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in South-East Asia**

**SAFE LANDFILL FOR DISPOSAL OF SLUDGE FROM TANNERY
EFFLUENT TREATMENT PLANTS**

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LIST OF SYMBOLS & ABBREVIATIONS

BOD ₅	:	Biochemical Oxygen Demand, 5 days
COD	:	Chemical Oxygen Demand
CETP	:	Common Effluent Treatment Plant
Cr ³⁺	:	Trivalent chromium
°C	:	Degree Celsius
DS	:	Dry solids
d	:	Day(s)
dia	:	Diameter
d.w.	:	Dry weight
EIA	:	Environmental Impact Assessment
ETP	:	Effluent treatment plant
h	:	Hour(s)
H	:	Horizontal
HDPE	:	High density poly ethylene
INR	:	Indian Rupee(s)
kg	:	Kilogram(s)
LDPE	:	Low density poly ethylene
l/s	:	Litres per second
m	:	Meter(s)
m/s	:	Meter(s) per second
m ²	:	Square meter(s)
m ³	:	Cubic meter(s) (1000 litres)
mg	:	Milligram(s)
mg/l	:	Milligrams per litre
mm	:	Millimetre(s)
min	:	Minute(s)
no.	:	Number(s)
ND	:	Not detected
PCC	:	Plain cement concrete
PVC	:	Polyvinyl chloride
ppm	:	Parts per million
RCC	:	Reinforced cement concrete
RePO	:	Regional Programme Office
s	:	Second(s)
SDB	:	Sludge drying beds
SS	:	Suspended solids
TNPCB	:	Tamil Nadu Pollution Control Board
t	:	Tonne (1000 kg)
TDS	:	Total dissolved solids
US \$:	United States Dollar(s)
UNIDO	:	United Nations Industrial Development Organization
V	:	Vertical

(Rate of exchange 1 US \$ = INR 46)

EXECUTIVE SUMMARY

Utilization or safe disposal of sludge generated by tannery effluent treatment plants poses a challenge in many a developing country of South East Asia where it has been categorized, mainly due to the presence of chromium, as hazardous. No viable option has emerged yet for utilization of a substantial quantity of sludge. Its safe disposal, therefore, is a priority in these countries.

With the technical assistance of UNIDO, CETP-Ranitec in Ranipet, Tamil Nadu, India, established a pilot scale landfill in October 1997, the first of its kind in the region, for temporary storage of sludge. The objectives of setting up this pilot scale safe landfill were:

- To enhance awareness of the need for and technical requirements of a safe landfill for tannery sludge.
- To construct a landfill appropriate to the requirements of countries of South East Asia in terms of design features and cost.

The capacity of the landfill, constructed in four rectangular cells, is 3300 m³. The landfill had been constructed as a shallow basin in cement concrete due to the high ground water table at site. The bottom of the landfill consisted of one layer of 50 mm of sieved sand, a 0.6 mm LDPE sheet on top of it and another layer of 50 mm sieved sand, covered by mass concrete of 50 mm thickness. The sides were also sealed with 50 mm pre cast cement concrete slabs, pointed with cement mortar. For leachate collection, channels on four sides of the cell, covered by pre cast concrete slabs, had been made. The floor as well as the channels sloped towards one corner of the cell where a leachate collection sump was provided. Dumping of the sludge was done manually using trolleys. The sludge dumped remained partly below ground but mostly above the landfill embankment. Three cells of the landfill have been filled up and covered, using three different materials – one with clay, the second with LDPE sheet and soil and the third with a mixture of sludge and clay. The results are satisfactory.

Unlike the cement concrete construction in the Ranitec landfill, conventional landfills use clay and geo-membrane liners as security barriers to prevent leachate entering the soil or ground water. Also the dumping of sludge is generally done by trucks. As the pilot unit at Ranitec could not be considered a representative model of conventional landfills, a more basic but representative model based on the Ranitec experience was established in CETP-Vishtec, Melvisharam, Tamilnadu, India in September 1999. This landfill, a rectangular basin with a capacity of 2700 m³, has clay bottom (60 cm), HDPE sheet of 1 mm thickness, covered by another layer clay of 7.5 cm and gravel of 20 cm on which lateral PVC pipes of 100 mm dia are laid for leachate collection and conveyance. This is covered by 10 cm of sieved sand and topped by 7.5 cm of clay. Sludge is dumped on top of it by trucks. Leachate conveyed from the landfill is collected in a leachate sump outside the landfill. In this landfill, the entire quantity of sludge to be disposed will remain within the embankment level.

Volume and quality of leachate generated have been carefully monitored and recorded during rainy, dry and post closure in Ranitec landfill. Chromium in leachate was below detectable limit (<0.1 mg/l). Not much leachate was generated due to compression of sludge disposed. Also, it has been noted that after closure, the leachate generation became negligible. The mass balance of sludge disposed in the three cells of Ranitec has also been computed and presented in the report. The volume of leachate from Vishtec landfill has been rather negligible, except during the rains. Its quality has also been analysed. The leachate collection sump in Vishtec has enough free board to accommodate the additional leachate during rains.

As a disposal option, spraying the leachate back on the top of the sludge dumped for natural evaporation has been demonstrated successfully. In both landfills this practice is followed. For tropical countries with sunshine during most part of the year, this option is indeed very relevant.

The major findings of the mass balance studies of sludge disposed in CETP-Ranitec landfill are:

- Contrary to expectation, liberation of leachate due to compression of sludge did not occur; and, very little volume of leachate was produced during the dry season.
- The presence of chromium in the leachate was below detectable limit (<0.1 mg/l). It is safe to conclude that chromium gets immobilized in the sludge.
- The closure of cells using clay etc. had been found sufficient to prevent seepage of water during rains, as is evident from low leachate volume, post-closure.
- Very little degradation of organic matter in the sludge was observed in the landfill.

The cost of construction of the landfill at Ranitec was US \$ 5.3/m³ and that at Vishtec, US \$ 7.5/m³. The operational cost has been estimated as US \$ 0.42 and US \$ 0.54 per m³ of sludge deposited, respectively. It is reported that the cost of disposal of sludge in secure landfills in Europe is more than US \$ 100 per tonne.

The data available from Ranitec and Vishtec landfills have confirmed that the design features of the landfill are appropriate for disposal of tannery sludge in the countries of this region.

To assist the tanners and pollution control agencies of the region, UNIDO has brought out, in collaboration with CTC, Lyon, France, a manual on 'Landfill for Tannery Sludge'. The manual, based on practical experience gained from the pilot landfills set up, provides guidelines on key design criteria, which include site selection, lay out, liner systems, drainage layer, closure procedure, leachate handling and monitoring. The manual has been widely distributed in the region.

1. BACKGROUND

The safe disposal of sludge generated by the common/individual effluent treatment plants poses a challenge to the tanning industry in many countries of South East Asia. As treating effluent from the tanneries is itself a new activity in these countries, the need to properly dispose the sludge generated in the process of treating effluent has been highlighted only in the recent past. Many initiatives, to convert sludge particularly with low chromium concentration (of less than 5000 mg/kg), are underway with mixed results.

Many countries of this region categorize sludge from tannery effluent treatment plants as hazardous, mainly due to the presence of chromium in it. In January 2000, the Government of India deleted sludge containing less than 5000 mg/kg of trivalent chromium or less than 50 mg/kg of hexavalent chromium from the list of hazardous wastes. It is expected that some other countries in the region may also adopt this approach. Despite this, it is expected that a sizeable quantity of sludge may contain chromium at levels more than this limit and therefore will have to be disposed in safe landfills.

Nevertheless, as the sludge resulting from treating tannery effluent is not highly toxic or hazardous, it is possible to safely dispose it in a landfill with appropriate protection in a cost-effective manner.

2. OBJECTIVES

UNIDO, under its Regional Programme, in co-operation with selected CETPs, took up pilot and demonstration safe landfills primarily with a view:

- ◆ To enhance awareness among the tanneries in the region of the importance of proper disposal of sludge.
- ◆ To demonstrate landfill construction and operation by way of setting up basic model temporary safe landfills for disposal of sludge.
- ◆ To collect data relating to leachate over a period of time.
- ◆ To encourage other (C)ETPs in the region to adopt proper modes of sludge disposal.
- ◆ To prepare and disseminate a reference manual on landfill for disposal of sludge.
- ◆ To present the findings to Pollution Control Authorities, to help formulate appropriate regulations concerning tannery sludge disposal.

3. STRATEGY AND LOCATION

In cooperation with the managements of the CETP-Ranitec, Ranipet and CETP-Vishtec, Melvisharam, Tamilnadu, India, UNIDO set up the following model safe landfills for disposal of sludge from tannery effluent treatment plants. The strategy of UNIDO has been:

- ◆ To assist implementation and monitoring of a landfill site at CETP-Ranitec, Ranipet, India, with a total effective area of 1600 m² and 3200 m³ capacity.

- ◆ Based on data collected, to implement and monitor another more representative landfill at CETP-Vishtec, Melvisharam, India, with a total effective area of 1300 m² and 2700 m³ capacity. This landfill is envisaged to be a typical representative of a large-scale landfill, with provision for dumping sludge by trucks.

4. AGENCIES INVOLVED

- ◆ Basic design of the temporary safe landfill at CETP-Ranitec was provided by UNIDO consultant, Mr. Pentti Rantala, of Finland, somewhat modified to suit local requirements.
- ◆ Mr. R. Swaminathan, UNIDO National Expert for design of Vishtec landfill.
- ◆ Mr. Michel Aloy and Mr. Thierry Poncet, CTC France.
- ◆ Managements of CETP-Ranitec and CETP-Vishtec for providing local inputs including land, regular maintenance and monitoring.

5. STATUS OF IMPLEMENTATION

The landfill at CETP-Ranitec was completed in October 1997 and has been in use since then.

At present, all the four cells in the landfill at CETP-Ranitec have been filled up and three of these, closed. The consolidation and closure of the fourth one is ongoing. Strict monitoring of the project continues.

The second, more representative, landfill at CETP-Vishtec, Melvisharam is in operation since September 1999 and has been filled to more than half its capacity.

6. LANDFILL AT CETP-RANITEC, RANIPET

6.1. Introduction

CETP-Ranitec is situated at Ranipet in V. C. Mottur in Walajah taluk of Vellore district. The CETP has been established for treatment of effluent discharged by 76 tanneries in the cluster, mostly processing raw to finished leather, largely by vegetable tanning. The CETP employs physical, chemical & biological processes to treat the effluent and in the process, generates a significant quantity of sludge, mainly from primary chemical treatment. The sludge is dewatered in sludge drying beds and a decanter centrifuge.

During the initial one and a half year's of operation (1996-97), the CETP was dumping the dewatered sludge in the unprotected open ground belonging to it. Since the chrome containing sludge was notified as hazardous in India, UNIDO offered assistance in development of a safe landfill system for temporary disposal to serve as a model.

The landfill, constructed in four cells, was developed generally based on the design prepared by Mr. Pentti Rantala, the schematic representation of which is given in Annex 1. The details of this landfill are discussed in subsequent sections.

6.2 Design

6.2.1 Location

The layout of the landfill is given in Annex 2A.

A low lying area beyond the sludge drying beds (dry in summer but marshy during rainy season) was made available by the CETP management. The ground water table reported for the proposed area was very high (1.0-1.5 m in summer and flooding in rainy season). Though land at a relatively elevated level with lower ground water table was preferred by RePO, all the surplus land available with the CETP was having more or less the same ground water table. Left with no other choice and also considering the proximity of the proposed site to the existing sludge drying beds, it was decided to implement the landfill at the location offered by the CETP.

6.2.2 Depth

Due to the high ground water table in the CETP premises, the depth of the landfill below the ground level was limited to less than one meter.

6.2.3 Layout

Since this landfill was the first of its kind in the region, in order to facilitate conducting various experiments, particularly with respect to filling pattern and covering options, the unit was constructed in four cells each of approximately 400 m² as shown in the layout plan given in Annex 2A. The site was provided with an approach road of 3 m width along the periphery and a lateral approach road of 2 m width between the cells.

6.2.4 Liner

Owing to the high ground water table, it was decided to give double liner with 600 micron thick LDPE sheet, mass plastering in the bottom and pre-cast slab cover for the sides. The bottom arrangement of the landfill consisted of 50 mm sieved sand, 0.6 mm LDPE sheet, 50 mm sieved sand and mass concrete of 50 mm thickness. The sides were sealed with 50 mm pre cast cement concrete slabs laid and pointed with cement mortar.

6.2.5. Feeding

Being small in size and considering that the site was close to the sludge drying yard, it was decided that the feeding to the disposal yard would be done by manually operated trolleys.

6.3 Implementation

6.3.1 Environmental Impact Assessment

As per the statutory requirement of TNPCB, a rapid Environmental Impact Assessment (EIA) study was conducted by the Anna University, Chennai and the study confirmed the suitability of the site according to the prescribed criteria.

6.3.2 Construction of landfill

As the area was low lying, it was filled with clay to raise it (about 2000 m² including boundary passage etc.) by approximately 1.0 m. Due to the bad condition of the soil and in the absence of any approach road, it took more than a month to complete the filling.

The construction was started in the first week of June 97 and completed by September 97. Some pictures of the various stages of construction of landfill may be seen in Annex 6. Following formal inauguration by the Joint Chief Environmental Engineer of TNPCB, regular disposal of sludge was started from October 1997. After the inauguration, some sludge was deposited simultaneously in all the cells, mainly to prevent damage to the flooring of the landfill due to likely upward thrust of ground water.

Some modifications, specifically for strengthening the embankments were done later by putting cut stone slabs on outer embankments and the approach road was also strengthened.

6.4 Leachate collection

The original design of Mr. Rantala did not provide for leachate collection and disposal, as it was envisaged as a temporary disposal site.

However, it was considered necessary to have a leachate collection arrangement, as the landfill was a demonstration unit. Normal leachate collection arrangement such as drainage layer etc. was perceived to be difficult in this landfill unit, as the depth available did not permit such an arrangement. Therefore a simple leachate collection system was provided. The arrangement consisted of a drain channel on four sides of each cell, covered with pre-cast slabs, with slope towards one side (leading the leachate flow to one corner of the cell). The leachate reaching the corner was collected in a leachate collection pit, from where it could be pumped out.

6.5 Operation & Monitoring

6.5.1 Commissioning

The landfill was commissioned in October 1997. The leachate collected in the leachate collection pit was pumped to the filtrate collection sump of sludge drying beds, which in turn was pumped to the receiving sump of the CETP.

6.5.2 Monitoring

The major objective of the landfill at Ranitec was to study the changes in sludge characteristics in the landfill and to obtain data regarding volume and quality of leachate. A monitoring schedule was accordingly prepared and collection of samples and analysis started.

All analyses were carried out in the laboratory of CETP-Ranitec. Composition of sludge disposed in terms of dry solids content, organic matter and chromium was tested for each lot of sludge disposed and the quantity disposed was noted. Samples of leachate from all the cells were collected as and when it was found in the collection pits.

As per the test results, no chromium could be found in the leachate and the concentration of other pollutants such as BOD, COD and TDS was inversely proportional to the volume of leachate.

6.5.2.1 Pumping the leachate back to the top of dumped sludge

On the suggestion of Mr. Mladen Bosnic, UNIDO consultant, leachate obtained in cell No. 2 was not taken to the filtrate sump but was pumped back to the sludge heap to let it evaporate. The idea was to evaluate the feasibility of disposal of leachate within the sludge disposal yard (particularly relevant to small sized off-site sludge landfills where establishing separate treatment facilities for leachate treatment would be difficult). This was considered workable because the volume of leachate collected was quite small.

Accordingly, the leachate was sprayed back weekly from second week of December 1997 on top of the deposited sludge heap. This arrangement was found very effective, as the volume of leachate progressively reduced and finally stopped altogether. The volume of leachate pumped out (measured approximately using the pumping rate) is given in figure 1: The rainfall during the period in the area too is given for reference.

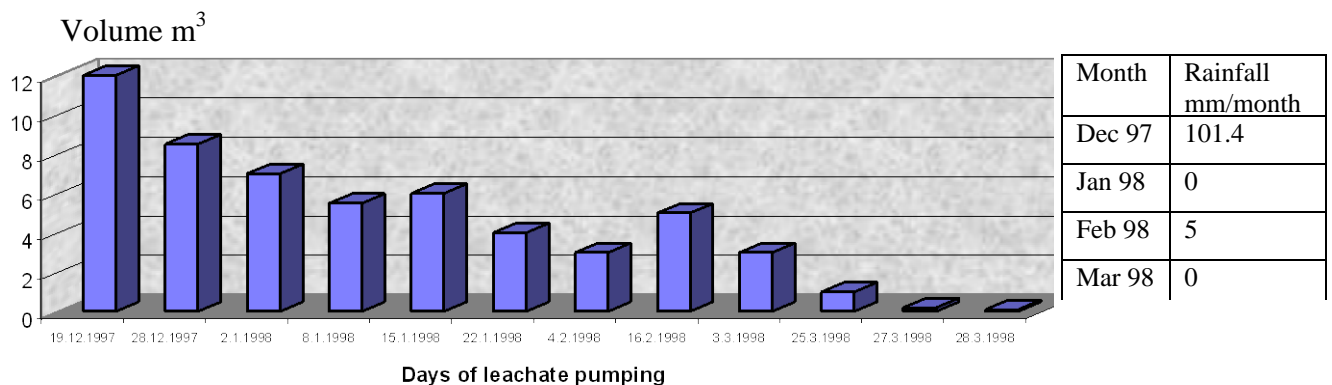


Figure 1: Reduction in leachate volume with leachate recycling

Following this experiment, the cell number 2 was cleared of the sludge deposited and was taken for mass balance studies (first part) and a detailed mass balance report was

prepared. The major result of the mass balance study was that chromium leaching from the sludge was practically nil. It indicated that only less stringent standards were required for landfills established for tannery sludge. The solidification of sludge taking place in the landfill possibly resulted in immobilisation of chromium.

6.5.3 Operation of the landfill

Given the design capacity of the landfill, all the four cells in the landfill should have been filled up within six months of operation. However, in reality this did not happen owing to the fact that the CETP had disposed only a part of its total sludge in the landfill and the balance was dumped in the temporary storage yard constructed earlier. The sludge from sludge drying beds situated close to the landfill only was disposed in it.

6.5.3.1 Quantity of sludge disposed

The quantity of sludge disposed in the four cells until 31 December 2000 is as follows:

Cell 1: 730 t

Cell 2: 740 t

Cell 3: 710 t

Cell 3: 660 t

6.5.3.2 Closure of the landfill cell

After consulting with experts, it was decided to close cell no. 1 using clay as top liner. Accordingly the sludge in cell no. 1 was well compacted manually and then covered with 20 cm clay layer during the first week of November 98. However, cracks were observed on the surface after one week. Thereafter two more layers of clay of 10 cm thickness each was applied in a paste form on the top of this cover. However, small cracks on the top layer of this cell persisted when the clay paste dried.

In general, the closure took considerable manual labour and a large quantity of clay. The experts of CTC, France pointed out the cracks and the unsuitability of providing top liner drain within the cell itself.

However, as considerable reduction of leachate quantity from the cell (virtually 0) was observed subsequent to closure, it is believed that despite minor cracks on the closure layer the procedure was adequate enough for local conditions.

It was decided to adopt different options of closure of the other cells and compare the merits of each. Cell no. 2 with was covered with 0.6 mm LDPE sheet and 10 cm clay/soil and cell no. 3 with 20 mm solidified sludge using clay as admixture.

The volume of leachate from all the three covered cells has been so low that further pumping of leachate from it has not been required.

6.6. Leachate Characterisation

6.6.1 Volume of Leachate

No regular and monitored pumping of leachate from the cells was carried out till the beginning of October, 98. From October 98 onwards, regular pumping of leachate was started. The volume of rain water that entered the cells and the leachate pumped out from October 98 till date are given in figure 2:

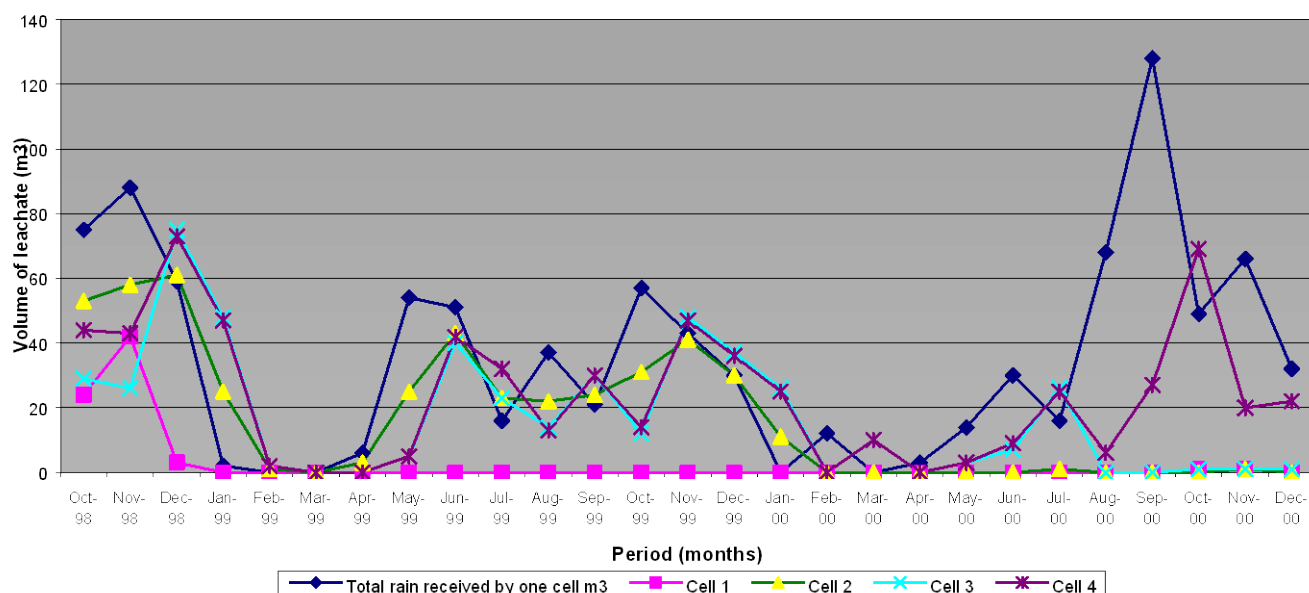


Figure 2: Rainwater versus leachate generation

Following closure of the cells, the leachate generation has become virtually negligible. This supports the hypothesis that much of the leachate generated from sludge dumped in the landfill is due to the entry of rainwater and not due to crushing of the sludge.

6.6.2 Leachate characteristics

The analysis of the leachate carried out during rainy and dry seasons, both before and after closure of the cells (analysed using the little volume of leachate available) is given in Table 1 & 2 below:

Table 1: Characteristics of leachate before closure

#	Parameter	Average value reported during rainy season	Average value reported during dry season
1.	PH	7.23	7.35
2.	TDS mg/l	8,046	27,877
3.	Chlorides mg/l	4,362	12,420
4.	COD mg/l	251	583
5.	Chromium mg/l	ND	ND

ND : Not detected (detection limit : 0.1 mg/l)

Table 2: Characteristics of leachate after closure

#	Parameter	Average value reported during rainy season	Average value reported during dry season
6.	pH	7.2	7.3
7.	TDS mg/l	46,432	47,960
8.	Chlorides mg/l	19,412	21,310
9.	COD mg/l	590	583
10.	Chromium mg/l	ND	ND

ND : Not detected (detection limit : 0.1 mg/l)

Observations:

Obviously, the concentration of pollutants in leachate had come down during heavy rains. Three interesting aspects could be observed:

- The rate of decrease of pollutants was lower than anticipated i.e. if one were to consider the dilution offered by (pure) rainwater, the concentration of pollutants should have been lower than the values reported in Table 1. This may suggest that rain water entering the deposited sludge dislodges some additional pollutants, besides what comes out through the normal leachate.
- The chromium concentration in leachate continued to be non detectable even during the rains.
- After the closure, as the rain water did not enter the cell, the volume of leachate generated declined drastically. In fact it had been found to be in the range of less than 10 litres over a period of 1.5 months. However the concentration was higher as there was no possibility of dilution.

6.7 Mass balance

Altogether three reports of mass balance of Ranitec landfill have been prepared for rainy & dry seasons, as well as post closure. The salient features of the mass balance are given in Annex 5. The general findings of the mass balance reports are:

- The presence of chromium in the leachate is below detectable limit (<0.1 mg/l). It is therefore safe to conclude that the chrome gets immobilised in the sludge.
- The procedure adopted for closure of cells, though not following traditional pattern, has been found sufficient to prevent seepage of water during rains, as is evident from the low leachate values.
- The fact that leachate generation was very low and it did not contain any harmful substances confirms that the design of the landfill is adequate & safe.

6.8 Future

As per the new regulations of the Government of India, sludge from CETP-Ranitec is not considered hazardous as it contains < 5000 mg/kg of total chromium & < 50 mg/l of hexavalent chromium. However, the CETP does not want to dump the sludge in the unprotected ground and is now constructing an encapsulated landfill (using clay liner at the bottom and over the sludge heap) within its premises. This arrangement is considered sufficient for the next 3 years and will cost around INR 3.5 million.

7. LANDFILL AT CETP-VISHTEC, MELVISHARAM

7.1 Background

The design of the landfill established at CETP-Ranitec is different from a conventional landfill. It is shallow with the top of the sludge layer above the embankment, whereas conventional landfills would be deep and the top layer of sludge below the embankment. Further, being small, the feeding to the landfill was done manually whereas all conventional landfills employ mechanical means of filling. After the basic purpose of the landfill at CETP-Ranitec viz., collection of data and raising awareness among the tanners on the need for a safe landfill for sludge was successfully achieved, the need for a landfill with more representative design, as a demonstration unit, was felt. Accordingly the landfill at CETP-Vishtec was planned in response to a request from it. Unlike in CETP-Ranitec, the ground water table at CETP-Vishtec was 5 m below the ground level, enabling the design of this unit in the conventional manner.

7.2 CETP, Melvisharam

CETP-Vishtec is situated at Melvisharam around 120 km from Chennai. The CETP has been established for treatment of effluent discharged by 37 tanneries (out of which 22 are currently operational) in the cluster, mostly processing raw to finished leather by vegetable tanning process. The CETP employs physical, chemical and biological treatment to treat effluent and generates a significant quantity of sludge, mainly from primary chemical treatment. The sludge is dewatered in sludge drying beds.

During the initial one year of its operation, the CETP was dumping the dewatered sludge in the unprotected ground within its own premises. Following the construction of landfill at CETP-Ranitec, this CETP too discontinued the practice of dumping the sludge in the unprotected ground and started disposing it on LDPE sheet laid on the ground. This system, though better than dumping it in the open ground, was not considered safe and the CETP approached UNIDO for assistance in developing a pilot landfill.

7.3 Design

7.3.1 Location

The layout of the landfill is given in Annex 2B & its design in Annex 3A & B. The CETP acquired the required land adjacent to its existing boundary, also providing adequate area for future expansion. The landfill was designed as a single unit.

7.3.2 Earthwork Excavation

The design of the landfill envisages it to be partly below and partly above the ground level. The waste layer (bottom) is 1m below the ground level and the total depth of drainage layer and clay foundation is around 0.9 m. Accordingly, the total depth of earth excavated was about 2 m.

7.3.3 Foundation

After excavation, foundation with clayey soil was laid to a depth of 600 mm (after compaction), which also acts as a barrier for leachate transport. The quality of clay used generally conformed to the following characteristics:

- Plasticity index: 10–15
- Optimum moisture content: 16 to 20%
- Particle size: 0.06 – 0.08 mm (40-50%)
- Clay fraction: 18-25%
- Permeability: 1×10^{-7} cm/sec (when compacted to 90-95%)

7.3.4 HDPE liner and clay cover

After giving smooth finish to the foundation, HDPE sheet (1 mm thickness) was laid over the entire bottom area and the sides. The HDPE sheet had permeation rate $\text{g/m}^2\text{-hr}$: <0.9 , density $>0.935 \text{ g/cm}^2$ and tensile strength of 337.5 kg/cm^2 . The sheet was sealed using thermal welding and was anchored in anchor trench. The size of anchor trench is 0.6 m in width and 0.6 m in depth. The HDPE sheet was taken into the anchor trench and filled with sand to prevent sliding/slipping. After laying the HDPE liner, a clay cover of 7.5 cm was given.

7.3.5 Drainage layer

A drainage layer comprising of a gravel (25-50 mm) bed of 20 cm was laid on the bottom and perforated PVC pipes of 120 mm diameter embedded on it to convey the leachate from the landfill to the sump. Lateral PVC pipes of 25 mm diameter have been placed at 10 m interval and laid perpendicular to the main pipe. On top of the pipes, fine sand of 10 cm thickness is spread. The leachate collected in the drainage layer is conveyed to the sump of 1 m^3 capacity through the 120 mm PVC pipe. Arrangements for pumping the leachate to the aeration tank of the CETP or spraying it back on the sludge dumped have been made.

7.3.6 Embankment

A clay embankment with sufficient stability and strength has been provided. The embankment of 3.0 m height is constructed above the ground level. The excavated material had been used for its construction. The inside and outside slope is 2H : 1V. and the width of embankment at the top is 2 m.

7.3.7 Ramp

The sludge is transported from the CETP to the landfill by truck. The truck moves to the top of landfill and then travels inside. For this purpose, a ramp lined with brick jelly with cement mortar has been constructed inside the landfill. The width of ramp is 4 m and the slope is 4 (horizontal) :1(vertical). The inside length of ramp is 9 m from the bottom edge of the embankment.

7.3.8 Others

A storm water drain has been constructed at 0.5 m away from the base of the embankment with 0.6 m width and 1.0 m depth. A metalled approach road, 3 m width, has been constructed for truck carrying sludge from CETP to the landfill.

7.4 Filling procedure

The detailed filling procedure of the landfill is given in Annex 4. A tractor-trailer is employed to cart the sludge to the landfill.

7.5 Environmental Impact Assessment

As per the statutory requirement of TNPCB, a rapid Environmental Impact Assessment (EIA) study was conducted by Anna University, Chennai and the study confirmed the suitability of the site.

7.6 Deviations made

The clay pasted on the inner side of the landfill embankment did not stick presumably due to the lower slope (2:1 against the normal 3:1) and also the smoothness of HDPE sheet laid. To strengthen the landfill, a layer of 15 cm thick RCC was laid on the top of the clay layer. The outside of embankment and the outer side of the ramp were strengthened by growing grass over the same.

7.7 Commissioning

The landfill was commissioned in September 1999. The filling of sludge using the tractor trailer has continued since then, with around 2800 t deposited until the end of December 2000. The landfill is filled up to half its capacity. The extra volume generated by the compression of the sludge deposited is expected to provide storage capacity for another one year for the sludge from CETP, given its current low inflow rate of effluent.

7.8 Leachate generation

Until now, leachate was generated by the landfill only during two stretches and the entire leachate was pumped back to the top of the landfill for evaporation. The volume of leachate generation during the two stretches of leachate pumping along with the total volume of water received by landfill as rainfall is given in Figure 3:

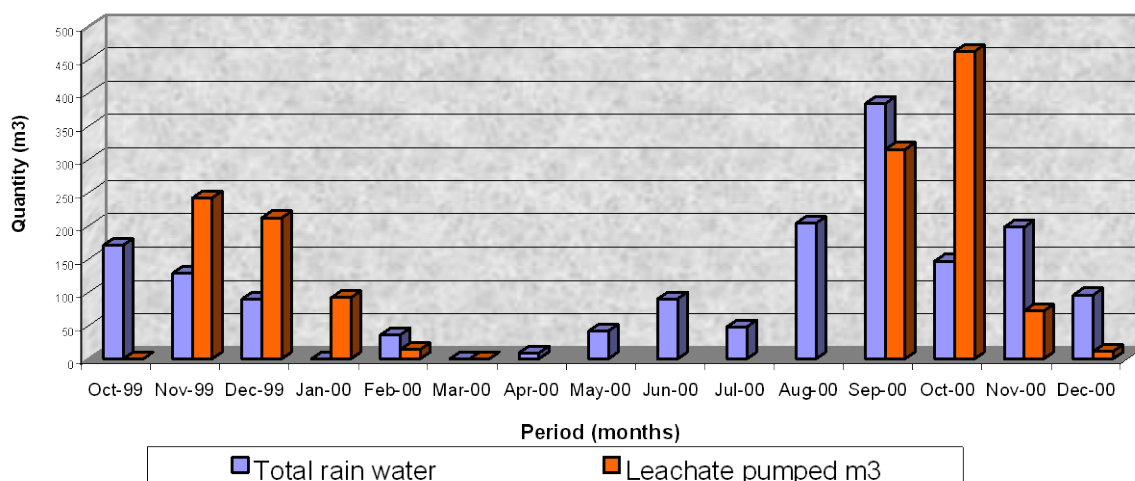


Figure 3: Water received by landfill due to rainfall and leachate generation

Characterisation of leachate

Since the leachate is not discharged outside, characterisation of leachate is less relevant. Analysis of the leachate was done during the first stretch of leachate pumping and as was expected, the leachate had shown an increase in concentration of pollutants at the later stages of pumping. Here also, the chromium was not detected in any of the samples. The average values of leachate analysis are as in Table 3:

Table 3: Average values of leachate analysis

Parameter	pH	TDS	COD	Chromium
Sample				
November 99	7.4	10412	512	ND
December 99	7.3	16120	675	ND
January 2000	7.4	16040	702	ND
February 2000	7.4	39410	920	ND

7.9 Observations

Following observations are made about the operation of landfill at Vishtec:

1. Pumping back leachate for disposal by evaporation.

In situations such as in the Vellore district of Tamilnadu, where the rainfall lasts only for a brief part of the year, pumping back the leachate to the landfill may be safely practised. This would obviate the need of having a separate treatment unit for the leachate. The presumed disadvantage is that for sometime during peak rains, the bottom portion of the landfill may remain wet. However, this water level will not be proportional to the volume of rainwater entering the landfill, as it has been noticed that a good volume of water is retained (like a sponge) by the dried up sludge on the top. Without taking this factor into account, one may assume that the maximum water level in case of Vishtec landfill, during the above period at any given point of time, would have been 0.35 m ($450 \text{ m}^3/1300 \text{ m}^2$ area). The only pre-condition in such a case is that the leachate collection sump should have sufficient free board to accommodate this level. The leachate collection sump at Vishtec landfill has just enough (0.4 m) free board to meet this requirement. If the rainfall becomes too heavy to offset this level, the leachate has to be pumped to the aeration tank of the CETP.

2. Design with clay and RCC cover on the inner sides of the embankment

It is rather unusual to have an RCC cover on top of the clay over the synthetic sheet liner on the embankment. This was necessitated by the slipping of clay over the HDPE sheet and due to the lower slope (2:1) than the normal (3:1) adopted. However, for a small unit as of Vishtec landfill, it was found economical to have the present arrangement rather than the higher slope. The additional cost for maintaining the slope at 3:1 was estimated to be INR 320,000 and discounting the possible additional volume of 900 m^3 , the additional cost for the same volume would have been around INR 210,000. But the RCC cover did cost only INR 115,000. As the purpose of the cover was to hold the clay over the sheet and to prevent direct exposure of the HDPE sheet to sunlight, even if the RCC cover corroded away in the course of time (which is unlikely given the characteristics of tannery sludge), the arrangement here would have served the purpose. Small installations may therefore consider this option. However, for larger installations increased slope of embankments with clay cover on the inner sides is recommended.

3. Disposal in cells

The disposal of sludge by truck as well as tractor-trailer could be done as planned and the sludge disposed got dried enough to allow the truck to run over it, in the process, compacting it. Due to this compaction, the effective capacity has increased, as is evident from the fact that nearly half the volume of the landfill is still available, whereas the volume of sludge dumped until now exceeds the designed capacity. However, it has not been feasible to deposit sludge in cells as planned due to the rather limited mobility possible for the tractor-trailer within the small landfill.

7.10 Future

The CETP is continuing the disposal of sludge in the landfill. At the present rate of sludge generation at 6-7 t/d (30-35% solids consistency), the landfill may be sufficient for further 300 days, assuming its remaining capacity at 2000 t.

8. COMPARISON OF FEATURES OF THE TWO MODEL LANDFILLS

An overall comparison of features of both landfills is attempted in Table 4:

Table 4: Comparison of features of the two model landfills

Parameters	Landfill at CETP-Ranitec, Ranipet	Landfill at CETP-Vishtec, Melvisharam
Location and waste to be disposed*	On site exclusively for tannery sludge - generation 64 m ³ /d (DS 35 %)	On site exclusively for tannery sludge - generation 15 m ³ /d (DS 35 %)
Groundwater table	1 m below ground level	More than 5 m below ground level
Total area of landfill site	2,500 m ²	5,000 m ²
Effective area of landfill site	1,100 m ²	1,300 m ²
Capacity landfill site**	3,300 m ³	2,700 m ³
Number of cells	4 separate cells - bottom size 36.5 x 6.5 m	1 cell - bottom size 25 x 15 m
Depth of landfill (including liner)	1 m below ground level	2 m below ground level
Slopes	Side slope 1H:1V	Side inner slope 3H:1V, side outer slope 2H:1V
Bottom liner system (from bottom to top)	50 mm sieved sand; 0.6 mm LDPE sheet; 50 mm sieved sand; 50 mm pre cast cement concrete slabs	600 mm compacted clay; 1 mm HDPE sheet; 75 mm clay; 200 mm gravel; 100 mm sand; 75 mm soil cover
Drainage / leachate collection system	Each cell side drainage bottom slope 150H:1V (width 200 mm) depth 200 - 300 mm (50 x 50 mm perforations in PCC) - leachate collection pit inside each cell - portable 1 HP pump with flexible hose pipe for leachate pumping from pit	0.2 m gravel; 0.1 m sand layer; main PVC pipe 120 mm; lateral PVC pipe 10 mm dia; spacing between pipes 10 m; leachate collection pit (effective capacity 1 m ³) outside landfill; 1 HP portable pump and flexible hose pipe
Filling method	Cellwise - wheelbarrow from SDBs / centrifuge to landfill	From SDBs - transport by truck or tractor-trailer
Capital cost (US \$ / m ³ capacity) - investment excluding land	US \$ 5.3 US \$ 0.4 - 0.6 / m ³ of sludge	US \$ 7.5 US \$ 0.4 - 0.6 / m ³ of sludge

Operational cost	(DS 30- 35 %)	(DS 30-35 %)
In operation since	October, 1997	September 1999
Main purpose	Evaluation of design for temporary safe disposal site; testing of leachate; sludge drying ; Mass balance ; study of different methods of closure of the landfill	Miniature landfill - demonstration site / model for large scale landfill for tannery sludge - monitoring

H : V = horizontal : vertical

Additional details of the system constructed at CETP-Vishtec, Melvisharam are given below:

- ◇ Free board (above waste layer) 0.75 m
- ◇ Landfill size at top waste layer 38 x 28 m

* The quantity indicated is the sludge generation at the designed capacity of the CETP. Since the effluent flow to the CETPs is lower than the designed value, sludge generation too is lower.

** Though the capacity of the landfill at Ranitec was calculated based on a sludge depth of 3 m, in practice the sludge depth was not more than 2-2.5 m.

9. COST

The investment cost of the landfill at Ranitec was INR 780,160 including the civil works, which works out to US \$ 5.3/m³ of sludge disposal capacity (excluding cost of land). The investment cost of the landfill at Vishtec was about INR 931,500 including all modifications which works out to US \$ 7.5 / m³ of sludge disposal capacity (excluding cost of land).

The operational cost of Ranitec and Vishtec per 10 m³ of sludge deposited is estimated in table 5:

Table 5: Operational cost

#	Item	Cost in INR	
		Ranitec	Vishtec
1	Labour	130	40
2	Vehicle hire charges	0	145
3	Monitoring	25	25
4	Miscellaneous including power for leachate pumping and possible closure charges.	40	40
	Total in INR for 10 m ³	195	250
	Total in INR per m ³ of sludge	19.5 (US \$ 0.42)	25 (US \$ 0.54)

10. ACHIEVEMENTS

An overall assessment of the achievements of the pilot landfills is given in Table 6 presenting the objectives vis-à-vis the results achieved:

Table 6: Achievements

Objectives	Results achieved
To enhance awareness of the tanneries in the region regarding the importance of proper disposal of sludge.	The landfills at Ranitec and Vishtec CETPs were the first ever attempts in the South-East Asia region to set up safe landfills for disposal of tannery sludge. This PDU has created considerable awareness among the tanneries, as is evident from the fact that many of the tanneries in Tamilandu have opted for disposal of sludge on land with impermeable bottom or have adopted alternative disposal methods, such as composting (where chrome content in the sludge is low) etc. The extent of awareness is such that CETP-Ranitec, though not required to construct landfill as per new regulation, is currently constructing an encapsulated landfill on its own, at a cost of around INR 3.5 million
To demonstrate concept of a safe temporary landfill for sludge disposal	The basic landfill at Ranitec has served well in demonstrating the concept of disposal of sludge in safe landfills; and closure techniques.
To collect data relating to leachate, etc over a period of time.	Data regarding characterisation of sludge and leachate collected, categorized and collated. As the chromium present in the leachate is below detectable level, the designed features of the landfill are adequate for tannery sludge.
Based on the data collected, to set up a more representative landfill site at another CETP	The landfill at Vishtec was constructed as a miniature of a larger landfill with conventional design and demonstrated mechanical filling
To encourage other (C)ETPs in the region to adopt proper sludge disposal practices.	Sidco CETP at Ranipet constructed a landfill with the same design as that of Ranitec. Most of the CETPs stopped dumping sludge on unprotected ground and are dumping sludge on land lined with LDPE sheets only. As per the TNPCB records, nearly 30 individual ETPs have opted for landfill as per the design provided in the UNIDO Manual.
To prepare and disseminate a manual that could be given to countries of the region as a reference manual for safe disposal of sludge.	The manual was prepared jointly by UNIDO and CTC France and has been widely distributed in this region.
To present the findings to Pollution Control Authorities to help formulate proper regulations concerning tannery sludge disposal.	The Government of India has declared sludge with less than 5000 mg/kg chromium III and 5000 mg/kg of chromium VI as non-hazardous. UNIDO's consultant (Mr. Swaminathan) was consulted by the Ministry in this regard.

11. CONCLUSION

If sufficient land is available for a cluster of tanneries within a reasonable distance, it is possible to achieve safe disposal of sludge, cost effectively, in a landfill exclusively

designed and operated for the purpose. The investment cost, excluding the cost of land, will be in the range of **US \$ 5 to 10/m³** and the operating cost, excluding the cost of closure of the landfill, will be in the range of **US \$ 0.4 to 1/m³**. This may be compared with cost of disposing tannery sludge, well exceeding **US \$ 100/t**, in many European countries.

The demonstration landfills have created a lot of interest and awareness among the tanners and officials of Bangladesh, China, Indonesia, Nepal, Sri Lanka, Thailand, Vietnam, Kenya and Philippines who visited these sites.

ACKNOWLEDGEMENT

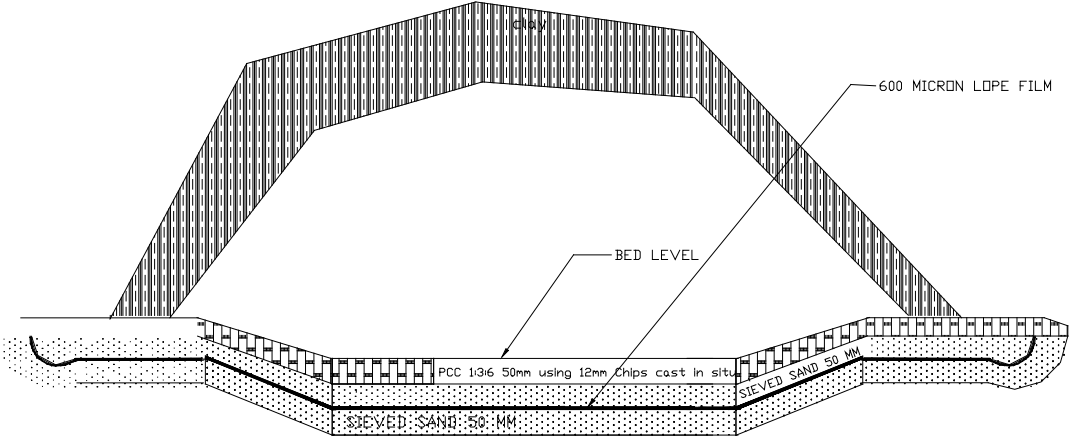
Contributions of the following individuals / organizations to the successful implementation of the project are gratefully acknowledged:

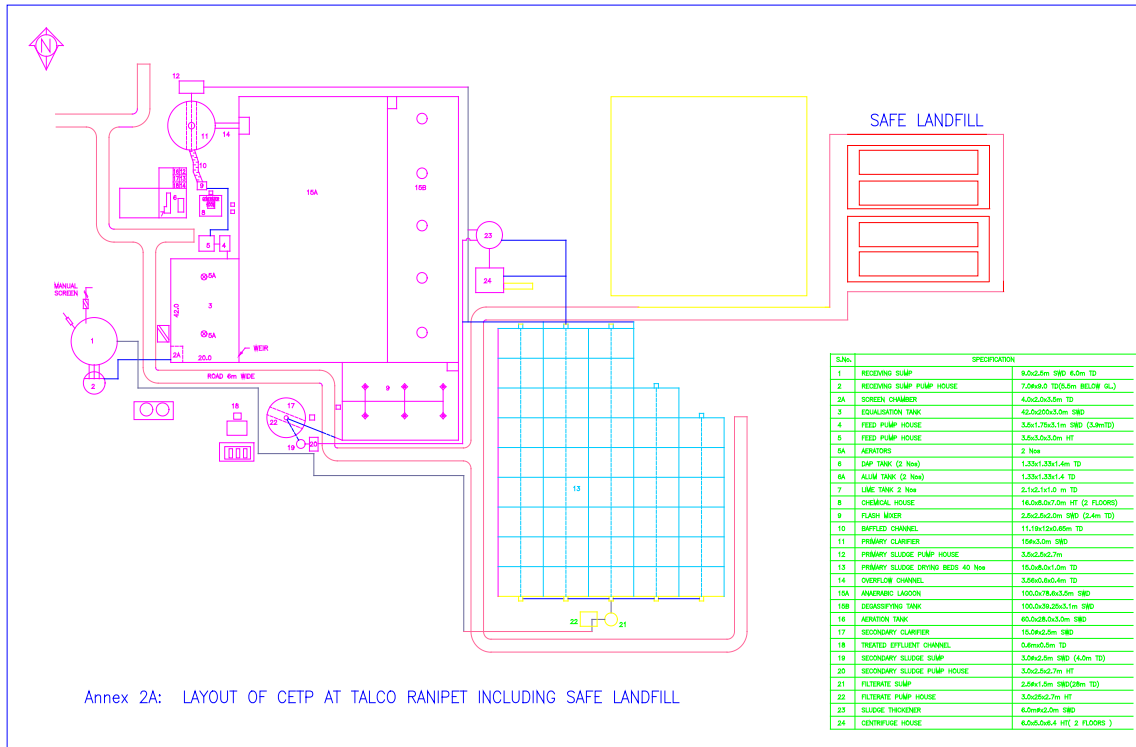
1. Mr. T. Poncet, CTC, France
2. Mr. Mladen Bosnic, TEH Projekt, Croatia
3. Tamil Nadu Pollution Control Board, Chennai
4. CETP-Ranitec, Ranipet
5. CETP-Vishtec, Melvisharam

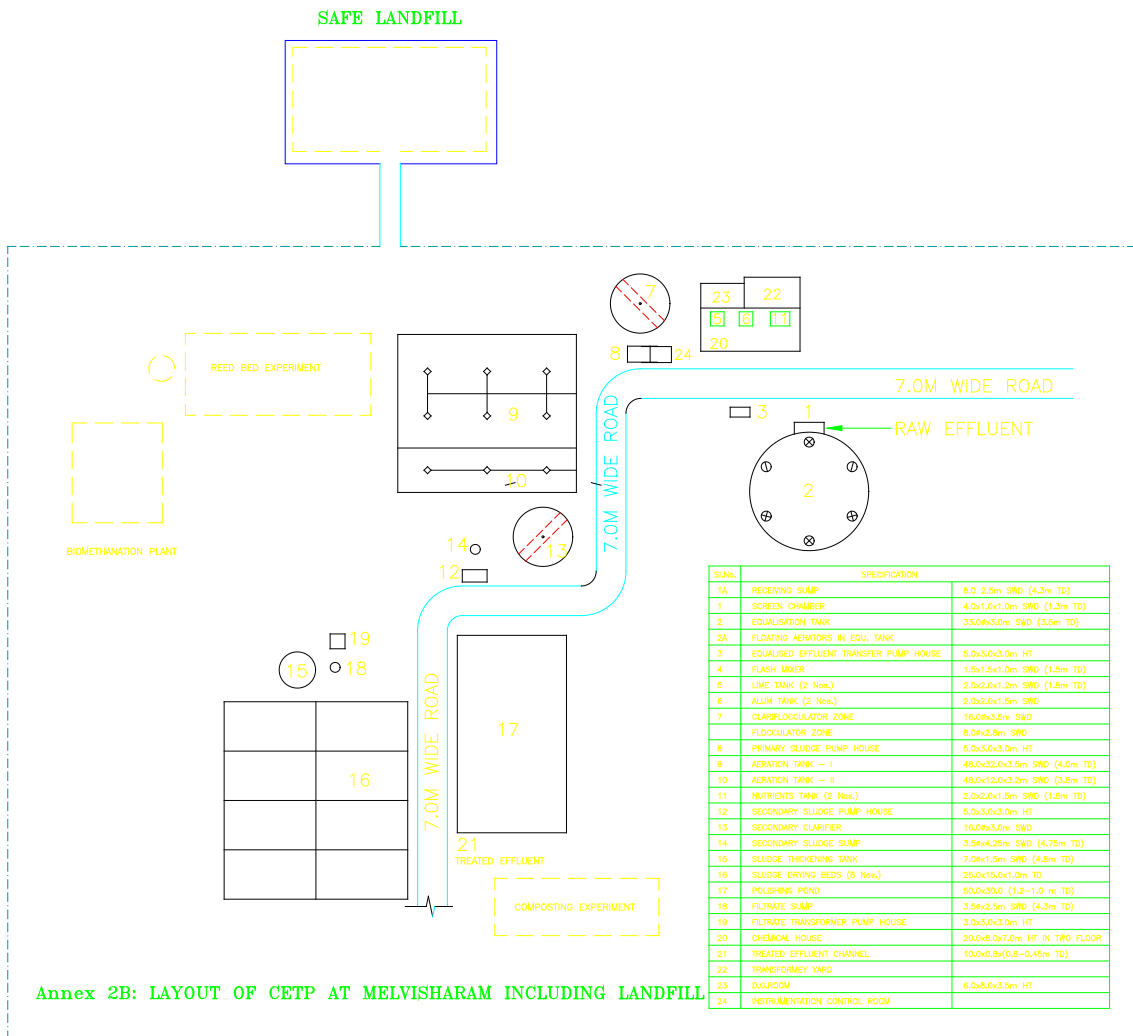
REFERENCES

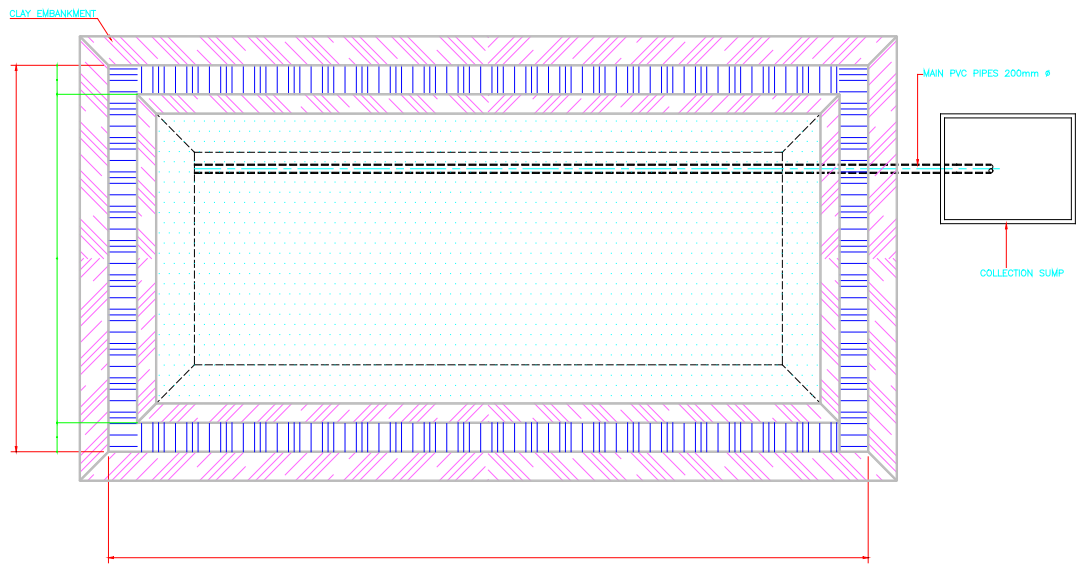
1. Manual on tannery sludge landfill, UNIDO, July 1999
2. Training manual on landfill of hazardous industrial wastes, UNEP, March 1994
3. Mission report of Mr. Pentti Rantala
4. Safe landfill of tannery solid waste and sludge in Tamil Nadu, India, Pentti Rantala, UNIDO, December 1995

ANNEX 1
DESIGN OF TEMPORARY LANDFILL PROPOSED BY Mr. PENTTI RANTALA









Annex 3B : VISHTEC LANDFILL – PLAN

Annex 4

Filling Procedure for Pilot Secure Landfill at Melvisharam

The landfill bottom has been divided into cells of 5 m x 5 m in size with varying depth. Each cell will correspond to the quantity of sludge in a day i.e., 15 m³. A total of 8 layers of filling is envisaged.

It is proposed to fix the layer depth as 0.6 m for the first layer. For subsequent 6 layers the depth of the layer will be 0.4 m. The depth of final layer will be 0.5 m. A ramp is to be constructed at end of the landfill for movement of trucks. This is likely to occupy the space of 3 cells.

A schematic cell arrangement at the bottom level is given in the figure. Initially the vehicle will turn back and start filling the cell 1 at the southern end. Then it will fill remaining cells in the order given in the figure i.e., from 2 to 10, each cell taking quantity dumped for one day. No waste will be dumped in A,B,C,D, & E.

After filling the first layer (10 days filling time), the waste will be dumped over the first layer to a depth of 0.4 m starting from 1 to 10. The same procedure will be followed till a height of 1.4 m is achieved i.e., three layers. The approximate time to be taken is around 30 days for filling three layers.

Once the waste layer depth of 1.4 m is achieved, it is proposed to fill A,B & C to 0.6 m depth as initial layer and again to continue the dumping for another 0.4 m depth. Thus a total of 1 m depth is achieved. It is suggested to fill these A,B, & C cells with dry sludge (old sludge) so that vehicle can move over the layer and compaction takes place.

After that the sludge will be disposed at 0.4 m layer. The suggested number of layers is two. Now the height would be 2.2 m. Now the ramp at C&D can be removed and the sludge will be disposed from the ramp on to A,B, C, D. The waste will be disposed over A,B, C & D for two layers of 0.4 m depth each.

Now the landfill will be more or less uniform in depth except a small portion of ramp at E. The ramp at E can be excavated and waste can be filled.

Initially, 0.6 m depth and subsequently 0.4 m depth can be filled daily.

Then final two layers of sludge to be disposed following the same pattern from 1 to 10 and then A,B,C, D & E. There could be minor variation due to change in volume of landfill at each stage due to changes in the sizes at the bottom and top of each layer. The approximate number of days likely to be taken for each layer as under:

Cycle	Layer	Depth (m)	Volume m3	Days
1	1	0.6	150	10
2	2	0.4	130	9
3	3	0.4	161	11
4	1 (ABC)	0.6	45	3
5	2(ABC)	0.4	45	3
6	4	0.4	195	13
7	5	0.4	229	15
8	3(ABC)	0.4	45	3
9	4(ABC)	0.4	45	3
10	1,2,3 (DE)	0.4	90	6
11	6	0.4	341	23
12	7	0.4	379	25
13	5,6,7 (ABC)	0.4	135	9
14	4,5,6,(DE)	0.4	90	6
15	7(DE)	0.4	30	2
16	8	0.5	440	30

The total number of days accounted for as per above table is 172 days. Due to slopes etc., the exact 180 days could not be accounted.

6	7	8
5	10	9
4	B	C
3	A	D
2	1	E

 **Ramp**

Annex 5
Mass balance of CETP- Ranitec landfill

Part-1: Mass balance during summer

Calculation basis

Cell selected for observation : Cell number 2

Observation period: 1 April to 30 July, 1998

Total rainfall during the period: 303 mm.

Total quantity of sludge disposed during the period = 680 t

Total quantity of rain water entering the cell = 85.4 m³

Total filtrate (leachate) quantity collected = 12.4 m³

(a) Water

Sampling point	Value in kg/t in sample number				Average
	1	2	3	4	
Sludge disposed	628	598	635	694	638.75
Sludge sample collected 30 July 1998	513	495	512	509	507.3

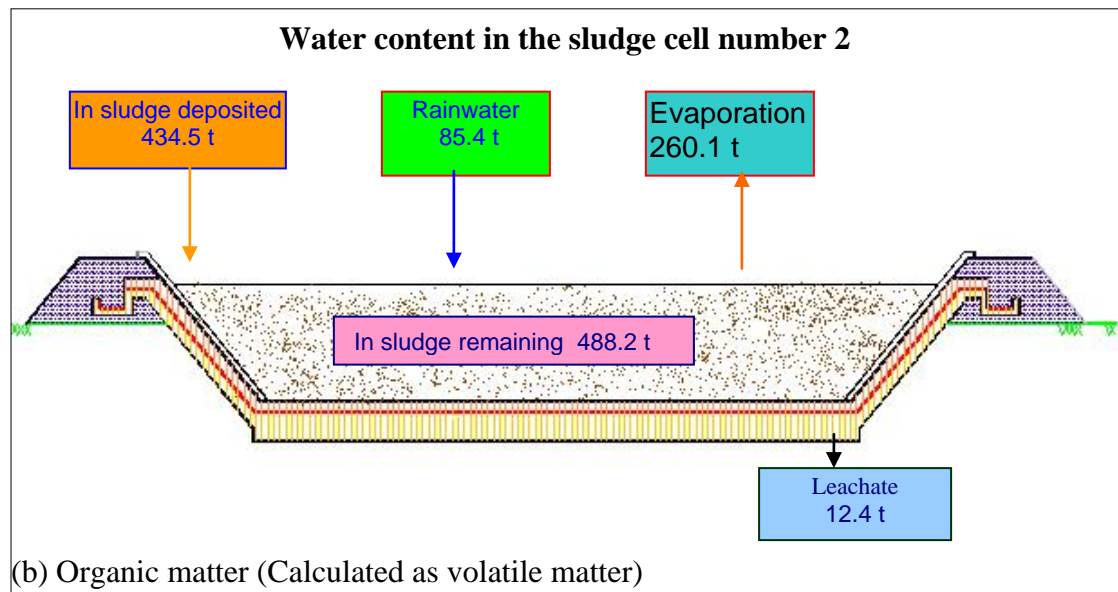
Total quantity of water in the sludge disposed = 680 x 639/1000 = 434.5 t.

Total quantity of sludge remaining in the cell on 30 July 1998 (measured) = 488.2 t.

Total quantity of water remaining in the sludge deposited = 488 x 507/1000 = 247.4 t.

Total quantity of water escaped from the sludge deposited by way of leachate = 12.4 t.

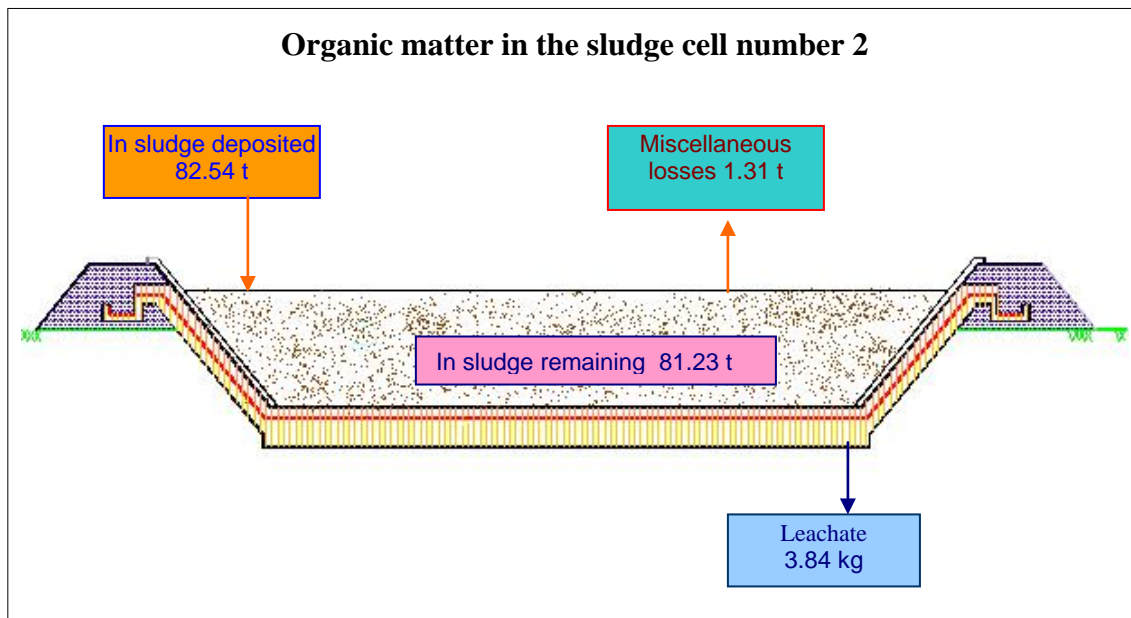
Total quantity of water escaped from the sludge deposited by way of evaporation = 434.5-247.4-12.4 + 85.4 = 260.1 t.



Sampling point	Value in kg/t in sample number				Average
	1	2	3	4	
Sludge disposed	112.32	127.4	126.4	119.4	121.38

Sludge sample collected on 30 July	162.6	171.2	163.4	168.6	166.45
Leachate (as COD) mg/l	324	331	245	341.5	310.38

Total quantity of organic matter in the sludge disposed = $680 \times 121.4/1000 = 82.54$ t.
 Total quantity of organic matter remaining in the sludge deposited = $488.2 \times 166.4/1000 = 81.23$ t.
 Total quantity of organic matter lost due to leachate = $310 \times 12.4 = 3.84$ kg
 Total quantity of organic matter reduced in the sludge deposit (due to biological action or analysis errors etc.) = $82.54 - 81.23 - 0.004 = 1.31$ t.

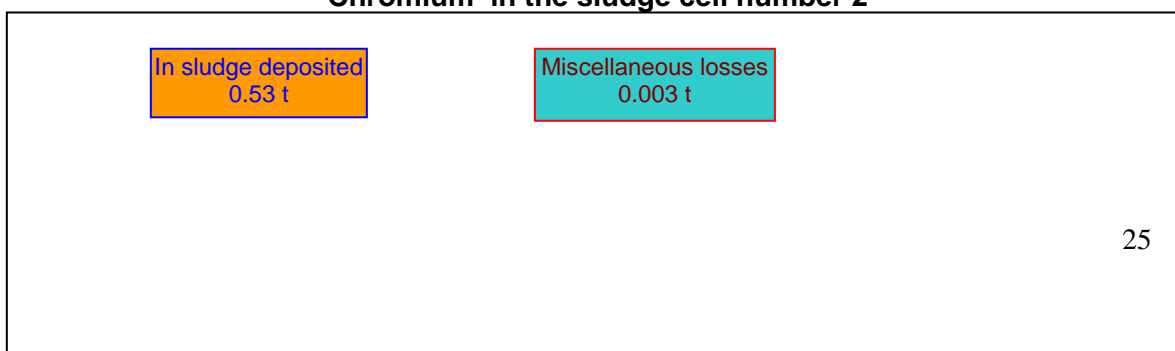


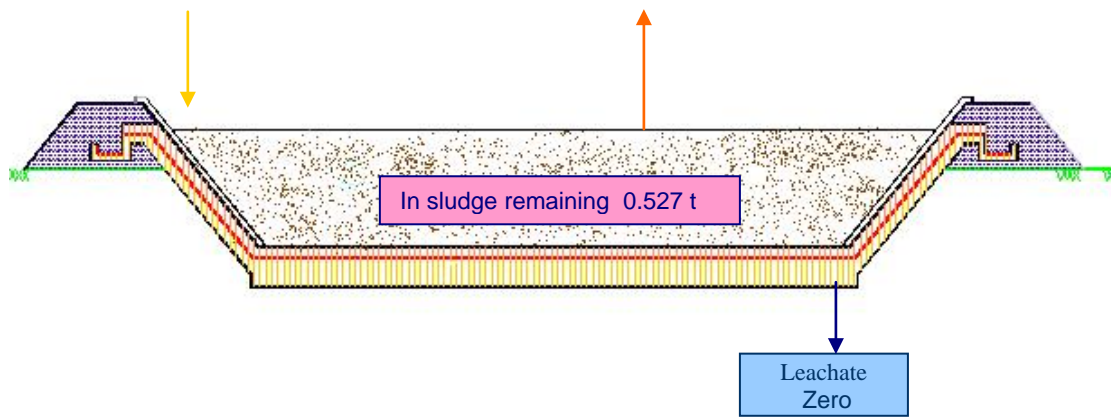
(c) Total chromium

Sampling point	Value in kg/t in sample number				
	1	2	3	4	Average
Sludge disposed	0.71	0.85	0.73	0.83	0.779
Sludge sample collected on 30 July	1.11	1.09	1.11	1.03	1.08
Leachate (as Cr.)	ND	ND	ND	ND	ND

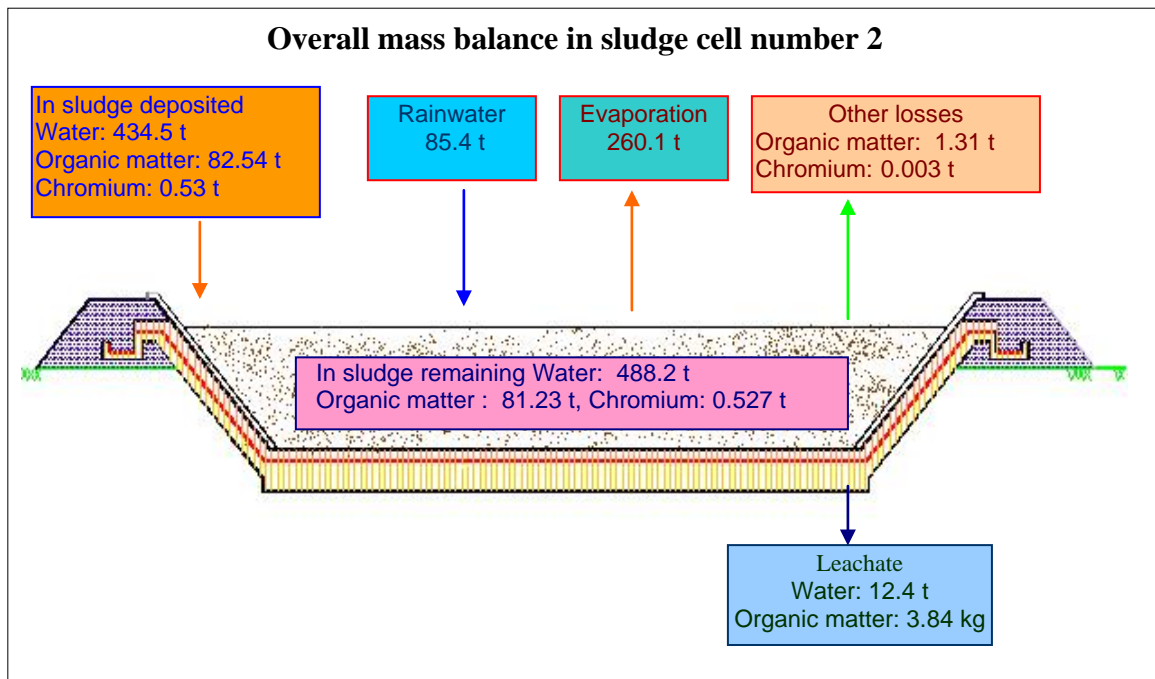
Total quantity of chromium in the sludge disposed = $680 \times 0.778.8/1000 = 0.53$ t.
 Total quantity of sludge remaining = 488.2 t.
 Total quantity of chromium remaining in the sludge deposited = $488.2 \times 1.08/1000 = 0.527$ t
 Total quantity of chromium reduced in the sludge deposited (due to analytical errors etc.) = 0.003 t.
 Total quantity of chromium lost due to leachate = Nil

Chromium in the sludge cell number 2





Overall mass balance of sludge landfill at Ranitec (Part –1)



Part-2 : Mass balance during rainy season:

Calculation basis

- Cell selected for observation : Cell number 3
- Observation period : Oct 98 to April, 1999
- Total rainfall during the period : 799 mm.
- Total quantity of sludge disposed so far = 492 t
- Total quantity of rain water entered the cell = 225 m³
- Total filtrate (leachate) quantity collected = 294 m³

(a) Water

	Value in kg/t in sample number								
Sampling point	1	2	3	4	5	6	7	8	9

Sludge disposed	702.2	694.3	697.2	686	698	705.2	688	694.3	692
Sludge sample taken on 6 January, 1999	612.8	618.8	617.3	612	614.6	619.4	----	----	----
Sludge sample taken on 6 April, 1999	522.4	560.6	539.6	532.7	542	553	537.2	526.5	582

Sampling point	10	11	12	13	14	15	16	17	Average
Sludge disposed	689	699.6	698.9	696.8	---	----	---	----	695.5
Sludge sample taken on 6 January, 1999	----	---	----	---	---	---	----	---	615.82
Sludge sample taken on 6 April, 1999	531	562.4	597.5	512.4	532	522.4	543	516.3	541.94

Total quantity of sludge deposited in the bed = 492 t

Total quantity of water in the sludge disposed: $492 \times 695.5/1000 = 342.18$ t

Total quantity of water entered the bed in the form of rain = 225 t (assuming specific gravity of rain water to be 1.0)

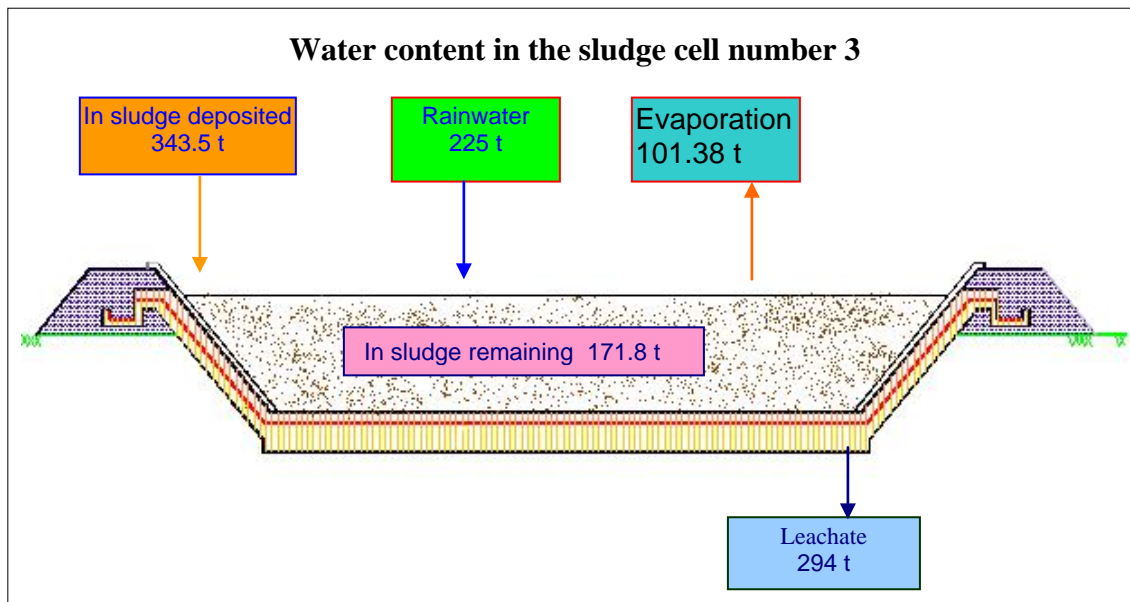
Total quantity of water entered the bed = $225 + 342.18 = 567.18$ t.

Total quantity of water escaped from the sludge deposited by way of leachate = 294 t.

Total quantity of sludge remaining in the heap after six months time (measured) = 317.6 t.

Total quantity of water remaining in the sludge deposited after six months = $317 \times 542/1000 = 171.8$ t

Total quantity of water escaped from the sludge deposited by way of evaporation = $342.18 + 225 - 171.8 - 294 = 101.38$ t.



(b) Organic matter (Calculated as volatile matter)

	Value in kg/t in sample number								
Sampling point	1	2	3	4	5	6	7	8	9
Sludge disposed	101.2	98.5	111	109.7	97	104	105.5	112	98
Sludge sample taken	152.4	156.3	145.7	163	142.4	168	159.4	153.2	169

on 6 April, 1999									
------------------	--	--	--	--	--	--	--	--	--

Sampling point	10	11	12	13	14	15	16	17	Average
Sludge disposed	106.5	108	112	114					105.95
Sludge sample taken on 6 April, 1999	162.6	155.4	167	139	146	156.2	155	159	155.86

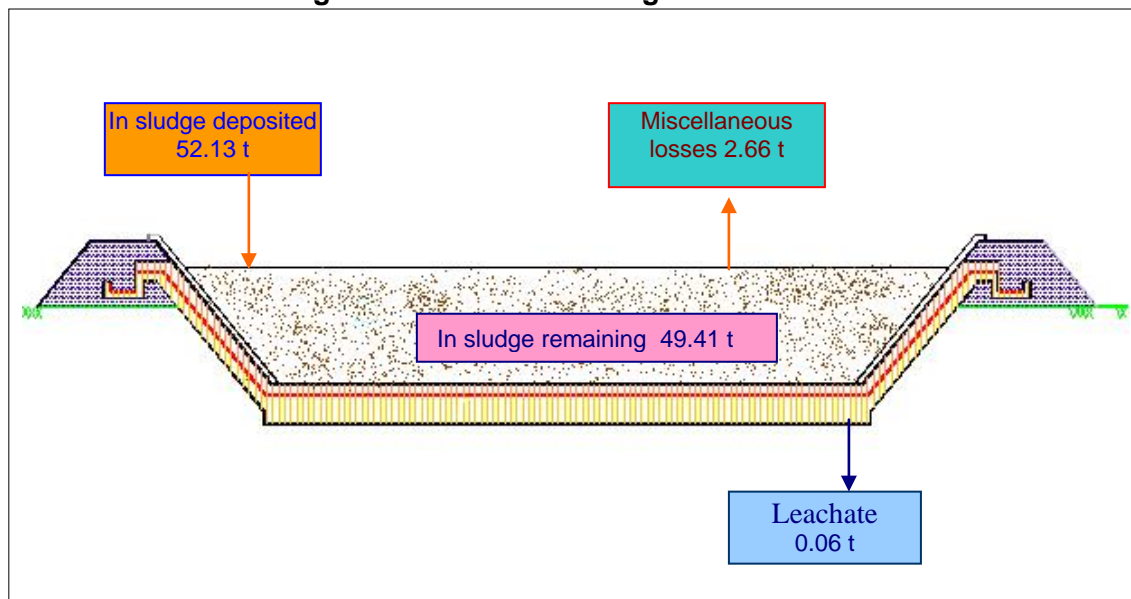
Total quantity of organic matter in the sludge disposed = $492 \times 106/1000 = 52.13 \text{ t}$.

Total quantity of organic matter escaped from the sludge deposited by way of leachate = 0.06 t

Total quantity of organic matter remaining in the sludge deposited after six months = $317 \times 155.9/1000 = 49.41 \text{ t}$

Total quantity of organic matter reduced in the sludge deposit (due to biological action or analysis errors etc.) = $52.13 - 49.41 - 0.06 = 2.66 \text{ t}$.

Organic matter in the sludge cell number 3



(c) Total chromium

Sampling point	Value in kg/t in sample number								
	1	2	3	4	5	6	7	8	9
Sludge disposed	0.98	1.1	0.97	1.36	0.78	1.2	14.5*	0.9	1.1
Sludge sample taken on 6 April, 1999	1.52	1.56	1.98	0.02*	12.6*	1.43	1.78	1.52	1.47
Sampling point	10	11	12	13	14	15	16	17	Average
Sludge disposed	1.2	0.98	1.2	0.82	---	---	---	--	1.1
Sludge sample taken on 6 April, 1999	1.56	8.2*	1.45	1.82	1.39	1.65	1.75	1.86	1.62

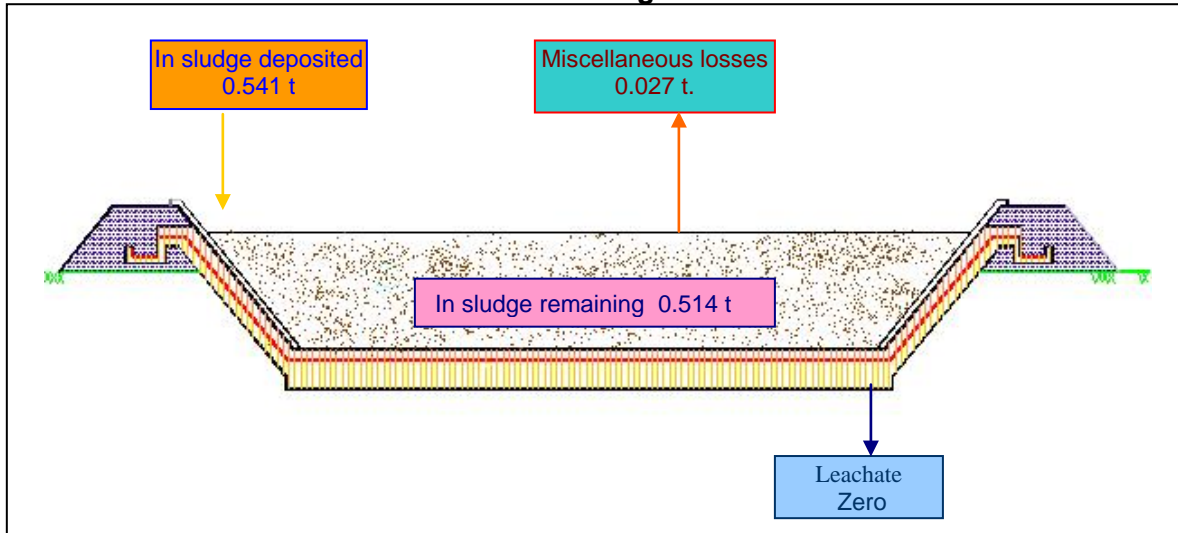
* These values seem to be erratic and hence not considered.

Total quantity of chromium in the sludge disposed = $492 \times 1.1/1000 = 0.541 \text{ t}$.

Total quantity of chromium escaped from the sludge deposited by way of leachate = Nil

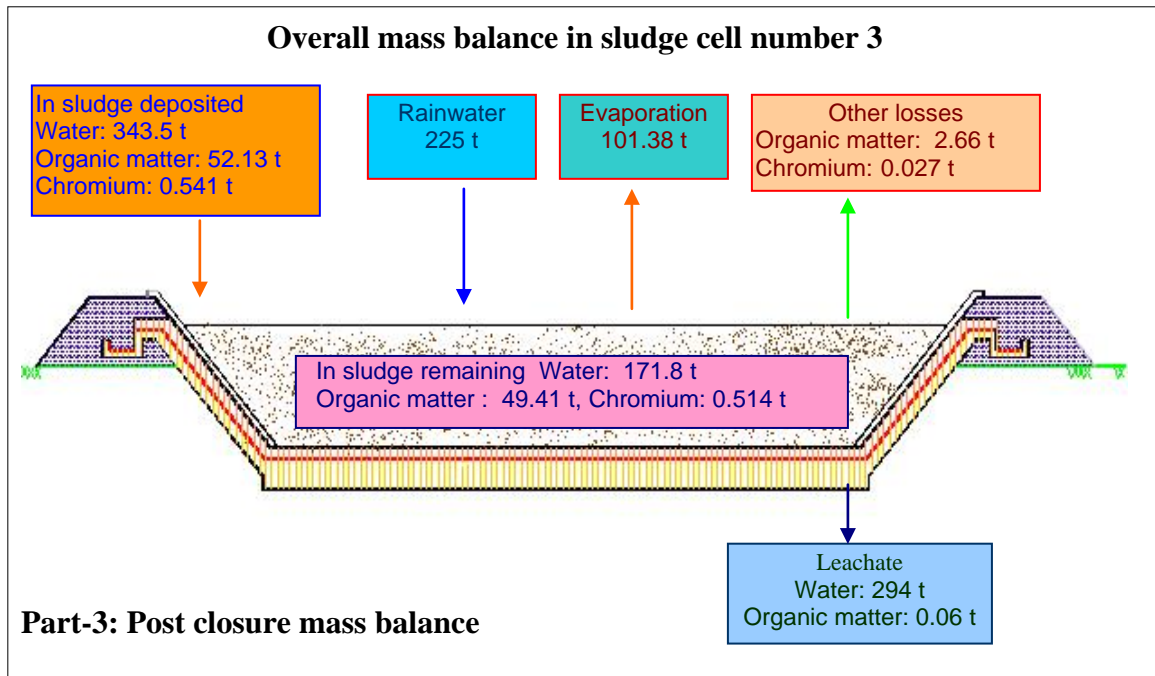
Total quantity of chromium remaining in the sludge deposited after six months = $317 \times 1.62/1000 = 0.514 \text{ t}$
 Total quantity of chromium found reduced in the sludge deposit (due to sampling or analysis errors etc.) = $0.541 - 0.514 = 0.027 \text{ t}$.

Chromium in the sludge cell number 3



Overall mass Balance of sludge landfill at Ranitec (Part -2)

Overall mass balance in sludge cell number 3



Part-3: Post closure mass balance

(i) Cell No. 1

Calculation basis

Cell selected for observation	:	Cell number 1
Observation period	:	Dec 98 to May 2000
Total quantity of sludge disposed	=	731 t
Total filtrate (leachate) quantity collected	=	5.9 m ³

(a) Water

Sampling point	Value in kg/t in sample number					Average
	1	2	3	4	5	
Sample prior to closure	565.2	562.3	568.2	564.8	564.4	564.98
Sludge sample taken during May, 2000	565.1	562.6	563.1	564.3	565.4	564.1

Total quantity of sludge deposited in the bed = 731 t

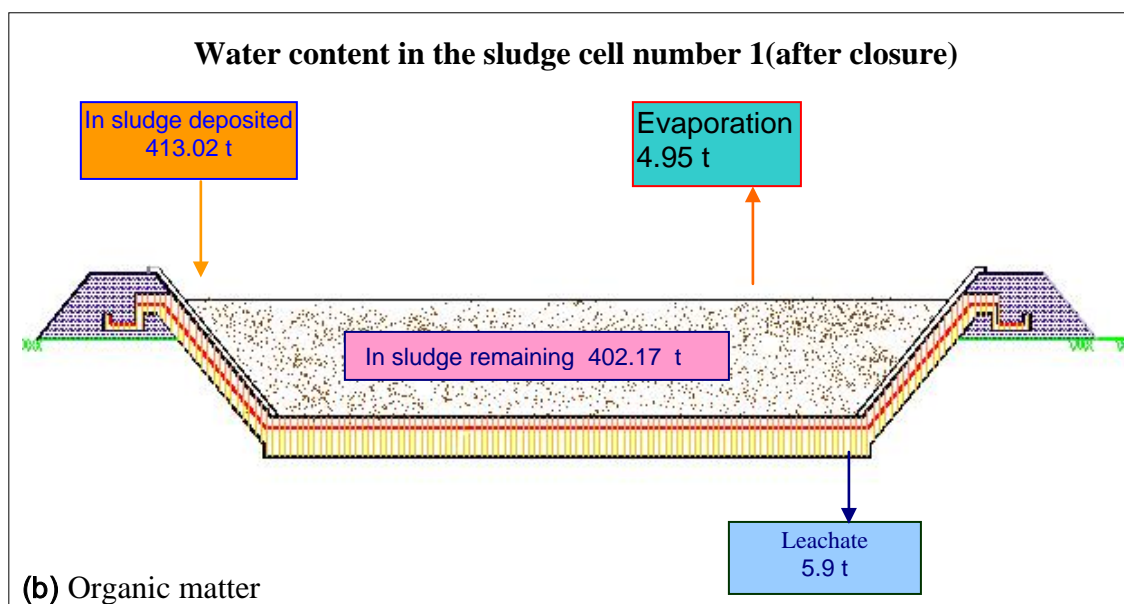
Total quantity of water in the sludge disposed: $731 \times 565/1000 = 413.02$ t

Total quantity of water escaped from the sludge by way of leachate = 5.9 t

Total quantity of sludge remaining in the heap after 15 months time (calculated by multiplying specific gravity of collected sludge mass with the volume) = 712.94 t

Total quantity of water remaining in the sludge deposited after six months = $712.94 \times 564.1/1000 = 402.17$ t.

Total quantity of water escaped from the sludge deposited by way of evaporation = $413.02 - 402.17 - 5.9 = 4.95$ t.



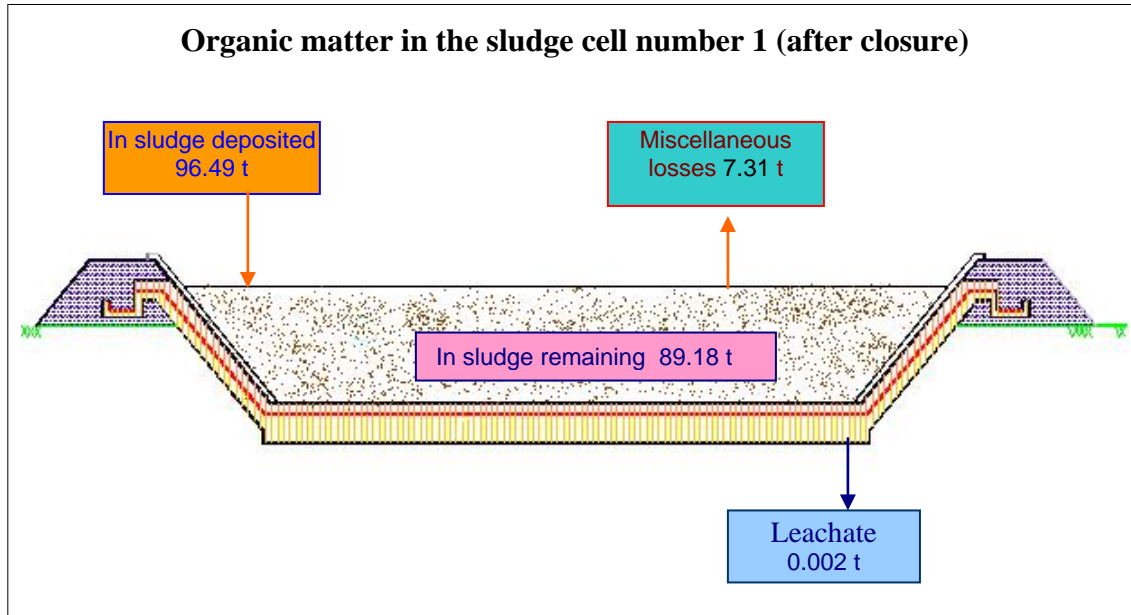
Sampling point	Value in kg/t in sample number					Average
	1	2	3	4	5	
Sample prior to closure	129.5	134.1	128	136	132.5	132
Sludge sample taken during May, 2000	122	126	131	122.5	124	125.1

Total quantity of organic matter in the sludge disposed = $731 \times 132/1000 = 96.49$ t

Total quantity of organic matter escaped from the sludge deposited by way of leachate = 0.002 t

Total quantity of organic matter remaining in the sludge deposited after six months = $712.94 \times 125.1/1000 = 89.18 \text{ t}$

Total quantity of organic matter reduced in the sludge deposit (due to biological action or analysis errors etc.) = $96.49 - 89.18 - 0.002 = 7.31 \text{ t}$.



(c) Total chromium in cell No. 1

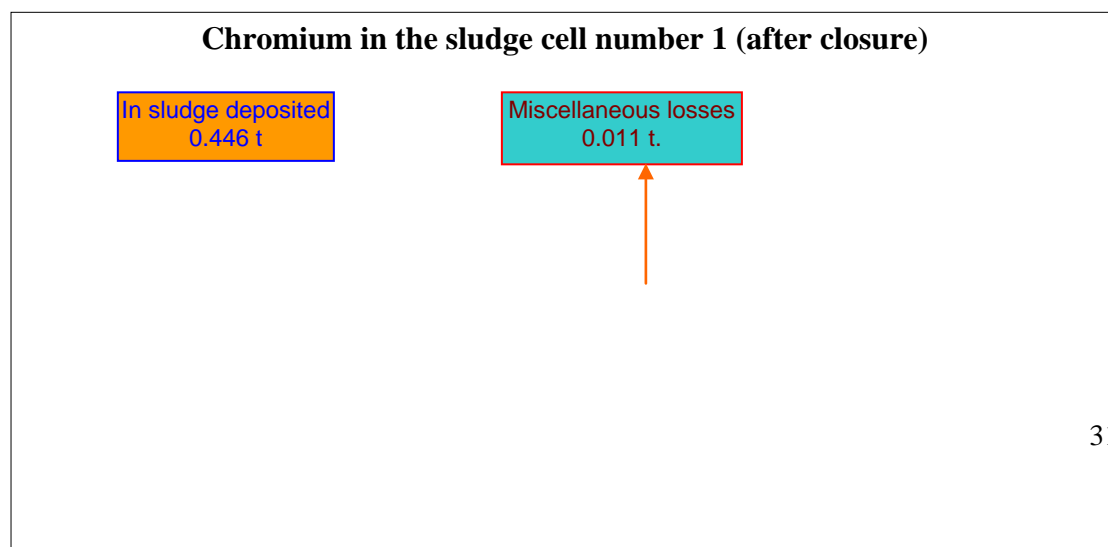
Sampling point	Value in kg/t in sample number					Average
	1	2	3	4	5	
Sample prior to closure	0.63	0.58	0.64	0.61	0.60	0.61
Sludge sample taken during May, 2000	0.62	0.62	0.60	0.59	0.61	0.61

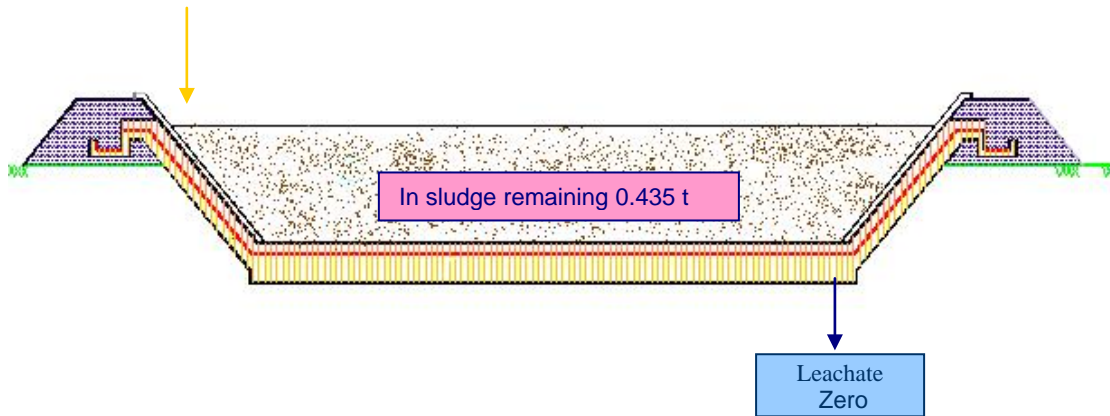
Total quantity of chromium in the sludge disposed = $731 \times 0.61/1000 = 0.446 \text{ t}$.

Total quantity of chromium escaped from the sludge deposited by way of leachate = Nil

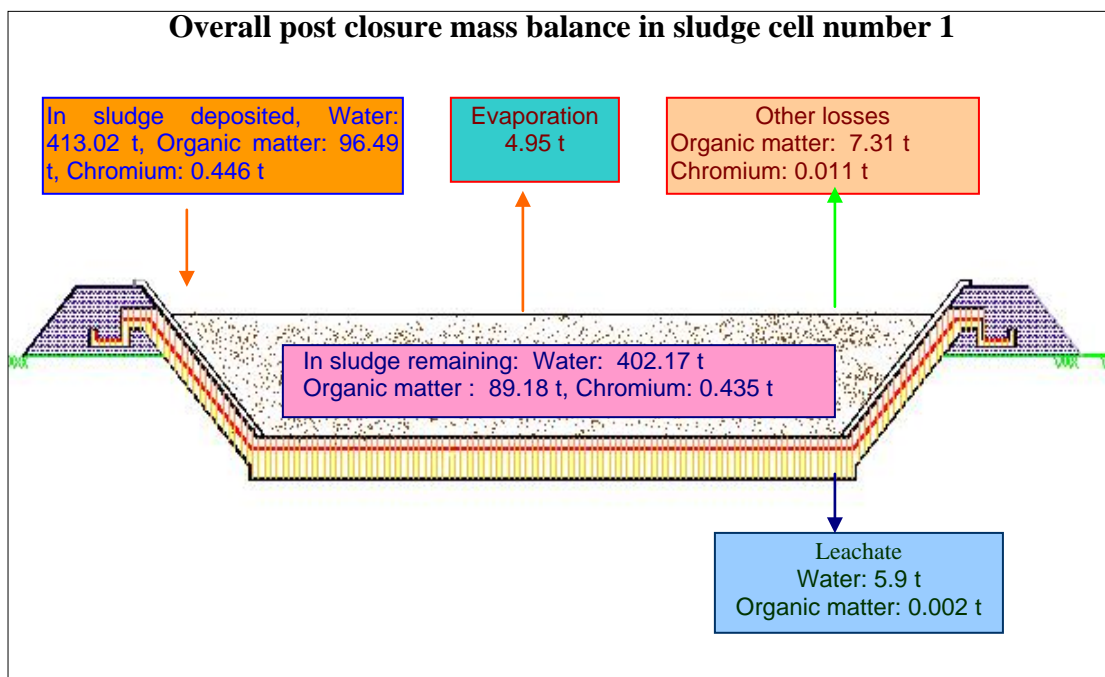
Total quantity of chromium remaining in the sludge deposited after fifteen months = $712.94 \times 0.61/1000 = 0.435 \text{ t}$

Total quantity of chromium found reduced in the sludge deposit (due to sampling or analysis errors etc.) = $0.446 - 0.435 = 0.011 \text{ t}$.





Overall Post closure mass balance of Cell-1 of sludge landfill at Ranitec (Part –3)



(ii) Cell No. 2

Calculation basis

Cell selected for observation	:	Cell number 2
Observation period	:	Feb to May 2000
Total designed volume of cell	=	844 m ³
Total quantity of sludge disposed	=	739.6 t
Total filtrate (leachate) quantity collected	=	1.1 m ³

(a) Water

	Value in kg/t in sample number					
Sampling point	1	2	3	4	5	Average
Sample prior to closure	609.6	608.2	615.2	612	616.1	612.22
Sludge sample taken during May, 2000	614.8	609	618.2	609.4	613.9	613.06

Total quantity of sludge deposited in the bed = 739.6 t

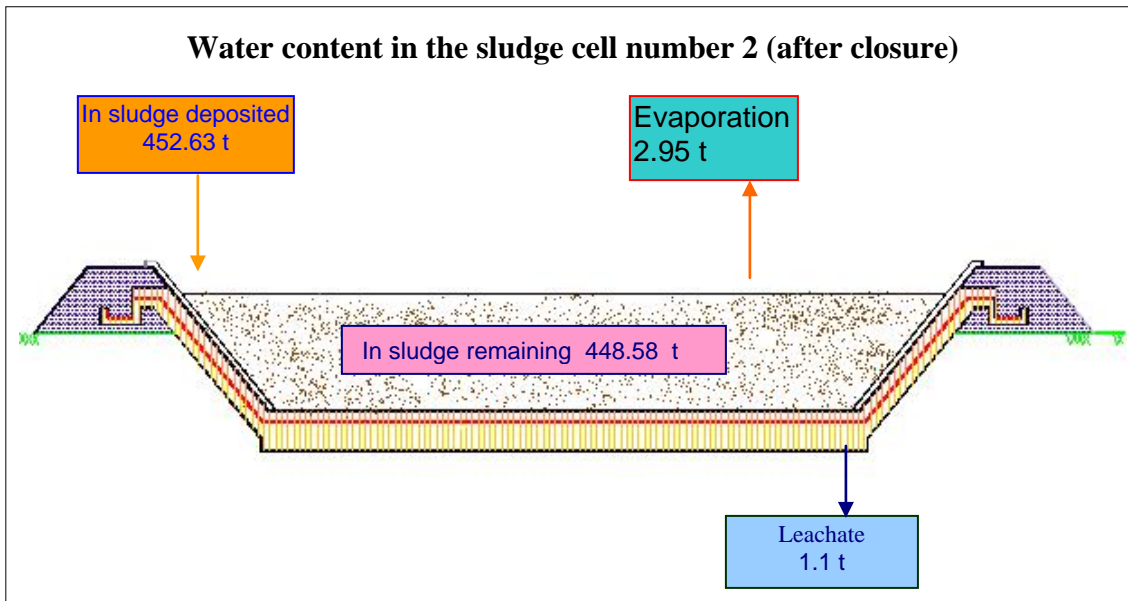
Total quantity of water in the sludge disposed: $739.6 \times 612/1000 = 452.63$ t

Total quantity of water escaped from the sludge deposited by way of leachate = 1.1 t

Total quantity of sludge remaining in the heap after 3 months time = 731.79 t

Total quantity of water remaining in the sludge deposited after six months = $731.79 \times 613/1000 = 448.58$ t.

Total quantity of water escaped from the sludge deposited by way of evaporation = $452.63 - 448.58 - 1.1 = 2.95$ t.



(b) Organic matter

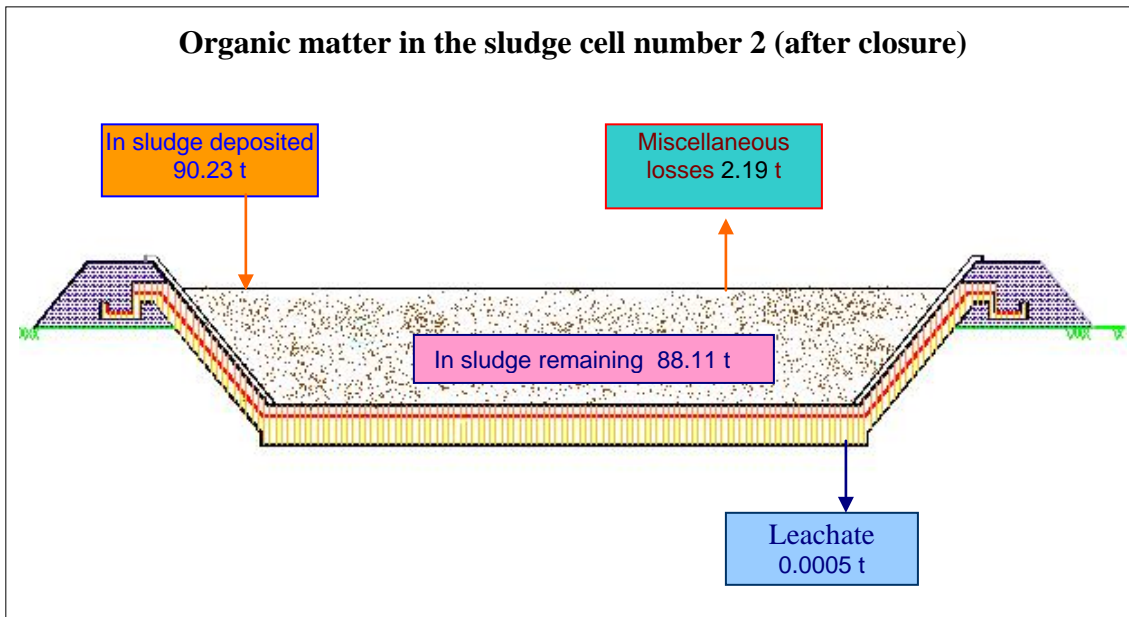
	Value in kg/t in sample number					
Sampling point	1	2	3	4	5	Average
Sample prior to closure	119	124	126	117	124	122
Sludge sample taken during May, 2000	119.1	122.2	125.1	118	117.6	120.4

Total quantity of organic matter in the sludge disposed = $739.59 \times 122/1000 = 90.23$ t

Total quantity of organic matter escaped from the sludge deposited by way of leachate = 0.0005 t

Total quantity of organic matter remaining in the sludge deposited after six months = $731.79 \times 120.4/1000 = 88.11$ t

Total quantity of organic matter reduced in the sludge deposit (due to biological action or analysis errors etc.) = $90.23 - 88.11 - 0.0005 = 2.19$ t.



(c) Total chromium in cell No. 1

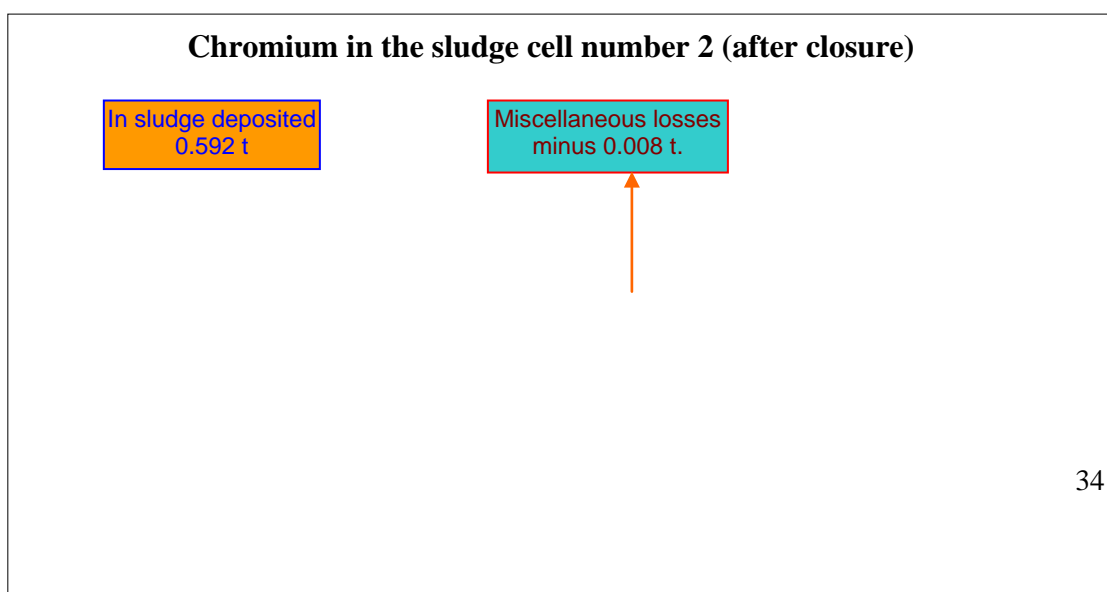
Sampling point	Value in kg/t in sample number					Average
	1	2	3	4	5	
Sample prior to closure	0.8	0.74	0.8	0.85	0.81	0.8
Sludge sample taken during May, 2000	0.85	0.80	0.82	0.79	0.82	0.82

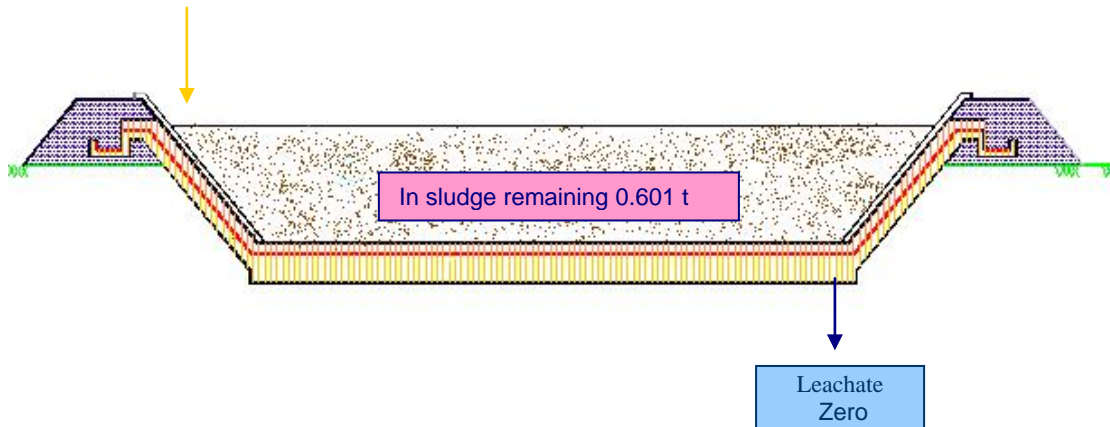
Total quantity of chromium in the sludge disposed = $739.6 \times 0.8 / 1000 = 0.592$ t.

Total quantity of chromium escaped from the sludge deposited by way of leachate = Nil

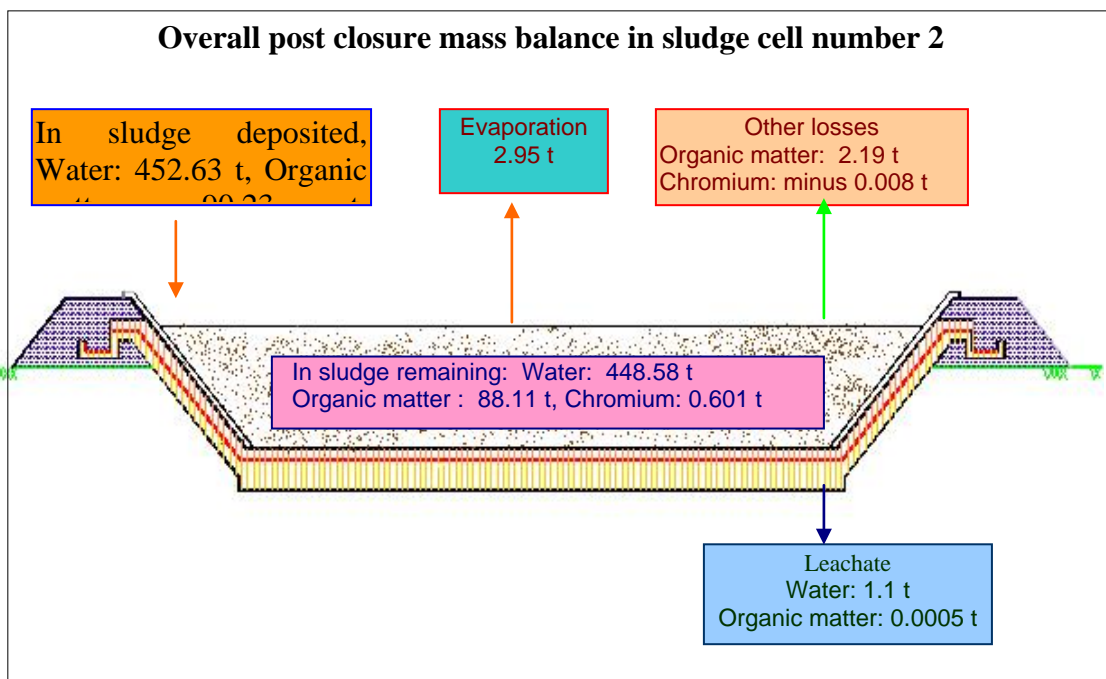
Total quantity of chromium remaining in the sludge deposited after fifteen months = $731.79 \times 0.82 / 1000 = 0.60$ t

Total quantity of chromium found reduced in the sludge deposit (due to sampling or analysis errors etc.) = $0.592 - 0.60 = -0.008$ t.





Overall Post closure mass balance of Cell-2 of sludge landfill at Ranitec (Part -3)



Annex-6
Various stages of construction in Ranitec landfill



Area identified for landfill



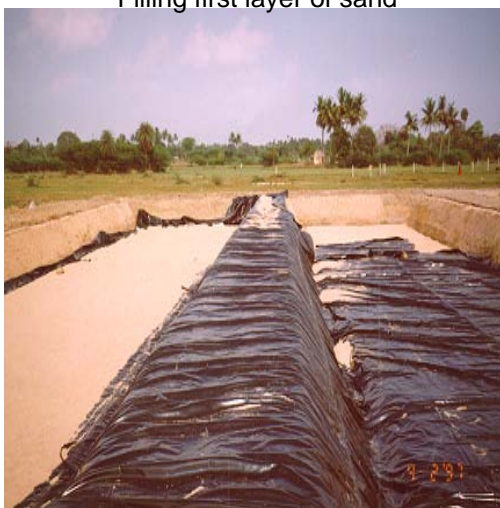
After excavation



Filling first layer of sand



Fixing concrete slab on sides



Laying LDPE sheet



After concreting bottom & sides



Inauguration of landfill



After first set of filling



Overview of the landfill at CETP-Vishtec, Melvisharam



Sludge deposited in the landfill