate	moderate	low	---
Traffic	very low	moderate-high	moderate-high	low	---
Energy	gain-high	very low-mod.	low-mod.	low-moderate	very low
Health (pathog)	---	?	?	---	?
Biota	---	?	?	---	?

Source: Niessen, W.R

The associated primary impacts associated with sludge incineration fall into the air pollution and energy categories. Air pollution can be a significant impact from sludge incineration particularly for older plants equipped with inadequate air pollution control equipment.

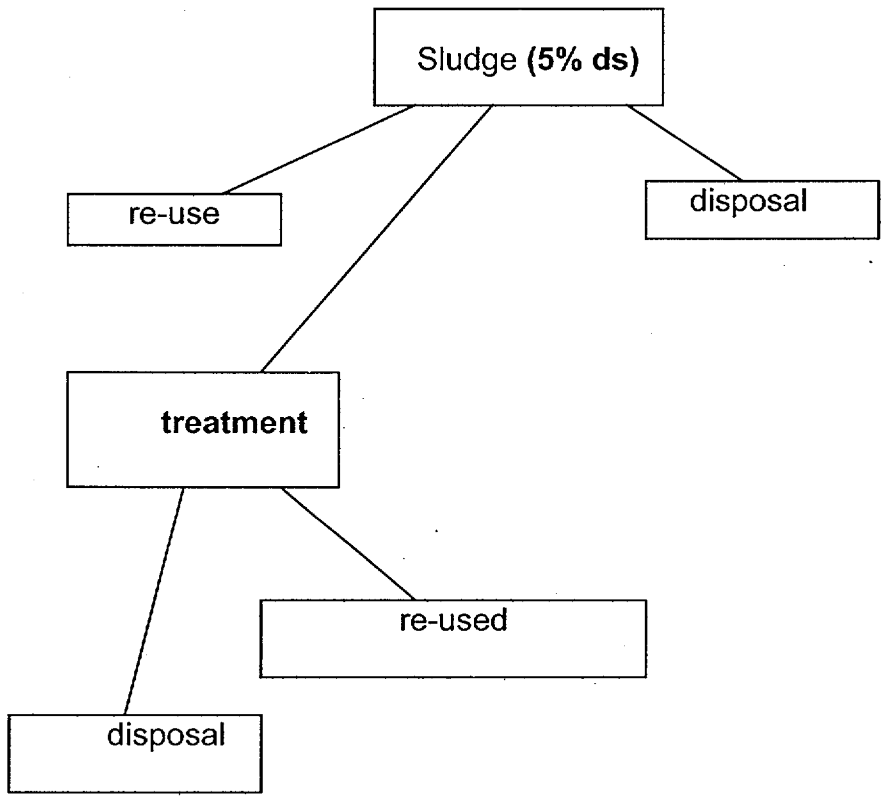
6 Economic aspects

Sludge handling and disposal is an expensive part of waste water treatment. Consequently, the identification of low cost treatment solutions is a high priority.

Sludge can be:
- disposed off
- re-used
- treated to improve disposal and/or utilisation properties.

Treatment processes may include
- volume reduction
- improvement of contents and/or properties
- processing to other products.

Figure III/6-1: Sludge handling paths



Source: own compilation

Any treatment of sludge is economically feasible once the end-product can be sold at least at cost price, or once the treatment leads to corresponding lower disposal costs. Giving sludge away, free of charge, for industrial and agricultural purposes incorporates that no additional costs (transport, taking-fee) are charged to the tannery and further handling is not the responsibility of the tannery.

6.1 Process cost

Cost estimations have been established for some of the major sludge handling routes described in chapter III/5. They include:

- **dewatering processes using**
  ⇒ belt press
  ⇒ filter plate press and
  ⇒ centrifuge

- **composting processes including**
  ⇒ windrow
  ⇒ aerated pile

- **combustion processes using**
  ⇒ multiple hearth incineration
  ⇒ fluid bed incineration

- **sludge hauling using**
  ⇒ liquid sludge hauling and
  ⇒ dewatered sludge hauling

- **landfill.**

Secondary utilisation, in either industrial or agricultural sectors, is not included in the cost estimation, because none of these applications should be the responsibility of the tanneries. Thus, normally only de-watering and/or transport costs will appear for the tannery. For landfill no minimum ds are required in China. Consequently the cost calculation does not consider any minimum de-watering procedure prior to landfill. Most of these examples are applied either as a single treatment process or within a process chain.

Cost estimates have been established for 4 different annual sludge production rates of 500, 5 000, and 50 000 t per year (at 5% ds). Annual production rates ranging from between 500 to 50,000 tons of sludge (at 5% ds) reflects the current range of production of Chinese tanneries considering various sizes and raw materials (compare Annex 1). The rate of 100,000 t (at 5% ds) of sludge production per year was chosen in order to provide indicative cost for treatment facilities operated jointly by a number of tanneries (e.g. for tanning centres). For all technologies cost have been calculated at the basis of 5% ds for the above mentioned production rates (compare Annex 3.2) and for the respective initial solid content of each method (compare Annex 3.3). The cost estimations for incineration have been included for comparison only. Due to the high capital and O&M cost, incineration is not normally used in treatment plants with capacities smaller than 5 Mio. m^3 per year.

Process cost estimations are based mainly on the algorithm developed by USEPA (compiled in "Handbook of estimating sludge management cost"). Additional information and calculation procedures were taken from WOODS, D.R. et al (1980) and PORCH, D. (1977). All prices have been adapted to current **Chinese** prices, although for some equipment prices have been approximated.

Main emphasis of the figures presented herewith is on obtaining preliminary cost estimates for various sludge management processes and to provide a baseline for comparison of different treatment routes. The estimations are based on typical design parameters which may vary at specific sites. Cost calculation for specific projects have to be newly calculated taking the local conditions and the design parameters into account.

Total base capital cost for sludge management processes include structural, mechanical, equipment, electrical and instrumentation costs. They do not include cost for engineering design, construction supervision, legal and administrative, interests during construction, and contingencies.

The annual M&O cost for sludge management processes do not include costs for administration and laboratory sampling/analysis. Thus, total annual O&M costs are estimated at being about 30% higher than given (10% laboratory and 20% administration).

The total estimated M&O costs calculated do not include revenues generated through the sale and/or use of sludge.

All figures are compiled in Annex 3, a summary is presented in Table III/6-1, from which the following brief conclusions may be drawn:

- none of the technical processes are economically suitable for the small production capacities of group I (production of 500 tons of sludge at 5% ds per year). The oversized equipment is reflected by considerably high capital cost. For these groups, either the technological processes have to be adjusted or special solutions fitting with the local framework conditions have to be designed.
- The same is valid for the next group (annual sludge production of 5,000 t at 5% ds), whereby the cost for low mechanised solutions (e.g. hauling, composting, landfill) are already considerably lower.
- Full advantage of the equipment is taken in case annual sludge production achieves 50,000 tons at 5% ds. Any further increase has no or only very little influence on the cost per dry ton.
- Incineration is by far the most expensive method of sludge treatment. Real capital cost will be even higher taking necessary devices and equipment for pollution control into account.

Table III/6-1: Summary of cost estimations (in US$/t ds)

			Annual sludge production in tons (at 5% ds)			
Process	solid content in (%)	solid content out (%)	500	5 000	50 000	100 000
• Belt press de-watering	5	20	210	37	9	8
• Centrifuge de-watering	5	25	353	51	11	10
• Plate press de-watering	5	35	390	75	15	15
• Multiple hearth incineration	35	98.5	462	186	20	20
• Fluidised bed incineration	35	98.5	434	103	51	44
• Windrow composting	35	65	132	19	6	5
• Aerated static pile method	35	65	102	16	6	6
• Liquid sludge truck hauling (20 km round trip)	5	5	158 (x)	32	13	14
• Liquid sludge truck hauling (30 km round trip)	5	5	165 (x)	39	16	17
• Liquid sludge truck hauling (50 km round trip)	5	5	178 (x)	52	21	22
• de-watered sludge truck hauling (20 km round trip)	35	35	27 (x)	6	1.6	1.6
• de-watered sludge truck hauling (30 km round trip)	35	35	28 (x)	7	1.8	2.0
• de-watered sludge truck hauling (50 km round trip)	35	35	30 (x)	9	2.2	2.8
• landfill	5		595	94	34	24
• landfill	20		149	24	8	6
• landfill	35		74	12	4	3

Source: compare Annex 3
Remarks: (x): Cost might be lower in case transport is done by a contractor

- Costs for truck hauling depend on volume and distance. Costs can be considerably reduced by using de-watering processes. The distance has impacts on the cost only where equipment is fully utilised (greater distances means more equipment) or in case volumes exceed 50.000 t/yr (due to the same reason).

- Landfill is the cheapest method of sludge treatment close to composting. Also, costs here vary widely with the solid concentration of sludge, which determines the land requirements and disposal work.

- Composting is one of the cheapest methods for sludge treatment requiring nevertheless, de-watering and final disposal measures.

For the bulk of the Chinese factories with sludge volumes ranging from between 500 to 5 000 tons per year, the solutions are not optimal from an economical point of view. The equipment and machinery cannot be reduced to the necessary low level, thus creating high capital cost. Substitution of machinery by comparably cheaper man-power, which in most of the state-owned factories is plentifully available, is not possible, except for landfill and composting. At a landfill site earth excavating, earth moving, and grading machinery could be partly substituted by man-power thus reducing capital and O&M cost. The same might be valid for composting with its already low capital component including front-end loader, turning machines and transport equipment.

Other possibilities might be seen in local industrial applications of sludge utilisation (brick making, asphalt, lime fertiliser, etc) or in land application. In these cases sludge will be given away free of charge or sold when market conditions are favourable and/or special pre-treatment measures are undertaken prior to selling.

Chinese prices are on average about 30% below European ones. This is mainly due to lower cost for equipment. Higher differences are obtained for treatment methods with higher proportions of manpower and cost for land. For latter items the price differences are about 60%.

Capital cost differs only slightly, except for the composting (mainly due to lower land prices) and the hauling process (mainly due to lower truck prices). O&M-cost shows a similar difference of about 30% for all processes which is mainly resulting from lower energy and labour cost. As a result, the treatment costs for one dry ton are about 30 - 50% higher in Europe. Exceptional figures are obtained for composting (470%) which is due to the lower land prices and for liquid truck hauling which is due to lower cost for trucks.

6.2 Sludge path cost

With regard to the sludge path, the whole chain of sludge handling steps shall be understood by the following: total base path cost can be estimated by adding the base capital and base O&M cost for each step chosen. Thus, most economic paths can be identified. Examples of some of the most common sludge handling paths have been calculated. The results are compiled in Annex 3 and summarised in Table III/6-2.

Table: III/6-2: Cost of various treatment paths

Treatment path	Initial sludge at 5% ds (tons/year)				Sludge volume reduction
	500	5,000	50,000	100,000	
Liquid sludge hauling (30 km) – landfill (5% ds)	760	133	50	45	O times
Plate press – hauling (30 km) – landfill (35% ds)	492	95	26	20	8 times
Centrifuge – aerated composting	455	67	17	14	13 times
Centrifuge – windrow composting – transport (30 km) – landfill	587	89	23	20	13 times
Plate press – incineration – hauling (30 km) – landfill	883	134	31	27	20 times
Source: Annex 3	All figures in Us $/t				
Reference: USEPA 1985					

Cheapest treatment paths are land-filling of de-watered sludge and composting, whereby with composting additional revenues could be achieved. Dewatering prior to transport and landfill is in all cases cheaper than direct hauling of liquid sludge. Treatment paths with incineration are the most expensive ones.

7 Conclusions

With respect to the suitability of various treatment methods described above, tannery sludge does not differ very much from that of municipal sources. Physical and chemical characteristics do mainly depend on the total waste water management system and the process technology introduced. Suitable treatment processes depend on those characteristics.

Some contents or physical characteristics of tannery sludge may limit or hamper its utilisation in certain treatment paths. As for example chromium exceeding national standards limits the utilisation in agriculture (land application, composting, fertiliser) and hampers certain product developments and landfill.

Consequently, the treatment of tannery sludge and the tanning process including pre-treatment steps are contingent upon each other. Most factors can be influenced by appropriate technologies as separation and separate treatment of chromium containing waste water streams or adopting of high chrome exhausting processes.

In Table III/7-1 all treatment technologies introduced in the previous chapters are compiled and evaluated with respect to:

- investments
- O&M cost
- qualification of personnel
- product quality
- environmental impacts.

The most promising technologies for the treatment of **tannery sludge** are summarised as follows:

- **Reuse techniques**

  A number of reuse techniques have been described above. The most important one is:

  ⇒ **land application on agricultural or forestry land**. With respect to the world-wide trends, and the high demand of fertiliser and soil conditioner, **land application** appears as one preferable solution. Chromium, salt, and nitrate concentration are the limiting factors which should be monitored. Sludge can be applied in either liquid or de-watered form on many fold ways. The technique does not require high level skills. The costs include transport to site only and are comperable low.

  Advantages
  - low capital and operational cost
  - easy to handle
  - no qualified staff required
  - starting at a low cost level possible

  Disadvantages
  - farmer unsatisfied with former trials
  - monitoring of application to be carried out by independent third party
  - applicable to sludge resulting from tanneries with chromium pre-treatment only

  Limiting factors:

- chromium	→ toxicity
- nitrate	→ ground water contamination
- potassium, phosphorous	→ nutrient demand of crops
- salinity	→ application form and resistivity of crops

  ⇒ **land reclamation:** Derelict land refers, in general to areas without an established soil cover such as colliery waste, shale tips, mine waste, China clay waste tips, sand dunes and the sides of embankments and cuttings, or pits filled with overburden from open-cast coal mining or with urban refuse and then covered with a layer of soil.

In most cases, the surface material is severely deficient in organic matter, leading to a lack of water holding capacity and poor soil structure, and it is almost always deficient in nitrogen and phosphorus. The composition of sludge is almost exactly corresponding to the needs of derelict land.

Table III/7-1: Evaluation of sludge treatment methods

Process	Investment	M&O cost	Qualification of Manpower	volume reduction (ds)	product quality	environmental impacts	Process experiences with tannery sludge
Marine disposal	Low	low	Low	100%	non	high	Well proven
Landfill	Moderate	moderate	low – moderate	Non	non	moderate	Well proven
Land application	Very low	very low	low – moderate	100%	good	low	Well proven
Combustion	Very high	very high	very high	98.5%	toxic ash	moderate - high	Well proven
Drying	High	moderate	Moderate	95%	good	low - moderate	Well proven
Composting	Low	moderate - high	Low	65%	very good	low	Little production
Pyrolysis	Very high	high	High	98%	very good	moderate - high	Laboratory test; 2 pilot plants
Land reclamation	Low	low	Low	100%	non	low - moderate	Well proven
Lime fertiliser	Low	low	Low	100%	very good	low	Tested, proven
Brick Kilns	Moderate	low	Low	100%	very good	low	Tested, some production
Asphalt	High	moderate	Moderate	100%	very good	Moderate	Tested; pilot plant
Cement	High	moderate	Moderate	100%	very good	Moderate	Tested; production
Light weight. Aggregates	High	moderate	Moderate	100%	good	Moderate	Tested; pilot plants
Energy (fuel)	Moderate -high	moderate	Moderate	100%	very good	moderate	Well proven
Biometha-nization	low-moderate	moderate	Moderate	80%	very good	moderate	Tested; pilot plant

Source: Own estimations

Remarks:

Investment cost: The valuation is based on very general figures because exact figures could not be obtained for all methods described

Volume reduction: Is calculated on the basis of raw sludge with 5% ds

Combustion: Initial/final water content 5%/0%. Reduction of 98.5% means evaporation of 95% water and 3.5% of organic solids (70% of 5% ds). Remains 1.5% as ash and a small amount of filter dust

Sludge composition: The assessments are valid for an average tannery sludge as described in chapter III/1.1.

With respect to tannery sludge the following experiences are available:

- **marine disposal:** No special experiences with tannery sludge are reported.
- **landfill:** Landfill is one of the main disposal options. In Germany about 90% of the tannery sludge is disposed off at landfill sites. Main reasons are cost and easy handling. The situation will remarkably change within the next few years towards a drastic reduction of landfill and an increasing re-utilisation.
- **land application:** A considerable number of studies and field research have been carried out in this subject. Summarised, tannery sludge can be used as fertiliser in general. Rather scientific than philosophical is the discussion on chromium. This is also reflected by the tremendous differences in chromium standards applied in different countries. However, land application requires sound monitoring and control.
- **combustion/energy recovery:** Combustion of tannery sludge is carried out in a number of tanneries especially in developing countries. It is considered as a fuel substitution thus reducing production cost. In developed countries it is not common due to high cost (pre-drying, mixing, pelletisation) and necessary measures for pollution control.
- **composting:** About 10% of the sludge from German tanneries is used in agriculture; mostly after composting. Experiences are also reported from United States.
- **pyrolysis:** No semi-industrial experiences are available yet. First plants are under operation for municipal waste and mixtures of sludge and solid wastes.
- **land reclamation:** No experiences with tannery sludge are known; but no restrictions are to be seen.
- **lime fertiliser:** No experiences with tannery sludge are reported.
- **brick kilns:** Trials with tannery sludge have been carried out in India indicating the technical suitability but problems in marketing
- **asphalt:** No special experiences with tannery sludge available, but no restrictions can be seen.
- **cement:** Tests have been carried out In Lhasa (Tibet), indicating that the quality of the cement was not influenced by adding of sludge and chromium containing solids (fleshings, trimmings). No special experiences at an industrial scale with tannery sludge are reported; but no restrictions can be seen.
- **light weight aggregates:** First tests at an semi-industrial stage have been carried out successfully in Germany and Italy. A plant is under construction in Italy.
- **biomethanisation:** Tests at an industrial scale have been carried out successfully in France. Further plants are under construction respectively in planning
- **cement stones:** Except the first very preliminary tests carried out in Nanjing, no special experiences with tannery sludge are available; experiences in utilisation of effluent treatment sludge for the production of cement stones are reported from Brasilia.

- **Product development**
  Sludge may be processed to produce a stable end product which can be sold and distributed as a fertiliser and/or soil amendment. The main technologies are:

⇒ **Calcinization:** This technology creates a sand-like final product in which heavy metals are stabilised. Disadvantages are the high cost (comparably to incineration cost).

⇒ **Brick kilns:** Utilisation in brick kilns makes use of the energy content as well as of the physical characteristics of the sludge solids. Utilisation of sludge can reduce production costs for the brick factory and improve the value of the brick. Thus, both sides have their specific advantages.

⇒ **Asphalt:** Utilisation in asphalt mixing harnesses the energy content of the sludge, while at the same time hazardous contents are fixed in the residuals which are used as filler in the asphalt. As pre-drying is a requested pre-treatment, costs are high and have to be compared with energy savings.

⇒ **Cement stone production:** Another promising technology might be the utilisation of sludge in cement stone production. Utilisation of sludge in cement stone production increases the insulation capacities and reduces production cost. Application is simple and does not need prior drying and large-scale equipment.

Advantages:

- low capital and operational cost (only de-watering required)
- easy to handle
- no qualified staff required
- applicable to all tanneries

Disadvantages:

- brick factories have to be convinced
- economic feasibility declines with increasing transport distances
- physical characteristics need to be proofed
- colour may be influenced

Limiting factors:

- risk of leaching.

Apart from the general questions of marketing and cost advantages further investigations and trials should consider the following aspects:

- fixation of chromium (chemical elutriation and mechanical removability of chromium from the surface)
- odour
- physical characteristics which have to meet the national standards
- long-term stability of chromium fixation.

⇒ **Light weight aggregates:** The production of light weight aggregates has been already successfully tested with tannery sludge and river sediments with high metal loads in Germany. Due to the high operation cost price, comparisons on the Chinese market should be carried out.

⇒ **Composting:** composting receives increasing attention due to its specific advantages, such as low capital cost and easy management and the production of a marketable product. The processes are well developed since the beginning of the seventies. Negative impressions resulted mainly from marketing problems. For tannery sludge, additional organic bulk material is necessary. Composting requires some capital input and operational cost. In case composting itself can be left to the farmers, the tasks of the tannery are the same as in land application. On the other hand composting in the tannery will might create a marketable product.

Advantages:

- low to moderate capital and operational cost
- volume reduction to 65% water content at reasonable cost basis
- easy to handle
- no qualified staff required
- starting at a low cost level possible by using static pile methods and available equipment
- marketable product might offer additional sources of income
- monitoring and process control can be carried out by own laboratory

Disadvantages:

- process and product control required which have to be introduced
- proper process know-how required
- applicable to sludge resulting from tanneries with chromium pre-treatment only
- in most case additional sources of carbon are required.

Limiting factors:

- chromium → toxicity
- C:N ratio → requires organic material (source of carbon)
- potassium, phosphorous → influence on marketing
- vegetable tanning agents → hampers destruction of organic material

⇒ **Lime fertiliser:** Lime fertiliser (Ca contents > 40%) is a valuable fertiliser or soil conditioner especially on acidic soils. The process is easy and requires only little additional equipment and manpower. Depending on the market situation, it might be a promising treatment process achieving a marketable product.

Advantages:

- low to moderate capital and operational cost
- easy to handle
- no qualified staff required
- starting at a low cost level possible
- good market arguments
- utilisation of other lime wastes possible

Disadvantages:

- market concept has to be established
- certification as fertiliser or soil conditioner might be necessary
- applicable to sludge resulting from tanneries with chromium pre-treatment only

Limiting factors:

- chromium → toxicity
- potassium, phosphorous → influence on marketing

⇒ **Co-Drying**

Drying is generally a solution for a cluster of tanneries (e.g. tanning cities) or for bigger single tanneries. For Da Chang it seems to be one of the favourable solutions.

Advantages:

- In case of co-drying: low to moderate capital and operational cost
- No additional work load for the tannery (except transportation of sludge)
- Very high volume reduction

Disadvantages:

- Dependence on outside owner and operator of the drying plant
- Problems may occur with the utilisation of the residuals

Limiting factors:

- Lime → influences pumping

- **Energy/resource recovery**
  Energy and resource recovery are attractive because they make use of the energy content of the sludge. Due to its relatively high calorific value, sludge has the potential as a low grade fuel for use in energy recovery schemes. Due to the high capital cost and sophisticated technology required, most of the energy recovery processes appear not to be applicable for single tanneries.

  ⇒ Utilisation of sludge in **boiler houses** seems to be one methodology which might be applicable. However, high investment for drying and pelletization is required. In addition, a functioning management of air pollution control is difficult to introduce and to operate on a sustainable basis.

  ⇒ **Methanization** of tannery wastes and sludge is another possibility which has already been tested with tannery sludge. The results seems promising but no further plant practising this method is known. It is reported that a pilot plant for tannery sludge and –waste will be erected in South India in the near future. Satisfactory amortisation times can be achieved on a daily capacity from 5 tons onwards.

- **Disposal techniques**
  Disposal options include application to sanitary landfill, incineration, and underground disposal:

  ⇒ **Sanitary landfill** of sludge, separately or with municipal solid waste can be an acceptable means of ultimate sludge disposal. It should be applied only if reuse or other utilisation is impossible. The geology, hydrology and hydro-geology of the landfill site must be carefully investigated. Landfill technique, when applied, depends on the water content of sludge, and the characteristics of the landfill area.

  ⇒ **Incineration** is considered as an ultimate sludge disposal technique even though the produced ash must still disposed of. This is usually accomplished by disposal to a sanitary landfill. Incineration is a high capital intensive method, requiring skilled labour, and huge amounts of sludge which are normally not available in a single tannery. Moreover, measures for air pollution control and safe disposal of ashes is required. The technology has been evaluated as being unsuitable for the treatment of sludge from single tanneries. However, it can be applied either in tanneries of a production exceeding 50 tons per day of salted raw hides or in case co-incineration is possible.

  ⇒ **Underground disposal:** Disposal of toxic and hazardous waste material in underground caverns, abandoned mines, as well as through deep well injection, has fairly widespread acceptance. These techniques could be used for the disposal of waste water sludge for either interim storage or ultimate disposal, but economics will probably minimise such practice.

From an economical point of view cheapest treatment methods are landfilling and composting whereby composting produces a marketable product. Revenues of which are not included. Highest cost have to be calculated for thermal processes as drying and incineration.

Although landfill and land application are currently the main treatment routes in industrialised countries, the ways towards a drastic reduction of landfill have been already taken. Regulations are already issued or under preparation.

In almost all countries main emphasis is laid on reuse or utilisation of sludge due to the set objectives to

- protect natural resources
- protect the environment, and
- reduce CO_2-emission.

In addition the tremendous costs resulting from necessary rehabilitation/ decontamination of old landfills and the increasing problems in identification of suitable sites might have effected the policy, too.

For land application European countries have issued their own regulations under the umbrella of the European directives. Application of sludge to agricultural land is regulated by three methods:

- limits on the route of addition of potentially toxic elements
- limits on the route of application of sludge dry solids
- limits on the route of addition of nutrients.

The first method is also applied in the USA, the second is the one mainly used in Europe. Limits on addition of nutrient is carried out in Denmark, Belgium, and the Netherlands.

IV Recommendations

1 Frame conditions

Any recommendation should consider the prevailing local frame conditions including social, cultural, political, and economical aspects.

- **Chinese Government**
  Governmental regulations do exist to some extent and new regulations are under preparation. But enforcement is weak and changes are not to be expected in the near future. Public operated treatment facilities as waste disposal sites or incineration plants are rare and many of them are designed and operated in an unacceptable manner. Furthermore, with the new act on solid waste disposal dumping of industrial waste will be prohibited at municipal landfill sites in future. Comparable regulations have been in force in Shanghai since 1996. And, last but not least, many of the Environment Protection Bureaux at provincial level, which are responsible for the enforcement of the regulations, are neither sufficiently capable nor qualified or motivated. Thus the enforcement remains weak depending more or less on the local situation of the EPB.

- **Tanneries**
  Sludge production of a single tannery is small compared with municipal sewage plants. It mainly depends on the number of raw hides produced and to a minor extent on the waste water treatment system and the method of further sludge management. Sludge production in Chinese tanneries is reported to range from between:
  ⇒ 25 - 5 000 t/year of raw sludge (compare Annex 1)
  ⇒ 4 - 800 t/year of de-watered sludge (30% solid content)
  ⇒ 1 - 260 t/year dried sludge (95% solid content).

  Tanneries will change their way of sludge handling where they are enforced to do. This can be through enforced governmental regulations, or by social pressure or customer's demand.

  The latter is for instance, valid for export orientated tanneries which mostly have to prove their environmentally acceptable production to their foreign customer. New governmental regulations are under preparation in the field of solid waste disposal which will effect also the tanneries and with regard to environmental management systems. It is planned that the export industry must be certified according to ISO 14 000 which will have remarkable impacts on the production and waste management of a great number of tanneries.

  Social pressure is growing rapidly in dense settled urban areas where people are effected by tannery emissions.

- **International standards**
  The solution recommended should match with the international state of technique taking into account available know-how and qualification of local personnel and should consider the latest discussions with regard to protection of environment and natural resources.

  For example, **ocean disposal** would be a possible solution for the coastal areas of China, where a number of large tanneries are located, meeting the criteria described above (easy to handle, low capital, low O&M cost). But due to the decisions already made in the EU to ban ocean dumping and the regulations issued by the US Government to protect the ocean, it appears insensitive to introduce these treatment path in China within the framework of a multinational project.

  The same is partly valid for **landfill**. Landfill plays certainly an important role in waste disposal also in future. However, in all industrialised countries great efforts have been undertaken to increase recycling, reuse and utilisation of waste instead of dumping. In the EU regulations have passed the parliament in which landfill has only third priority in disposal options after reuse and thermal utilisation. France and Germany are to issue regulations mentioning that wastes containing more than 5-10% organic matter are prohibited for disposal.

- **Limiting factors**
  Main limiting factors for the introduction of disposal techniques to tannery sludge can be seen in:
  - concentration of **chromium**
    - ⇒ has **impacts** on
      - * land application
      - * composting
      - * lime fertiliser
      - * combustion
    - ⇒ requires **additional measures** in
      - * combustion
      - * brick kiln
      - * land fill
    - ⇒ can be **controlled** by
      - * separate effluent treatment
      - * recycling, precipitation, pre-treatment.

  - concentration of **organic solids** (55-60% instead of 56-80% for municipal sludge)
    - ⇒ has **impacts** on
      - * all processes using the calorific value of the sludge
    - ⇒ requires **additional measures** in
      - * all processes (auxiliary fuel, further de-watering)

⇒ can be **controlled** by
  * adding of other solid dry organic wastes
  * further de-watering.

- low values of **potassium and phosphorous**
  ⇒ has **impacts** on
    * all processes where sludge is used as fertiliser
  ⇒ requires **additional measures** in
    * application where higher values are required (crop demand)
  ⇒ can be **controlled** by
    * selection of crops.

- **Conclusions**

The current situation as well as its prospective changes in the near future leads to the following assumptions:

⇒ From the technical point of view most of the new technologies described in chapter III/2 can be applied by the Chinese tanneries. Exceptions are the incineration processes, due to the high capital cost and the high sludge volumes required

⇒ The methods introduced must take care of possible secondary emissions. Examples are air pollution by heating processes and soil contamination by land application.

⇒ Solutions have to be adopted to the different sizes, production and treatment technologies of the tanneries

⇒ Disposal or treatment of tannery sludge cannot substitute adequate measures for reduction of waste and toxic substances during the production process. An environmentally friendly and clean production is a pre-requisite for the selection and establishment of an optimal sludge disposal route at a sustainable and low cost level.

⇒ And finally it has to be pointed out, that „**the solution**" for the disposal of tannery sludge does not exist. Each technology described has its own advantages and disadvantages and has to be adopted to the respective specific site conditions.

2 Legal aspects

Handling of sludge should be guided and regulated by the Chinese Government through appropriate legislative measures and by encouraging tanneries in developing of new treatment paths.

Governmental regulations are required especially in the field of sludge handling and final disposal. Recently the tanneries are forced to operate effluent treatment facilities but are left alone with the increasing quantities of sludge resulting from these. This policy leads finally to a transformation of environmental pollution from the water to the solid side only, with almost no positive effect although considerable efforts and investments are undertaken.

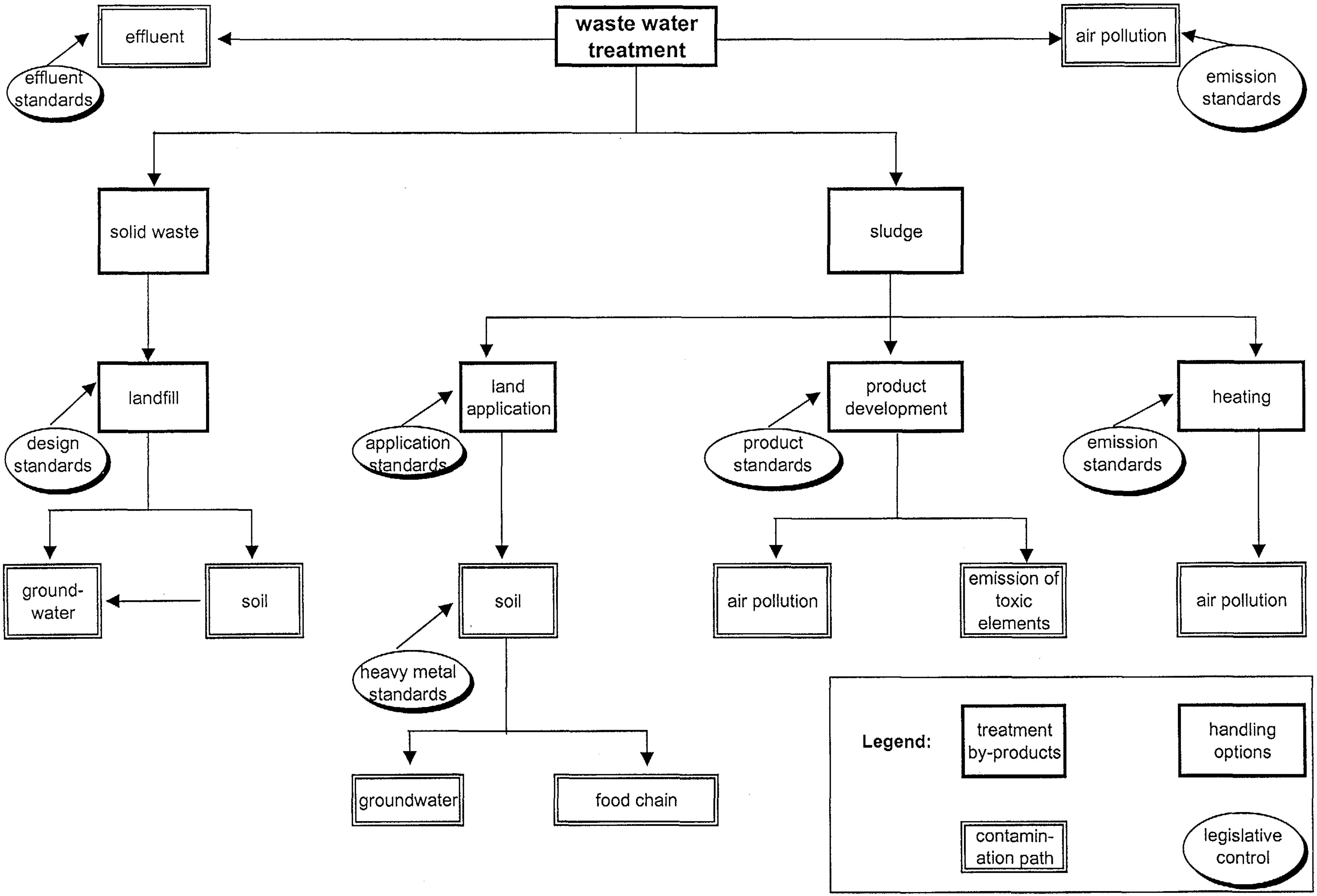
The concerned regulations should therefor consider all by-products and possible secondary pollution created during the treatment process. A principle flow-chart of contamination paths and possibilities of legislative control is presented in Figure IV/2-1.

Regulations could include the following sectors:
- standards for land fill sites including site selection, design and operation
- standards for the characterisation of sludge as toxic or non-toxic waste including appropriate recommendations for handling of toxic sludge.
- standards for air pollution (emission control) applicable to boiler houses and other plants utilising sludge (e.g. brick kilns).

With respect to the governmental policy to strengthen the introduction of ISO 14 000 and ISO 9 000 for all exporting industries and due to the high export rate of the tanning industry it might be worthwhile to discuss the introduction of waste handling manuals which are anyhow part of the International Standards mentioned above.

Finally the Government may support the utilisation of tannery sludge by introducing financial and other subsidies. One positive example is the tax free status of products made by using waste or recycling material. Other possibilities might be
- direct financial support for environmental investments
- higher depreciation rates for environmental investments
- substitution of higher production cost due to environmental sound sludge handling.

Figure IV/2-1: Legislative control of waste water treatment



3 Project proposal

A sludge management system should consider the following criteria:

- cost efficient
- easy to handle
- low to moderate O&M cost whereby manpower requirements in state-owned tanneries are of minor importance
- technical applicability to processes and production
- little additional working load
- additional treatment measures should be left outside the factory to a maximum extent. Firstly, sludge treatment is not a traditional field of activity, consequently tannery labour is not very familiar with it. Secondly, the tannery is mainly interested in disposing of the sludge, which may effect the quality of the treatment and of the sludge accordingly. Thirdly, the acceptance of the new method will increase with less cost for the factory.
- the new system should aim to demonstrate appropriate sludge management solutions matching with international standards and policies
- low environmental impacts.

Due to the diverse structure of the Chinese tanneries with a wide range of sludge volumes and sludge properties, the different tanning processes and effluent treatment technologies, and, last but not least, due to the different regional/local frame conditions, a set of possible solutions covering different conditions are recommended. Consequently, in contrast to the original plan to identify one single technology and to establish a demonstration plant it is recommended to carry out practical full-scale tests for the selected technologies. During the execution of the test program it will become clear whether the respective technology is really applicable with respect to frame conditions (production, tanning technology, regional/local situation) and whether a demonstration plant is necessary for further demonstration and dissemination. The results should be compiled and disseminated; tanneries ready for adoption should be supported at least by the provision of technical advice.

The technologies proposed for further consideration include the main treatment paths (land application, thermal treatment, product utilisation). The test program presented includes all project sites and takes into consideration specific advantageous local frame conditions as already available basic experiences, existing hardware, and interested user groups.

The following project sites have been chosen (the treatment technologies proposed are described lateron):

- **Da Chang, Shanghai** for co-drying (activities started in the field of utilisation in fertiliser factory and co-composting should be continued)
- **Nanjing** for production of cement stones and
- **Xian** for composting and lime fertiliser.

For the overall monitoring and co-ordination of the programme the **Xian Institute of North-West Light Industry** was chosen.

3.1 Co-Drying

Working Program:

The test program proposed includes

- analyses of tannery sludge (especially organic contents, heavy metals); 5 times
- running of full scale tests with a mixture of (tannery sludge / own sludge) 1:2; 1:3; 1:4; 1:5, in order to identify optimal mixtures
- running of additional full scale test with optimal mixture
- analyses of final product after each run including chromium content and -eluation
- summarising the results in a final report.

The total quantity of sludge required from the tannery for the tests is about 150 tons. The tests could be started immediately and finished within six weeks. The residuals must be taken back by the Factory in case the local Environmental Protection Bureau rejects a final disposal at the dumping site currently used by the Chemical Plant.

Table IV/3-1: Cost Calculation Co-Drying

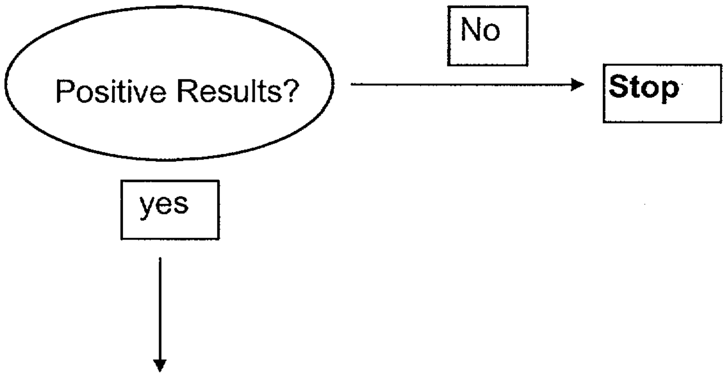
Item	Unit	Unit Cost (RMB)	Quantity	Total Cost (RMB)
Sludge handling (transport, unloading, mixing, manual feeding) including drying for 5 test runs	no	12,000	5	60,000
Analyses of final products	no	3,000	5	15,000
Analyses of tannery sludge	no	3,000	5	15,000
Miscellaneous	l.s.	10,000	1	10,000
Transport of residuals	tons	200	50	10,000
TOTAL				**110,000**

It is recommended to place the works under a sub-contract to the chemical plant which is responsible for the execution of the whole program including transportation and contracting the laboratory. The tests would be carried out by the drying plant; the analyses by an experienced associated laboratory located near-by.

3.2 Cement stone production

Working program:

- manufacturing of stones with different sludge ratios of 5%, 10%, 15% and 20%
- execution of standard tests according to Chinese standard regulations, evaluation and interpretation of results



- analysis of elutriation of chromium out of bare and plastered stones
- construction of test wall to investigate long-term stability of chromium fixation
- execution of composting test
- evaluation and interpretation of results
- applying for certification according to national regulations
- final report.

Table IV/3-2: Cost Calculation Cement Stone Production

Item	Unit	Unit Cost (RMB)	Quantity	Total Cost (RMB)
Stone manufacturing: 50 stones per mixture; final mixture 300 stones (PDX 24)	no	4	500	2,000
Elutriation equipment	no	30,000	1	30,000
Standard test fees	no	3,000	15	45,000
Certification fee	no	10,000	1	10,000
Transport of sludge	l.s.	3,000	1	3,000
Miscellaneous	l.s.	15,000	1	15,000
TOTAL				**105,000**

Remark: Cost for analysis and testing are included in sub-contract Xian Institute

3.3 Composting

Working Program:

Xian was selected as location for the testing of composting due to the following reasons:

- more than 20 years experience in utilisation of tannery sludge in agriculture
- the program could be easy monitored by the Xian Institute of North-West Light Industry
- the user groups are strongly interested in the continuation of the sludge utilisation.

Main limiting factor is the chromium concentration which has to be below the national standards. The chromium problem was discussed at the very beginning by using the experiences gained during the study tour to Germany. The current chromium content of the sludge in Xian tannery is about 20,000 mg/kg ds, thus exceeding the national standards 20 fold. Main reasons are

- only part of the chromium containing water is collected separately
- the direct recycling system generates chromium containing excess float (about 15%) which flows directly to the effluent treatment plant.

Consequently the modification of the existing waste water collection system and pre-treatment was discussed (Figure IV/3-1):

1. Concentration of chromium containing processes and total separation of waste water streams
2. Separate treatment of the chromium containing surplus water by the introduction of a precipitation step after the chrome recycling tank prior to the effluent treatment plant. The sludge produced there, which is of very little volume, can be dumped at an appropriate dumping site or reused within the production process.

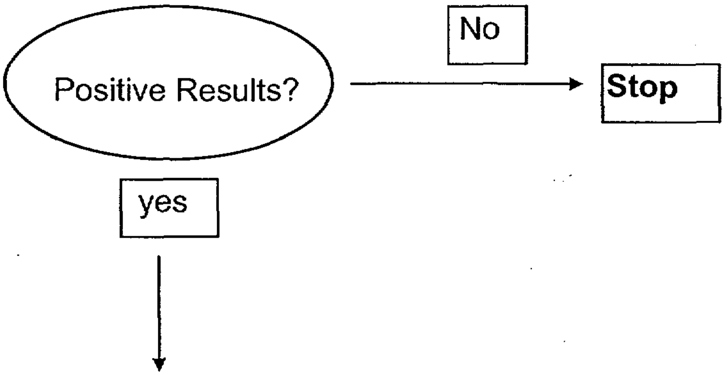
Further Steps

The working program concentrates on two issues:

- **Finishing of separate chromium containing waste water collection system**
  - ⇒ execution of precipitation tests at laboratory level
  - ⇒ design of system
  - ⇒ cost estimation, tendering, purchasing of equipment
  - ⇒ construction
  - ⇒ reporting

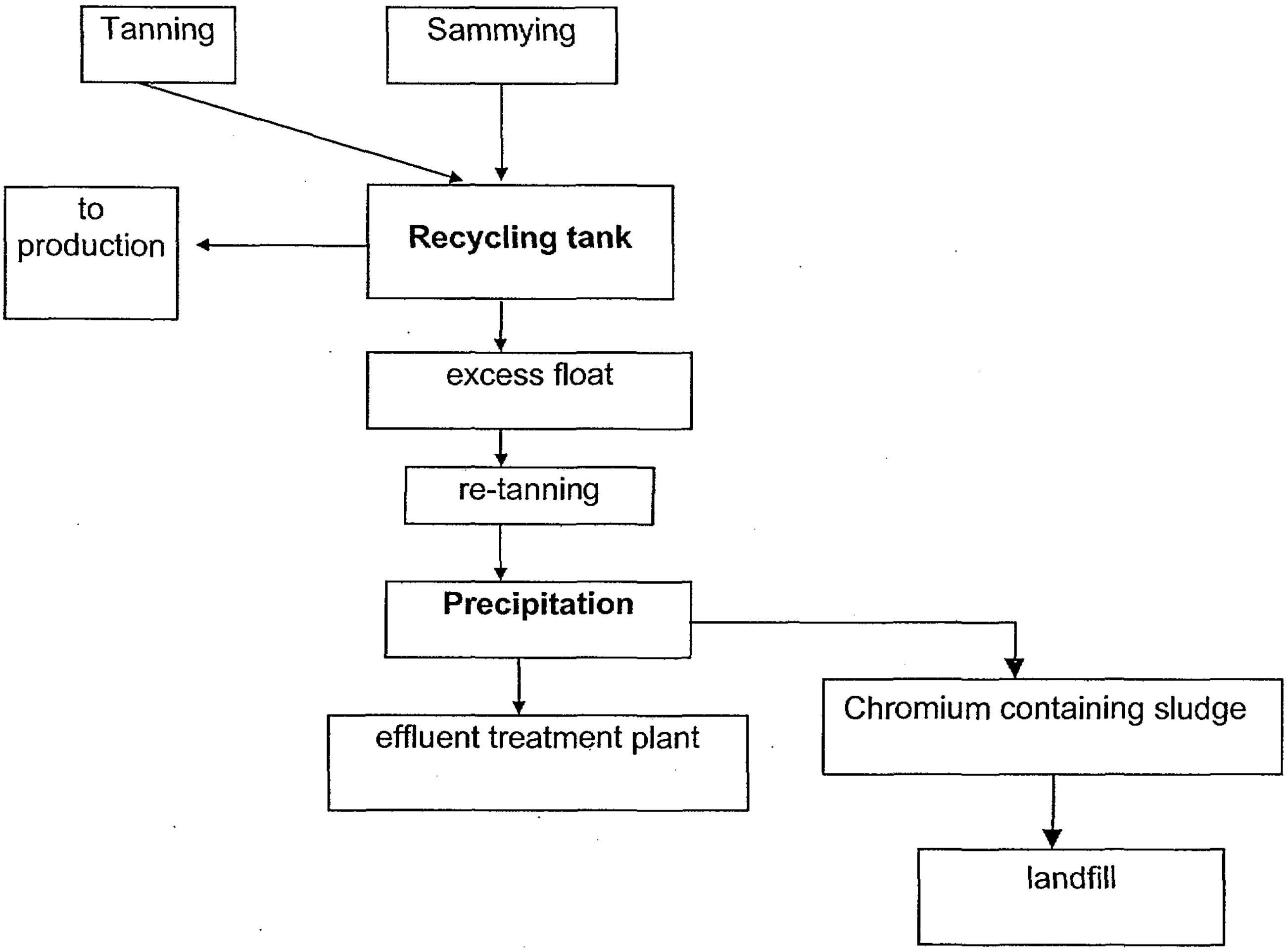
- **Execution of composting tests**
  - ⇒ execution of chromium analyses of fields already manured by using sludge for several times
  - ⇒ selection and design of composting site
  - ⇒ cost estimation, tendering, purchasing of equipment

⇒ construction
⇒ execution of composting
⇒ analysis and tests of compost performance and quality



⇒ applying for certification
⇒ final reporting.

Figure IV/3-1: Flow chart of chromium separation



Analysis and research on the chromium up-take by plants and the general field of toxicology is not included, because sufficient international research has been done during the past. The results indicate that where certain thresholds are met, there are no negative impacts on crops and human beings to be expected. The existing standard of 1,000 mg/kg Cr in sludge used for agriculture is in conformity with international standards and guarantees the exclusion of negative impacts.

No cost estimation can be presented for the above mentioned working program yet. Main reasons are:

- the necessary construction work within the tannery is not yet known
- the final surplus flow of chromium containing waste water must be calculated
- the location of the composting test site is not fixed
- a decision should be made on the design of the composting site: a cheaper provisional solution using a tamped floor, plastic roof, or a technological sound solution with concrete floor, drainage system, and stable roof.

The cost estimation will be finished after adequate decisions are made respectively after the designs are made available by the tannery.

3.4 Lime fertiliser

Working Program:

Sludge can be used as lime fertiliser in case chromium standards can be met and in case Ca-content is higher than 40% ds. It is recommended that general tests at laboratory scale only should be carried out by the Xian Institute. The costs are included in their monitoring programme.
The working program includes:

- preparation of Ca-fertiliser using different kinds of lime
- analysis of performance, nutrient contents
- reporting.

Table IV/3-3: Time Schedule

			Month									
Activity	**Deadline**	**Responsible**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Contractual Procedure												
ToR Chemical Plant	31.03.98	CTA	XXXX									
ToR Xian Institute	31.03.98	CTA	XXXX									
ToR International	31.03.98	CTA	XXXX									
Workplan Xian Institute	10.04.98	Xian Institute	XXXX	X								
Contract chemical plant	15.04.98	NPO, UNIDO		XX								
Contract Xian Institute	30.04.98	NPO, UNIDO		XXXX								
Contract International	30.04.98	NPO, UNIDO		XXXX								
2. Da Chang												
Information on compost users	30.04.98	Da Chang tannery	XXXX	XXXX								
Execution of test programme	31.05.98	Chemical Plant		XX	XXXX							
Market research for final products	15.06.98	Xian , international				XX						
Final report	15.07.98	Chemical Plant				XX	XX					
Contractual negotiations	31.08.98	Da Chang tannery				XX	XXXX	XXXX				
3. Nanjing												
Negotiations with relevant institutions	31.03.98	Nanjing tannery	XXXX									
Elaboration of working programme	31.03.98	Nanjing tannery	XXXX									
Preparation of working programme	30.04.98	Nanjing tannery		XXXX								
Production of stones with different sludge portions	30.06.98	Xian Institute			XXXX	XXXX						
Testing acc. to standard	31.07.98	Xian Institute					XXXX					
Progress report	15.08.98	Xian Institute						XX				
Composting of sludge	31.07.98	Xian Institute			XXXX	XXXX	XXXX					
Production and testing of stones	15.09.98	Xian Institute						XXXX	XX			
Applying for certification acc. to regulations	30.09.98	Xian Institute							XXX			
Final report	15.10.98	Xian Institute								XX		

Table IV/3-3: Time Schedule (continued)

Activity	Deadline	Responsible	Month 3	4	5	6	7	8	9	10	11	12
4. Xian tannery												
Precipitation tests	15.04.98	Xian Institute	XX	XX								
Design of separation of chrome effluent	30.04.98	Xian tannery		XXXX								
Cost estimation, tendering	15.05.98	international		XX	XX							
Purchasing	15.07.98	UNIDO			XX	XXXX	XX					
Construction	15.08.98	Xian tannery					XX	XX				
Progress report	31.08.98	Xian Institute						XX				
Design of composting site	15.05.98	CTA, international		XX	XX							
Cost estimation, tendering	20.05.98	international			XXX							
Purchasing	15.07.98	UNIDO			XX	XXXX	XX					
Construction	15.07.98	Xian Institute			X	XXXX	XX					
Progress report	31.07.98	Xian Institute					XX					
Composting	30.11.98	Xian Institute, international					XX	XXXX	XXXX	XXXX	XXXX	
Elaboration of application rules	30.11.98	Xian Institute, international								XXXX	XXXX	
Applying for certification of compost	30.11.98	Xian Institute									XXXX	
Final report	15.12.98	Xian Institute										XX
4. Xian Institute; lime tests												
Elaboration of working programme	15.04.98	Xian Institute	XX	XX								
Execution of test programme	31.05.98	Xian Institute		XXXX	XXXX							
Elaboration of guidelines	30.06.98	Xian Institute			XXX	XXXX						
Final report	15.07.98	Xian Institute					XX					
Dissemination of results	30.09.98	Xian Institute					XXXX	XXXX	XXXX			

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(2 of 2)

INTEGRATION

Project No. US/CPR/97/022

Study on
Safe Disposal of Tannery Sludge
In
The People's Republic of China

Final Report

Volume II: Annexes

Juli 1998

for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION,
Vienna

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The final report includes two volumes: Volume I: Main Report
Volume II: Annexes

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ANNEX 1

Report of the North-West Institute for Light Industry, Xian

Investigation Report

On Present Situation of China's Tanning Wastewater and Sludge and Their Treatments

Expert Group of Investigation
on Present Situation of Tanning Wastewater and Sludge
from
Northwest Institute of Light Industry

Date: Oct. 10, 1997

According to the requirement from the Industrial Development Organisation of the UN, under the support of China Leather Association with full consideration of the practical situation of Tanning industry in China, we sent „Investigation Tables about Sewage and Sludge Situation and Its Treatment“ to over 300 tanneries in China, carried out telephone consultations and on-the-spot investigations. After data processing according to the information feedback from 100 typical tanneries, we have done the necessary statistical analyses. Among the 100 tanneries, there are 10 large-scale tanneries with a yearly production of one million sheets of skins, 24 small-scaled ones with a yearly production of less than 100,000 sheets but more than 30,000 sheets, and 66 ones with a mid-scaled productivity. These tanneries are located in east China, south China, north China, central China, southwestern, northwestern, and northeastern areas. They are either state-owned, collective-owned tanneries, private companies, joint-ventures, or foreign enterprises, with products of pig skins, ox skins, sheep skins, shoe upper leather, clothing leather, case hide, and bottom leather, etc. which are very typical, showing the real actual situation of sludge and its treatment in tanneries of different scales, with diversified products, in different areas and by various sewage treatment methods.

We have done statistical work on the selected 100 tanneries information feedback (see the attached tables), and now the analytical report about the statistical data is as follows:

I. Introduction

According to the present situation of China, our country's leather industry has had its own distinct characteristics and distribution because of the effects of raw hide resources, economic developing level, technological ability, traditional ideas, management level and our reform and opening up policies. Tanneries are located mainly in these provinces like Zhejiang, Jiangsu, Shandong, Henan, Hebei and so on which cover majorly east China, central China, and north China. Next, the tanneries lie in northwestern, southwestern and south China, including Xi'an, Lanzhou, Xinjiang, Sichuan, Yunnan, Guangdong and Guangxi. The least is situated in northeastern area. Therefore, the distribution is like that. In Table I, the most data are from east China, while the data from northeastern area are the least. In the more developed east China, the factories are mainly large-scale and mid-size tanneries which are state-owned, collective-owned or joint ventures with foreign countries, with complete categories of products like pig skins, ox skins, sheep skins, shoe upper leather, clothing leather, case hide and their corresponding leather goods. What is special is the leather dress city of Haining which is praised as „Home of Leather“, mainly engaged in Sheep skins goods. Jinhua area in Zhejiang is rich in its good-quality pig skins, making pig-skin clothes and cases. „Zujia Group“ in Zhejiang as a representative is mainly making ox hide shoe upper leather. Henan as a representative in central China mainly makes ox-skin with a small quantity of sheep-skins. In more developed Guangdong province, blue at home and abroad is majorly processed. Hebei as a representative of north China takes sheep skin as the main products. Xinjiang in northwestern China and Inner Mongolia in north China have a rich resource of good-Quality sheep skins, so they mainly make sheep skins. Shandong as a representative in east China and Sichuan as a representative in southwestern produce mainly pig skins. Meanwhile, because of the requirements of environmental protection, severely-polluting tanning industry have to be transferred to middle and small cities and towns from big cities. Therefore, in modern big cities such as Beijing, Shanghai, Tianjin, Chongquing, etc. tanneries are becoming less and less.

At present, China's tanning technology is undergoing a big change and innovation concerning the post-procedure, but the pre-procedure letting out a large discharge of sewage has little progress. Dehairing is mainly done by ash alkali method with a small percentage of zyme dehairing. Light leather is tanned mainly with Cr; heavy leather is tanned with plants. Thus we believe that considering the present tanning situation of China, the tanning technology has little effect on the discharge amount of sludge no matter what kinds of products. Only is there a little difference in the contents amount of sludge ingredient.

II. Sewage Situation:

(1) Discharge

Sludge caused by tanneries is the main pollutant. The amount of sewage is large, its ingredients are complex and pollution is very severe. From the 100 tanneries, those with pig-skin or ox-skin or sheep-skin production singly and with comprehensive data are selected. Their productivity and discharge amount are listed respectively in Table II, Table III and Table IV,. As for those that produce pig skins, sheep skins, ox skins or two of the three, the sewage amounts aren't separated. some factories starting with processing blue or with an incomplete data have not been included in the tables.

From the tables, it can be seen that the average discharge of sewage from pig-skin tanneries is 43 tons/ton pig skins and mostly between 40 and 50 tons. For ox-skin tanneries, it is one an average 58.6 tons/ton ox skins; 171.7 tons/ton sheep skins. All the above mentioned discharge amount is higher than the average water consumption: 30 - 40 tons/ton raw hide for ordinary tanneries while 20 -30 tons/ton raw hide for modern tanneries. Therefore, in order to slove the problem of pollution of tanneries, saving water and lessening discharge are two important factors.

(2) Sewage Treatment Situation

There are three categories for the selected 100 tanneries.

First, direct discharge takes up 23% of all investigated tanneries mainly in northwestern and southwestern areas where the economy is backward and environmental protection starts late. Among tanneries of these two areas, ones with a direct discharge without sewage treatment occupies 39% in northwestern area while 30% in southwestern area. These tanneries among the investigated ones cover 75.8 % in northwestern and 54% in the southwestern area. Among the 23 tanneries, one is near a sewage treatment station into which it discharges directly after a payment of certain sum of discharging fee; The sewage is treated by the sewage treatment station. Another one in a basin has purchased a piece of waste land where a pit is dug out to hold the sewage; another three ones have little sewage because they start with blue processing;

another three ones are building sewage treatment stations; the rest of all discharge sewage freely after paying a certain sum of money.

China has a very strict sewage discharge standard and management regulation. In more developed areas, the environmental protection is done well and sewage treatment is controlled seriously. So the sewage treatment is in a good condition, but when it comes to the backward places, only a fine of money is in place of solving the problem, especially in the northwestern area. Although there is no sewage caused by the tanneries with direct discharge, yet a new task is raised. As more and more sewage treatment plants turn up, sludge treatment can not be neglected, which has brought about the importance of our research project.

Second, partial treatment taking up 16%. Without sewage treatment stations, the tanneries recover the dehairing and waste Cr liquid respectively, treat them respectively and then discharge them. For example, treating dehairing waste liquid is treated with gas-explosion sedimentation; the waste Cr liquid is recovered or sedimentated by adding alkali. Cr is reused after recovery by way of plate press filtering. The sewage stations are under construction in some of such tanneries. Yet sewage can not meet the discharge standard set by China due to individual treatment. Because of the enlargement of production in some tanneries, the present sewage treatment equipment can not meet the need. Because the benefit of the tanneries is not good, it's difficult for them to pay for such large amount of money on sewage treatment expense. So they have to treat the sewage partially.

Some tanneries of the above mentioned two categories have been forced to adjust the situation within a certain period of time to treat the sewage in order to reach the standard of discharge regulations.

Third, complete treatment taking up 61% of the investigated tanneries. In these areas, they have a good production and they pay great attention to environmental protection as well. Data in Table I also show such a situation. The tanneries with complete sewage treatment cover the following percentage among the investigated tanneries: 75. 9% in east China, 54. 5% in south China. 86. 7% in north China, 87. 5% in central China. The methods for sewage treatment fall into two kinds. 54 tanneries adopt SBR while only 7 ones use gas-explosion sedimentation.

III. Sludge Situation

1. Sludge Discharge Amount (see Table V)

From the investigation, all the tanneries have not measured the water content in the sludge. Because sludge comes from the pool and is concentrated and dried in different ways. The forms of sludge are various. The range of water content is large, from 30% to 98%. So it is impossible to have a precise statistics of the discharge amount; the data can only be used as a reference since there is not a regular pattern.

2. Primary Sludge Treatment

At present the emphasis on „Three Wastes“ treatment in tanneries is put majorly on sewage. Sludge coming from sewage treatment is not paid enough attention. Therefore, most tanneries do not have equipment correspondence to sludge treatment. The sludge after sewage treatment usually contains 98% water content, which is hard to be transported. So it needs to be concentrated and dried. Investigation results show that there are mainly three kinds of primary concentration methods.

First, sludge is got out from the pools manually and remains dry on the drying field until the water content reduces to 30 - 40 % and then is piled up. This method takes up large area and is subject to the weather effects and is costly and time-consuming.

Second, there is no drying field in many tanneries which can only dry the sludge by dripping beside the pools. The water content is about 50 - 70%.

Third, the sludge is pumped into the concentration pools and is filtered to dry with sandy soil or coal cinder as a filter. In some more advanced tanneries, the sludge is directly pressed or adding alkaline aluminum chloride into sludge and then it is pressed dry with plate and frame presser filter. The water content is about 40 - 70%.

3. Sludge Further Treatment (see data in Table I)

(1) Piling Up

This method is adopted by 53 tanneries, some of which start to treat sewage. They haven't found a good way to treat sludge properly. They have to pile up sludge in the tannery or near the sewage treatment pools waiting for treatment. Therefore, many tanneries eagerly hope to achieve support from the United Nations and China Leather Association in this respect. Some other ones place the sludge with daily garbage or industrial wastes together and then expect the urban sanitation trucks to carry them to garbage stations for centralized treatment.

(2) Embedment

This is utilized by 46 tanneries. One of them directly embeds dried sludge inside the tannery. Quite a few ones transport the sludge singly or mix it with urban garbage to urban garbage stations where the urban garbage mixture is centrally embeded. The distance between the tannery and the garbage station is various. It's usually 10 - 50 km. Some tanneries dig pits outside tanneries for one time embedment or for 5 to 10 years. Some tanneries even let local farmers take sludge away to mix it with earth freely and farmers use the mixture for filling low land or fields. In Xinji Tanning Industrial Area in Hebei, the sludge is embeded outside the villages, 5 km from the tanneries. It's considered that the two above-mentioned methods are negative treatment methods. The material available from sludge hasn't been exploited. The pollution problem of sludge to environment can't be completely solved. The sludge has to be piled up for the moment or is embeded after treatment.

(3) Using as Fertilizers

There are 9 tanneries which use sludge as fertilizers. Among the 100 investigated tanneries, without any treatment, the dried sludge (40% water content) is carried away by local farmers (living 5 to 10 km from tanneries) who mostly use sludge for farming (except one for planting trees) in fields of wheat, maize and rice etc. Farmers take the sludge in the field to be mixed with other farm manure or crop stalks at a mixture rate of 1 : 100 or 1 : 4 or mixed them at well and then spread the mixture onto the fields after half a year. More detailed information and experiment results haven't obtained until now.

(4) Incineration

Only one tannery use the sludge as fuel. Mixed with coal, the dried sludge is burned in the boiler. The different mixture rate is uncertain. As for the burning waste gas or the left ash, there is no further study and treatment.

(5) Using as Building Materials

Six tanneries use the sludge as building materials. One tannery filters the sludge containing 98% water content with coal cinder and mixes the sludge and cinder for bricks. What will happen later on is not clear. Another tannery is near mountainous area. Farmers take the sludge away to be mixed with clay and stones for making foundations and constructing houses. The others mix the sludge with clay and coal cinder at will for road base and for the roads in front of tanneries or farmers carry sludge away for filling low land and building roads.

The above-mentioned three ways of treatment are feasible in our opinions, but not perfect and need to be further studied.

4. Ways of Sludge Taken from Tanneries

It's necessary for the dried sludge to be taken out of tanneries. Seven tanneries let environmental sanitation department or farmers take sludge away; the rest sludge is transported by tanneries themselves. As for the means of transportation, 17 tanneries use rickshaw and the rest of all use motor vehicles. Concerning the time of leaving tanneries, there is no regulations except that two tanneries limit it to be at night or non-work time. For the expense of sludge leaving tanneries, most tanneries pay different fees to the collectors except that four ones charge purchasing fees from the collectors. The fees are various in different places. Some tanneries have no fixed price. The price is decided at that moment when the collectors take sludge away.

IV. Law, Regulations and Standards

In recent years, our government attaches great importance to environmental protection. So the environmental protection work has made great progress. The laws and regulations are perfected continuously. Various laws and regulations appear in succession. Especially, for protecting the water resources, there are rigorous environmental laws and executive standard in China, such as

Prevention and Control Law for Water Pollution of the People's Republic of China, Huaihe Basin Prevention and Control Law for Water Pollution, Integrated Wastewater Discharge Standard of the People's Republic of China and Effluent Standard for Pollutants from Leather Industry of the People's Republic of China. According to the feedback of the investigation, for the tannery wastewater, most tanneries rigorously carry out the national laws and regulations as well as standards above mentioned. Combining with the local situation, some areas such as Shanghai, Jiangsu and Zhejiang, Shandong, Guangzhou and Xinjiang lay down more rigorous local regulations, rules and standards. On the basis of national laws regulations, they also carry out wastewater discharge permission system. Especially, in Huaihe basin, Changjiang River, Huanghe River, the Pearl River and coastal areas, the management of environmental protection is more strict.

Compared with the industry developed countries of the world, the environmental protection work in China started a bit later. At present the emphasis on „three Wastes" is wastewater. Especially in tanning trade, the less investment, quick result, easy production and low cost of sewage disposal method is being studied and spread mainly. From the investigation, it's seen that rather a part of tanneries haven't harnessed wastewater at all or have done it incompletely in China because they can't afford the big cost of wastewater disposal. In their reports, with earnest hope, many tanneries appealed for help from the United Nations and Leather Association in this respect.

Compared with wastewater, the pollution of sludge is lighter, slower and less than that of wastewater, for sludge is the outcome of sewage disposal. Therefore, at present, the sludge hasn't been paid enough attention. In China, Legal Provisions for Prevention Pollution of solid Pollutants is just in its preliminary stage. There are no specialized laws and regulations or standards about tannery sludge. But Provisions for Prevention Pollution of Wastes, Stench and Heat. In the following laws and regulations, such as Legal Provisions for Prevention the Ocean Environmental Pollution from Wastes and Law for Prevention and Control Water Pollution of the People's Republic of China, which concern the provisions of preventing surface water and underground water from pollution for dumping, embedment and storage of the intense poisonous waste cinders, industrial wastes, urban garbage, other solid wastes and pollutants. Aiming at the sludge applied in the farmland, which comes from urban sewage disposal station, urban underground water precipitation pool, underground water sludge in some stations which produce organism and the precipitation sludge from rivers, streams, lakes, reservoirs, pools, gutters and canals, the Law of the People's Republic of China Control Standards for Pollutants in Sludge from Agriculture Use is made out. For various thoroughly decomposed urban daily wastes and urban garbage compost plant products, applied in farmland, which can't be mixed into industrial waste and other wastes, Control Standards for Urban Wastes for Agriculture Use is made up.

From the investigation, at present, only very few areas stipulate that sludge is piled up or embeded at the assigned places, or carry out the Legal Provisions for Prevention from Solid Wastes from Pollution. Most areas have no concrete provisions yet.

V. Typical Factories on Treatment of Wastewater and Sludge

1. 3513 Factory of People's Liberation Army of China

The factory is also called Xi'an Tannery Shoemaking Factory. It was founded in 1958. With more than 3000 staff and workers, and 100 million yuan output, it is a large-scaled enterprise of tanning and shoemaking production as a whole. When the factory expands its production, it has done large amount of work in the environmental protection and has brought about tangible results at the same time: Therefore, the factory was approved by the society and government department concerned. In 1989, it was conferred the title „An Army-wide Advanced Unit of Environmental Protection". In 1990, it was conferred „A National Advanced Enterprise of Environmental Protection". „An Advanced Unit of Shaanxi Province Environmental protection Civilization and Safety in Production". In 1994, „Shaanxi Province Ten-Excellent Advanced Units of Harnessing Pollution Sources".

The factory has an annual production of 189 thousand sheets of hide and discharge amount of wastewater in 30,800 tons per month. The sewage disposal station covers 2664 m2 area and the factory has invested 1.8 million yuan. The capacity of daily sewage treatment is 3400 m2 by choosing the „Efflux Aeration Active Sludge" method to harness the wastewater. This treatment technology ever won the Second-award of "Army-wide Science and Technology Advanced Achievement" in 1990. At present, the sewage disposal station has become a „window" in harnessing tanning wastewater in Shaanxi Province. A large number of people at home and abroad have come to visit and inspect the station. In March of 1996, after the joint investigation of higher officials from the Industry Development Organization of the United Nations, China Leather Association and China Light Industry Ministry, the project was named a model project as „Industry Development Organization of the United Nations Assisting China Leather Industry to Harness Wastewater and to Control Pollution".

In 1989, this factory was fitted with professional supervisers and set up and environmental supervising station. Up to today, the station has possessed over 300.000 yuan fixed-assets, and more than 30 sets of instruments and equipments. They can monitor more than 50 convention projects of water, gas, sound and dust. In 1991, this station took part in the certificate examination of Shaanxi Province Environmental Supervision and all the items were up to standard. Now the station has become the environment supervising center in the northwestern area of military supplies system.

In the sewage disposal station, there is a 600 m2 sludge dewatering workshop. The silt from the first precipitating pool, the surplus active sludge from the second precipitating pool and coacervation substance after medicaments coacervation are concentrated and then are dewatered by plate and frame filter press. Then the coacervation substance is made into mud lump and piled up and the following treatment experiments are carried out.

(1) Generating Methane

Putting the sludge into the pot, and carrying out the small-scaled sludge anaerobic digest experiments, we have made rapid program in gas production from sludges and laid the foundation for sludge multifolds uses. Yet because of expenses shortage, the experiment ends there.

(2) Incineration

After mixing the sludge with coal enough in a proportion about 1:50, the mixture is sent into boilers to incinerate. After a period of time, it can be found that coagulum coheres on the conveyer belt and it is hard to clean. Moreover, waste gas and waste ash probably cause second pollution. Therefore, the further experiments is stopped there.

(3) Sludge as Fertilizers

The factory is located in Xi'an southern suburb, next tot the suburb county villages. Some workers come from the nearby villages and have close connection with the villages. So they cooperate with each other to carry on farmland experiments. The concrete method is that the farmers carry the dried sludge to the edge of the field, mixing it with farm manure in a proportion of 1:4 and then piled them up for half a year. After enough ferment and decomposed, they are applied in the field. In the past seven years, unusual phenomena haven't been found on crops. As to the ingredients of crop fruits and composition of the soil, there are no survey.

Sludge is transported by the farmers with motor vehicles from the factory. The factory pays an expense of 2,000 yuan every years.

2. Haerbin Tannery

With an annual production of 240,000 sheets of hide and a wastewater discharge amount of 190.000 tons per years, Hearbin Tannery is an old tannery in Heilongjiang Province. Besides strictly executing the national environmental laws and regulations, Haerbin City also drew up more rigorous industrial wastewater discharge standards. In developing its production, the factory harnesses „Three Wastes“ unremittingly. To the tannery wastewater disposal, they are not only satisfied with the existing active sludge method. In recent years, through small, middle and productive experiments, they have shortened the time of biochemical disposal of the tannery wastewater to 4 - 6 hours, even 2 - 4 hours, saving 80 percent of energy, and lowered the wastewater disposal expenses greatly. They have also paid more attention to tanning sludge. As a good resource available, Haerbin City government departments concerned have raised a claim of disposal and making use of tanning sludge. The factory technicians associating with local agricultural department, using their own sludge, have developed and set up a „multi-source nutrition nursery garden“. Now, they have finished the crops experiments in small area and passed the survey of the Provincial Agricultural Department. They earnestly hope to get the help from the United Nations and Leather Association so as to widen the experiment furtherly and spread its uses.

VI. Conclusion

In accordance with the investigation, at present, in tanning trade of China, the emphasis on harnessing „Three Wastes" is wastewater disposal. The sludge treatment following wastewater starts a bit late and it hasn't raised enough attention. The sludge is just regarded as the common industrial waste. Therefore, we believe that all the methods on this base can't solve the pollution problem totally. All the treatment methods used today - piling up, embedment, using as fertilizers and as building materials, are not perfect enough. So we can't spread it simply. Only after further study can we determine its feasibility. At the same time, it is more urgent to study and absorb the advanced experiences from other countries of the world, especially, from the industry developed countries. Combining with our actual conditions and finding out the feasible ways of treatment on tanning sludge and its application, we can bring benefits to the future generations. Let's work hard together for our globe, for our family and for owning a clear and blue sky!

October 10, 10997
Expert Group of Investigation on
Treatment of Tannery Sludge and Its Application
from
Northwest Institute of Light Industry

Annex 1

	Region	East-China	South-China	North-China	West-China	South-West-China	North-West-China	North-East-China	Summe
	Total Sample	**29**	**11**	**15**	**16**	**13**	**12**	**4**	**100**
	state-owned	7	5	3	6	3	7	2	33
	Collectiv	13	1	1	4	10	2	1	32
Management	Private	2	0	10	4	0	1	0	17
	Joint-Venture	7	3	1	2	0	1	1	15
	Foreign	0	2	0	0	0	1	0	3
	Large (1)	5	2	0	1	2	0	0	10
Size	Medium (2)	21	9	7	8	5	12	4	66
	Small (3)	3	0	8	7	6	0	0	24
	Cattle	11	11	3	13	8	11	4	61
Raw Material	Pig	15	5	1	3	10	2	2	38
	Sheep	6	0	13	5	5	8	1	38
	No treatment	4	1	1	0	7	9	1	23
Water Treatment	Part treatment	3	4	1	2	3	1	2	16
	Whole treatment	22	6	13	14	3	2	1	61
	Ex factory supply	1	0	0	0	0	0	0	1
	Composting	17	3	2	16	5	2	3	43
	Fertilizer	2	2	2	0	1	2	0	9
Sludge utilization	Landfill	14	7	14	7	3	1	0	46
	Combustion	0	0	0	1	0	0	0	1
	Building material	5	1	1	0	0	0	0	7
	husbandry feed	0	0	0	0	0	0	0	0

Remarks:
(1): big tanneries: > 1 Mio pieces of raw hide per year (all are included in sample)
(2): medium tanneries: >100,000; < 1 Mio pieces of raw hide per year (10% are included in sample)
(3): small tanneries: < 100,000 pieces of raw hide per year (total number in China unknown)
(4): Factories without treatment plant in operation
*: only valid for factoires with sludge treatment

Pig Production			
No	Production in 10,000 pieces per year	Waste water generated in 10,000 t per month	Average waste water per ton of raw hide
1	40	1.60	44.0
2	30	1.25	45.8
3	10	0.24	26.4
4	70	2.50	39.3
5	35	1.56	49.0
6	100	4.00	44.0
7	70	3.45	54.2
8	15	0.75	55.0
9	90	4.50	55.0
10	17.11	0.50	32.1
11	40	2.10	57.8
12	60	2.92	54.0
13	60	2.60	47.7
14	40	0.48	13.2
15	200	7.50	41.2
16	200	7.50	41.2
17	80	3.34	46.0
18	400	13.9	38.2
19	75	3.38	49.5
20	50	1.68	37.0
21	30	1.25	45.8
		Total Average	**43.0**
1 piece pig skin = 10 kg			

Cattle Production			
No	Production in 10,000 pieces per year	Waste water generated in 10,000 t per month	Average waste water per ton of raw hide
1	110	7.88	39.4
2	10	1.80	99.0
3	10	2.40	132.0
4	15	2.25	82.5
5	12	0.68	30.9
6	15	2.70	99.0
7	40	3.60	49.5
8	20	3.38	92.8
9	18.9	3.08	89.6
10	7.5	1.22	89.5
11	4	1.50	206.2
12	10	1.65	90.8
13	15	1.00	36.7
14	20	2.00	55.0
15	9	1.35	82.5
16	10	1.60	88.0
17	15	2.00	73.3
18	22.5	2.64	64.5
19	60	3.60	33.2
20	18	2.00	61.1
21	20	2.88	79.1
22	5	0.56	61.9
23	4	0.56	77.3
24	7	0.79	61.9
25	20	1.0	27.5
26	10	0.38	20.6
27	24	1.72	39.3
28	18	2.00	61.1
29	25	3.0	66.0
		Total Average:	**58.6**
1 piece cattle hide = 20 kg			

Sheep Production			
No	Production in 10,000 pieces per year	Waste water generated in 10,000 t per month	Average waste water per ton of raw hide
1	37.5	0.41	120.3
2	25	0.40	176.0
3	62.5	0.68	119.7
4	37.5	0.52	152.5
5	62.5	0.88	154.9
6	150	2.10	154.0
7	20	0.35	192.5
8	38	0.46	133.2
9	20	0.37	203.5
10	100	1.45	159.5
11	25	0.43	189.2
12	75	0.87	127.6
13	100	1.50	165.0
14	200	4.50	247.5
15	22	0.324	162.0
16	25	0.37	162.8
		Total Average	**171.7**
1 piece sheep skin = 2 kg			

Annex 1

Sludge Production					
No	Main Production	Production 10,000 pcs/year	Waste water 10,000 t/month	Sludge t/month	 t/10,000 t waste water
1	cattle, sheep	3, 6	1.5	2.7	1.8
2	cattle, pig	7.4	0.27	2.16	7.98
3	cattle	10	1.65	18.0	10.9
4	cattle, sheep	18.9	3.08	11.9	3.84
5	cattle	24	1.72	5.16	3.0
6	pig	7	0.43	4.02	9.3
7	cattle	5	0.56	2.7	4.8
8	cattle	200	4.50	22.4	4.98
9	cattle	10	1.6	2.7	1.68
10	cattle	15	20	90	4.5
11	cattle	135	2.48	3.6	1.44
12	cattle, sheep	22.5	2.64	39.6	15.0
13	cattle, sheep	11, 35	4.5	15.7	3.48
14	sheep	100	1.5	28.2	18.8
15	cattle	10	0.38	7.5	19.7
16	cattle	200	6.75	50.6	7.5
17	cattle	200	9.0	58.3	6.48
18	pig	35	1.17	2.52	2.16
19	sheep	37.5	0.52	4.75	9.13
20	sheep	25	0.40	3.03	7.58
21	pig	40	1.6	12	7.5
22	cattle	15	2.25	30	13.3
23	pig, sheep	17.11	0.5	6	12
24	pig	40	0.48	9.6	20.0
25	pig	200	4.5	11.3	2.52
26	pig	200	7.5	22.5	3
27	pig	200	7.5	108	14.4
28	pig	80	3.34	12.6	3.78
29	pig	50	0.68	5.04	7.44

Annex 1

Sludge Production					
No	Main Production	Production 10,000 pcs/year	Waste water 10,000 t/month	Sludge t/month	 t/10,000 t waste water
30	pig	40	0.24	2.7	11.3
31	pig	70	1.0	2.4	2.4
32	pig	35	1.56	31.0	19.9
33	cattle	110	7.9	90.0	11.4
34	pig, sheep	220	7.0	91.8	13.1
35	cattle	10	2.4	14.8	6.18
36	cattle, sheep	15, 200	2.86	14.9	5.22
37	cattle	10	1.8	9.0	4.98
38	pig	90	4.5	23.8	5.28
39	pig	15	0.75	22.5	30
40	cattle	18	2	8.1	4.05
41	cattle	60	3.6	148.5	41.3
42	sheep	62.5	0.88	8.67	9.85
43	cattle	20	2.88	9.45	3.3
44	cattle	20	1.0	6.75	6.75
45	sheep	62.5	0.68	3.10	4.55
46	sheep	75	0.87	5.28	6.06
47	sheep	25	0.43	4.86	11.3
48	sheep	100	1.45	6.70	4.62
49	sheep	38	0.46	3.57	4.66
50	sheep	20	0.37	5.69	9.23
51	sheep	20	0.35	2.50	7.14
52	cattle	7	0.79	13.5	17.1
53	sheep	150	2.1	11.5	5.46
54	cattle	50	4.5	45.9	10.2
55	sheep	37.5	0.41	1.97	4.8
56	cattle	4	0.56	1.35	2.4
57	sheep	25	0.37	3.27	8.84
58	sheep	22	0.324	1.44	4.44
	solid content in sludge: 40%			**Average:**	**8.05**

Annex 1

No	Enterprise Name	Table 2	Table 3	Table 4	Table 5
1	Yili Jianhua Leather General Factory	—	11	—	1
2	Yunnan Yuxi Leather Factory	—	—	—	2
3	Shanghai Hongguang Tannery	—	12	—	3
4	The No. 3513 Factory China Xinxing (Croup)	—	9	—	4
5	Harbin Tannery	—	27	—	5
6	Yunnan Lijian fur Leather Factory	—	—	—	6
7	Yunnan Ruibiao Leather Co., Ltd	—	—	—	8
8	Wuhan Leather Manufacture Corp.	—	16	—	9
9	The No. 3515 Factory China Xinxing (Croup)	—	17	—	10
10	Zhuzhou Global leather Co. Ltd.	—	—	—	11
11	Pingdingshan Tannery	—	18	—	12
12	The No. 3514 Factory China Xinxing (Croup)	—	—	—	13
13	Xinji Dongliuk Leather Industry Corp.	—	—	13	14
14	Enping Jianghong Enter-prise corp.	—	26	—	15
15	Nanhai Tannery	—	—	—	16
16	Guanzhoou Development Leather Co. Ltd.	—	—	—	17
17	Langshan Tannery	—	—	—	18
18	Shandong Luyi Beschin Leather Co., Ltd.	—	—	—	—
19	Nanjing Tannery	1	—	—	21
20	The No. 3516 Factory China Yining (Group.)	—	4	—	22
21	Linhai Tannery	10	—	—	23
22	Weifang Huiyuan Tannery Co. Ltd.	14	—	—	24
23	Xuebao Group Baosen Co. Ltd.	—	—	14	25
24	Shandong Weihai Tannery	15	—	—	26
25	Shandong Yantai Tannery	16	—	—	27
26	Shandong Liju Maode Leather Co. Ltd.	17	—	—	28
27	Shandong Yishui Shoe-making Factory	20	—	—	29
28	Qidong Sheep Leather Factory	3	—	—	30
29	Suzhou General Leather Factory	4	—	—	31
30	Zhenjiang Tannery	5	—	—	32
31	Xuzhou Globe-eagle Leather Co.	—	1	—	33
32	Haining Leather Group Co., Ltd.	—	—	—	34
33	Shanghai Riohina Leather Co., Ltd	—	3	—	35
34	Anhui Fuyang Feilong Tannery Co., Ltd.	—	—	—	36
35	Anhui Shengli Leather Copr.	—	2	—	37
36	Longchang Group	9	—	—	38

Annex 1

No	Enterprise Name	Table 2	Table 3	Table 4	Table 5
37	Dongyang General Leather Factory	8	—	—	39
38	Huaiyang leather Products Co. Ltd	—	20	—	40
39	Henan Shoe City Leather Products Co., Ltd.	—	19	—	41
40	Xiangcheng Gunahui Tannery	—	21	—	43
41	Xiangcheng Tannery	—	—	9	50
42	Dingji Minxzu Tannery	—	—	7	51
43	Keling Feida Tannery	—	24	—	52
44	Lianhua Leather Group	—	—	—	54
45	Xiangcheng Xili Tannery	—	23	—	56
46	Bianguan Tannery	—	22	—	7
47	Jiangyin Leather Factory	2	—	—	—
48	Jiangmen General Tannery	—	—	—	—
49	Tianchengchan Tannery Co., Ltd.	—	25	—	44
50	Xingji	—	—	4	19
51	Xingji Yunfa Tannery	—	—	15	58
52	Xingji Gengmao Tannery	—	—	2	20
53	Xingji Linzili Lianhe Tannery	—	—	16	57
54	Xingji Tenyue Tannery	—	—	1	55
55	Xingji jinmaqiu Leather Goods Factory	—	—	8	49
56	Xingji Fuli Fur Factory	—	—	5	42
57	Xingji Huayin Tannery	—	—	3	45
58	Xingji Huada Leather Factory	—	—	12	46
59	Xingji Hendeli Fur & Leather Co., Ltd.	—	—	10	48
60	Xinghi Dongming Leather Co. Ltd.	—	—	6	53
61	Dingji Deying Tannery	—	—	11	47
62	Chengdu Juxing Leather Corp.	11	—	—	—
63	Liaoning Kiayuan Tannery	21	—	—	—
64	Yulin Leather General Factory	—	15	—	—
65	Yunnan Detiao Leather Factory	—	—	—	—
66	Zhanjiang Tannery	—	—	—	—
67	Haikou Tannery	—	—	—	—
68	Zhaofu leather Product Co., Ltd.	—	—	—	—
69	Guangxi Hechi Area Leather Factory	—	—	—	—
70	Taiyuan Leather General Factory	—	—	—	—
71	Hubei Jianli Tannery	—	—	—	—
72	Rizhao General Tannery	19	—	—	—
73	Nanchang Tannery	—	—	—	—
74	Yugang Xianfeng Tanning Co., Ltd.	—	14	—	—
75	Chengdu General Tannery	—	—	—	—
76	Jiangsu Jingjiang Tannery	6	—	—	—
77	Neijiang Tannery	12	—	—	—
78	Zunyi Tannery	—	—	—	—
79	Dujiangyan Tannery	13	—	—	—
80	Tongren Area Leather Factory	—	—	—	—

No	Enterprise Name	Table 2	Table 3	Table 4	Table 5
81	Mianyang Tannery	7	—	—	—
82	Huaxin Leather Industry Cooperated Company	—	—	—	—
83	Longxi Leather Factory	—	—	—	—
84	Guizhou Duyun Tannery	—	—	—	—
85	Dalian Fullshing Tannery Co., Ltd.	—	28	—	—
86	Urumqi No. 1 Tannery	—	6	—	—
87	Urumqi No. 2 Tannery	—	7	—	—
88	Aletai Leather Group Co., Ltd.	—	8	—	—
89	Lanzhou Leather Factory	—	—	—	—
90	Qinghai No. 1 Tannery	—	13	—	—
91	Zhejiang Zujia Group Corp.	—	5	—	—
92	Huantai Genneral Tannery	—	—	—	—
93	Wendeng Tannery Group Corp.	18	—	—	—
94	Ouhai Dongda Leather Co. Ltd.	—	—	—	—
95	ZHongshan Rixin Tannery	—	—	—	—
96	Bayi Jina Tannery	—	—	—	—
97	Baifu Leather Co., Ltd.	—	10	—	—
98	Hualiang Leather Industry Corp.	—	29	—	—
99	Jilin Taonan Tannery	—	—	—	—
100	Guizhong Weining Leather Factory	—	—	—	—

ANNEX 2

Engineering Aspects of Landfill

3.1 INTRODUCTION

Good design of facilities is a key component in ecologically sound landfill disposal (other components are siting, waste pre-treatment, and safe operation). The engineering aspects of landfills must take the natural site features into account, as well as the construction of artificial barriers to leachate movement, cell construction, site capping and so on.

Landfill design has developed considerably in recent years. The main emphasis has been to introduce greater safeguards against escape of contaminants from the site. The key issue in this respect is to minimise leachate generation and escape by paying close attention to surface water management, as well as avoiding the entry of liquid waste to the site.

However, it is likely that some liquids will penetrate the site, and so barriers to leachate escape must be provided. This is done using natural soil or artificial membrane liners to limit leachate movement.

Other engineering aspects include gas collection (where biodegradable wastes are involved), proper site stability, and diversion of surface drainage. In some landfills, special measures are taken to deal with wastes—such as asbestos, encapsulated wastes, for example.

However sophisticated in itself, landfill site engineering has to pay regard to the way the site will be operated, and also to long-term security after closure. Accordingly, site design must allow for easy operation and systematic monitoring.

Actual design is a lengthy task. The exercises in this session give an insight into several aspects of landfill engineering, such as the selection of the best method and leachate control. In real situations, a number of special wastes are often confronted, and an exercise on this is also included.

3.2 BACKGROUND INFORMATION

Table 3.1: Landfill engineering disciplines

Chemical engineering	Electrical engineering	Meteorology
Chemistry	Environmental engineering	Microbiology
Civil engineering	Geotechnics	Reclamation
Climatology	Horticulture	Soil mechanics
Cost and benefit analyses	Hydrology	Transportation economics
Ecology	Landscaping	Water engineering

Source: *Disposal and Recovery of Municipal Solid Waste*, Ed. M.E.Hemstock. Butterworths, 1983.

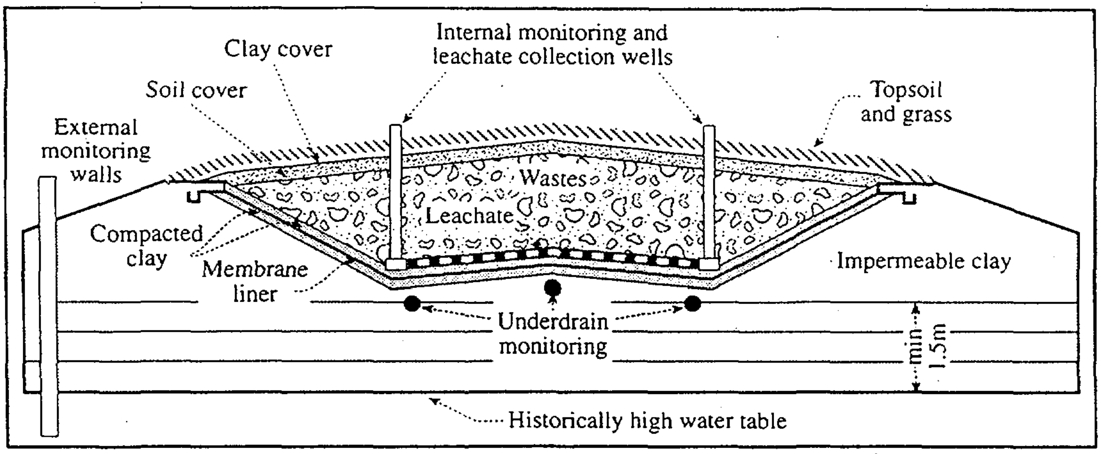
Table 3.2: Landfill types and methods

Landfill concepts
1. ***Attenuate and disperse*** sites where leachate and waste is allowed to escape into the environment at a controlled rate. Pollution is reduced by degradation and attenuation within the landfills and by dilution of the leachate plume in the aquifer. 2. ***Containment*** sites are aimed at isolating wastes and leachate from the surrounding environment for a considerable time. 3. ***Archival*** sites are specifically engineered to contain wastes indefinitely, but also to permit later identification and retrieval.
Methods of landfill
1. ***Co-disposal:*** when hazardous wastes are deposited with or into household or similar wastes with the objective of taking advantage of the attenuation process occurring in such wastes. Wastes must be critically assessed prior to being introduced to ensure that they are compatible with household waste. There are several ways of arranging co-disposal operations, such as trench disposal, or mixing directly with waste deposited on the face. 2. ***Monodisposal:*** where wastes having the same general physical and chemical form, often by lagooning in the case of sludge. Once deposited, the wastes do not necessarily remain in the same physical form—for example, lagooned sludges are generally allowed to dewater; but usually would remain in the same chemical form. Highly polluting wastes would not normally be disposed of in this manner. 3. ***Multi-disposal:*** where the practice of disposing chemically different wastes in the same sites with the aim of reducing the polluting potential of the individual wastes.

Table 3.3: Landfill lining

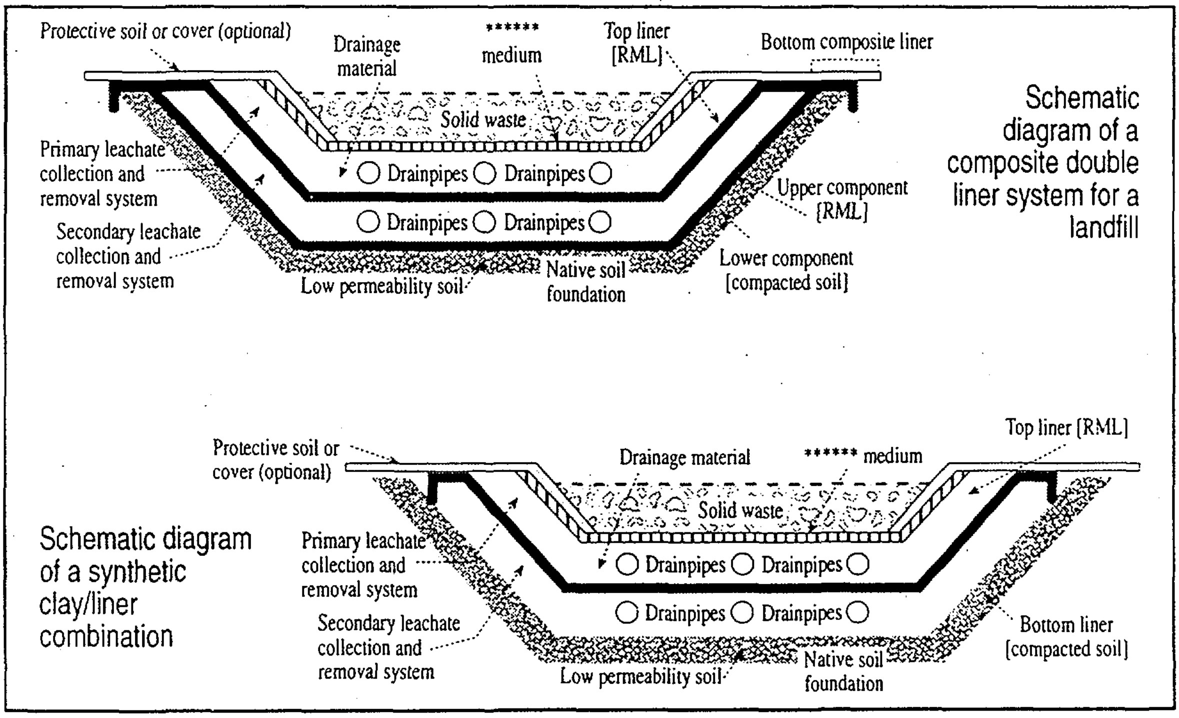
Selecting a liner depends on—
• degree of protection desired against leachate escape • effectiveness: liner types and waste types • cost: both acquisition and installation • installation time • durability
Potential disadvantages of the liner
• the expected life of liners has not been established. Liners have been used at landfills over a relatively short period (less than 10 years), whereas effectiveness must be assured for many decades • effects of various waste types on liners over time are not well understood • difficulty of assuring the quality of the installation • waste disposal operations can tear the liner, causing leachate seepage • changes in hydraulic conductivity of the underlying or surrounding soil cause the groundwater to rise, which exerts upward pressure on the liner • once the liner is in place and waste is deposited, liner failure cannot be easily detected or readily repaired

Figure 3.1: Schematic cross-section of a landfill



Source: *Environmental Science and Engineering*, Prentice Hall

Figure 3.2: Composite liner systems



Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

Figure 3.3: Leachate monitoring borehole

Figure 3.3a *Basement layer system (Germany)*

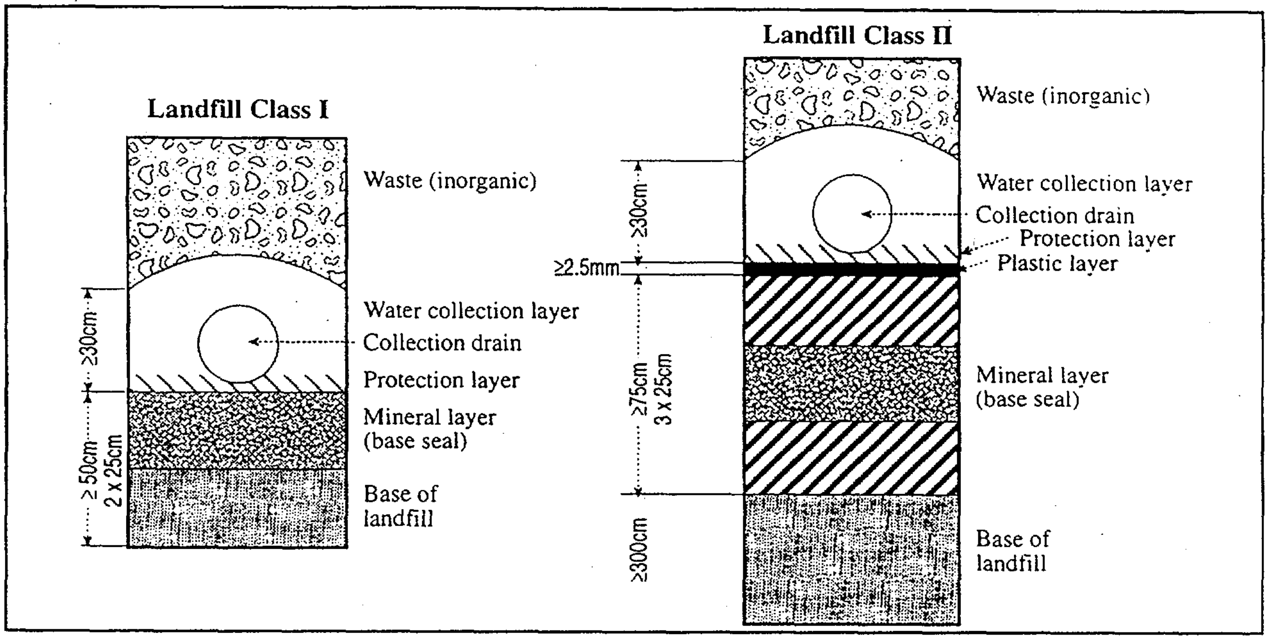


Figure 3.3b *Landfill cross section—base liner (Cibinong, Indonesia)*

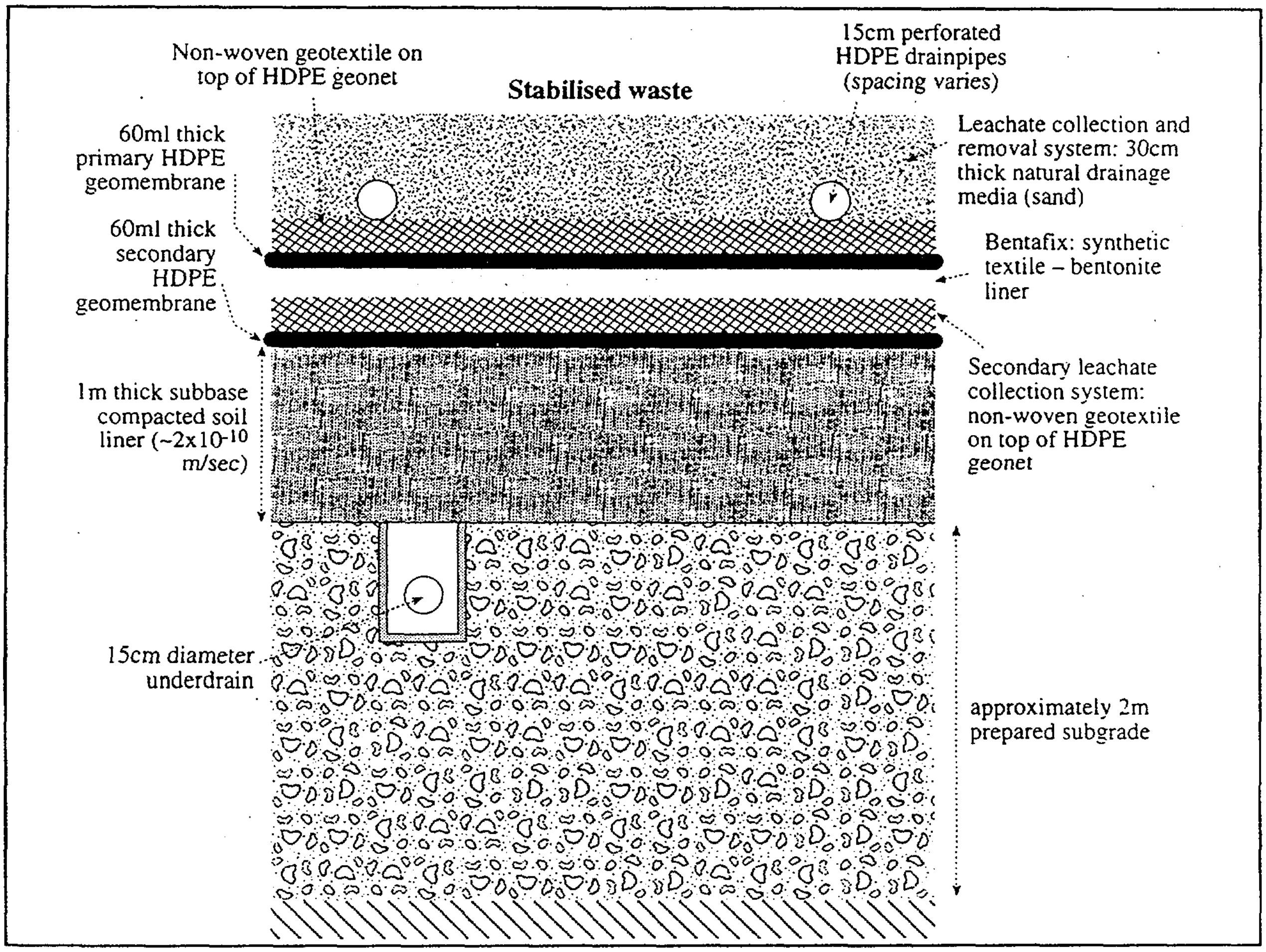


Table 3.4: Characteristics, advantages, and disadvantages of different synthetic liners

Liner material	Characteristics	Range of costs [1]	Advantages	Disadvantages
Chlorosulfonated polyethylene	Family of polymers prepared by reacting polyethylene with chlorine and sulphur dioxide	M	Good resistance to ozone, heat, acids and alkalis, easy to seam	Tensile strength increases on ageing: good tensile when supported: poor resistance to oil
Linear low density polyethylene; very low density polyethylene	Blown or sheet extruded	M to H (based on thickness)	Good resistance to oils and chemicals, resistant to weathering; available in 40–120mm thickness	
Polypropylene	Calendered, blown or sheet extruded	M to H (based on thickness)	Easy to seam in the field, available in 40–120mm thickness	
Ethylene interpolymer alloy	Calendered (reinforced)	M to H	Good chemical resistance, available in 30–80mm, good UV control	
Neoprene	Synthetic rubber based on chloroprene	H	Resistant to oils, weathering, ozone and ultraviolet radiation, to puncture, abrasion and mechanical damage	Difficult to seam or repair
Polyvinyl chloride	Produced in roll form in various widths and thicknesses; polymerisation of vinyl chloride monomer	L	Good resistance to inorganics, good tensile, elongation, puncture, and abrasion resistant properties, wide range of physical properties, easy to seam	Attacked by many organics, including hydrocarbons, solvents and oils; not recommended for exposure to weathering and ultraviolet light conditions
Thermoplastic elastomers	Relatively new class of polymeric materials ranging from highly polar to non-polar	M	Excellent oil, fuel and water resistance with high tensile strength and excellent resistance to weathering and ozone	None reported
High density polyethylene	Blow or sheet extended PE	M to H (based on thickness)	Good resistance to oils and chemicals; resistant to weathering; available in 20–150mm thicknesses, resistance to high temperature	Thicker sheets require more field seams; subject to stress cracking; subject to puncture at lower thicknesses; poor tear propagation.

All ratings are based on proprietary compounded materials designed for that specific application.

Source: US Environmental Protection Agency Handbook *Remedial Action at Waste Disposal Sites*, EPA 625/6–85-006, Cincinnati, Ohio; Office of Research and Development [1985]

[1] Range of costs: L = \$1.4/yd^2, M = \$4.8/y^2, H = \$8.12/yd^2 (installed costs).

Table 3.5: Values of porosity and hydraulic conductivity

		Hydraulic Conductivity	
Soil type	**Porosity %**	**Description**	**K (m/sec)** [2]
Gravel	25-40	High permeability	Over 1×10^{-3}
Sand to fine sand	25-50	Medium permeability	1×10^{-3} to 1×10^{-5}
Silty sand to dirty sand	30-50	Low permeability	1×10^{-5} to 1×10^{-7}
Silt	35-50	Very low permeability	1×10^{-7} to 1×10^{-9}
Clay	40-70	Practically impervious	less than 1×10^{-9}

Source: **For porosity values**, Freeze, R.A., and Cherry, J.A., *Groundwater*, Englewood Cliffs, N.J.: Prentice Hall, 1979, pp. 36-37. **For hydraulic conductivity values**, Theil, P. 'Subsurface Disposal of Storm Water' in *Modern Sewer Design*, Canadian Edition, ed. Committee of Sheet Steel Producers, Washington, D.C.: American Iron and Steel Institute, 1980, pp. 175-193. From: *Environmental Science and Engineering*, J.G. Henry and G.W. Heinke. Prentice Hall International Editions.

Significance of soil permeability values

Permeability value (K_s)	**Equivalent movement of liquid and associated contaminants**	
(m/sec)	(m/year)	(feet/year)
1×10^{-3}	31500	100 000
1×10^{-5}	315.0	1000
1×10^{-7}	3.2	10
1×10^{-9}	0.03	0.1

The above is only indicative as actual flow rates will depend on the hydraulic gradient and other factors. Contaminants may not move at the same rate as the water, due to attenuation or solute potential.

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

[2] Conversions: m/sec x 0.0197 = feet/min; m/sec x 28.80 = feet/day; m/sec x 212 = qpd/ft^2

Table 3.6: Landfill leachate

Factors which affect movement of leachate in a landfill site	
• geohydrologic conditions	• disposal methods and operating conditions
• climatic conditions	• types of waste
• engineering design	• age of site

Estimation of leachate seepage velocity

Darcy's Law: Q = KA*(dh/dL)

Where: Q *is the seepage discharge flow rate*; A *is a cross-section area of the bed*; K *is the coefficient of permeability*; dh/dL is *the hydraulic gradient*

Estimation of amount of leachate produced

$$L_0 = L - E - aW$$

Where:

L_0	*is the free leachate retained at the site (m^3/annum)*
L	*is the total liquid input (precipitation + liquid waste + surface and groundwater inflow + liquid content of waste) in m^3/annum*
E	*is the evapotranspiration losses in m^3/annum*
a	*is the absorptive capacity of the waste in m^3/tonne*
W	*is the weight of the waste deposited in tonnes/annum*

Leachate treatment methods	
• recirculation through landfill	• on-site treatment: chemical/physical treatment
• spray irrigation	• biological treatment
• evaporation in collection pond	• evaporation of leachate in collection pond
• discharged to municipal wastewater collection system	

Table 3.7: Composition of some leachates from landfills
(all results in mg/l except pH value)

	Household waste	**Pitsea** [UK] *Industrial* 43%	**Rainham** [3] [UK] *Industrial/ Household*	**Granmo** [NORWAY] *Industrial* 66%	**Cedar Hill** [USA] *Industrial/ Household*
pH value	5.8–7.5	8.0–8.5	6.9–8.0	6.8	5.4
COD	100–62 400	850–1350		470	38 800
BOD	2–38 000	80–250		320	24 500
TOC	20–19 000	200–650	77–10 000	100	
Volatile acids (C1–C6)	ND–3700	20	600–10 000	10	7100
Ammoniacal–N	5–1000	200–600	90–1700	120	
Organic–N	ND–770	5–20		62	
Nitrate–N	0.5–5			0.04	
Nitrate–N	0.2–2	0.10–10	8.0		
o-Phosphate	0.02–3	0.20		0.6 (total)	11.3 (total)
Chloride	100–3000	3400	400–1300	680	
Sulphate	60–460	340	150–1100	30	
Sodium (Na)	40–2800	2185	2000	462	
Potassium (K)	20–2050	888	50–125	200	
Magnesium (Mg)	10–480	214		66	
Calcium (Ca)	1.0–165	88		188	
Chromium (Cr)	0.05–1.0	0.05	0.5	0.02	1.05
Manganese (Mn)	0.3–250	0.5			
Iron (Fe)	0.1–2050	10	0.6–1000	70	810
Nickel (Ni)	0.05–1.70	0.04	0.5	0.1	1.20
Copper (Cu)	0.01–1.15	0.09	0.5	0.09	1.30
Zinc (Zn)	0.05–130	0.16	1.0–10	0.06	155
Cadmium (Cd)	0.005–0.01	0.02		0.0005	0.03
Lead (Pb)	0.05–0.60	0.10	0.5	0.004	1.40
Monohydric phenols		0.01	ND–2.0		
Total cyanide		0.01	0.09–0.52		
Organochloride pesticides		0.01			
Organophosphorous pesticides		0.05			
PCBs		0.05			

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

[3] Samples obtained from boreholes within the fill.

Table 3.8: Landfill design factors

1. Design objectives

A. Safe and permanent treatment and disposal of hazardous and toxic wastes

a All wastes will be required to be assessed for their suitability for landfill. Wastes should be rendered inert prior to placement in the landfill to the extent practicable.

b A successful treatment facility will—
- *recover useful materials from waste*
- *reduce quantities to be landfilled*
- *prepare waste for disposal (render contaminants as insoluble as practicable).*

B. Provide an economic balance between public and environmental well-being and impacts on the nation's industrial sector

2. Factors influencing design

A. Public acceptance and support

B. Permitting and regulatory compliance (compromise between various government agencies and municipalities)

C. Site access and topography

D. Availability of suitable land

E. Availability of technology, equipment and spare parts

F. Geotechnical aspects of the site

G. Climate and availability of climatological data

H. Design of contaminant control mechanisms and monitoring systems

I. After-use of the site.

3. Administrative and processing facility design

A. Transportation

a Impacts on connection to the regional transit system (roads, highways, railroads)

b Internal facility circulation—
- *minimise cross traffic*
- *one way traffic is preferred*

c Wheel cleaning and vehicle wash facilities.

B. Administration area

a Administrative building for—
- *operations engineering*
- *record keeping and accounting*
- *security headquarters*

b Weighbridge and reception point (with sanitary facilities, utilities etc.)—
- *Entrance and exit scale to avoid traffic conflicts*

c Loading inspection area

d Parking lot for personnel and visitors

e Pullout area for incoming vehicles applying for permits at the administrative building.

C. Waste receiving area

a Loading docks for drums and bulk waste

b Storage and segregation area for drums and bulk wastes

c Transfer area for roll-offs and trailers

d Hot pad, holding quarantine area for non-conforming, leaking or unidentified loads.

D. Process treatment

a Physical/chemical treatment (including for leachate): these process treatments prepare waste for landfill. They oxidise cyanide wastes, reduce hexavalent chromium, precipitate and remove heavy metals and remove organic contaminants and suspended solids

b Solidification and stabilisation: utilises cementitious reactions to incorporate the waste material in a solid matrix with greatly reduced susceptibility to leaching.

E. Infrastructure and support facilities

a Maintenance (workshops etc.)

b Emergency equipment (fire, spillage)

c Monitoring (weather station, laboratory facilities for waste analysis).

4. Excavation and disposal area design

A. Hydrogeological information

a Soil (depth, texture, structure, porosity, permeability, moisture, ease of excavation, stability, pH and cation exchange capacity)

b Bedrock (depth, type, presence of fractures, location of surface outcrops)

c Groundwater (average depth, seasonal fluctuations, hydraulic gradient and direction of flow, rate of flow, quality, uses)

d Proximity of surface waters

e Seismicity of the region.

B. Design of landfilling area

a Select landfilling method

b Knowing projected waste stream quantities and types of waste expected, determine capacity for 30 to 40 year design life

c Specify design dimensions (trench or cell width, depth, length, spacing, number, and interim cover and final cover thickness)

d Specify operational features (use of cover soil, method of cover application, need for imported soil, equipment requirements, personnel requirements)

e Specify final landforms (contours, slopes).

C. Disposal area layout

a Optimise land use and facilitate operations

b Provide security fencing and buffer zones, escape routes

c Follow government regulations, observe property set-backs.

D. Liner design

a Consult manufacturers and installers of flexible membrane liners

b Evaluate compatibility of liner materials with expected leachate.

E. Leachate collection system

a Sumps and monitoring wells

b Manholes and risers

c Leachate treatment.

F. Drainage design

a Run-on-runoff control systems

b On-site runoff may or may not need treatment.

G. Closure plan

a Impermeable cap design

b Gas generation control

c Long term ground water monitoring

d Restoration and after-care.

H. Construction and disposal sequence

I. Quality assurance plan

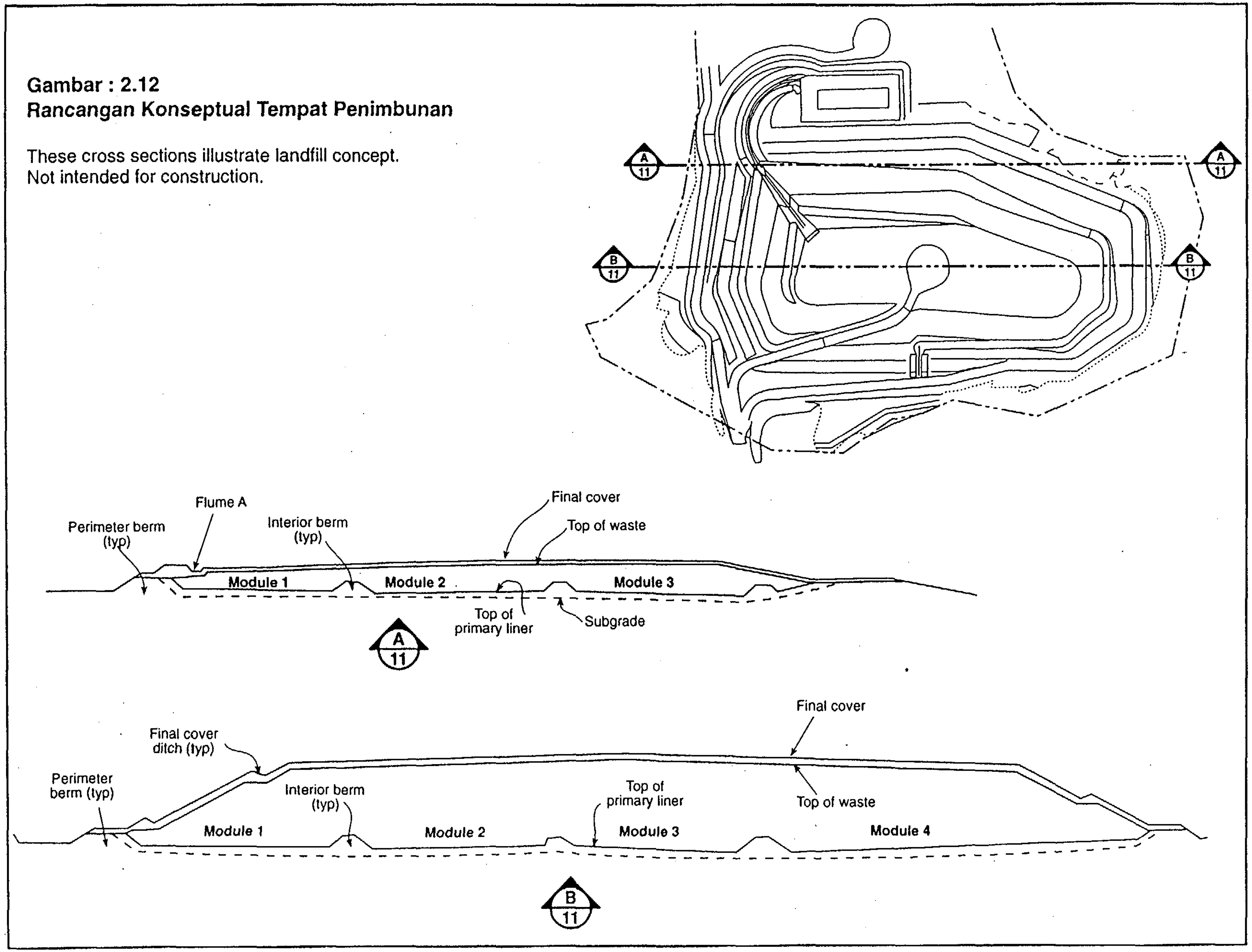
J. Construction specifications, cost estimate and operations plan.

Source: Udanax Environmental Consultancy, Udanax City.

Table 3.9: Landfill design criteria

1.	**General constraints**
	a 15 m minimum from edge of landfill to property line *b* Base of liner foundation must be 2.4 m above water table.
2.	**Recommended slopes**
	a Final cover— • *minimum 2%; recommended 5%; maximum 33%* *b* Interim and perimeter berms • *1% to 5%* *c* Base • *2% desirable; 0.5% minimum.*
3.	**Landfill liners**
	Permeability <= 1 x 10^{-7} cm/s *a* Clay liners • *minimum amount of clay 25-28 % by weight; compacted to 95 % maximum density* *b* Flexible membrane liners • *synthetic polymer liners; resistance to chemical attack.*
4.	**Leachate and gas collection system**
	The leachate collection and removal system consists of a network of drains to collect and remove any accumulation of leachate that might develop in the bottom of the landfill, and it prevents migration of leachate to the subsurface. *a* Collection drain layer • *layer permeability not less than 10^{-3} m/sec; minimum thickness 30 cm; minimum slope 3%* *b* Drain Pipe • *size & hydraulic capacity: large enough to carry-off the collected leachate* • *spacing (recommend by U.S. EPA)* *size : 15 cm diameter perforated or slotted; spacing: 5 to 60 m apart* *c* Gas Collection • *active or passive system using vertical/horizontal wells or venting trenches.* *Unless the landfill is to receive mainly inert wastes an active (i.e. pumped) a gas collection system is needed.*
5.	**Final cover**
	Settlement allowance: need to surcharge contours by 10-25% depending on wastes landfilled. *a* Geometry of the design • *avoid ponding* • *adequate drainage without inducing unacceptable erosion* • *adequate landscape integration* *b* Arrangement (US EPA Regulation) • *vegetated top layer with minimum thickness 60 cm* • *middle drainage layer with minimum thickness of 30 cm and permeability of 10^{-3} m/sec* • *low permeability bottom layer (10^{-9} m/sec) with two-component system: i] membrane liner; ii] underlain by at least 60 cm of compacted clay*
6.	**Run-on/Run-off systems**
	This system consists of combination of dikes, berms, ditches and sumps to intercept run-off from off-site areas and divert it away from the landfill. The system is also designed to collect, store and if necessary treat any precipitation falling directly on the landfill. Design criteria: 24 hour 25 year storm event.

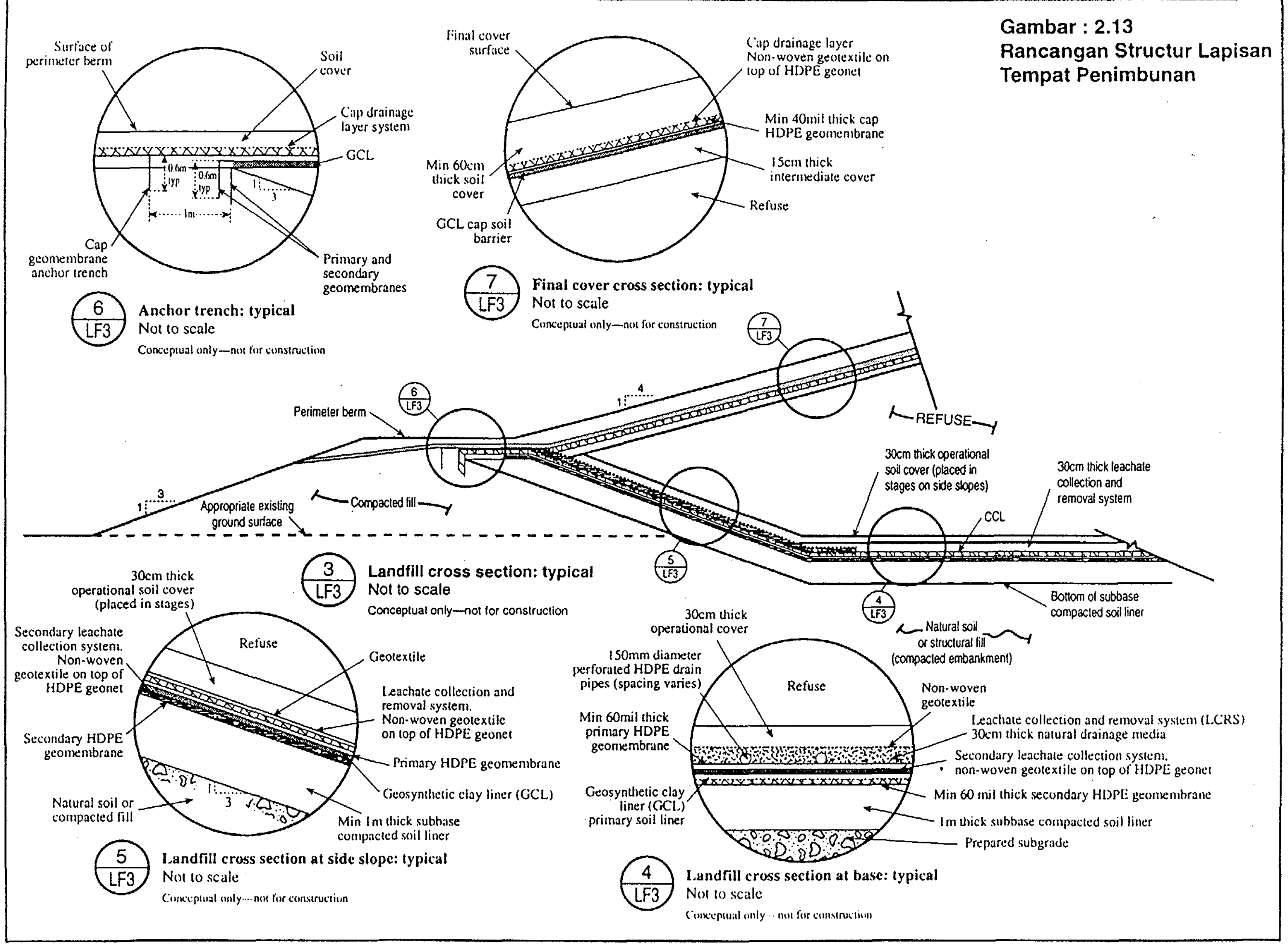
Source: Udanax Environmental Consultancy, Udanax City.

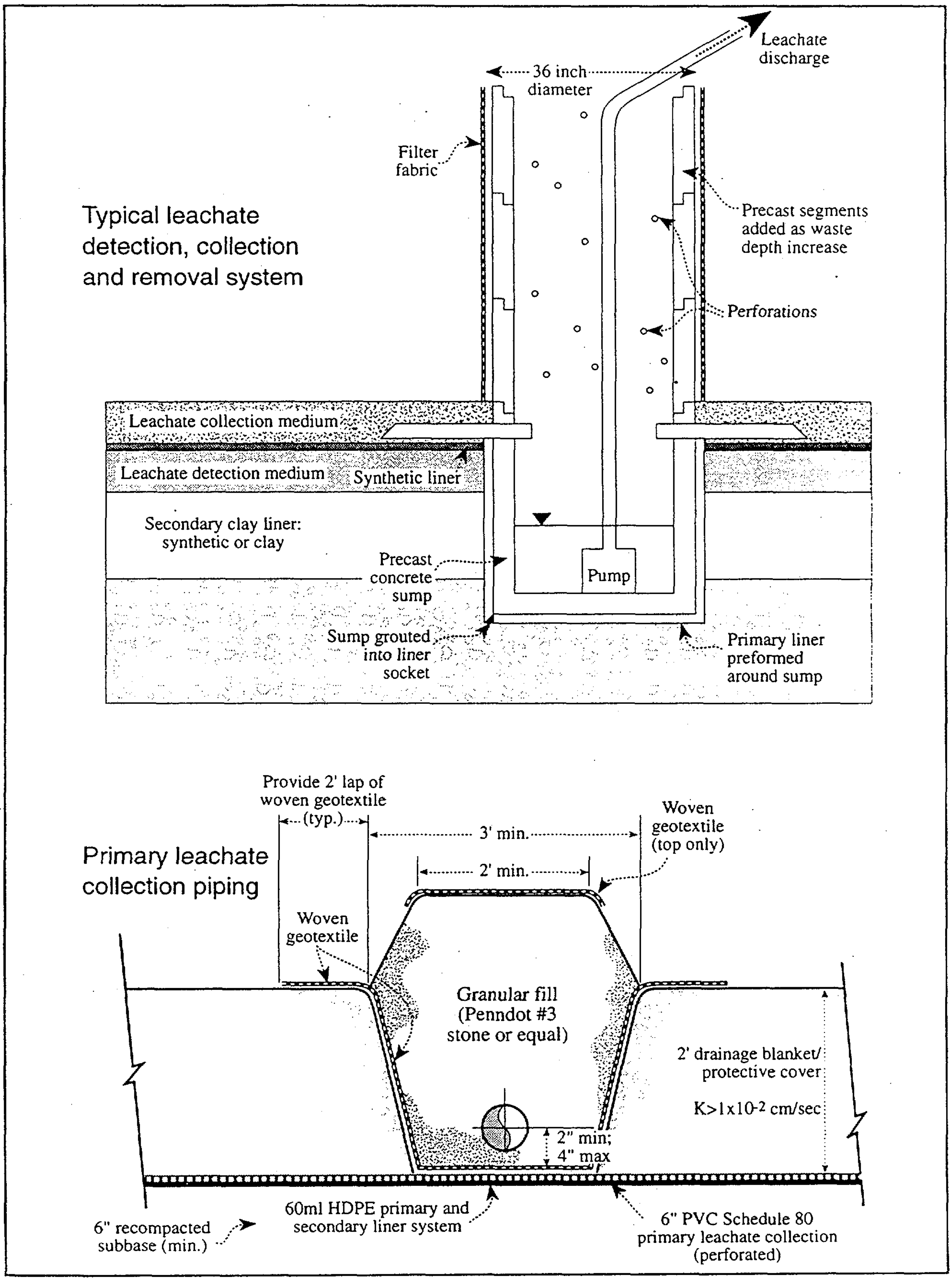


Source: EMDI, Indonesia

Figure 3.5: Example of design of hazardous waste landfill *(Indonesia)*

Gambar : 2.13
Rancangan Structur Lapisan Tempat Penimbunan





Source: Dames and Moore

Table 3.10: Indicative site development costs

Assumptions

1. **Site investigation proves the site suitable for waste disposal**
2. **Access to the site by rail is achieved**
3. **Overhead power lines cannot be relocated**
4. **Streams on site can be diverted** (if not, site volume may be reduced slightly)
5. **Filling rate of 300,000 m^3/a is achieved**
6. **Site volume = 7 million m^3**
7. **Area suitable for landfill = 434,000 m^2 (average fill depth = 16m)**
8. Site life = 23 years

1. Planning and site licence

Site investigation	$80,000	Appeal costs	$400,000
Preparation of EIA and application	$220,000	Licence application	$14,000
Application fee	$13,000	Topographic survey	$12,000

2. Rail transfer facility

The facility will need to be built level with the existing rail track, around 6m above the surrounding land.

This is a very rough estimate and will require considerable work to be accurately assessed.
Fill, track, points, ballast, signals and access ramps and mobile crane. $4,000,000

3. Access

Required for employees and plant.

Upgrade existing farm track 400 x 5m^2 at \$20/m^2 .... $40,000

New road to reception area (350x5) + 100m^2 of passing bays at \$40/m^2 .... $74,000

4. Reception area

Hardstanding 2,500m^2 at \$ 20/m^2	$50,000	Telecom	Snil
Office	$14,000	Sewage (septic tank)	$4,000
Canteen	$14,000	Fuel Tank	$9,000
Electricity	$100,000	Workshop	$14,000
Water	$30,000		

5. Preparation of base

1m of "soil" to be stripped and stockpiled from the initial area to be prepared. Thereafter stockpiling will not be needed. Soil stripped from a new area will be used directly to restore a filled area.

Total area = 434,000 m^3. Annually 434,000/23 will be needed—i.e. 18,900 m^2/a

Prior to site opening two years landfilling space will be prepared.

Soil strip and stockpile = 2 x 18,900m^3 at \$2.80/m^3 .... $106,000

Rework 1m depth of clay = 2 x 18,900m^3 at \$3.60 .... $136,000

Thereafter annually:

Soil will be stripped and used for restoration (years 1 to 21): see *Restoration* section.

Rework 1m depth of clay = 18,900m^3 at \$3.60 .... $68,000

Additionally, annually allow for movement of 10,000m^3 for bunding etc at \$3.20 .... $34,000

6. Leachate drainage

Using perforated pipe surrounded by shredded tyres. Runs to be spaced at 20m centres.

Tyres shred 2.5m^3/m run — Section = \$25.00/m
Back haul at, say, \$6.00/m^3 = \$15/m — Geotextile at \$6.00/m
Slotted aquapipe 125mm at \$74/3m

Base of site .... Cost/linear m = \$41.00

1m of pipe services 20m^2 of floor
Cost per m^2 of floor = \$41.00/20 = \$2.05
Annually require 18,900m^2 of floor to be covered

Therefore annual cost is \$38.800/a

Leachate chimneys: allow a further \$12.000/a

Provision of an artificial membrane if required

HDPE geotextile at \$4.00/m^2
2.5mm HDPE membrane at \$12.00/m^2 .... \$27.20/m^2
HDPE geotextile at \$4.00/m^2
Sand blinding at \$7.20/m^2

This gives an annual cost of \$38.40 x 18,900 .... \$726.000/a

7. Leachate generation and treatment [4]

Year cost	Area	15% of effective rainfall *(m/yr)*	Volume of leachate *(m³)*	Capital cost *(\$)*	Treatment running
1	18,900	0.055	1,040	60,000	20.800
2	37,800	0.055	2,079		41.580
3	56,700	0.055	3,118		62.360
4	75,600	0.055	4,160		83.200
5	94,500	0.055	5,200		104.000
6	113,400	0.055	6,240		124.800
7	132,300	0.055	7,280	60,000	145.600
8	151,200	0.055	8,320		166.400
9	170,100	0.055	9,360		187.200
10	189,000	0.055	10,400		208.000
11	207,900	0.055	11,440		228.800
12	226,800	0.055	12,480		249.600
13	245,700	0.055	13,520		270.400
14	264,600	0.055	14,560	60,000	291.200
15	283,500	0.055	15,600		312.000
16	302,400	0.055	16,640		332.800
17	321,300	0.055	17,680		353.600
18	340,200	0.055	18,720		374.400
19	359,100	0.055	19,760		395.200
20	378,000	0.055	20,800		416.000
21	396,000	0.055	21,840	60,000	436.800
22	415,000	0.055	22,880		457.600
23	434,700	0.055	23,920		478.400
24	434,700	0.055	23,920		478.400
25	434,700	0.055	23,920		478.400

Continues 20+ years

[4] Based on an activated sludge system, treating 7.300m^3/a at \$60,000 per plant. Cost of treatment = \$20/m^3.

8. Landfill gas control

Based on estimated costs of:

Capital = \$0.30/m^3 of waste imported; Running cost = \$0.050/m^3 in situ;
Volume placed annually = 300,000m^3

Year	Volume of waste		Capital	Running
	Input/yr	Cumulative input	\$	\$
1	300,000	300,000	90,000	15,000
2	300,000	600,000	90,000	30,000
3	300,000	900,000	90,000	45,000
4	300,000	1,200,000	90,000	60,000
5	300,000	1,500,000	90,000	75,000
6	300,000	1,800,000	90,000	90,000
7	300,000	2,100,000	90,000	105,000
8	300,000	2,400,000	90,000	120,000
9	300,000	2,700,000	90,000	135,000
10	300,000	3,000,000	90,000	150,000
11	300,000	3,300,000	90,000	165,000
12	300,000	3,600,000	90,000	180,000
13	300,000	3,900,000	90,000	195,000
14	300,000	4,200,000	90,000	210,000
15	300,000	4,500,000	90,000	225,000
16	300,000	4,800,000	90,000	240,000
17	300,000	5,100,000	90,000	255,000
18	300,000	5,400,000	90,000	270,000
19	300,000	5,700,000	90,000	285,000
20	300,000	6,000,000	90,000	300,000
21	300,000	6,300,000	90,000	311,000
22	300,000	6,600,000	90,000	330,000
23	300,000	6,900,000	90,000	345,000
24	NIL	6,900,000	NIL	345,000
25	NIL	6,900,000	NIL	345,000

9. Surface water pick up drains

2,800m of ditching at \$12/m \$33,600

10. Capping and restoration

Engineering cap: to be placed each year following filling
Area to be capped annually = 18,900 m^2
Using on-site material 18,900m^3 at \$3.60/m^2 .... \$68,000/a

Alternative cost if VLDPE is used
Geotextiles and VLDPE = \$12.20/m^2 .... \$241,560

Replacement of soil (agricultural cap)
18,900 m^3 at \$2.80/m^3 .... \$52,920/a

11. Fencing

Given that the site is isolated security fencing may not be needed except for a compound around the reception area—say, 300m at $30/m $9.000

(Should it be needed around the entire site, the cost would be 2,800m at $30/m) $84.000

12. Monitoring

Groundwater monitoring boreholes: 6 at $8,000 each $48.000

Gas probes: say, 30 at $200 each $6.000

Environmental monitoring: annually $60.000/a

13. Consultants

VTU surveys, levelling etc $12.000/a

Supervision of earthworks by geotechnical engineer $8.000/a

Materials testing $6.000/a

14. Site roads

Initially one main site road 800m x 8m at $50/m^2 .... $320.000

Maintenance $30.000/a

Annually site road construction: allow a contingency of $40.000

Source: Shanks McEwen, UK.

ANNEX 3

Cost Estimation

The Annex consists of three parts:

Annex 3.1 contains typical parameters used for calculations, and in Annex 3.2 cost calculation based on sludge treatment process are compiled.

Cost estimates have been established for 4 different annual sludge production rates of 500, 5 000, and 50 000 t per year (at 5% ds). Annual production rates ranging from between 500 to 50,000 tons of sludge (at 5% ds) reflects the current range of production of Chinese tanneries considering various sizes and raw materials (compare Annex 1). The rate of 100,000 t (at 5% ds) of sludge production per year was chosen in order to provide indicative cost for treatment facilities operated jointly by a number of tanneries (e.g. for tanning centres).

For all technologies cost have been calculated at the basis of 5% ds for the above mentioned production rates (compare Annex 3.2) and for the respective initial solid content of each method (compare Annex 3.3). The cost estimations for incineration have been included for comparison only. Due to the high capital and O&M cost, incineration is not normally used in treatment plants with capacities smaller than 5 Mio. m^3 per year.

Finally, in Annex 3.3 cost calculations for selected sludge treatment paths have been compiled. These cost are based on the process cost presented in Annex 3.2 but taking in to consideration the different volume due to different water contents. For each process step the initial water content and the composting sludge volume are mentioned.

3.1 Basic Parameters required for Mass Balance

Table A/3.1-1 TYPICAL PARAMETERS REQUIRED FOR CALCULATING A MASS BALANCE FOR THE CONVERSION PROCESSES

Process	Parameter	Range
Anaerobic Digestion	Influent volatile solids	50-80%
	Volatile solids destroyed	40-60%
	Return stream suspended solids concentration	3,000-15,000 mg/l
Aerobic Digestion	Influent volatile solids	50-80%
	Volatile solids destroyed	33-70%
	Return stream suspended solids concentration	5,000-30,000 mg/l/
Lime Stabilization	Dosage - Primary sludge	0.05-0.07 kg/kg dry/ solids
	Dosage - Activated sludge	0.1-0.2 kg/kg dry/ solids
	Dosage-Combined sludge	0.1-0.2 kg/kg dry/ solids
Thermal Conditioning	Raw solids concentration	1.5-15%
	Influent volatile solids	50-80%
	Volatile solids destroyed	30-40%
	Return stream suspended solids concentration	1,000-5,000 mg/l
Chemical Conditioning:		
- Lime	Raw primary and waste activated	50-136 kg/t ds
		70-170 kg/t ds
	Digested primary and waste activated	
- Ferric Chloride	Primary	18-50 kg/t ds
	Waste activated	50-90 kg/t ds
	Digested combined	30-90 kg/t ds
- Polymers	Primary	0.2-0.4 kg/t ds
	Waste activated	4-7 kg/t ds
	Digested combined	2-5 kg/t ds
Composting	Solids concentration of sludge cake	20-50%
	Solids concentration of recycle	60-75%
	Solids concentration of bulking agent	50-85%
	Solids concentration of compost mixture	40-50%
	Volatile solids concentration of sludge cake - Digested sludge	40-60%
	Volatile solids concentration of sludge cake - Raw sludge	60-80%
	Volatile solids concentration of recycle	
	Volatile solids concentration of bulking agentVolatile solids	0-90%
	concentration of compost mixture	55-90%
	Volatile solids destroyed in sludge cake	40-80%
	Volatile solids destroyed in recycle	
	Volatile solids destroyed in bulking agent	33-56%
	Volatile solids destroyed in compost	0-20%
	product	0-40%
		20-60%

Table A/3.1-2 TYPICAL INFLUENT SOLIDS CONCENTRATIONS, CAPTURE VALUES, AND EXPECTED EFFLUENT SOLIDS CONCENTRATIONS FROM VARIOUS TREATMENT PROCESSES

Process	Typical Influent Solids Concentration (%)	Process Solids Capture (%)	Effluent Solids Concentration (%)
Gravity Thickeners			
Primary Only	2-7	85-92	4-10
Primary and Waste-Activated	1.5-6	80-90	3-7
Primary and Trickling Filter Humus	3-6	80-90	7-10
Flotation Thickener			
Waste-Activated Only	0.4-1.5	80-95	2-7
Anaerobic Digester			
PrimaryOnly	2-10		3-12
Primary and Waste Activated	1.5-6		2-8
Primary and Trickling Filter Humus	2-6		3-8
Aerobic Digester			
PrimaryOnly	2-6		2.5-7
Primary and Waste Activated	1.5-4		2-5
Waste-Activated Only	0.3-2		0.8-2.5
Thermal Conditioning			
Primary Only	1-6	90-92	1.5-8
Primary and Waste-Activated	1-6	90	1.5-12
Centrifuge Dewatering			
Primary Only	4-8	90-97	20-40
Primary and Waste-Activated	0.5-3	85-90	16-25
Primary and Trickling Filter Humus	2-5	90-97	20-30
Anaerobically Digested Primary and Waste-Activated	1-8	85-99	12-30
Thermally Conditioned Primary and Waste-Activated	4-8	85-99	38-50
Belt Filter Press			
Primary Only	3-10	85-99	28-44
Primary and Waste-Activated	3-6	85-99	20-40
Primary and Trickling Filter Humus	3-6	85-99	20-40
Anaerobically Digested Primary and Waste-Activated	1-8	85-99	38-50
Thermally Conditioned Primary and Waste-Activated	4-8	85-99	38-50
Pressure Filtration			
Primary Only	5-10	85-99	45-50
Waste-Activated Only	3-5	85-99	37-45
Primary and Waste-Activated	3-6	85-99	35-50
Primary and Trickling Filter Humus	3-6	85-99	35-50
Anaerobically Digested Primary and Waste-Activated	2-10	85-99	40-50
Thermally Conditioned Primary and Waste-Activated	3-7	85-99	30-48

(continued)

Process	Typical Influent Solids Concentration (%)	Process Solids Capture (%)	Effluent Solids Concentration (%)
Vacuum Filtration			
Primary Only	3-8	90-98	25-30
Waste-Activated Only	3-5	75-80	12-18
Primary and Waste-Activated	2-4	85-99	15-30
Primary and Trickling Filter Humus	2-4	85-99	15-30
Anaerobically Digested Primary and Waste-Activated	2-8	70-80	15-28
Thermally Conditioned Primary and Waste-Activated	3-7	70-95	30-50
Drying Beds			
Primary Only	2-9	>99	20-40
Waste-Activated Only	0.7-4	87	10-20
Primary and Waste-Activated	2-5	85-100	10-30
Primary and Trickling Filter Humus	2-5	85-100	10-30
Anaerobically Digested Primary and Waste-Activated	3-8	86	10-45
Thermally Conditioned Primary and Waste-Activated	3-7	99	15-45
Multiple Hearth Incineration	16-40		
Fluidized Bed Incineration	15-60		
Windrow Composting	15-40		45-65
Static Aerated Pile Composting	30-50		40-65

3.2 Sludge Treatment Processes

CENTRIFUGE DEWATERING

Centrifuge dewatering is a process in which centrifugal force is applied to promote the separation of solids from the liquid in a sludge. Dewatering is accomplished through clarification and solids compaction. Depending upon the physical properties of the sludge (particle size and density, temperature, and sludge age), the solids concentration in the dewatered cake varies from 10 to 25 percent.

The selection and design of a centrifuge is dependent on a number of factors determined through a pilot test program. Process variables include the feed flow rate, rotational speed of the centrifuge, differential speed of the scroll, depth of the settling zone, chemical use, and the physical properties of the sludge. Design parameters are established by individual equipment manufacturers, and include maximum operating speed, feed inlet, and conveyor and bowl type. Although there are numerous types of centrifuges available, only two have found prominence in dewatering sludges: the imperforate basket and the solid bowl conveyor.

The most common type of centrifuge used in wastewater sludge management is the solid bowl, also referred to as a scroll centrifuge. Solid bowl centrifuges are classified as either high g or low g; high-g centrifuges operate above 1,400 rpm, and low-g centrifuges operate at less than 1,400 rpm. In the solid bowl type, sludge is fed at a constant flow rate into a rotating bowl where it separates into a dense cake containing the solids, and a dilute centrate stream. Centrate is usually returned to the primary clarifier or sludge thickener.

Base capital costs in this algorithm include the purchase and installation of one or more low-g solid bowl centrifuges. The number of centrifuges required is based on sludge flow, according to the following matrix:

Sludge Flow (gal/min)	Number of Centrifuges
≤ 500	1
> 500 but ≤ 1,000	2
> 1,000 but ≤ 1,500	3
> 1,500 but ≤ 2,000	4

In addition base capital cost include the construction of a building of sufficient area to house the units and ancillary equipment's purchase and installation of pipe; and electrical instrumentation. O+M cost include labor, electrical energy and materials.

Hours per day operated: 8
Days per year process is operated: 365

Table: A/3.2-1	**Cost Estimation: Centrifuge Dewatering**					
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed	MSV	m^3/hr	0.18	1,7	17,3	36,7
Labour	L	hr/yr	744	748	944	1.291
Process energy	PE	kWhr/yr	2.656	20.380	175.514	321.903
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Labour cost	COSTLB	$/yr	744	748	944	1.291
Energy cost	COSTEL	$/yr	159	1.223	10.531	19.314
Material and wear parts	COSTPM	$/yr	2.123	2.211	3.070	4.017
Total base capital cost	**TBCC**	**$**	**58.000**	**85.000**	**132.000**	**275.000**
Annual base capital cost	**ABCC**	**$/yr**	**5.800**	**8.500**	**13.200**	**27.500**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**3.027**	**4.181**	**14.545**	**24.622**
Total annual cost	**TACOST**	**$/yr**	**8.827**	**12.681**	**27.745**	**52.122**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**17,7**	**2,5**	**0,6**	**0,5**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	253	51	11	10
Cost do not include chemical conditioning						
Working time: 8 hr/day; 360 days			high energy cost but little space required			
Lifetime of equipment: 10 years						
Lifetime of buildings: 25 years						
Solid content: in: 5% / out: 25%						
Reference: USEPA 1985						

BELT FILTER DEWATERING

Belt filters have become increasingly popular in the United States, often selected as the method for dewatering sludges at new treatment plants. This popularity is due to the high dewatering capabilities and low power requirements of the process.

Belt filters employ single or double moving belts made of woven synthetic fiber to dewater sludges continuously. The belts pass over and between rollers which exert increasing pressure on the sludge as it moves with the belts. sludges are dewatered initially through the action capillarity and gravity, and afterwards by increasing pressure and shear force over the length of the filtration zone. The dried cake is removed from the filter belt by a flexible scraper. A second scraper and sprayed water are used to clean the belt.

sludge conditioning is important in this process in order to achieve optimal dewatering performance. costs obtained in this algorithms in Appendices A-13, A-14, and A-15.

Process design is based on solids and hydraulic loading. However, solids loading appears to be the more critical of the two. Belt filters are purchased from the manufacturer in standard belt widths. In this algorithm, single or multiple units of 0.5-, 1-, and 2-meter widths are considered. to estimate the width of a belt filter, the loading rate (lb sludge/meter/hr) is the key design parameter, as shown in the table below.

Influent Suspended solids (%)	1-2	3-4	5-6
Loading Rate (dry solids lb/hr/meter of belt width)	400-600	600-800	800-900

Capital cost in this algorithm include purchase and installation of one or more belt press units and ancillary equipment, and a building to house belt presses with adequate room for safe operation and maintenance. Annual O&M costs include labor, electrical energy, and parts and materials.

Table: A/3.2-2			Cost Estimation: Belt Press Dewatering			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed	MSV	m^3/hr	0.18	1,7	17,3	36,7
Labour	L	hr/yr	106	1.064	1.900	2.700
Process energy	PE	kWhr/yr	800	1.600	3.500	7.800
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Labour cost	COSTLB	$/yr	106	1.064	1.900	2.700
Energy cost	COSTEL	$/yr	48	96	210	468
Material and wear parts	COSTPM	$/yr	107	1.070	8.550	16.360
Total base capital cost	**TBCC**	**$**	**50.000**	**70.000**	**125.000**	**223.000**
Annual base capital cost	**ABCC**	**$/yr**	**5.000**	**7.000**	**12.500**	**22.300**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**292**	**2.928**	**14.291**	**26.103**
Total annual cost	**TACOST**	**$/yr**	**5.292**	**9.928**	**26.791**	**48.403**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**10,5**	**1,8**	**0,5**	**0,4**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	210	37	9	8

Cost do not include chemical conditioning — loading rate: 300 kg/m*hr
Working time: 8 hr/day; 360 days
Lifetime of equipment: 10 years
Lifetime of buildings: 25 years
Solid content: in: 5% / out: 20%
Reference: USEPA 1985

RECESSED PLATE FILTER PRESS DEWATERING

Recessed plate pressure filters consist of numerous parallel plates, recessed on both sides with a filter cloth hung over the face of each plate. The number of plates is determined by sludge volume and cycle time. The process, which operates in a batch mode, uses high pressures to force water from the sludge.

The process operates by pumping conditioned sludge into the void spaces between each plate where a sludge cake forms. Pressure within the chamber builds up to approximately 1600 to 1700 Pa, and is maintained for a 1- to 4-hour period. Filtrate is collected in drainage ports and discharged to a common drain. As solids accumulate in the press, the head loss increases with a subsequent decrease in filtrate flow. The pressure cycle ends when the chambers are completely filled, and the filtrate flow approaches zero. The plates are then opened, and the filter cake drops onto conveyors or into hoppers for removal.

In this dewatering process, sludge conditioning is imperative. Costs for conditioning are not included.

Due to relatively high capital and O&M costs, this dewatering process is usually considered for sludge of poor dewaterability and/or where a final cake solids content over 30 percent is desired, as necessary. Filter presses are ideal for dewatering sludges in preparation for incineration. The cyclic operation may be a disadvantage at some treatment facilities. Several manufacturers have developed new designs which have minimized or virtually eliminated cyclical operation.

Capital cost include purchase and installation of filter press units, feed pumps, including are stand-by units and building for housing the units. Operation and maintenance costs include labor, electrical energy and maintenance material.

- Hours per day operated: 8
- Days per year operated: 365
- Sludge solids content: 40%

Table: A/3.2-3			Cost Estimation: Plate Press Dewatering			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed	MSV	m^3/hr	0.18	1,7	17,3	36,7
Cake volume	CV	m^3/day	930,0	880,0	8.813,0	17.627,0
Total chambers required	TCV	m^3	0,045	0,42	4,2	8,4
Labour	L	hr/yr	233	1.457	1.480	1.487
Process energy	PE	kWhr/yr	9.280	59.600	137.850	225.000
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Labour cost	COSTLB	$/yr	233	1.457	1.480	1.487
Energy cost	COSTEL	$/yr	557	3.576	8.271	13.500
Material and wear parts	COSTPM	$/yr	460	2.830	6.890	12.580
Total base capital cost	**TBCC**	**$**	**85.000**	**110.000**	**220.000**	**480.000**
Annual base capital cost	**ABCC**	**$/yr**	**8.500**	**11.000**	**22.000**	**48.000**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**1.250**	**7.863**	**16.641**	**27.567**
Total annual cost	**TACOST**	**$/yr**	**9.750**	**18.863**	**38.641**	**75.567**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**1710,0**	**350,0**	**71,6**	**70,0**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	390	75	15	15

Cost do not include chemical conditioning
Working time: 8 hr/day; 360days
Lifetime of equipment: 10 years
Lifetime of buildings: 25 years
solid content at beginning : 5%; final: 35%
Reference: USEPA 1985

FLUIDIZED BED INCINERATION

Fluidized bed incinerators utilize a fluidized bed of sand as a heat reservoir to promote uniform combustion of sludge. Air is injected into the bottom of the incinerator at a pressure of 20 to 30 Pa to fluidize the bed. The bed temperature is controlled at approximately 700 to 800 °C using gas or fuel oil, as necessary. Combustion is controlled by varying the sludge feed and/or the air flow to the reactor vessel to completely oxidize all organic matter in the sludge.

Dewatered sludge is injected either above or directly into the fluidized sand bed. Solids remain in the sand bed until the particles are reduced to mineral ash. Ash is carried out of the top of the furnace by the upflowing exhaust gases where it is removed by air pollution control devices. Venturi scrubbers, electrostatic precipitators, and cyclones have been used to control pollutants from incinerators, as specified by federal, state, or local requirements.

Fluidized bed furnaces are reliable due to the presence of few mechanical components compared with other incineration devices. In addition, minimal pollutants emissions are produced under proper operating conditions. However, the process is complex and requires the use of trained personal to maintain efficient operation. Since capital and O&M costs are relatively high, fluidized bed incinerators are typically limited to larger treatment plants and at locations where land disposal of sludges is limited or prohibited.

Fluidized bed incinerators are purchased as package units from manufacturers in standard sizes which begin at 1,8 m in diameter and increase in 0,3 m increments up to 7,60 m. Size is based on numerous factors, including:

- Solids loading rate.
- Percent solids in sludge.
- Percent volatile solids.
- Sludge heat value.
- Hours per week of operation.

Base capital costs include purchase and installation of the incinerator, installation of controls and other ancillary equipment, and construction of a building to house the incinerator. Base capital costs do not include pollution control devices, since this cost depends upon the degree of control required. Pollution control can add between 10 and 25 percent tot the base capital cost, depending on the equipment used. Heat recovery devices are not included in the costs.

Base annual O&M costs include labor, electrical energy, auxiliary and startup fuel, and replacement parts and materials.

Costs and requirements were obtained by varying sludge volume and solids concentration entering the incinerator, using the following input parameters:

- Operation hours per day = 24 hr/day.
- Operation days per year = 360 days/yr.
- Heat value of sludge = 274 KJ/kg.
- Sludge percent volatile solids = 70 percent.
- Ambient air temperature = 40°F.
- Operating temperature = 600 °C.
- Detention time = 15 seconds.
- Sand-to-sludge ratio = 2,7 kg/kg.
- Specific weight of sand = 1760 kg/m^3.
- Cost of standard 4,6 m-diameter incinerator = 1,8 Mio $.
- Feed sludge suspended solids concentration: 40%
- Volatile suspended solid concentration: 60%
- Fuel efficiency factor: 1.1
- Fuel treating value: 40.000 KJ/l

Table: A/3.2-4		Cost Estimation: Fluidized Bed Incineration				
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed per day	DSV	m^3/day	85	828	8.324	16.648
Loading rate	LR	kg/hr	24	236	2.360	4.717
Heating value	HV	Btu/hr	3.682	36.816	368.160	736.320
Incinerator diameter	D	m	0,6	1,8	5,2	7,6
Fuel requirement	FO	l/yr	26.116	232.020	2.342.915	4.428.450
Maintenance labor	ML	hr/yr	4.150	7.520	15.700	28.600
Operational labor	OL	hr/yr	890	3.100	10.200	14.800
Process energy	PE	kWhr/yr	51.000	110.000	900.000	1.600.000
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	5.040	10.620	25.900	43.400
Energy cost	COSTEL	$/yr	3.060	6.600	54.000	96.000
Fuel cost	COSTFUEL	$/yr	7.574	67.286	679.445	1.284.251
Total base capital cost	**TBCC**	**$**	**680.000**	**1.170.000**	**2.435.000**	**3.090.000**
Annual base capital cost	**ABCC**	**$/yr**	**68.000**	**117.000**	**243.500**	**309.000**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**18.734**	**89.771**	**770.303**	**1.437.556**
Total annual cost	**TACOST**	**$/yr**	**86.734**	**206.771**	**1.013.803**	**1.746.556**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**23,6**	**5,6**	**2,8**	**2,4**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	434	103	51	44

Cost do not include pollution control and heat recovery

Working time: 24 hr/day; 360 days

Lifetime of equipment: 10 years

Lifetime buildings: 25 years

solid content: in: 40%

Reference: USEPA 1985

process normally not used below 5 mgd

no land cost included

MULTIPLE HEARTH INCINERATION

Multiple hearth incinerators are multi-chambered vertically mounted furnaces with hearth located above one another. Within each hearth is a set of rabble arms used to move the sludge in a spiral pattern around each hearth. Dewatered sludge is fed into the top of the incinerator and is swept radially towards the center, where the sludge drops to the second hearth, and passes downward to the next hearth. This pattern is continued through subsequent hearths. As the sludge moves toward the bottom, further oxidation occurs, yielding an ash which is removed from the bottom. Hot rising gases flow in a direction counter-current to the sludge flow.

Multiple hearth incineration is a two-stage process consisting of sludge drying on the upper hearths and combustion of volatile solids on the lower hearths. The process reduces dewatered sludge solids (greater than 15 percent solids) to an inert ash that is readily disposed. Auxiliary fuel is usually required for feed sludge concentrations between 15 and 30 percent solids. Feed solids greater than 50 percent solids (excluding conditioning chemicals) are typically not incinerated, since temperatures in excess of the refractory material and metallurgical limits of the furnace may be achieved.

Base capital costs in the algorithm include purchase of the incinerator and auxiliary equipment from the manufacturer, installation of all equipment, and construction of a building to house the incinerator. Base annual O&M costs include labor, electrical energy, auxiliary fuel, and replacement parts and materials.

Input Data

- Daily sludge volume, SV
- Volatile suspended solid concentration: 60%
- Hours per day operated: 24
- Days per year process is operated: 360
- Btu per lb of volatile solids in sludge: 10,000
- Heating temperature: 1,400 °F
- Ambient air temperature 60 °F
- Radiation losses: 5%
- Heat counted of fuel oil: 144,000 BTU/gal.

Table: A/3.2-5			Cost Estimation:Multiple Hearth Incineration			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed per day	DSV	m^3/day	1,4	13,6	137	274
Loading rate	LR	kg/hr	24	236	2.360	4.714
Heating value	HV	Btu/hr	3.682	36.816	368.160	736.320
Fuel requirement	FO	l/yr	26.117	232.021	2.342.915	4.428.450
Maintenance and operation labor	ML	hr/yr	1.850	3.100	21.800	38.000
Process energy	PE	kWhr/yr	200.000	300.400	1.810.000	7.500.000
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	1.850	3.100	21.800	38.000
Energy cost	COSTEL	$/yr	12.000	18.024	108.600	450.000
Fuel cost	COSTFUEL	$/yr	7.574	67.286	679.445	1.284.251
Material and wear parts	COSTPM	$/yr	8.500	11.300	29.500	38.000
Total base capital cost	**TBCC**	**$**	**700.000**	**1.300.000**	**2.500.000**	**3.200.000**
Annual base capital cost	**ABCC**	**$/yr**	**176.600**	**250.000**	**354.000**	**450.000**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**22.350**	**32.424**	**159.900**	**526.000**
Total annual cost	TACOST	$/yr	198.950	282.424	513.900	976.000
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**185,0**	**33,0**	**8,2**	**7,9**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	462	81	20	20

Cost do not include pollution control and heat recovery

process normally not used below 5 mgd

Working time: 24 hr/day; 360 days

land cost not included

Lifetime of equipment: 10 years

Lifetime bulding: 25 years

solid content: 40%

Reference: USEPA 1985

COMPOSTING - WINDROW METHOD

In windrow composting, dewatered sludge is mixed with a bulking agent and spread on paved but uncovered areas in windrows with an approximately triangular or trapezoidal cross sectional area of 35 ft^2. The most economical and most commonly used bulking agents in the windrow process are previously composted sludge and sawdust. Windrows are approximately 14 ft wide, with access areas between windrows of 10 ft. Windrows are 300 ft long, or less for small plants. Sludge remains in windrows for approximately 30 days, with periodic turning to maintain aerobic conditions and to provide mixing. At the end of the composting period, the sludge is moved to a storage area for additional curing. With properly controlled operation, high temperatures achieved during composting can destroy virtually all pathogens and parasites. However, compost is a suitable medium for regrowth of bacteria, and precautions must be taken to prevent reinfection. Windrow composting may be adversely affected by cold or wet weather.

The algorithm is based on the construction and operation of a windrow composting facility with the following conditions:

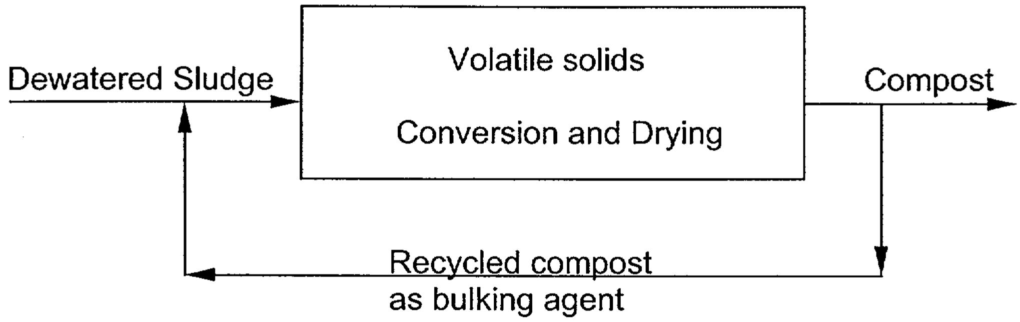
- Windrow and access areas are paved with asphalt; the storage area is unpaved.
- Dewatered sludge is mixed with previously composted sludge to obtain an initial solids concentration of approximately 40 percent.
- Windrows are turned mechanically once a day for the first 2 weeks, and three times per week thereafter.
- Compost mix remains in the composting area for 30 days.

Capital costs include site clearing and grading, paving of composting area, purchase of windrow turning machine and front-end loader, purchase and construction of unloading and mixing structure, and construction of a maintenance and operation building. Operation and maintenance costs include operation and maintenance labor, fuel for composting and ancillary machinery, and O&M materials and supplies. Led costs are not included be care most of the chines tanneries have sufficient space on their yard.

The following algorithm was developed for windrow composting using previously composted sludge as the bulking agent.

The process is shown schematically in the flow diagram below. Reference to the diagram should aid the reader in following the material balance calculations that follow. In these calculations, it is assumed that no changes occur to the recycled compost used as bulking agent, since any further conversion taking place in the recycled compost is negligible compared with the conversion of solids in the dewatered sludge.

Windrow Composting Process



Specific weight of compost: 513 kg/m^3
Mixed dewatered sludge and compost specific weight: 1,000 kg/m^3
Sludge solid concentration in dewatered sludge: 20% ds
Volatile solids in dewatered sludge: 35% ds
Volatile solids destroyed during composting: 30% ds
Compost solids after composting: 65 %
Dewatered sludge specific weight: 1080 kg/m^3
Compost specific weight: 513 kg/m^3
Mixed dewatered sludge and compost specific weight: 1,000 kg/m^3
Windrow cross section: 3,2 m^2
Windrow length: 90 m
Truck unloading and mixing area: 90 m^2/ton. ds
Finished compost storage area: 90 m^2/ton. ds
Clearing of site: light grading 30%
Clearing of site: medium grading 40%
Clearing of site: extensive grading 30%

Table: A/3.2-6			Cost Estimation:Windrow Composting			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge to be processed per day	DSV	m^3/day	1,4	13,6	137	274
Tons of compost produced per day	CPW	tons/day	0,4	4,4	44	88
Total area required	TLAR	m²	800	4.500	47.000	93.000
Fuel requirement	FO	l/yr	59.425	81.757	264.572	479.560
Equipment cost	COSTEQ	$	45.200	47.500	70.000	105.000
Maintenance and operation labor	ML	hr/yr	2.120	3.000	10.800	20.000
Labour unit cost	COSTL	$/hr	1	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	2.120	3.000	10.800	20.000
Fuel cost	COSTFUEL	$/yr	17.233	23.710	76.726	139.072
Material and wear parts	COSTPM	$/yr	2.260	2.375	3.500	5.250
Total base capital cost	**TBCC**	**$**	**49.600**	**125.700**	**428.500**	**844.000**
Annual base capital cost	**ABCC**	**$/yr**	**4.696**	**7.878**	**21.340**	**40.060**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**21.613**	**29.085**	**91.026**	**164.322**
Total annual cost	**TACOST**	**$/yr**	**26.309**	**36.963**	**112.366**	**204.382**
Total cost per m³ of compost	**TACOSTCO**	**$/m³**	**84**	**12**	**4**	**3**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**52,6**	**7,4**	**2,2**	**2,0**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	132	18	6	5
Lifetime of equipment: 10 years	turning intervall: daily during the first 2 weeks					
Lifetime of buildings: 25 years	three times a week thereof					
solid content: in: 35% / out: 65%	composting period: 30 days					
Reference: USEPA 1985						

COMPOSTING - AERATED STATIC PILE METHOD:

Aerated static pile composting is similar in principle to windrow composting, previously discussed. However, in the aerated static pile composting process, the mixture of dewatered sludge and bulking agent remains fixed (as opposed to the periodic turning procedure used in the windrow method), and a forced ventilation system maintains aerobic conditions. A layer of previously composted sludge placed over the surface of the pile provides insulation, allowing for thigh temperatures throughout the pile. Because the piles do not need to be turned, and the outer layer of previously composted sludge provides insulation, static pile composting is less affected by inclement weather than windrow composting. Both digested and raw dewatered sludges have been composted by this technique.

Bulking agents used in aerated static pile composting include wood chips, rice hulls, or straw. Previously composted sludge is not a suitable bulking agent, since a porous structure must be maintained to allow movement through the pile. This algorithm assumes the use of wood chips as the bulking agent.

Composting, even with the aerated static pile method, is largely a materials handling process.

The physical characteristics of the sludge and bulking agent must be defined at various stages of the process. Volatile solids and water are removed during processing, which substantially reduces the sludge weight but does not appreciably reduce the volume.

The aerated static pile process consists of unloading and mixing, aerated pile composting, drying, screening, and storage. An area is also provided for storage of bulking agent.

1. **Unloading and mixing**. Dewatered sludge is delivered to the unloading and mixing structure. The structure is covered and paved. Sludge is unloaded directly onto a bed of bulking agent (wood chips). The sludge and bulking agent are then mixed with a mobile composting/mixing machine or front-end loader, depending on the size of the operation.

2. **Composting**. The sludge/bulking agent mixture is moved from the unloading and mixing structure to composting pads by front-end loader. Composting pads are paved but uncovered, with aeration piping and drainage collection permanently installed in trenches. One blower is provided for each 200 m^2 of composting area. Sludge is placed in the extended pile configuration and insulated with screened finished compost. space is provided for 30 days of composting and curing.

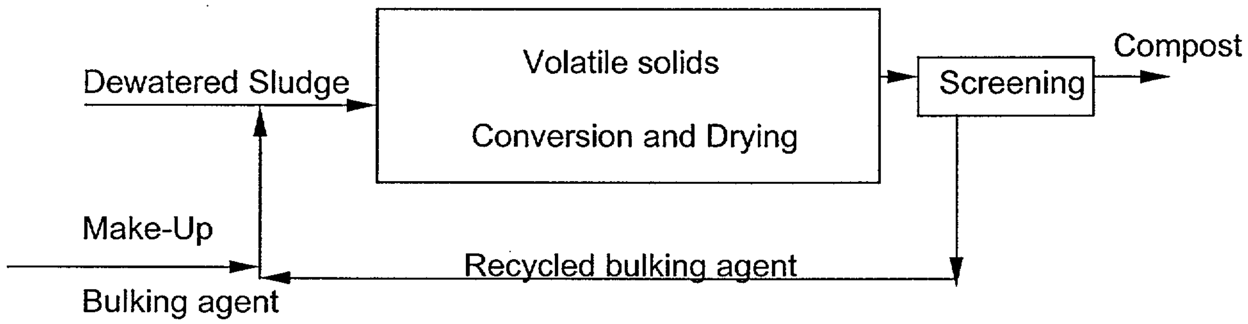
3. **Drying**. A covered and paved structure provides 5 days of drying time. The structure is open on both ends, similar to the unloading and mixing structure. The sludge/bulking agent mixture is moved from the

composting pads to the drying area and turned to achieve at least 50 percent solids by natural drying.

4. **Screening**. The sludge/bulking agent mixture is moved from the drying structure by a front-end loader to a totally enclosed screening building. Screening removes about 75 percent of the bulking agent. Compost is transferred to an unpaved and uncovered storage area, and screened bulking agent is returned to the unloading and mixing structure.

The process is shown schematically in the flow diagram below. In the following calculations, it is assumed that no changes occur to the bulking agent during composting, since any conversion of the bulking agent should be negligible compared to conversion of volatile solids in the dewatered sludge.

Aerated Static Pile Composting



Specific weight of compost: 513 kg/m^3
Mixed dewatered sludge and compost specific weight: 1,000 kg/m^3
Sludge solid concentration in dewatered sludge: 20% ds
Volatile solids in dewatered sludge: 35% ds
Volatile solids destroyed during composting: 45% ds
Compost solids after composting: 65 %
Mixed dewatered sludge and bulking agent specific weight: 1100 kg/m^3
Windrow cross section: 3,2 m^2
Windrow length: 90 m
Truck unloading and mixing area: 30 m^2/ton. ds
Finished compost storage area: 90 m^2/ton. ds
Clearing of site: light grading 30%
Clearing of site: medium grading 40%
Clearing of site: extensive grading 30%
Bulking agent mixed with dewatered sludge: 1.9 m^3/t dewatered sludge.
New bulking agent mixing ratio: 0.48 m^3/t
New bulking agent specific weight: 300 kg/m^3
recycled bulking agent mixing ratio: 0,57 m^3/t
recycled bulking agent specific weight: 360 kg/m^3
composting area: 630 m^2/t ds day
drying area: 30 m^2/t ds day
storage area: 80 m^2/t ds day
bulking agent storage area: 180 m^2/t ds day

Table: A/3.2-7			Cost Estimation:Aerated Static Pile Method			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge processed per day	DSV	m³/day	1,4	13,6	137	274
Compost produced	CPW	tons/day	0,9	8,7	87	174
Compost produced	CPW	m³/day	1,4	13,3	133	266
Bulking agent	BAV	m³/day	0,8	7,6	77	153
Total area required	AT	m²	500	4.700	47.000	94.000
Housing area required	HA	m²	150	170	330	460
Fuel requirement	FO	l/yr	30.660	41.640	155.190	294.100
Energy requirement	EU	kWhr/yr	640	6.400	64.000	128.000
Equipment cost	COSTEQ	$	44.400	52.700	123.000	190.000
Maintenance and operation labor	L	hr/yr	2.000	2.900	11.000	20.400
Labour unit cost	COSTL	$/hr	1	1	1	1
Energy unit cost	COSTE	$/kWhr	0,06	0,06	0,06	0,06
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	2.000	2.900	11.000	20.400
Fuel cost	COSTFUEL	$/yr	8.891	12.076	45.005	85.289
Energy cost	COSTEL	$/yr	38	384	3.840	7.680
Material and wear parts	COSTPM	$/yr	2.220	2.635	6.150	9.500
Bulking agent cost	COSTBA	$/yr	365	3.650	36.500	73.000
Total base capital cost	**TBCC**	**$**	**47.600**	**106.600**	**309.300**	**945.000**
Annual base capital cost	**ABCC**	**$/yr**	**4.568**	**7.426**	**19.752**	**49.200**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**15.735**	**24.280**	**108.645**	**205.369**
Total annual cost	**TACOST**	**$/yr**	**20.303**	**31.706**	**128.397**	**254.569**
Total cost per m³ of compost	**TACOSTCO**	**$/m³**	**62**	**10**	**4**	**4**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**40,6**	**6,3**	**2,6**	**2,5**
Total cost per ton of dry sludge	TCOSTDS	$/t ds	102	16	6	6

Lifetime of equipment: 10 years
Lifetime of buildings: 25 years — bulking agent: wood chips
solid content: in: 35% / out: 65%+A158
Reference: USEPA 1985

LIQUID SLUDGE TRUCK HAULING; INCLUDING SLUDGE LOADING FACILITIES

Truck hauling is a flexible and widely used method for transporting sludge to a disposal site or other sludge management facility. Truck hauling is most applicable as small- and medium-sized treatment facilities. One advantage of truck hauling is the flexibility that it provides, since terminal points and haul routes can be changed readily at relatively low cost. Generally, truck hauling is more economical than railroad or pipeline when transporting sludges less than 150 miles. Diesel-equipped vehicles are the economic choice for larger trucks and trucks with high annual mileage operation.

Specially designed tank trucks are used for hauling liquid sludge (sludge containing less than 15 percent solids). Tank configurations and volumes vary depending on sludge loading and unloading times, haul distance, and frequency of trips. In most applications, tanker trucks for hauling liquid sludge are usually less than 6,000 gallons. Tanker dimensions and maximum load of the vehicle are limited by state law.

In the following algorithm, capital costs include purchase of specially designed tank trucks and construction of sludge loading facilities at the treatment plant. The loading facility consists of a concrete slab and appropriate piping and valving set at a height of 3,70 m to load the tanker from the top. Base annual O&M costs include driver labor, operational labor, fuel, vehicle maintenance, and loading facility maintenance.

- working days per year: 250
- working hours per day: 8
- truck loading time at treatment plant: 0,4 hr.
- truck unloading time at disposal site: 0,8 hr.
- average speed: 40 km/hr.

Table: A/3.2-8	Cost Estimation:Liquid Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m^3/day	1,4	1,4	1,4
Sludge processed per year	SPY	t/yr	500	500	500
Number of round trips	NRT	trips/yr	84	84	84
Fuel requirement	FO	l/yr	496	746	1.234
Maintenance and operation labor	DT	hr/yr	143	164	202
Equipment cost	COSTEQ	$	20.000	20.000	20.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	172	197	242
Fuel cost	COSTDSL	$/yr	144	216	358
Vehicle maintenance cost	VMC	$/yr	147	221	365
Loading area facility maintenance cost	MCOSTLA	$/yr	250	250	250
Total base capital cost	**COSTBA**	**$**	**20.000**	**20.000**	**20.000**
Annual base capital cost	**TBCC**	**$/yr**	**3.333**	**3.333**	3.333
Total operation and maintenance cost	**ABCC**	**$/yr**	**712**	**884**	**1.215**
Cost per km	**COKM**	**$/km**	**0,42**	**0,35**	**0,29**
Total annual cost	**COSTOM**	**$/m³**	**4.046**	**4.217**	**4.549**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**8,1**	**8,4**	**9,1**
Total cost per ton of dry sludge	TACOSTCO		158	165	178
Working time: 250 days	1 truck a' 6 m^3				
Lifetime of equipment: 6 years					
solid content: in: 5%					
Lifetime of buildings: 25 years					
Reference: USEPA 1985					

Table: A/3.2-9	Cost Estimation:Liquid Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m³/day	13,7	13,7	13,7
Sludge processed per year	SPY	t/yr	5.000	5.000	5.000
Number of round trips	NRT	trips/yr	821	821	821
Fuel requirement	FO	l/yr	4.857	7.306	12.112
Maintenance and operation labor	DT	hr/yr	1.400	1.600	1.970
Equipment cost	COSTEQ	$	24.000	24.000	24.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	1.680	1.920	2.364
Fuel cost	COSTDSL	$/yr	1.409	2.119	3.512
Vehicle maintenance cost	VMC	$/yr	1.440	2.160	3.560
Loading area facility maintenance cost	MCOSTLA	$/yr	250	250	250
Total base capital cost	COSTBA	**$**	**20.000**	**20.000**	**20.000**
Annual base capital cost	**TBCC**	**$/yr**	**3.333**	**3.333**	**3.333**
Total operation and maintenance cost	**ABCC**	**$/yr**	**4.779**	**6.449**	**9.686**
Total annual cost	**COSTOM**	**$/m³**	**8.112**	**9.782**	**13.020**
Cost per km	**COKM**	**$/km**	**0,49**	**0,40**	**0,32**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**1,6**	**2,0**	**2,6**
Total cost per ton of dry sludge	TACOSTCO		32	39	52

Working time: 250 days — 1 truck a' 6 m³
Lifetime of equipment: 6 years
Lifetime of buildings: 25 years
solid content: in: 5%
Reference: USEPA 1985

Table: A/3.2-10	Cost Estimation:Liquid Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m³/day	137	137	137
Sludge processed per year	SPY	t/yr	50.000	50.000	50.000
Number of round trips	NRT	trips/yr	2.200	2.200	2.200
Fuel requirement	FO	l/yr	20.818	31.415	51.628
Maintenance and operation labor	DT	hr/yr	3.750	4.300	5.290
Equipment cost	COSTEQ	$	97.000	97.000	97.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	4.500	5.160	6.348
Fuel cost	COSTDSL	$/yr	6.037	9.110	14.972
Vehicle maintenance cost	VMC	$/yr	5.500	8.270	13.640
Loading area facility maintenance cost	MCOSTLA	$/yr	850	850	850
Total base capital cost	COSTBA	**$**	**97.000**	**97.000**	**97.000**
Annual base capital cost	**TBCC**	**$/yr**	16.167	16.167	16.167
Total operation and maintenance cost	**ABCC**	**$/yr**	**16.887**	**23.390**	**35.810**
Total annual cost	**COSTOM**	**$/m³**	**33.054**	**39.557**	**51.977**
Cost per km	**COKM**	**$/km**	**0,75**	**0,60**	**0,47**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**0,7**	**0,8**	**1,0**
Total cost per ton of dry sludge	TACOSTCO		13	16	21

Working time: 250 days — 2 trucks a' 16 m³

Lifetime of equipment: 6 years

Lifetime of buildings: 25 years

solid content: in: 5%

Reference: USEPA 1985

Table: A/3.2-11	Cost Estimation:Liquid Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m^3/day	274	274	274
Sludge processed per year	SPY	t/yr	100.000	100.000	100.000
Number of round trips	NRT	trips/yr	4.400	4.400	4.400
Fuel requirement	FO	l/yr	41.635	62.831	103.104
Maintenance and operation labor	DT	hr/yr	7.500	8.600	10.540
Equipment cost	COSTEQ	$	221.000	221.000	221.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	9.000	10.320	12.648
Fuel cost	COSTDSL	$/yr	12.074	18.221	29.900
Vehicle maintenance cost	VMC	$/yr	11.000	16.540	27.280
Loading area facility maintenance cost	MCOSTLA	$/yr	1.050	1.050	1.050
Total base capital cost	COSTBA	**$**	**221.000**	**221.000**	**221.000**
Annual base capital cost	**TBCC**	**$/yr**	**36.833**	**36.833**	**36.833**
Total operation and maintenance cost	**ABCC**	**$/yr**	**33.124**	**46.131**	**70.878**
Total annual cost	**COSTOM**	**$/$m^3$**	**69.957**	**82.964**	**107.711**
Cost per km	**COKM**	**$/km**	**0,79**	**0,63**	**0,49**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**0,7**	**0,8**	**1,1**
Total cost per ton of dry sludge	TACOSTCO		14	17	22

Working time: 250 days — 5 trucks a' 16 m^3
Lifetime of equipment: 6 years
Lifetime of buildings: 25 years
solid content: in: 5%
Reference: USEPA 1985

DEWATERED SLUDGE TRUCK HAULING, INCLUDING SLUDGE LOADING

Truck hauling is a commonly employed sludge transport method, particularly at small and medium treatment facilities. Truck hauling is less capital-intensive than other transport methods for hauling sludges over distances less than 150 miles. An additional benefit of this method is the flexibility that it provides when changing terminal points and haul routes.

Dewatered sludge (sludge containing more than 15 percent solids) is hauled in trucks similar to general purpose or standard highway trucks. Standard truck capacities range from 5 to 28 m^3; however, maximum loads are limited by state laws. Diesel-equipped vehicles are generally the most economic choice for larger trucks and trucks with high annual mileage operation.

Capital costs in the following include construction of a truck loading facility designed to accommodate the sludge volume within the operating schedule. costs include construction of a concrete loading slab, and purchase of skip loaders and trucks. Annual O&M costs include vehicle and loading facility maintenance, driver and operational labor, and diesel fuel for vehicles.

Table: A/3.2-12	Cost Estimation:Dewatered Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m³/day	1,4	1,4	1,4
Sludge processed per year	SPY	t/yr	500	500	500
Number of round trips	NRT	trips/yr	95	95	95
Fuel requirement	FO	l/yr	500	750	1.238
Maintenance and operation labor	DT	hr/yr	162	185	232
Equipment cost	COSTEQ	$	20.000	20.000	20.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	194	222	278
Fuel cost	COSTDSL	$/yr	145	218	359
Vehicle maintenance cost	VMC	$/yr	154	232	383
Loading area facility maintenance cost	MCOSTLA	$/yr	250	250	250
Total base capital cost	**COSTBA**	**$**	**20.000**	**20.000**	**20.000**
Annual base capital cost	**TBCC**	**$/yr**	**3.333**	**3.333**	**3.333**
Total operation and maintenance cost	**ABCC**	**$/yr**	**743**	**922**	**1.270**
Total annual cost	**COSTOM**	**$/m³**	**4.077**	**4.255**	**4.604**
Cost per km	**COKM**	**$/km**	**2,15**	**1,49**	**0,97**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**8,2**	**8,5**	**9,2**
Total cost per ton of dry sludge	TACOSTCO		27	28	30
Working time: 250 days	1 truck a' 5 m³				
Lifetime of equipment: 6 years					
Lifetime of buildings: 25 years					
solid content: in: 35%					
Reference: USEPA 1985					

Table: A/3.2-13	Cost Estimation:Dewatered Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m^3/day	13,7	13,7	13,7
Sludge processed per year	SPY	t/yr	5.000	5.000	5.000
Number of round trips	NRT	trips/yr	654	654	654
Fuel requirement	FO	l/yr	3.865	5.814	9.577
Maintenance and operation labor	DT	hr/yr	1.145	1.300	1.600
Equipment cost	COSTEQ	$	29.000	29.000	29.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	1.374	1.560	1.920
Fuel cost	COSTDSL	$/yr	1.121	1.686	2.777
Vehicle maintenance cost	VMC	$/yr	1.280	1.970	3.240
Loading area facility maintenance cost	MCOSTLA	$/yr	450	450	450
Total base capital cost	**COSTBA**	**$**	**29.000**	**29.000**	**29.000**
Annual base capital cost	**TBCC**	**$/yr**	**4.833**	**4.833**	4.833
Total operation and maintenance cost	ABCC	**$/yr**	**4.225**	**5.666**	**8.387**
Total annual cost	**COSTOM**	**$/m³**	**9.058**	**10.499**	**13.221**
Cost per km	**COKM**	**$/km**	**0,69**	**0,54**	**0,40**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**1,8**	**2,1**	**2,6**
Total cost per ton of dry sludge	TACOSTCO		6	7	9
Working time: 250 days	1 truck a' 5 m^3				
Lifetime of equipment: 6 years					
Lifetime of buildings: 25 years					
solid content: in: 35%					
Reference: USEPA 1985					

Table: A/3.2-14	Cost Estimation:Dewatered Sludge Truck Hauling				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m³/day	137	137	137
Sludge processed per year	SPY	t/yr	50.000	50.000	50.000
Number of round trips	NRT	trips/yr	1.005	1.005	1.005
Fuel requirement	FO	l/yr	9.501	14.308	23.581
Maintenance and operation labor	DT	hr/yr	1.760	1.960	2.450
Equipment cost	COSTEQ	$	87.000	87.000	87.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	2.112	2.352	2.940
Fuel cost	COSTDSL	$/yr	2.755	4.149	6.838
Vehicle maintenance cost	VMC	$/yr	3.400	5.100	8.410
Loading area facility maintenance cost	MCOSTLA	$/yr	850	850	850
Total base capital cost	**COSTBA**	**$**	**87.000**	**87.000**	**87.000**
Annual base capital cost	**TBCC**	**$/yr**	**14.500**	**14.500**	14.500
Total operation and maintenance cost	**ABCC**	**$/yr**	**9.117**	**12.451**	**19.038**
Total annual cost	**COSTOM**	**$/yr**	**23.617**	**26.951**	**33.538**
Cost per km	**COKM**	**$/km**	**1,17**	**0,89**	**0,67**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**0,5**	**0,5**	**0,7**
Total cost per ton of dry sludge	TACOSTCO		1,6	1,8	2,2
Working time: 250 days	2 trucks a' 27 m³				
Lifetime of equipment: 6 years					
Lifetime of buildings: 25 years					
solid content: in: 35%					
Reference: USEPA 1985					

Table: A/3.2-15	**Cost Estimation:Dewatered Sludge Truck Hauling**				
Item	Abbreviation	Unit	Round trip haule distance (km)		
			20	30	50
Sludge processed per day	DSV	m³/day	274	274	274
Sludge processed per year	SPY	t/yr	100.000	100.000	100.000
Number of round trips	NRT	trips/yr	3.630	3.630	3.630
Fuel requirement	FO	l/yr	34.444	51.476	85.163
Maintenance and operation labor	DT	hr/yr	6.350	7.100	8.860
Equipment cost	COSTEQ	$	196.000	196.000	196.000
Labour unit cost	COSTL	hr/yr	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	7.620	8.520	10.632
Fuel cost	COSTDSL	$/yr	9.989	14.928	24.697
Vehicle maintenance cost	VMC	$/yr	12.300	18.400	30.400
Loading area facility maintenance cost	MCOSTLA	$/yr	1.050	1.050	1.050
Total base capital cost	COSTBA	**$/yr**	**97.000**	**97.000**	**97.000**
Annual base capital cost	**TBCC**	**$**	**16.167**	**16.167**	**16.167**
Total operation and maintenance cost	**ABCC**	**$/yr**	**30.959**	**42.898**	**66.779**
Total annual cost	**COSTOM**	**$/m³**	**47.125**	**59.065**	**82.946**
Cost per km	**COKM**	**$/km**	**0,65**	**0,54**	**0,46**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**0,5**	**0,6**	**0,8**
Total cost per ton of dry sludge	TACOSTCO		1,6	2,0	2,8
Working time: 250 days	5 trucks a' 27 m³				
Lifetime of equipment: 6 years					
Lifetime of buildings: 25 years					
solid content: in: 35%					
Reference: USEPA 1985					

LAND DISPOSAL TO SLUDGE LANDFILL

This process algorithm covers sludge landfills owned and operated by the sludge generating agency for the exclusive purpose of disposing of dewatered sewage sludge. Many municipalities dispose of their sewage sludge to landfills operated by other private or public entities. In these cases the municipality usually pays a disposal (tipping) fee to the landfill owner based upon cost per unit weight or volume of sludge. This process algorithm does not cover landfill disposal to another entity.

Sludge landfilling is defined as a disposal method involving the burial of sludge, i.e., the application of sludge on the land and subsequent burial by applying a layer of cover soil over the sludge. Cover is usually applied daily. Not included in this process are sludge to land applications by spreading where the sludge is spread on the soil surface or injected in the top soil layer, e.g., dedicated land disposal site, application to food chain crops, etc.

Sludge landfill methods in use are:

- Narrow trenching, which is defined as sludge disposal to trenches less than 3 m wide,
- Wide trenching, which is defined as sludge disposal to trenches more than 3 m wide.
- Codisposal with municipal refuse in a conventional municipal refuse landfill. As previously noted, this disposal method is not included in this process.

For the purpose of this algorithm, it is assumed that the sludge landfill methods involving trenching are conducted on a site owned by the agency which generates the sludge. In addition to the purchase of land, the base capital cost obtained using this algorithm includes site improvements (brush clearing, grading, etc.), installation of monitoring wells, purchase of excavation vehicles, and purchase of earth-moving vehicles. Total base annual cost includes operation labor, diesel fuel for machinery, machinery maintenance, and site maintenance.

Note that this process cost algorithm does not include any costs for transporting sludge from the treatment plant to the landfill site, nor any costs involved in the treatment of sludge, e.g., stabilization, dewatering, etc.

From a regulatory viewpoint, a sludge landfill may be considered similar to a hazardous waste disposal site. In many instances there will be required ground water quality protection improvements, such as liners, leachate collection systems, etc., as well as surface water quality protection improvements, such as surface drainage control/collection structures. In a general cost program such as this one, it is impossible to take into account all of these types of site-specific variables. The user is particularly cautioned that this algorithm does not include the cost of liners or leachate collection systems.

- landfill site life: 20 yrs
- trench wide: 3 m
- trench depth: 3 m
- trench spacing: 4,50 m
- annual application period: 240 days
- daily application period: 7 hr
- fraction of landfill site used for other purpose than sludge trenching: 30%
- fraction of landfill disposal site requiring cleaning of brush and trees: 70%
- fraction of landfill site requiring initial grading: 70%
- Efficiency of excavation equipment: 70%
- depth of care material: 0.6 m

Table: A/3.2-16			Cost Estimation:Landfill			
Item	Abbreviation	Unit	Quantity of sludge to be processed (t/year)			
			500	5.000	50.000	100.000
Sludge processed per day	DSV	m³/day	1,4	13,6	137,0	274,0
Total area required	TLAR	m²	13.400,0	133.600,0	1.336.000,0	13.400.000,0
Land cost	COSTLAND	$	1.650,0	16.500,0	165.000,0	330.000,0
Land preparation cost	LPCOST	$	1.150,0	11.500,0	115.000,0	230.000,0
Fuel requirement	FO	l/yr	996,0	9.841,0	48.070,0	70.969,0
Cost of observation wells	COSTMW	$	10.000,0	10.000,0	30.000,0	60.000,0
Equipment cost	COSTEQ	$	77.000,0	77.000,0	228.000,0	196.000,0
Maintenance and operation labor	L	hr/yr	5.700	5.700	5.700	5.700
Labour unit cost	COSTL	$/hr	1	1	1	1
Fuel unit cost	COSTFO	$/l	0,29	0,29	0,29	0,29
Labour cost	COSTLB	$/yr	5.700	5.700	5.700	5.700
Fuel cost	COSTFUEL	$/yr	289	2.854	13.940	20.581
Material and wear parts	VMC	$/yr	507	5.010	23.300	37.100
Total base capital cost	**TBCC**	**$**	**90.460**	**121.600**	**604.000**	**948.000**
Annual base capital cost	**ABCC**	**$/yr**	**8.373**	**9.930**	**41.600**	**57.200**
Total operation and maintenance cost	**COSTOM**	**$/yr**	**6.496**	**13.564**	**42.940**	**63.381**
Total annual cost	**TACOST**	**$/yr**	**14.869**	**23.494**	**84.540**	**120.581**
Total cost per ton of sludge processed	**TCOSTSP**	**$/t**	**29,7**	**4,7**	**1,7**	**1,2**
Total cost per ton of dry sludge (5% ds)	**TCOSTDS**	**$/t ds**	**595**	**94**	**34**	**24**
Total cost per ton of dry sludge (20% ds)	**TCOSTDS**	**$/t ds**	**149**	**23**	**8**	**6**
Total cost per ton of dry sludge (40% ds)	**TCOSTDS**	**$/t ds**	**74**	**12**	**4**	**3**

1 earth excavation and one earth-moving machine

Working time: 8 hr/day; 250 days
Lifetime of equipment: 10 years
Lifetime of buildings: 20 years
solid content in: 5%; 20%; 40%
Reference: USEPA 1985

3.3 Sludge Treatment Paths

Table: A/3.3-1	**Plate Press Dewatering - Multiple Hearth Incineration - Truck hauling (30 km) - Landfill**				
Item	Unit				
plate press dewatering					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	23.500	23.500	46.300	94.100
O&M cost	$/yr	1.300	7.900	16.600	27.600
multiple hearth incineration					
Initial sludge volume	t/yr	63	625	6.250	12.500
initial sludge solid content (ds)	%	40	40	40	40
annual capital cost	$/yr	170.000	176.600	255.000	276.000
O&M cost	$/yr	15.000	23.100	33.500	64.300
truck hauling					
Initial sludge volume	t/yr	25	254	2.538	5.076
initial sludge solid content (ds)	%	99	99	99	99
annual capital cost	$/yr	3.300	3.300	4.000	4.800
O&M cost	$/yr	400	600	3.500	5.700
landfill					
Initial sludge volume	t/yr	25	254	2.538	5.076
initial sludge solid content (ds)	%	99	99	99	99
annual capital cost	$/yr	2.000	4.000	21.200	10.000
O&M cost	$/yr	2.200	5.200	10.000	13.600
Total annual capital cost	$/yr	198.800	207.400	326.500	384.900
Total O&M cost	$/yr	18.900	36.800	63.600	111.200
Total annual cost	**$/yr**	**217.700**	**244.200**	**390.100**	**496.100**
Total annual cost per ton of raw sludge	**$/t**	**435,4**	**48,8**	**7,8**	**5,0**
Source: Own estimation; compare Table A/3.2-3, A/3.2-5, A/.3-12 - A/3.2-15, A/3.2-16.					
Reference: USEPA 1985					

Table: A/3.3-2	Centrifuge Dewatering - Areated Static Pile Composting				
Item	Unit				
centrifuge dewatering					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	16.400	18.300	32.900	45.200
O&M cost	$/yr	3.000	4.200	14.500	24.600
areated static pile composting					
Initial sludge volume	t/yr	63	625	6.250	12.500
initial sludge solid content (ds)	%	40	40	40	40
annual capital cost	$/yr	1.500	4.700	8.700	10.300
O&M cost	$/yr	9.000	16.200	25.500	39.400
Total annual capital cost	$/yr	17.900	23.000	41.600	55.500
Total O&M cost	$/yr	12.000	20.400	40.000	64.000
Total annual cost	**$/yr**	29.900	43.400	81.600	119.500
Total annual cost per ton of raw sludge	**$/t**	**59,8**	**8,7**	**1,6**	**1,2**
Source: Own estimation; compare Table A/3.2-1, A/3.2-7.					
Reference: USEPA 1985					

Table: A/3.3-3	Centrifuge Dewatering - Windrow Composting - Truck Hauling (30 km) - Landfill				
Item	Unit				
centrifuge dewatering					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	16.400	18.300	32.900	45.200
O&M cost	$/yr	3.000	4.200	14.500	24.600
windrow composting					
Initial sludge volume	t/yr	63	625	6.250	12.500
initial sludge solid content (ds)	%	40	40	40	40
annual capital cost	$/yr	1.500	5.000	8.300	11.200
O&M cost	$/yr	9.500	22.100	30.100	44.600
truck hauling					
Initial sludge volume	t/yr	38	385	3.846	7.692
initial sludge solid content (ds)	%	65	65	65	65
annual capital cost	$/yr	3.300	3.300	4.800	4.800
O&M cost	$/yr	600	700	4.200	7.700
landfill					
Initial sludge volume	t/yr	38	385	3.846	7.692
initial sludge solid content (ds)	%	65	65	65	65
annual capital cost	$/yr	3.100	6.500	9.300	11.500
O&M cost	$/yr	500	5.100	10.700	15.000
Total annual capital cost	$/yr	24.300	33.100	55.300	72.700
Total O&M cost	$/yr	13.600	32.100	59.500	91.900
Total annual cost	**$/yr**	**37.900**	**65.200**	**114.800**	**164.600**
Total annual cost per ton of raw sludge	**$/t**	**75,8**	**13,0**	**2,3**	**1,6**
Source: Own estimation; compare Table A/3.2-1, A/3.2-6, A/3.2-12 - A/3.2-15, A/3.2-16.					
Reference: USEPA 1985					

Table: A/3.3-4	Liquid Sludge Truck hauling (30 km) - Landfill				
Item	Unit				
hauling					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	3.300	3.300	16.200	36.800
O&M cost	$/yr	900	6.500	23.400	46.200
landfill					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	8.400	9.900	41.600	57.200
O&M cost	$/yr	6.500	13.600	43.000	63.400
Total annual capital cost	$/yr	11.700	13.200	57.800	94.000
Total O&M cost	$/yr	7.400	20.100	66.400	109.600
Total annual cost	**$/yr**	**19.100**	**33.300**	**124.200**	**203.600**
Total annual cost per ton of raw sludge	**$/t**	**38,2**	**6,7**	**2,5**	**2,0**
Source: Own estimation; compare Table A/3.2-8 - A/3.2-11, A/3.2-16.					
Reference: USEPA 1985					

Table: A/3.3-5	Plate Press Dewatering - Sludge Hauling (30 km) - Landfill				
Item	Unit				
plate press dewatering					
Initial sludge volume	t/yr	500	5.000	50.000	100.000
initial sludge solid content (ds)	%	5	5	5	5
annual capital cost	$/yr	23.500	23.500	46.300	94.100
O&M cost	$/yr	1.300	7.900	16.600	27.600
hauling					
Initial sludge volume	t/yr	63	625	6.250	12.500
initial sludge solid content (ds)	%	40	40	40	40
annual capital cost	$/yr	3.300	3.300	3.300	3.300
O&M cost	$/yr	100	900	15.000	18.000
landfill					
Initial sludge volume	t/yr	63	625	6.250	12.500
initial sludge solid content (ds)	%	40	40	40	40
annual capital cost	$/yr	3.400	8.700	10.500	13.000
O&M cost	$/yr	700	7.000	15.500	19.500
Total annual capital cost	$/yr	30.200	35.500	60.100	110.400
Total O&M cost	$/yr	2.100	15.800	47.100	65.100
Total annual cost	**$/yr**	**32.300**	**51.300**	**107.200**	**175.500**
Total annual cost per ton of raw sludge	**$/t**	**64,6**	**10,3**	**2,1**	**1,8**
Source: Own estimation; compare Table A/3.2-3, A/3.2-12 - A/3.2-15, A/3.2-16.					
Reference: USEPA 1985					

ANNEX 4

Waste Water effluent Standards

ARGENTINA		
Parameter	**Surface**	**Sewer**
pH	5.5 - 10.0	5.5 - 10.0
Temperature ° C	45	45
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l	0.5	0.5
BOD_5 mg 0_2/l	50	200
COD mg/l	250	700
Sulphide mg S^{2-}/l		1
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	0.5	2
TDS mg/l		
Chlorides mg/l	*	*
Sulphates mg/l	*	1000
Ammonia mg N/l	3	10
TNK mg/N/l	10	30
Phosphorus mg P/l		
Oil/grease mg/l	100	100
Phenols mg/l	0.5	0.5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l	1	2

AUSTRALIA		
Parameter	**Surface**	**Sewer**
pH	6.0 - 9.0	6.0 - 10.0
Temperature ° C	45	38
Conductivity µs/cm		
Suspended solids mg/l	60	*
Settleable solids ml/l		
BOD_5 mg 0_2/l	40	*
COD mg/l		
Sulphide mg S^{2-}/l		1.0 - 5.0
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	0.3	1.0 - 20.0
TDS mg/l		
Chlorides mg/l	*	*
Sulphates mg/l		2000
Ammonia mg N/l		100 - 200
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		100 - 1000
Phenols mg/l	0.05 - 0.5	100
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	none	30
Nitrogenous mg/l	none	none
Chlorinated mg/l	none	5

AUSTRIA		
Parameter	**Surface**	**Sewer**
pH	6.5 - 8.5	6.0 - 9.5
Temperature ° C	30	30
Conductivity µs/cm		
Suspended solids mg/l	70	150
Settleable solids ml/l		
BOD_5 mg 0_2/l	25	
COD mg/l	200	
Sulphide mg S^{+A90}/l	0.1	2
Chrome (III) mg/l		
Chrome (VI) mg/l	0.1	0.1
Chrome total mg/l	1	3
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		*
Ammonia mg N/l	15	*
TNK mg/N/l	*	
Phosphorus mg P/l	2.0	
Oil/grease mg/l	20	100
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	10	20
Nitrogenous mg/l		
Chlorinated mg/l	0.5	0.5

BRAZIL		
Parameter	**Surface**	**Sewer**
pH	5.0 - 9.0	
Temperature ° C	< 40	40
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l	1.0	
BOD_5 mg 0_2/l	60	
COD mg/l		
Sulphide mg S^{2-}/l	0.2	5
Chrome (III) mg/l		5
Chrome (VI) mg/l		
Chrome total mg/l	0.5	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l	5	
TNK mg/N/l	10	
Phosphorus mg P/l	1	
Oil/grease mg/l	20 - 30	100
Phenols mg/l	0.1 - 0.5	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

Annex 4

CHINA Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C		35
Conductivity µs/cm		
Suspended solids mg/l	200	500
Settleable solids ml/l		10
BOD_5 mg 0_2/l	150	500
COD mg/l	300	500
Sulphide mg S^{2-}/l	1	10
Chrome (III) mg/l	1.5	2.0
Chrome (VI) mg/l		0.5
Chrome total mg/l	1.5	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		100
Phenols mg/l		5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

COLOMBIA Parameter	Surface	Sewer
pH		5 - 9
Temperature ° C	40	
Conductivity µs/cm		
Suspended solids mg/l		1000
Settleable solids ml/l		
BOD_5 mg 0_2/l		
COD mg/l		1000
Sulphide mg S^{2-}/l		
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	5	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		250
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

CROATIA Parameter	Surface	Sewer
pH	*	6.5 - 9.0
Temperature ° C	*	40
Conductivity µs/cm		
Suspended solids mg/l	*	400
Settleable solids ml/l	*	15
BOD_5 mg 0_2/l	*	450
COD mg/l	*	700
Sulphide mg S^{+A142}/l	*	1
Chrome (III) mg/l	*	
Chrome (VI) mg/l	*	
Chrome total mg/l	*	
TDS mg/l		
Chlorides mg/l	*	
Sulphates mg/l	*	300
Ammonia mg N/l	*	15
TNK mg/N/l	*	80
Phosphorus mg P/l		
Oil/grease mg/l	*	100
Phenols mg/l	*	1.5
Detergents mg/l		
Solvents mg/l:	*	trace
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

CZECH REP. Parameter	Surface	Sewer
pH		
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l		
BOD_5 mg 0_2/l	50	
COD mg/l	300	
Sulphide mg S^{2-}/l	2	
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	2	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

Annex 4

DENMARK Parameter	Surface	Sewer
pH	6.5 - 8.5	6.5 - 9.0
Temperature ° C	30	35
Conductivity µs/cm		
Suspended solids mg/l	30	
Settleable solids ml/l		
BOD_5 mg 0_2/l		
COD mg/l		
Sulphide mg S^{2-}/l	2	
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	0.2	2
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l	300	
Ammonia mg N/l	2.0	
TNK mg/N/l	5	
Phosphorus mg P/l		
Oil/grease mg/l	5	
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

EGYPT Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	200	200
Settleable solids ml/l		
BOD_5 mg 0_2/l	500	500
COD mg/l	100	100
Sulphide mg S^{2-}/l	10	10
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	1	1
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l	100	100
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	100	100
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

FINLAND Parameter	Surface	Sewer
pH	6.0 - 10.0	6.0 - 10.0
Temperature ° C	35	35
Conductivity µs/cm		
Suspended solids mg/l	*	*
Settleable solids ml/l		
BOD_5 mg 0_2/l	*	*
COD mg/l	*	*
Sulphide mg S^{2-}/l	5	5
Chrome (III) mg/l	0 - 0.5	0 - 0.5
Chrome (VI) mg/l	none	none
Chrome total mg/l	10	20
TDS mg/l		
Chlorides mg/l		2500
Sulphates mg/l		400
Ammonia mg N/l		50
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		50
Detergents mg/l		
Solvents mg/l:	3	3
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

FRANCE Parameter	Surface	Sewer
pH	5.5 - 8.5	6.5 - 8.5
Temperature ° C	30	30
Conductivity µs/cm		
Suspended solids mg/l	35	600
Settleable solids ml/l		
BOD_5 mg 0_2/l	30	800
COD mg/l	125	2000
Sulphide mg S^{+E195}/l		2
Chrome (III) mg/l	1.5	1.5
Chrome (VI) mg/l	0.1	0.1
Chrome total mg/l		
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l	30	150
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l	0.1	0.1
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	10	10
Nitrogenous mg/l		
Chlorinated mg/l	AOX 5	AOX 5

Annex 4

GERMANY Parameter	Surface	Sewer
pH		6.5 - 10.0
Temperature ° C		35
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l		
BOD_5 mg 0_2/l		
COD mg/l	250	
Sulphide mg S^{2-}/l	1 - 2	1 - 2
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	0.5 - 1	0.5 - 1
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		*
Ammonia mg N/l	10	*
TNK mg/N/l		
Phosphorus mg P/l	2	
Oil/grease mg/l		*
Phenols mg/l		*
Detergents mg/l		
Solvents mg/l:		*
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l	AOX 0.5	AOX 1

GREECE Parameter	Surface	Sewer
pH	6.5 - 9.0	6.5 - 9.0
Temperature ° C	28 - 35	35
Conductivity µs/cm		
Suspended solids mg/l	25 - 50	500
Settleable solids ml/l	0 - 0.5	10
BOD_5 mg 0_2/l	15 - 40	500
COD mg/l	45 - 150	1000
Sulphide mg S^{2-}/l	1 - 2	1
Chrome (III) mg/l	0.1 - 2	2
Chrome (VI) mg/l	0.02 - 0.5	0.5
Chrome total mg/l	2.5	2.5
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l	1000	1500
Ammonia mg N/l	10 - 20	25
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	5 - 20	40
Phenols mg/l	0.25 - 0.5	5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	0.2	
Nitrogenous mg/l	0.1 - 0.2	
Chlorinated mg/l	1	

HUNGARY Parameter	Surface	Sewer
pH	5.0 - 10.0	6.5 - 10.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l		
BOD_5 mg 0_2/l		
COD mg/l	50 - 150	
Sulphide mg $S^{2+A185-}$/l	0.01 - 5	1
Chrome (III) mg/l	2.0 - 5.0	5
Chrome (VI) mg/l	0.5 - 1	1
Chrome total mg/l		5
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		400
Ammonia mg N/l	2 - 3	200
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	8 - 50	60
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

INDIA Parameter	Surface	Sewer
pH	5.5 - 9.0	5.5 - 9.0
Temperature ° C	40 - 45	40 - 45
Conductivity µs/cm		
Suspended solids mg/l	100	100
Settleable solids ml/l		
BOD_5 mg 0_2/l	30	500
COD mg/l	250	250
Sulphide mg S^{2-}/l	2	2
Chrome (III) mg/l	2	2
Chrome (VI) mg/l		
Chrome total mg/l	2	2
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l	1000	1000
Ammonia mg N/l	50	50
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	30 - 100	30 - 100
Phenols mg/l	5 -50	5 -50
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

Annex 4

INDONESIA Parameter	Surface	Sewer
pH	6.0 - 9.0	
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	150	150
Settleable solids ml/l		
BOD_5 mg 0_2/l	150	150
COD mg/l	300	300
Sulphide mg S^{2-}/l		
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	2	2
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l	10	10
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	5	5
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

IRAN Parameter	Surface	Sewer
pH	6.5 - 8.5	
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	40	
Settleable solids ml/l		
BOD_5 mg 0_2/l	30	
COD mg/l	40	
Sulphide mg S^{2-}/l	2	
Chrome (III) mg/l	3	
Chrome (VI) mg/l	0.5	
Chrome total mg/l		
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l	400	
Ammonia mg N/l	3.5	
TNK mg/N/l		
Phosphorus mg P/l	4	
Oil/grease mg/l		
Phenols mg/l	1	
Detergents mg/l	1.5	
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

IRELAND Parameter	Surface	Sewer
pH	7.5 -10.0	7.5 - 10.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	800 - 1000	800 - 1000
Settleable solids ml/l		
BOD_5 mg 0_2/l	500 - 1700	500 - 1700
COD mg/l	1500 - 2600	1500 - 2600
Sulphide mg S^{2-}/l	5 - 35	5 - 35
Chrome (III) mg/l	15	15
Chrome (VI) mg/l	0.1	0.1
Chrome total mg/l		
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l	15 - 200	15 - 200
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	30	30
Phenols mg/l	0.05	0.05
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l	0.05	0.05

ITALY Parameter	Surface	Sewer
pH	5.5 - 9.5	5.5 - 9.5
Temperature ° C	30 - 35	30 - 35
Conductivity µs/cm		
Suspended solids mg/l	40 - 80	200
Settleable solids ml/l		
BOD_5 mg 0_2/l	40	250
COD mg/l	160	500
Sulphide mg S^{2-}/l	1	2
Chrome (III) mg/l		4
Chrome (VI) mg/l	0.2	0.2
Chrome total mg/l	2	4
TDS mg/l		
Chlorides mg/l	1200	1200
Sulphates mg/l	1000	1000
Ammonia mg N/l	10 - 15	30
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	20	40
Phenols mg/l	0.5	1
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	0.2	0.4
Nitrogenous mg/l	0.1	0.2
Chlorinated mg/l	1	2

Annex 4

JAPAN Parameter	Surface	Sewer
pH	5.0 - 9.0	5.0 - 9.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	200	200 - 300
Settleable solids ml/l		
BOD_5 mg 0_2/l	160	160
COD mg/l	160	160
Sulphide mg S^{2-}/l	2	2
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	2	2
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l	1	
Oil/grease mg/l	30	30 - 50
Phenols mg/l	5	5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

KENYA Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C	25	
Conductivity µs/cm		
Suspended solids mg/l	30	300
Settleable solids ml/l		
BOD_5 mg 0_2/l	20	450
COD mg/l		
Sulphide mg S^{2-}/l		
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	1	
TDS mg/l		
Chlorides mg/l		3000
Sulphates mg/l		100
Ammonia mg N/l		100
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	trace	100
Phenols mg/l	2	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

MEXICO Parameter	Surface	Sewer
pH	6.0 - 9.0	
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	200	
Settleable solids ml/l	5.0	
BOD_5 mg 0_2/l	200	
COD mg/l		
Sulphide mg S^{2-}/l	0.1	
Chrome (III) mg/l		
Chrome (VI) mg/l	0.1	
Chrome total mg/l	1.0	
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	30	
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

NETHERLANDS Parameter	Surface	Sewer
pH	6.5 - 8.5	6.5 - 10.0
Temperature ° C	30	30
Conductivity µs/cm		
Suspended solids mg/l	80	*
Settleable solids ml/l		
BOD_5 mg 0_2/l	5	*
COD mg/l	*	*
Sulphide mg S^{2-}/l	*	*
Chrome (III) mg/l		1
Chrome (VI) mg/l	none	none
Chrome total mg/l	0.05	2
TDS mg/l		
Chlorides mg/l	200	*
Sulphates mg/l	150	300
Ammonia mg N/l	*	*
TNK mg/N/l	3	
Phosphorus mg P/l		
Oil/grease mg/l	*	*
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:	none	none
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

Annex 4

NEW ZEALAND Parameter	Surface	Sewer
pH		6.0 - 9.0
Temperature ° C		55
Conductivity µs/cm		
Suspended solids mg/l		
Settleable solids ml/l		
BOD_5 mg 0_2/l		
COD mg/l		
Sulphide mg S^{2-}/l		1 - 5
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l		5 - 50
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

NICARAGUA Parameter+E260	Surface	Sewer
pH	6.0 - 9.0	6.0 - 10.0
Temperature ° C		50
Conductivity µs/cm		
Suspended solids mg/l	150	400
Settleable solids ml/l	5	
BOD_5 mg 0_2/l	120	400
COD mg/l	250	900
Sulphide mg S^{2-}/l	0.2	5
Chrome (III) mg/l		
Chrome (VI) mg/l		0.5
Chrome total mg/l	10	3.5
TDS mg/l		1500
Chlorides mg/l		1500
Sulphates mg/l		1500
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	30	150
Phenols mg/l	0.1	1
Detergents mg/l		10
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

PAKISTAN *Parameter*	*Surface*	*Sewer*
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C	40	
Conductivity µs/cm		
Suspended solids mg/l	200	
Settleable solids ml/l		
BOD_5 mg 0_2/l	80	
COD mg/l	150	
Sulphide mg S^{2-}/l	1	
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	1	
TDS mg/l		
Chlorides mg/l	1000	
Sulphates mg/l	1000	
Ammonia mg N/l	40	
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	10	
Phenols mg/l	0.3	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

POLAND *Parameter*	*Surface*	*Sewer*
pH	6.5 - 9.0	
Temperature ° C	35	
Conductivity µs/cm		
Suspended solids mg/l	35	
Settleable solids ml/l		
BOD_5 mg 0_2/l	30	
COD mg/l	150	
Sulphide mg S^{2-}/l	0.2	
Chrome (III) mg/l	0.5	
Chrome (VI) mg/l	0.2	
Chrome total mg/l		
TDS mg/l	2000	
Chlorides mg/l	1000	
Sulphates mg/l	500	
Ammonia mg N/l	6	
TNK mg/N/l	30	
Phosphorus mg P/l	5	
Oil/grease mg/l	50	
Phenols mg/l	0.5	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

SOUTH AFRICA Parameter	Surface	Sewer
pH	5.5 - 9.5	5.5 - 12.0
Temperature ° C	35	43
Conductivity µs/cm		
Suspended solids mg/l	25	400 - 2000
Settleable solids ml/l	N/S	N/S
BOD_5 mg 0_2/l	N/S (10)	N/S (200 - 1400)
COD mg/l	30	2000 - 5000
Sulphide mg S^{2-}/l	1	5 - 50
Chrome (III) mg/l	0.5	N/S
Chrome (VI) mg/l	0.05	N/S
Chrome total mg/l	0.5	5 - 50
TDS mg/l		
Chlorides mg/l	N/S	1000
Sulphates mg/l	N/S	500 - 1000
Ammonia mg N/l	10	20 - 30
TNK mg/N/l	N/S	50
Phosphorus mg P/l		
Oil/grease mg/l	2.5	50 - 100
Phenols mg/l	0.1	
Detergents mg/l		
Solvents mg/l:	N/S	N/S
Hydrocarbons mg/l	N/S	N/S
Nitrogenous mg/l	N/S	N/S
Chlorinated mg/l	N/S	N/S

SPAIN Parameter	Surface	Sewer
pH	5.5 - 9.5	8.0 - 10.0
Temperature ° C	30	
Conductivity µs/cm		
Suspended solids mg/l	80 - 300	500 - 750
Settleable solids ml/l	0.5 - 2	
BOD_5 mg 0_2/l	40 - 300	750 - 1000
COD mg/l	160 - 500	1500 - 2500
Sulphide mg S^{2-}/l	1 - 2	1 - 20
Chrome (III) mg/l	2 - 4	
Chrome (VI) mg/l	0.2 - 0.5	0.5
Chrome total mg/l		3 - 5
TDS mg/l		
Chlorides mg/l	2000	2000
Sulphates mg/l	2000	2000
Ammonia mg N/l	15 - 50	85
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	20 - 40	150
Phenols mg/l	0.5 - 1	2
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	none	none
Nitrogenous mg/l		
Chlorinated mg/l		

SRI LANKA Parameter	Surface	Sewer
pH	5.5 - 9.0	
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	100	
Settleable solids ml/l		
BOD_5 mg 0_2/l	60	
COD mg/l	250	
Sulphide mg S^{2-}/l	2.0	
Chrome (III) mg/l		
Chrome (VI) mg/l	0.5	
Chrome total mg/l	2.0	
TDS mg/l		
Chlorides mg/l	1000	
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	10.0	
Phenols mg/l	1.0	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

SWITZERLAND Parameter	Surface	Sewer
pH	6.5 - 8.5	6.0 - 9.5
Temperature ° C	30	40
Conductivity µs/cm		
Suspended solids mg/l	20	
Settleable solids ml/l		
BOD_5 mg 0_2/l	20	
COD mg/l		
Sulphide mg S^{2-}/l	0.1	1
Chrome (III) mg/l	2	2
Chrome (VI) mg/l	0.1	0.5
Chrome total mg/l	2	2
TDS mg/l		
Chlorides mg/l	200	
Sulphates mg/l		300
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	20	
Phenols mg/l	5	5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l	20	20
Nitrogenous mg/l		
Chlorinated mg/l	0.1	0.1

Annex 4

TANZANIA Parameter	Surface	Sewer
pH	5.5 - 9.0	
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	100	
Settleable solids ml/l		
BOD_5 mg 0_2/l	30	
COD mg/l		
Sulphide mg S^{2-}/l		
Chrome (III) mg/l		
Chrome (VI) mg/l	0.1	
Chrome total mg/l		
TDS mg/l		
Chlorides mg/l	1000	
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

THAILAND Parameter	Surface	Sewer
pH	5.5 - 9.0	
Temperature ° C	40	
Conductivity µs/cm		
Suspended solids mg/l	150	
Settleable solids ml/l		
BOD_5 mg 0_2/l	20 - 60	
COD mg/l		
Sulphide mg S^{2-}/l	1	
Chrome (III) mg/l	0.75	
Chrome (VI) mg/l	0.25	
Chrome total mg/l		
TDS mg/l	5000	
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l	15	
Phenols mg/l	1	
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

TUNISIA Parameter	Surface	Sewer
pH	6.5 - 8.5	6.5 - 9.0
Temperature ° C	25	35
Conductivity µs/cm		
Suspended solids mg/l	30	400
Settleable solids ml/l	0.3	
BOD5 mg 02/l	30	400
COD mg/l	90	1000
Sulphide mg S2-/l	0.1	3
Chrome (III) mg/l	0.5	2
Chrome (VI) mg/l	0.05	0.5
Chrome total mg/l		
TDS mg/l		
Chlorides mg/l	600	700
Sulphates mg/l	400	600
Ammonia mg N/l		
TNK mg/N/l	1	100
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

UGANDA Parameter	Surface	Sewer
pH	6.0 - 8.0	
Temperature ° C	20 - 35	
Conductivity µs/cm		
Suspended solids mg/l	50	
Settleable solids ml/l		
BOD5 mg 02/l	30	
COD mg/l	100	
Sulphide mg S2-/l	1.0	
Chrome (III) mg/l		
Chrome (VI) mg/l	0.05	
Chrome total mg/l	1.0	
TDS mg/l	1000	
Chlorides mg/l	30	
Sulphates mg/l	500	
Ammonia mg N/l	10	
TNK mg/N/l	10	
Phosphorus mg P/l	10.0	
Oil/grease mg/l	10	
Phenols mg/l	0.2	
Detergents mg/l	10.0	
Solvents mg/l:		
Hydrocarbons mg/l	*	
Nitrogenous mg/l	*	
Chlorinated mg/l	*	

Annex 4

UK Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 10.0
Temperature ° C	25	40
Conductivity µs/cm		
Suspended solids mg/l	30 - 50	500 - 1000
Settleable solids ml/l		
BOD_5 mg 0_2/l	20 - 30	
COD mg/l		2000 - 6000
Sulphide mg S^{2-}/l	1	2 - 5
Chrome (III) mg/l	2 - 5	10 - 35
Chrome (VI) mg/l	0.1	0.1
Chrome total mg/l	1 - 2	1 - 20
TDS mg/l		
Chlorides mg/l	4000	5000
Sulphates mg/l		1000 - 1200
Ammonia mg N/l	100	10 - 100
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		50 - 500
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:	none	none
Hydrocarbons mg/l	none	none
Nitrogenous mg/l	none	none
Chlorinated mg/l	none	none

USA Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 10.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	60	
Settleable solids ml/l		
BOD_5 mg 0_2/l	40	
COD mg/l		
Sulphide mg S^{2-}/l		24
Chrome (III) mg/l		8 - 19
Chrome (VI) mg/l		
Chrome total mg/l	1	8 - 19
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l		
Oil/grease mg/l		
Phenols mg/l		10
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

VENEZUELA Parameter	Surface	Sewer
pH	6.0 - 9.0	6.0 - 9.0
Temperature ° C		
Conductivity µs/cm		
Suspended solids mg/l	60	400
Settleable solids ml/l		
BOD_5 mg 0_2/l	60	400
COD mg/l	350	1000
Sulphide mg S^{2-}/l	0.5	2
Chrome (III) mg/l		
Chrome (VI) mg/l	0.5	0.5
Chrome total mg/l	2	3
TDS mg/l		
Chlorides mg/l		300
Sulphates mg/l		400
Ammonia mg N/l		
TNK mg/N/l	10	80
Phosphorus mg P/l		
Oil/grease mg/l	20	150
Phenols mg/l	0.5	0.5
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

VIETNAM Parameter	Surface	Sewer
pH	5.5 - 9.0	5.0 - 9.0
Temperature ° C	40	45
Conductivity µs/cm		
Suspended solids mg/l	100	200
Settleable solids ml/l		
BOD_5 mg 0_2/l	50	100
COD mg/l	100	400
Sulphide mg S^{2-}/l	0.5	1.0
Chrome (III) mg/l	1.0	2.0
Chrome (VI) mg/l		
Chrome total mg/l	2.0	2.0
TDS mg/l		
Chlorides mg/l		
Sulphates mg/l		
Ammonia mg N/l		
TNK mg/N/l	60	60
Phosphorus mg P/l		
Oil/grease mg/l	10	30
Phenols mg/l		
Detergents mg/l		
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

ZAMBIA Parameter	Surface	Sewer
pH	6.0 - 9.0	
Temperature ° C	40	
Conductivity µs/cm	4300	
Suspended solids mg/l	100	
Settleable solids ml/l	0.5	
BOD_5 mg 0_2/l	50	
COD mg/l	90	
Sulphide mg S^{2-}/l	0.1	
Chrome (III) mg/l		
Chrome (VI) mg/l	0.1	
Chrome total mg/l		
TDS mg/l	3000	
Chlorides mg/l	800	
Sulphates mg/l	1500	
Ammonia mg N/l	10	
TNK mg/N/l	15	
Phosphorus mg P/l	1	
Oil/grease mg/l	20	
Phenols mg/l	0.2	
Detergents mg/l	2.0	
Solvents mg/l:		
Hydrocarbons mg/l	10	
Nitrogenous mg/l		
Chlorinated mg/l	0.5	

ZIMBABWE Parameter	Surface	Sewer
pH	6.8 - 9.0	> 7.5
Temperature ° C	45 max.	45
Conductivity µs/cm		
Suspended solids mg/l	600	6000
Settleable solids ml/l	10	
BOD_5 mg 0_2/l	1000	
COD mg/l	3000	6000
Sulphide mg S^{2-}/l		200
Chrome (III) mg/l		
Chrome (VI) mg/l		
Chrome total mg/l	10	10
TDS mg/l		
Chlorides mg/l	1000	4000
Sulphates mg/l	1000	300
Ammonia mg N/l		
TNK mg/N/l		
Phosphorus mg P/l	30	
Oil/grease mg/l	50	450
Phenols mg/l		
Detergents mg/l	20	
Solvents mg/l:		
Hydrocarbons mg/l		
Nitrogenous mg/l		
Chlorinated mg/l		

* specific requirements have to be fulfilled. The figures in the table were complied from various sources and cannot be considered as official.
M. Bosnic et al UNIDO 1998

ANNEX 5

Quality Standards for Compost processed from Sewage Sludge

Güte- und Prüfbestimmungen für Komposte aus Abwasserschlamm

Fassung vom Juli 1993

Gütegemeinschaft Kompost (GK) im ANS e.V.

Inhalt

Anlagen 2 und 3 werden derzeit überarbeitet!

1. Allgemeines

1.1 Zweck

Die Gütegemeinschaft Kompost (GK) im ANS e.V. verleiht laut Satzung und Gütezeichenordnung des ANS e.V. ein Gütesiegel zur Qualitätssicherung von Komposten.

In den vorliegenden Güte- und Prüfbestimmungen sind u.a. die zugelassenen Inhaltsstoffe, Richtwerte für Schwermetalle und organische Schadstoffe und die Prüfmethodik für Komposte aus Abwasserschlamm festgelegt.

Insoweit ist sichergestellt, daß die Mitgliedsbetriebe in der GK nur Materialien und Methoden einsetzen, mit denen die vorgegebenen Qualitätsanforderungen erfüllt werden.

1.2 Geltungsbereich

Die Güte- und Prüfbestimmungen gelten für Kompost im Sinne des Absatzes 2.1.

1.3 Geltende Vorschriften

Es gelten die jeweils gültigen Gesetze, Verordnungen, Erlasse, Normen und Vorschriften, die für die Güte- und Prüfbestimmungen relevant sind.

2. Gütebestimmungen

2.1 Definition

Fertigkompost ist das Endprodukt der Kompostierung, bei dem insbesondere die leicht abbaubare organische Substanz weitgehend biologisch umgesetzt ist.

Frischkompost ist Rottegut mit höheren Gehalten an leichtabbaubarer organischer Substanz, das zu intensiver Rotte fähig ist oder sich in intensiver Rotte befindet.

Kompost der Rottegrade II und III wird als Frischkompost, Kompost der Rottegrade IV und V als Fertigkompost bezeichnet.

2.2 Merkmale

Ein Kompost, der das Gütesiegel der GK trägt, muß die in Anlage 1 beschriebenen Kriterien erfüllen.

3. Prüfbestimmungen

3.1 Grundsätze

Art, Methode und Umfang der Prüfungen richten sich nach den vom Güteausschuß der GK erlassenen Güte- und Prüfbestimmungen in der jeweils gültigen Fassung.

3.2 Erstprüfung

Der Prüfungsumfang und die Prüfungsverfahren ergeben sich aus der Anlage 2. Das Prüfverfahren zur Erlangung des Gütesiegels dauert mindestens 6 Monate, sofern nicht entsprechende Analysenergebnisse von Halbjahresproben aus drei aufeinander folgenden Jahren vorgelegt werden.

In jedem Fall muß die Prüfung durch einen neutralen Prüfer durchgeführt werden.

Dabei sind folgende Prüfungstermine einzuhalten:

- In der ersten Woche eines jeden Monats bei Monatsproben.

- Bei Halbjahresproben ein Abstand von mindestens fünf und höchstens sieben Monaten.

- Wiederholungsprüfungen werden bei negativem Ausgang der regulären Prüfungen vom Güteausschuß der GK angeordnet oder können vom Zeichenbenutzer beantragt werden.

Die Probenahme und die Behandlung der Probe richten sich nach Abschnitt 4 dieser Bestimmungen.

3.3 Eigenprüfung

Mit der Eigenprüfung hat der Benutzer des Gütesiegels die Qualität seines gütegesicherten Kompostes selbst zu prüfen und zu überwachen bzw. hierfür geeignete Untersuchungsstellen zu beauftragen. Die nach Abschnitt 3.2 und 3.4 vorgeschriebenen Prüfungen dürfen die Eigenprüfung nicht ersetzen.

Der Prüfungsumfang umfaßt auf jeden Fall den Nachweis der seuchenhygienischen Wirksamkeit des Rotteprozesses (Temperaturmessungen), sowie freiwillig vorrangig solche Untersuchungen, die für die Anwendungsempfehlungen von Bedeutung sind. Die Prüfungsverfahren ergeben sich aus der Anlage 2.

Über Durchführung und Ergebnis der Eigenprüfung hat der Zeichenbenutzer dem Güteausschuß der GK gegenüber uneingeschränkte Nachweis- und Auskunftspflicht.

Die Probenahme und die Behandlung der Probe richten sich nach Abschnitt 4 dieser Bestimmungen.

Die Prüfungsergebnisse sind zu protokollieren. Sie sind mindestens fünf Jahre aufzubewahren und auf Verlangen dem neutralen Prüfer vorzulegen.

3.4 Fremdprüfung

Der Prüfungsumfang und die Prüfungsverfahren ergeben sich aus der Anlage 2. Die Prüfung wird durch einen neutralen Prüfer durchgeführt.

Im Überwachungsverfahren sind für Komposte folgende Prüfungstermine einzuhalten:

- Einmal pro Quartal, außer organische Schadstoffe.

- Organische Schadstoffe alle 2 Jahre.

- Art und Umfang von Wiederholungsprüfungen werden im Falle des negativen Ausganges der regulären Fremdprüfung oder bei Beanstandung einer Lieferung vom Güteausschuß der GK angeordnet oder können vom Zeichenbenutzer beantragt werden.

Der eingesetzte Abwasserschlamm (Originalsubstanz) ist zweimal pro Jahr gemäß den Bestimmungen AbfKlärV zu untersuchen und muß deren Grenzwerte erfüllen.

Die Probenahme und die Behandlung der Probe richten sich nach Abschnitt 4 dieser Bestimmungen.

3.5 Kontrollverfahren

Der Obmann des Güteausschusses der GK hat sich die Eigennachweise der nach Abschnitt 3.3 durchzuführenden Prüfungen bei Bedarf vorlegen bzw. zusenden zu lassen.

Der Obmann des Güteausschusses der GK hat sich eine Ausfertigung der Untersuchungsberichte nach Anlage 3 der nach Abschnitt 3.2 und 3.4 durchzuführenden Prüfungen ständig zusenden zu lassen.

3.6 Auswertung und Berichtswesen

Der Güteausschuß der GK ist verantwortlich für die Auswertung der Untersuchungsergebnisse und das Berichtswesen.

Der Einzelbericht ist auf die Einhaltung der Güte- und Prüfbestimmungen zu prüfen. Richtwertüberschreitungen beurteilt und entscheidet er nach den vorliegenden Güte- und Prüfbestimmungen. Insbesondere ordnet er Wiederholungsprüfungen im erforderlichen Umfang an.

In allen Fällen, in denen nach der Vereinssatzung des ANS e.V., der Gütezeichenordnung und den Durchführungsbestimmungen für die Verleihung und Führung des Güte-zeichens eine Entscheidung der Mitgliederversammlung der GK erforderlich wird, hat er diese unverzüglich zu informieren.

4. Probeentnahme und Behandlung der Proben

4.1 Probeentnahme

Erst- und Fremdprüfung

Der neutrale Prüfer entnimmt im Auftrag des Anlagenbetreibers aus der verkaufsfähigen Charge gemäß Anlage 2 eine Probe. Eine Gegenprobe von mindestens einem Liter ist in getrocknetem Zustand bis zur nächsten Analyse aufzubewahren.

Eigenprüfung

Das Verfahren der Probenahme gilt entsprechend auch in den Fällen, in denen Proben für eigene Prüfungen entnommen werden.

4.2 Behandlung der Probe

Das beauftragte Untersuchungslabor ist vom Anlagenbetreiber zu verpflichten, den Untersuchungsbericht so zeitgerecht zu versenden, daß er höchstens 20 Arbeitstage nach Eingang der Probe beim Auftraggeber eintrifft. In allen Fällen einer Verzögerung wird der Auftraggeber informiert.

Die gleiche Frist gilt für die Zusendung einer Ausfertigung des Untersuchungsberichtes gemäß Anlage 3 an den Güteausschuß der GK.

4.3 Beanstandungen

Bei Beanstandungen steht dem Siegelbenutzer das Recht zu, auf seine Kosten eine Nachuntersuchung durch ein anderes anerkanntes Untersuchungslabor durchführen zu lassen. Sollten die Befunde wesentlich voneinander abweichen, so kann der Güteausschuß der GK eine dritte Untersuchung veranlassen.

Der Güteausschuß der GK entscheidet darüber, welche Abweichungen wesentlich sind und welche Werte für die Auswertung zugrunde gelegt werden.

Der Siegelbenutzer verpflichtet sich, etwa festgestellte Mängel unverzüglich abzustellen.

5. Kennzeichnung

Kompost, der den Güte- und Prüfbestimmungen entspricht, wird mit nachfolgendem Gütesiegel gekennzeichnet:

Für die Anwendung des Gütesiegels gelten ausschließlich die Satzungs- und Zeichenunterlagen der GK.

6. Änderungen

Änderungen dieser Güte- und Prüfbestimmungen bedürfen der Genehmigung durch die Mitgliederversammlung der GK. Sie werden durch Mitteilung des Güteausschusses an die Gütezeichenbenutzer nach einer angemessenen Übergangsfrist in Kraft gesetzt.

ANLAGE 1

Güte- und Qualitätskriterien für Abwasserschlamm-Komposte

Die folgenden Güte- und Qualitätskriterien gelten für Frisch- und Fertigkomposte. Sollen einzelne Bestimmungen nur für Frisch- oder für Fertigkompost gelten, so ist dies im Text durch Unterstreichung der beiden Befriffe separat vermerkt.

1. Seuchenhygiene, Freiheit von keimfähigen Samen und Pflanzenteilen

Der gewählte Rotteprozeß muß zu einem seuchenhygienisch unbedenklichen Kompost und zur Abtötung keimfähiger Samen und austriebsfähiger Pflanzenteile führen. Dies ist durch das jeweilige Kompostierungsverfahren sicherzustellen.

Die Kompost-Produzenten haben Temperaturaufzeichnungen durchzuführen und diese mindestens 12 Monate zur Einsicht aufzubewahren.

2. Verunreinigungen

Der Kompost muß weitgehend frei sein von wahrnehmbaren Verunreinigungen. Verunreinigungen sind artfremde Stoffe, wie z.B. Kunststoffe, Glas und Metalle.

Der Gesamtgehalt an Verunreinigungen größer als zwei Millimeter darf maximal 0,5 Gewichtsprozent in der Trockensubstanz betragen.

3. Steine

Der Anteil an Steinen größer als fünf Millimeter darf fünf Gewichtsprozent in der Trockensubstanz nicht überschreiten.

4. Rottegrad

Frischkompost muß dem Rottegrad II oder III nach Merkblatt 10 der Länderarbeitsgemeinschaft Abfall entsprechen.

Fertigkompost muß dem Rottegrad IV oder V nach Merkblatt 10 der Länderarbeitsgemeinschaft Abfall entsprechen.

5. Pflanzenverträglichkeit

Die Pflanzenverträglichkeit von Fertigkompost ist in Form eines Keimpflanzentests nachzuweisen. Für Frischkompost entfällt dieser Nachweis.

6. Wassergehalt

Der Wassergehalt für lose Ware darf maximal 65 Gewichtsprozente betragen, für Sackware maximal 35 Gewichtsprozente. Werden atmungsaktive Säcke verwendet und beträgt die Lagerzeit unter 6 Wochen, darf Sackware bis zu 45 Gewichtsprozente Wasser enthalten.

7. Organische Substanz

Der Gehalt an organischer Substanz wird gemessen als Glühverlust. Er muß für Fertigkomposte mindestens 30 Gewichtsprozente der Trockensubstanz und für Frischkomposte mindestens 40 Gewichtsprozente der Trockensubstanz betragen.

8. Sonstige Inhaltsstoffe

8.1 Richtwerte für Schwermetalle

Die Richtwerte für Schwermetalle in Abwasserschlamm-Komposten betragen bezogen auf die Trockensubstanz bei Ausbringung auf Böden mit einem pH-Wert größer oder gleich 6:

Metall	Chemisches Symbol	Einheit	Ausbringungsmenge (pH ≥ 6)	
			5 Mg TS/ha, 3 a	10 Mg TS/ha, 3 a
Blei	Pb	[mg/kg]	670	335
Cadmium	Cd	[mg/kg]	5	2,5
Chrom	Cr	[mg/kg]	670	335
Kupfer	Cu	[mg/kg]	600	300
Nickel	Ni	[mg/kg]	150	75
Quecksilber	Hg	[mg/kg]	4	2
Zink	Zn	[mg/kg]	1.870	935

Bei Ausbringung auf Böden, die im Rahmen der Bodenschätzung als leichte Böden eingestuft sind und deren Tongehalt unter 5 % liegt oder deren pH-Wert bei über 5 und unter 6 sind für Cadmium und Zink die folgenden Richtwerte im Kompost bezogen auf die Trockensubstanz einzuhalten:

Metall	Chemisches Symbol	Einheit	Ausbringungsmenge (5 < pH < 6)	
			5 Mg TS/ha, 3 a	10 Mg TS/ha, 3 a
Cadmium	Cd	[mg/kg]	2,5	1,2
Zink	Zn	[mg/kg]	1.500	750

8.2 Richtwerte für organische Schadstoffe

Die Richtwerte für polychlorierte Biphenyle (PCB) betragen für die Komponenten 28, 52, 101, 138, 153, 180 bezogen auf die Trockensubstanz jeweils 0,1 mg/kg.

Der Richtwert für polychlorierte Dibenzodioxine/Dibenzofurane (PCDD/PCDF) beträgt 50 Nanogramm Toxizitätsäquivalente je kg Trockensubstanz, berechnet als I-TEQ nach der 17. BImSchG-VO.

Ein Richtwert für die Summe der halogenorganischen Verbindungen, ausgedrückt als Summenparameter AOX, kann derzeit für Komposte nicht angegeben werden. Im zur Kompostierung eingesetzten Abwasserschlamm beträgt der Richtwert bezogen auf die Trockensubstanz 500 mg/kg.

8.3 Richtwertüberschreitungen

Die Richtwerte in 8.1 und 8.2 gelten auch als eingehalten, wenn das arithmetische Mittel aus den im Rahmen der Güte- und Prüfbestimmungen analysierten Proben eines Jahres unter dem Richtwert liegt. Dabei dürfen Einzelproben den Richtwert um maximal 10 % überschreiten.

9. Deklarationspflichtige Parameter

9.1 Art des Kompostes (Frisch- oder Fertigkompost) und Zusammensetzung des Ausgangsmaterials (Abwasserschlammanteil, Zuschlagstoffe)

9.2 Maximalkorn

9.3 Rohdichte

9.4 Salzgehalt

9.5 pH-Wert

9.6 Pflanzennährstoffe

Gesamtgehalte	Lösliche Gehalte
- Stickstoff (N)	- Stickstoff (N)
- Phosphor (P_2O_5)	- Phosphor (P_2O_5)
- Kalium (K_2O)	- Kalium (K_2O)
- Magnesium (MgO)	
- Calcium (CaO)	

Angegeben wird der durchschnittliche Gesamtgehalt in Gewichtsprozent der Frischsubstanz (nach Düngemittelverordnung) und der Trockensubstanz, auf mögliche Schwankungen ist hinzuweisen

9.7 Organische Substanz als Glühverlust

9.8 Bei Gebinden muß das Nettogewicht in Kilogramm oder das Volumen in Litern oder Kubikmetern angegeben sein.

9.9 Hinweise zur sachgerechten Anwendung

9.10 Name und Anschrift des Herstellers oder dessen, der den Kompost in Verkehr bringt.

GÜTEGEMEINSCHAFT KOMPOST (GK) im ANS e.V.

Untersuchungsbericht (Muster 1993) Blatt 1

Probenbezeichnung:

Entnahmeort:

Entnahmedatum:

Probenehmer:

Beobachtungen bei der Probenahme:

(z.B. Wetter, Zustand der Miete, Aktivität des Rottegutes etc.)

Art und Mengen der Ausgangsmaterialien:

Untersuchungslabor:

Probeneingang:

GÜTEGEMEINSCHAFT KOMPOST (GK) im ANS e.V.

Untersuchungsbericht (Muster 1993) Blatt 2

Ergebnisse der Untersuchung

1. Seuchenhygiene, Freiheit von keimfähigen Samen und Pflanzenteilen

(Überprüfung der Temperaturaufzeichnungen und Prüfung gemäß Anhang 1 der Prüfbestimmungen)

2. Rottegrad nach LAGA M10 ....

3. Pflanzenverträglichkeit

(Überprüfung gemäß Anhang 2 der Prüfbestimmungen)

4. Maximalkorn .... mm

5. AOX-Wert des eingesetzten Abwasserschlammes .... mg/kg TS

6. Kompostanalysen

Analyse	Einheit	Frisch-substanz	Trocken-substanz	Richtwert GK	
				5 Mg TS/ha, 3a	10 Mg TS/ha, 3a
Spalten-Nr.	1	2	3	4	5
Schüttgewicht	[g/l]	.....	-	D)[1]	
pH-Wert	[-]	.....	-	D)[1]	Wie Spalte 4
Salzgehalt	[%]	.....	.....	D)[1]	
Wassergehalt	[%]	.....	-	≤ 65)[2]	
Organische Substanz	[%]	-	.....	≥ 30)[3]	
Lösliche Gehalte:					
Stickstoff (N)	[%]	.....	.....	D)[1]	Wie Spalte 4
Phosphor (P_2O_5)	[%]	.....	.....	D)[1]	
Kalium (K_2O)	[%]	.....	.....	D)[1]	
Gesamtgehalte:					
Stickstoff (N_{ges})	[%]	.....	.....	D)[1]	Wie Spalte 4
Phosphor (P_2O_5)	[%]	.....	.....	D)[1]	
Kalium (K_2O)	[%]	.....	.....	D)[1]	
Calcium (CaO)	[%]	.....	.....	D)[1]	
Magnesium (MgO)	[%]	.....	.....	D)[1]	

)[1] Deklarationspflicht
)[2] Für Sackware ≤ 35 %, in atmungsaktiven Säcken ≤ 45 %
)[3] Für Frischkompost ≥ 40 %

GÜTEGEMEINSCHAFT KOMPOST (GK) im ANS e.V.

Untersuchungsbericht (Muster 1993) Blatt 3

Fortsetzung Kompost-Analysen:

Analyse	Einheit	Frisch-substanz	Trocken-substanz	Richtwert GK	
				5 Mg TS/ha, 3a	10 Mg TS/ha, 3a
Spalten-Nr.	1	2	3	4	5
Blei	[mg/kg]	-	.....	670	335
Cadmium	[mg/kg]	-	.....	5)[1]	2,5)[2]
Chrom	[mg/kg]	-	.....	670	335
Kupfer	[mg/kg]	-	.....	600	300
Nickel	[mg/kg]	-	.....	150	75
Quecksilber	[mg/kg]	-	.....	4	2
Zink	[mg/kg]	-	.....	1.870)[1]	935)[2]
PCB Nr. 28	[mg/kg]	-	.....	0,1	Wie Spalte 4
Nr. 52	[mg/kg]	-	.....	0,1	
Nr. 101	[mg/kg]	-	.....	0,1	
Nr. 138	[mg/kg]	-	.....	0,1	
Nr. 153	[mg/kg]	-	.....	0,1	
Nr. 180)	[mg/kg]	-	.....	0,1	
PCDD/F I-TEQ	[ng/kg]	-	.....	50	Wie Spalte 4
Verunreinigungen	[%]	-	.....	≤ 0,5	Wie Spalte 4
Steine größer 5 mm	[%]	-	.....	≤ 5	

)[1] Für leichte Böden und Tongehalt unter 5% oder pH-Werte im Boden von 5-6:
Cd ≤ 2,5 mg/kg und Zn ≤ 1.500 mg/kg

)[2] Für leichte Böden und Tongehalt unter 5% oder pH-Werte im Boden von 5-6:
Cd ≤ 1,2 mg/kg und Zn ≤ 750 mg/kg

ANNEX 6

Control Standards for Pollutants in Sludge for Agricultural Use in China

中华人民共和国国家标准

UDC 628.191
:628.336

GB 4284—84

农用污泥中污染物控制标准

Control standards for pollutants in sludges from agricultural use

为贯彻执行《中华人民共和国环境保护法（试行）》，防治农用污泥对土壤、农作物、地面水、地下水的污染，特制订本标准。

本标准适用于在农田中施用城市污水处理厂污泥、城市下水沉淀池的污泥、某些有机物生产厂的下水污泥以及江、河、湖、库、塘、沟、渠的沉淀底泥。

1 标准值

1.1 农田施用污泥中污染物的最高容许含量应符合下表规定。

农用污泥中污染物控制标准值　　mg/kg干污泥

项　目	最高容许含量	
	在酸性土壤上 (pH＜6.5)	在中性和碱性土壤上 (pH＞6.5)
镉及其化合物（以Cd计）	5	20
汞及其化合物（以Hg计）	5	15
铅及其化合物（以Pb计）	300	1000
铬及其化合物（以Cr计）*	600	1000
砷及其化合物（以As计）	75	75
硼及其化合物（以水溶性B计）	150	150
矿物油	3000	3000
苯并（a）芘	3	3
铜及其化合物（以Cu计）**	250	500
锌及其化合物（以Zn计）**	500	1000
镍及其化合物（以Ni计）**	100	200

* 铬的控制标准适用于一般含六价铬极少的具有农用价值的各种污泥，不适用于含有大量六价铬的工业废渣或某些化工厂的沉积物。

** 暂作参考标准。

2 其他规定

2.1 施用符合本标准污泥时，一般每年每亩用量不超过2000kg（以干污泥计）。污泥中任何一项无机化合物含量接近于本标准时，连续在同一块土壤上施用，不得超过20年。含无机化合物较少的石油化工污泥，连续施用可超过20年。在隔年施用时，矿物油和苯并（a）芘的标准可适当放宽。

中华人民共和国城乡建设环境保护部1984－05－18发布　　1985－03－01实施