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in South-East Asia**

USING TREATED TANNERY EFFLUENT FOR IRRIGATION

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LIST OF SYMBOLS & ABBREVIATIONS

BDL	:	Below Detectable Limit
BOD ₅	:	Biochemical Oxygen Demand, 5 days
°C	:	Degree Celsius
CETP	:	Common Effluent Treatment Plant
Cl	:	Chlorides
cm	:	Centimeter
COD	:	Chemical Oxygen Demand
DO	:	Dissolved Oxygen
d	:	Day
dia	:	Diameter
EC	:	Electrical Conductivity
h	:	Hour(s)
ha	:	Hectare
HD	:	High density
HP	:	Horse power
ILIFO	:	Indian Leather Industry Foundation
INR	:	Indian Rupees
kg	:	Kilogram
kg/ac	:	Kilogram per acre
kW	:	KiloWatt
l	:	Litre
l/s	:	Litres per second
m	:	Meter
m ²	:	Square meter
m ³	:	Cubic meter (1000 litres)
mg/l	:	Milligrams per litre
no.	:	Number
pH	:	Negative logarithm of hydrogen ion concentration
PVC	:	Poly Vinyl Chloride
s	:	Seconds
SIDCO	:	Small Industries Development Corporation
t	:	Tonne (1000 kg)
TOC	:	Total Organic Carbon
TDS	:	Total dissolved solids
TSS	:	Total suspended solids
UNIDO	:	United Nations Industrial Development Organisation
V	:	Volt
W	:	Watt
w/w	:	Weight/ weight
μ	:	Micron

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EXECUTIVE SUMMARY

In arid areas even treated effluent is a valuable resource. Responding to the request of the management of a private sector tannery and of a CETP in Tamil Nadu, India, UNIDO provided technical assistance to two large scale demonstration projects in Tamil Nadu to evaluate the feasibility of using treated tannery effluent for irrigation purposes, under its Regional Programme for pollution control in the tanning industry in South East Asia.

The dual objectives of these projects were to:

- identify saline resistant plants and assess their growth properties; and
- monitor the impact that the continuous application of treated effluent had on the soil and ground water.

As trials of irrigation by a CETP using tannery effluent, high in salinity, with over 12000 mg/l of TDS, had resulted in poor plant growth and adverse impact on soil and ground water, the private tannery and the CETP working with UNIDO confined their irrigation trials to the use of treated tannery effluent with TDS not exceeding 5000 mg/l and chlorides not exceeding 900 mg/l. Generally, levels of TDS and chlorides in the effluent emanating from tanneries processing semi-finished hides and skins to finished leather meet with these requirements.

Presidency Kid Leather (P) Ltd (PKL), Kannivakkam, Tamilnadu, processing semi processed goat skins and cow hides to finished leather, generates about 120 m³/d of effluent. PKL has secured the permission of TNPCB to use its treated effluent for irrigation. TDS and chlorides of its treated effluent are generally below 4500 mg/l and 900 mg/l respectively. PKL started using its treated effluent for irrigation in 1995. In an area of about 4.5 hectares, PKL has developed a large plantation of casaurina trees in the past over five years. Monitoring of ground water and soil began only after UNIDO started giving technical assistance to this project in 1997. Quality of ground water at 3 m depth is analysed, once in a quarter, for pH, BOD, TDS, COD, Cr, Cl and SO₄²⁻. There are four sampling points within and one outside (control) the irrigation plot. Soil samples from 0.5 m and 1 m depth, taken from three spots (two inside and one outside the irrigation plot), tested once in six months, have been analysed for pH, soil organic matter, Cr, TDS and N. All data has been meticulously maintained and reviewed by UNIDO from time to time.

CETP-SIDCO, Ranipet, treats effluent discharged by 86 tanneries, all processing semi finished hides and skins to finished leather. The treated effluent of this CETP contains TDS of <4500 mg/l and chlorides of <900 mg/l. This CETP has established a mini forest in a degraded plot of land, about 3.55 ha, with technical assistance and support of UNIDO where eight varieties of inedible plants have been grown. The mini forest was set up in January 1999 and about 800 m³/d of treated effluent has been applied for irrigation of this plot. Growth of plants, soil and ground water have been monitored regularly. The quality of treated effluent is tested daily for pH, BOD, TDS, Cl, SO₄²⁻, EC and weekly for total chromium, percent sodium, TKN, NO₃ and PO₄. Soil is tested, once in three months, for pH, N kg/ac, P₂O₅ kg/ac, K₂O kg/ac from the surface, 0.3 m and 0.6 m depth, from six points in the mini forest. Ground water is tested twice a month, at 6' and 40' depth, from four points for pH, TDS, Cl, SO₄²⁻, BOD, total chromium and percent sodium. All data has been meticulously recorded and interpreted.

A mass balance report has been prepared of TDS, chlorides and sulphates discharged into the irrigation plot in the mini forest. Based on the data collected, the report has tentatively concluded that in the given area of 3.7 hectares, about 550 m³/d of treated effluent of the characteristics specified in the report could be applied for irrigation without causing any adverse impact on soil or ground water, based on the rainfall in the past two years. The plant density is about 2500 per acre of mixed plantation.

A thorough analysis and interpretation of the mass of data collected lead to the following tentative conclusions:

1. That effluent containing TDS [up to 5000 mg/l] and chloride [up to 900 mg/l] can be used to irrigate inedible crops.
2. Saline-resistant species have been found to include *Casuarina equisetifolia*, *Acacia mangium*, *Eucalyptus tereticornis* and *Azadirachta indica*. Other species such as *Tectona grandis*, *Terminalia arjuna* and *Pongamia pinnata* survive, but at a slow rate of growth.
3. Continued use of treated tannery effluent, conforming to characteristics indicated in the report, has not resulted in any significant adverse impact on soil and ground water until now.
4. The total extent of environmental damage is contained by confining effluent discharge to a limited area where a certain amount of pollution can be absorbed by the plants.
5. Using their own effluent treatment plants, many tanneries can achieve zero-discharge status, provided that: (a) the effluent contains TDS at <5000 mg/l and chlorides at <900 mg/l; and, (b) they have enough land at their disposal to justify using treated effluent for irrigation purposes.

However, it is recommended that the project sites should be monitored for a longer period before any definite conclusions can be drawn.

1. BACKGROUND

In arid areas, even treated effluent can be a valuable resource. In order to ascertain the viability of using treated effluent for irrigation, UNIDO, under its Regional Programme for Pollution Control in the Tanning Industry in South East Asia, took up pilot and demonstration projects in close cooperation with some tanneries and CETPs. One rather small experimental plot in the premises of CETP, Ranitec, Ranipet, implemented jointly by Tamilnadu Agricultural University, Coimbatore and the CETP management, under the aegis of AISHTMA, monitored for sometime by UNIDO's RePO, Chennai, attempted to use treated effluent high in TDS (>12000 mg/l). The growth of plants was not impressive. Build up of chlorides in soil and ground water was also posing a serious concern. Unlike other components and salts contributing to TDS, chlorides (the major component in the effluent from tanneries processing raw hides/skins to finished leather) cannot be disintegrated in irrigation systems. A chloride build up in soil and ground water will render these vital resources useless. UNIDO, therefore, took up pilot and demonstration projects with effluent containing comparatively lower TDS (<5000 mg/l), emanating from tanneries processing semi processed hides and skins to leather and continuously monitored the plant growth and impact on soil and ground water for more than 2 years.

2. OBJECTIVES

The primary objectives of the pilot and demonstration facilities, developed by a tannery and a CETP management, with the technical assistance of UNIDO's Regional Programme, are:

- To identify saline resistant varieties of inedible plants with commercial potential.
- To develop a mini forest using treated effluent emanating from tanneries processing semi processed to finished leather with <5000 mg/l TDS and <900 mg/l of chlorides; and, to carefully monitor the ground water, soil and growth of plants.
- To prepare mass balance of TDS applied through irrigation and based thereon, calculating area and number of plants/acre for absorbing 100 m³ of effluent per day, without any adverse impact on soil or ground water.
- To disseminate the results to the industry and pollution control authorities for appropriate application.

3. LOCATION

Presidency Kid Leather (PKL), Kannivakkam, Tamilnadu, India has a tannery which processes semi processed hides and skins to finished leather. It has an ETP of its own and UNIDO assisted the tannery in modernization of this ETP. This tannery started using the treated effluent for irrigation sometime in 1995. About 4.85 hectares of land have been planted with *Casuarina* and a small experimental plot with *Acacia mangium* and flowering plants. UNIDO has assisted the tannery in monitoring the ground water and soil over a period of more than 4 years.

Another major pilot and demonstration afforestation project, using treated effluent for irrigation, has been implemented by the management of CETP-SIDCO, Ranipet, Tamilnadu, India, with the technical assistance of UNIDO. This CETP, with 86 member tanners, processes effluent from tanneries processing semi finished hides and skins to finished leather. The effluent received contains TDS of <5000 mg/l, much of it being contributed by sulphates

and chlorides generally remaining below 900 mg/l. This large scale afforestation project, in an area of 35600 m² indeed followed two smaller experiments in plots of 800 m² and 1600 m² carried out by the CETP on its own to ascertain the varieties of plants that could survive and grow in saline effluent. Very close monitoring of plant growth, soil and ground water has been carried out over a period of more than 2 years.

4. AGENCIES INVOLVED

UNIDO provided technical assistance to the following agencies in implementation and monitoring of these project:

- Presidency Kid Leathers Ltd, Kannivakkam, Chennai, India.
- Indian Leather Industry Foundation (ILIFO), Chennai.
- Ranipet SIDCO Finished Leather Effluent Treatment Co. Ltd.

5. IRRIGATION PROJECT IN PKL

5.1 About the tannery

The tannery processes kid leather from wet blue to finished stage. Approximately 100-120 m³/d of effluent is generated from the process, which at present is treated partially in the tannery's own ETP. A reed bed system, installed by the tannery in cooperation with UNIDO, is operational at the tannery (from August 1997) where some volume (40-45%) of effluent is treated. Treated effluent from both sections is used for irrigation.

The treated effluent of PKL generally contains TDS at a level of < 4500 mg/l and chlorides, at < 900 mg/l. Originally, TNPCB had prescribed the same tolerance limits as applicable to inland surface water discharge to this ETP too. Later, based on an application by the tannery and the suggestion of UNIDO, TNPCB gave consent to the tannery to use the treated effluent for irrigation and discharge standards as applicable for the use of treated effluent for irrigation were applied. Though the current level of TDS and chlorides are somewhat higher than those prescribed by the TNPCB for irrigation (2100 mg/l TDS and 600 mg/l chlorides), based on the request of PKL and UNIDO, TNPCB has permitted the tannery to evaluate the feasibility of utilising such effluent for irrigation of inedible plants.

5.2 Rationale of the project

The idea of utilizing the treated effluent for irrigation came up, mainly due to the geographical constraints faced by the tannery such as absence of an appropriate recipient for the effluent discharged. Further, plenty of vacant land was available with the tannery. After the permission of TNPCB was obtained, the tannery started using treated effluent for irrigation. *Casuarina* was selected because:

- a) It is saline resistant
- b) It is inedible
- c) Its uptake of water is high.

These experiments were started in February 1995.

5.3 Details of the experiments

5.3.1 Main irrigation experiment

PKL utilizes all its treated effluent in their irrigation plot where *Casuarina* has been planted. The treated effluent is conveyed to the plot measuring approximately 4.85 hectares (12 acres) through main PVC pipeline of 90 mm diameter and 13 branch lines of 63 mm, spreading through the entire area. All branch lines are provided with control valves of 63 mm OD. The total length of the pipeline including branch lines is 700 m. Treated effluent, collected in a sump is pumped through these pipelines to irrigate the entire area.

The *Casuarina* saplings were planted with a gap of 0.6 m through out the rectangular shaped plot.



Pic. 1: View of *Casuarina* plantation at PKL (June 2000)

5.3.2 Associated experiments

At the suggestion of UNIDO, PKL started two experimental plots of irrigation, one of flowering plants, the monitoring of which was done by Tamil Nadu Agricultural University, Coimbatore and the other, of *Acacia mangium*. The plot of flowering plant was trifurcated and three separate modes of irrigation (fresh water, 100% treated effluent and treated effluent and fresh water in the ratio 50:50) were maintained. Unfortunately, no concrete conclusions from the monitoring could be obtained from TNAU. The second experiment was concerning plantation of *Acacia mangium* supplied by a private company. The plants had grown to a height of > 8 m within two years and the survival rate was around 85%.



Pic.2: Experiment with flowering plants



Pic.3 Experiment with *Acacia mangium*

5.4 Operation and Monitoring

5.4.1 Plant growth

No organized monitoring of plant growth was done in the beginning. Later when such monitoring was started, the trees had grown very tall and further monitoring of height could not be done. However to assess the growth rate of trees vis-à-vis those grown using ground water, two plots were selected in 1997; and one was planted with 60 and the other with 40 saplings of *Casuarina*. The plot with 60 saplings was irrigated by treated effluent and the one with 40 by ground water, with TDS around 600 mg/l.

The average growth of trees in both plots (two sections in the area irrigated with effluent and one in that with ground water) can be seen in the figures 1 & 2:

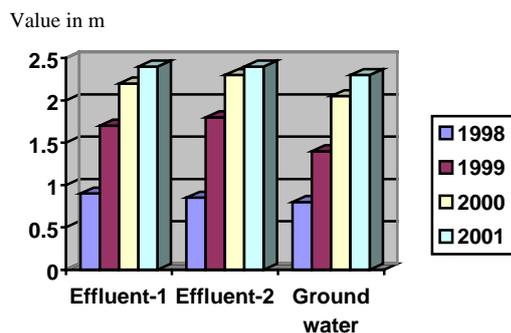


Figure 1: Growth (m)

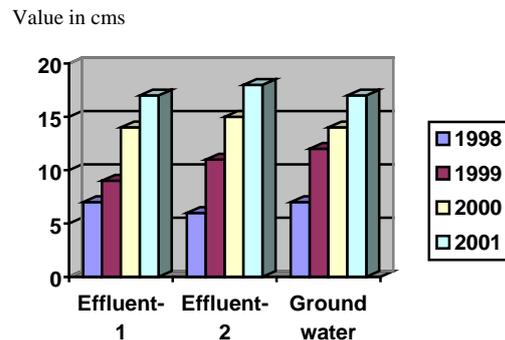


Figure 2: Girth (cms)

5.4.2. Ground water

PKL at UNIDO's suggestion had installed piezometers to collect samples from a depth of 3m in 1997 to initiate ground water sampling.

The characteristics of effluent used for irrigation is checked every day and ground water analysis is done once in three months. Ground water sample is taken at 5 points at 10 feet depth, four within the irrigated area and one control (outside the factory compound). The

average values of analysis reports of effluent for the last three years (average of 12 sets of sample) and the ground water sample (Feb, 2001) are given in table 1 below.

Table 1: Analysis of effluent and ground water samples

Sampling point	pH	TDS	COD	Chromium	Chlorides	Sulphates
Effluent	7.3	7110	550	0.7	1220	2540
P-1*	6.9	1620	4	ND	515	430
P-2*	6.95	1735	6	ND	540	485
P-3*	7.0	1765	6	ND	575	510
P-4*	6.9	1820	5	ND	545	425
Control*	6.8	1710	1	ND	480	410

Note: All analyses done in PKL laboratory. ND: Not detected (the detection limit is 0.5 mg/l)

* Ground water samples (February 2001)

The variation in TDS in these samples (as half yearly averages) over the last four years is given in figure 3.

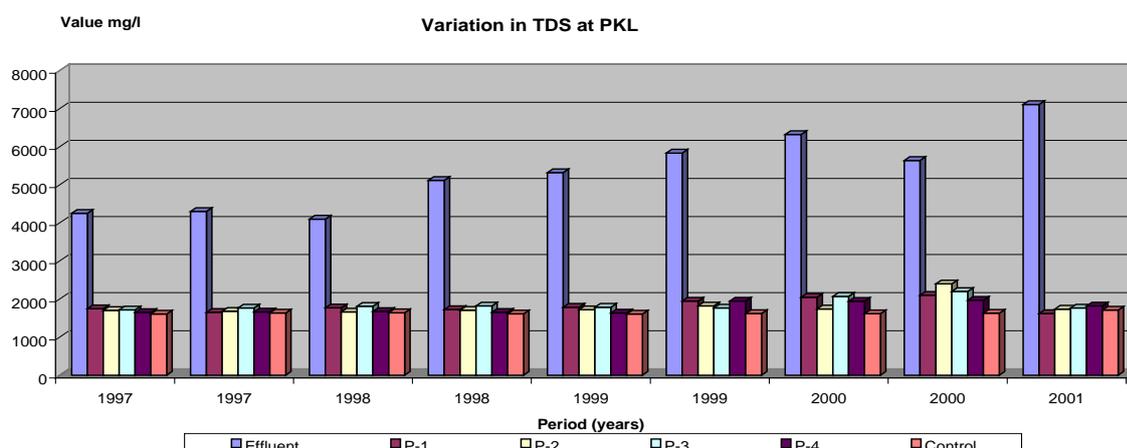


Figure 3: Variation in TDS in samples (as half yearly averages) over the last four years

5.4.3. Soil characteristics

Soil samples were collected once in six months from two depths, 0.5 m and 1.0 m, in three locations, two inside and one outside the irrigation plot. Average of values from six sets of soil samples is given table 2 below:

Table 2: Soil analysis report

Location	Collection point	PH	Soil Organic matter	Chromium	TDS ppm	Nitrogen kg/ha
Inside the plot -1	0.5 m depth	6.9	0.13%	ND	410	72
	1.0 m depth	6.95	0.21%	ND	425	65
Inside the plot-2	0.5 m depth	6.8	0.36%	ND	525	40
	1.0 m depth	6.6	0.21%	ND	560	88
Outside the plot	0.5 m depth	7.05	0.06%	ND	445	54
	1.0 m depth	6.95	0.12%	ND	465	66

Note: All analyses done at PKL laboratory, ND: Not detected, detection limit 0.5 mg/l, acid leaching and analysis done for chromium testing.

Since there was no significant variation in the values obtained during the period 1997-2000, the gradation map is not given.

5.4.4 Meteorological parameters

The average rainfall in PKL during the observation period is given in figure 4 below:

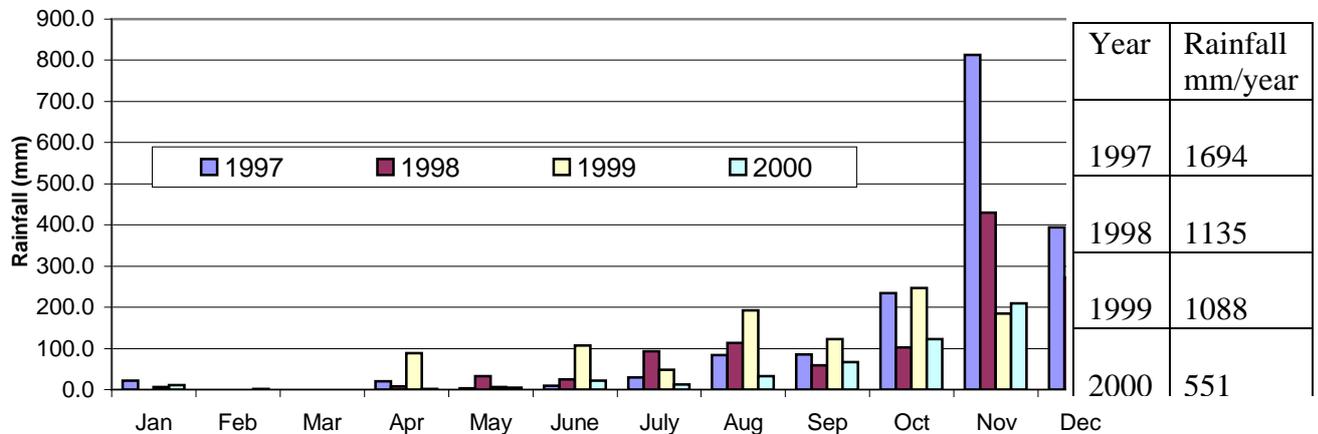


Figure 4: Average rain fall in Chennai (mm)

5.5 Evaluation of results

5.5.1 General observations

After about 6 years of continued irrigation using treated effluent in the project site, the following inferences may be drawn:

- ❖ The growth of plants in the main plot could not be measured because the same had grown very tall (well above 6 m) by 1997. These appeared quite healthy indicating that there was no adverse effect on their growth due to continued irrigation by the treated effluent.
- ❖ In the experiment relating to growth rate of plants irrigated by fresh water and treated effluent, it was found that height of trees irrigated by effluent was certainly more than that irrigated by fresh water. In terms girth, however, both seemed to be doing equally well.
- ❖ The variation of ground water characteristics over the period 1998-1999 indicated that no notable accretion to contaminants in ground water had occurred due to continuous irrigation by treated effluent. However, as can be seen from the graph, the TDS values started very marginally increasing for the period 1999-2000. It has been noted that there is a considerable increase in TDS in the treated effluent too in this period and the rainfall during the year was scanty. Trend in the coming months will give a clearer picture.
- ❖ Practically no change in the soil characteristics was observed. However, the soil inside the irrigation area seemed to be distinctly acidic compared to the control plot. Similarly the soil organics also seemed to be more in the area irrigated by treated effluent.

5.5.2 Mass balance

It has been noted that during the last three years a total of 450.7 t of TDS, which included 71.44 t of chlorides and 179.9 t of sulphates, was admitted into the irrigation area (average 98 m³/d, 88200 m³ for three years, assuming 300 working days in an year), which works out to a feed rate of 9.27 kg of TDS per m² (the loading rate of chlorides and sulphates were 1.47 kg/m² and 3.7

kg/m² respectively). Though this loading is not very high, absorption of this quantity of TDS needs to be explained. Assuming that the sulphate salt which forms the bulk of the total TDS may have, hypothetically speaking, undergone some microbial degradation by soil microbes and by some form or other (possibly elemental sulphur) absorbed by the plants, the disappearance of the chlorides needs an explanation. And the explanation is that the average rainfall in the area (700-1200 mm/year) is more than sufficient to dilute the effluent to keep the TDS, chlorides and sulphates in the same level of concentration.

Continuous monitoring by the tannery management is still ongoing.

5.6 Status and future

5.6.1 Present status

In the context of the original specific objectives, the current status is as follows:

Specific objectives	Present status
Test and confirm the survival of the selected plant species (<i>Casuarina</i>) irrigated by the treated tannery effluent.	The survival and growth of the selected plant have been confirmed.
To test and confirm the absence of or the extent of ground water and soil contamination due to continuous irrigation by treated tannery effluent.	Data collected so far has established the trend over the past four years and relatively insignificant level of contamination of ground water. This is explained by low rainfall in the latter year. However, continued monitoring for a longer period is recommended.
Preparation of mass balance of TDS	Mass balance prepared with required information.
To achieve zero discharge status for the tannery.	Achieved.

5.6.2 Future

Continued monitoring will be done by the management.

6. IRRIGATION EXPERIMENTS AT CETP-SIDCO

6.1 Initial experiments

The CETP-SIDCO treats effluent from 86 tanneries in the Sipcot industrial area of Ranipet. These tanneries process semi processed hides and skins to finished leather.

The treated effluent of CETP-SIDCO generally contains TDS at a level of < 4500 mg/l and chlorides, < 900 mg/l. Though these levels are higher than those prescribed by the TNPCB for irrigation (2100 mg/l TDS and 600 mg/l chlorides), with the concurrence of the Board, it was decided by UNIDO to evaluate the feasibility of utilising such effluent for irrigation of inedible plants.

The reason why CETP-SIDCO was selected as the location for these experiments was that, besides the relatively lower TDS in the effluent, some experiments along these lines had already started in the CETP. These experiments were done by the CETP attempting irrigation of many

varieties of plants using the treated effluent. However, this project lacked any concrete monitoring plan and UNIDO decided to carry out these experiments in a proper manner with adequate monitoring to study the build up, if any, of pollutants in ground water or soil. Further, the initial experiments involved some edible crops too, which were discontinued under the experiments carried out with the technical assistance of UNIDO.

Accordingly, experiments were planned in CETP-SIDCO in a methodical manner and it was decided in the beginning that the project would have adequate time for studying ill effects, if any, on soil and ground water. It was also decided that UNIDO would be involved in the project only if the results from initial experiments were satisfactory.

Initially a trial plot of 400 m² was developed in April 1997, just to assess the survival of different plants in the saline treated effluent. This experiment established that the treated effluent did not affect the survival or growth of selected plants. On the contrary, it seemed to help. The trees grown included *silk cotton*, *eucalyptus* and *casuarina*.

Following encouraging results from this experiment, another experiment was implemented in a larger plot of 800 m² area in which eight varieties of plants were tried. Here, the major objective was to identify the different varieties that could sustain and grow when irrigated by treated effluent and also to test various combinations of feeding. The plants grown in this experiment included 1. *Pongamia pinnata* (Pongam), 2. *Azadirachta indica* (Neem), 3. *Casuarina equisetifolia* (Casuarina), 4. *Tectona grandis* (Teek), 5. *Acacia arabica* (Karuvel), 6. *Eucalyptus tereticornis* (Eucalyptus), 7. *Dendrocalamus strictus* (Bamboo) and 8. *Acacia mangium* (Mangium). Also various combinations of feeding pattern including 100% treated effluent, treated effluent and ground water in the ratio of 50:50, ground water alone, treated effluent with sludge, fresh water with composted sludge etc. were tested. The results established the feasibility of using treated effluent for irrigation. The growth of trees was impressive.

6.2 Experiments with *Acacia mangium* in a 1600 m² plot

6.2.1 Further experiments

As mentioned above, the early experiments were mainly to establish the survival of plants when irrigated by saline effluent and were not monitored for other parameters. Based on the experience gained, a third experiment with the support of Indian Leather Industry Foundation (ILIFO) and technical guidance of UNIDO was taken up. In this project, *Acacia mangium*, which was growing very well in the treated effluent as observed in the earlier experiment, was selected for plantation. An area of 1600 m² behind the CETP, adjacent to the experimental plot No. 2 (800 m² area), was chosen.

The major specific objectives of this project were:

- ❖ to test and confirm the survival and growth of the selected variety (*Acacia mangium*) irrigated by the treated tannery effluent.
- ❖ to test and verify the volume of effluent admissible to the field with respect to density of tree plantation.
- ❖ to test and confirm the extent of ground water and soil contamination due to continuous irrigation by treated tannery effluent.
- ❖ to compare two popular modes of irrigation (flood irrigation versus ridges and furrows) with respect to water uptake, ground water contamination etc.

6.2.2 Implementation

The land available for the experiment was an irregular shaped plot of 1600 m². The experiment commenced in July, 98. Plantation and collection of baseline data were done. The monitoring started on 25 August 1998. The reason for this delay in monitoring was that the earthwork levelling and formation of ridges and furrow required flooding the area over a considerable period of time before the ground was adequately softened to allow civil works.

The area before development and its latest view now are below



Pic. 4: Barren land before development



Pic.5: Acacia mangium plantation in December 2000

This project has a multi-partite arrangement with its implementation done jointly by CETP-SIDCO and M/s Archana Agrotech Pvt. Ltd. Financial assistance had been provided by the Indian Leather Industry Foundation (ILIFO). UNIDO's Regional Programme Office provided technical assistance to this project and prescribed the monitoring schedule.

Separately ILIFO had engaged the services of Ms. Shanmugavadivu as an agricultural expert to implement the project and monitor it as per the monitoring schedule provided in 6.2.3.

6.2.3 Monitoring

Piezo meters were installed in various parts of the irrigated plot to sample the ground water quality. The parameters being monitored are given below:

- ❖ The treated effluent used for irrigation was checked every day for all the parameters specified by the TNPCB for the CETP viz., pH, Total dissolved solids, Chlorides, Sulphates, EC, BOD, of 20° C, COD, (on a daily basis) Total chromium, Percent sodium, Total Kjeldahl Nitrogen, Nitrates as NO₃, Phosphates as PO₄ (on a weekly basis)
- ❖ Soil samples inside and outside the irrigation plot for parameters such as pH, N kg/acre, P₂O₅ kg/acre, K₂ O kg/acre and Cr kg/acre. A total of 24 samples (4 samples from inside irrigation plot - 4 samples from outside irrigation plot - 2 at 25 m away (in opposite directions), 1 at 50 m away from the plot and 1 from uncontaminated area) – all were checked at three depths: 0.3 m, 0.6 m and 1.0 m.
- ❖ Ground water samples at two depths (0.9 m and 1.8 m) inside the irrigation plot and at 1.8 m outside the irrigation plot, Number of sampling points: 4 (6 samples). Parameters checked in ground water samples were pH, TDS, Chlorides, Sulphates, BOD₅, Total chromium and Percent sodium

- ❖ Other parameters such as volume of treated effluent admitted into each plot of trees, growth factors such as height and girth of trees, meteorological data such as humidity, rainfall, temperature etc.

The area was divided into two sections, one for flood irrigation and the other into ridges and furrows. These two sections were monitored separately to find out which was better. The data was collected from the start up till December 2000 and thereafter the monitoring was focussed on the miniforest project only.

6.2.4 Baseline data

To ascertain baseline data before the implementation of the project, samples of soil and ground water were collected from the project area and analysed. The results are given in Tables in Annex 1.

6.2.5. Results obtained

6.2.5.1. Volume of effluent used for irrigation

The volume of effluent used in the plot for irrigation is given in figure 5 below:

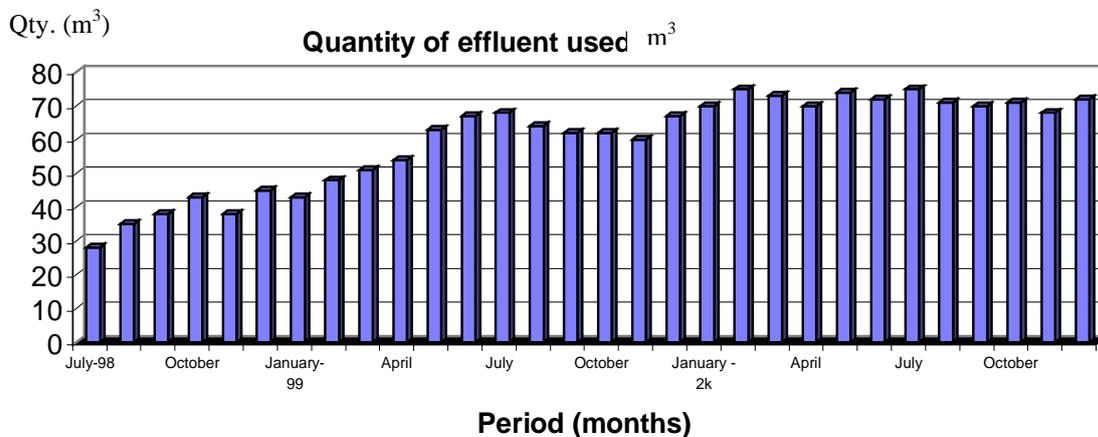


Figure 5: Volume of effluent used

6.2.5.2. Plant growth

Certain plants were earmarked both in the flood irrigation area (A1 - A6) as well as the ridges and furrows area (B1 - B6) for monitoring growth. Height of the plants and girth of their stem were measured once a week till January 1999. Later, as the trees had grown quite tall, the measuring of height was discontinued and the girth of stem was measured once a month.

The average growth rate (height) observed may be seen in figure 6 below:

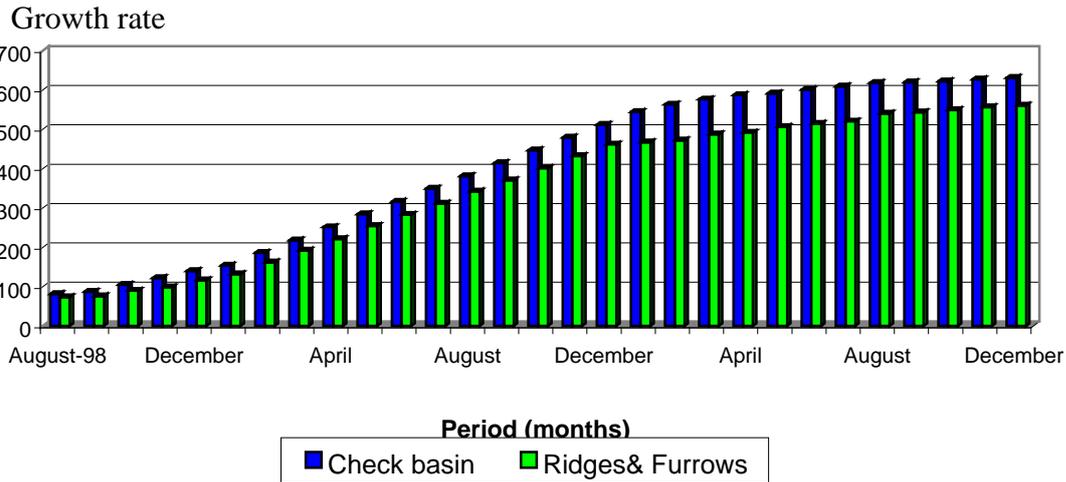


Figure 6: Growth rate of trees- Height (cm)

6.2 5.3. Groundwater samples

Ground water samples were collected from the following points and analysed in the CETP laboratory every month:

- (1) Near secondary clarifier at 1.8 m depth;
- (2) SIPCOT land bore (1.8 m);
- (3) Flood irrigation site (0.9 m);
- (4) Flood irrigation site (1.8 m);
- (5) Ridges and furrows area (0.9 m);
- (6) Ridges and furrows area (1.8 m)

The variations in the levels of TDS, chlorides and sulphates observed in the project site are given in the tables 3 – 5 given below:

Table 3: Variations in average TDS levels

	Near Secondary Clarifier (1.8m)	Sipcot Land (100 m outside the plot) Bore (1.8 m)	Flood Irrigation (1.8 m)	Flood Irrigation (0.9 m)	Ridges & Furrows Irrigation (0.9 m)	Ridges & Furrows Irrigation (1.8 m)
Jul-98	-	1920	1900	2320	4900	5000
August	2220	3040	3000	4580	2440	4600
September	1900	2460	1860	2040	1182	3720
October	1515	3390	2987	3070	2655	3725
Feb-99	-	1800	3860	-	4700	5600
March	4960	2840	2960	-	4680	6200
April	-	3520	3540	-	4400	5940
June	5720	4020	5200	6000	5020	-
July	5800	4520	4760	-	4580	-
August	-	3835	4316	-	3146	4316
September	-	4128	4836	5791	3855	3348
October	2678	3569	4264	6337	1585	4465
November	2873	4147	4140	4836	1820	4673
December	3224	4264	5063	-	1794	4686
Jan-00	3100	3861	4387	3295	3776	3176

February	3997	-	-	3217	3919	4602
March	-	4017	-	3445	4407	3965
April	-	4126	-	3620	-	4040
May	-	5040	3800	-	-	4800
June	3088	4089	4420	-	4544	5629
July	2444	4251	3867	4812	4719	3861
August	2099	3575	4592	4192	4690	4914
September	2111	3955	4235	4555	4780	5110
October	2235	3650	4320	4520	4230	5330
November	2115	3140	3890	4110	3940	5115
December	2255	3640	4315	4115	4245	5420

Table 4: Variations in average Chlorides levels

	Near Secondary Clarifier (1.8 m)	Sipcot Land (100 m outside the plot) Bore (1.8 m)	Flood Irrigation (1.8 m)	Flood Irrigation (0.9 m)	Ridges & Furrows Irrigation (1.8 m)	Ridges & Furrows Irrigation (0.9 m)
	HS1	HS2	HS3	HS4	HS5	HS6
Jul-98	-	384	341	700	856	887
August	302	579	596	643	252	689
September	273	621	335	385	414	703
October	127	559	462	482	510	649
Feb-99	-	455	445	-	705	830
March	765	450	305	-	780	970
April	-	545	853	-	625	1070
June	836	660	1364	-	792	1054
July	922	826	902	-	936	-
August	-	828	908	-	804	964
September	-	753	884	1175	612	730
October	554	744	871	1193	680	748
November	472	823	770	963	350	962
December	501	855	789	971	364	961
Jan-00	604	783	604	512	802	734
February	780	-	-	621	807	973
March		709		928	602	680
April	-	762	-	910	-	720
May		889	981	-	-	936
June	505	775	815	-	923	984
July	390	781	693	1199	215	919
August	309	626	788	1043	383	862
September	310	635	765	1140	378	914
October	312	640	755	1050	390	925
November	335	610	732	935	330	812
December	390	695	845	1312	490	1020

Table 5: Variations in average Sulphates levels

	Near Secondary Clarifier (1.8 m)	Sipcot Land (100 m outside the plot) Bore (1.8 m)	Flood Irrigation (1.8 m)	Flood Irrigation (0.9 m)	Ridges & Furrows Irrigation (1.8 m)	Ridges & Furrows Irrigation (0.9 m)
Aug-98	905	1004	1382	1460	818	1798
September	642	720	785	813	707	962
October	407	873	700	896	935	965
Feb-99	-	456	931	-	975	1102
March	1020	960	672	-	1045	1059
April	-	1004	1020	-	1045	1145
June	1139	913	1176	-	1082	1106
July	1149	995	1028	-	1036	-
August	-	1129	956	-	1106	1156
Jan-00	984	1024	1032	909	983	901
February	1024	-	-	909	1074	885
March	-	1246	-	1142	999	867
April	-	1126	-	1180	-	856
May	-	1133	1588	-	-	1152
June	1785	1419	1979	-	2049	2209
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	1810	1145	1625	1240	2110	1190
October	-	-	-	-	-	-
November	1720	1012	1245	1012	1650	--
December	--	--	1310	--	--	1210

6.2.5.4 Meteorological data

Rainfall data in the site is given in the figure 7 below. The data was collected from the nearest meteorological station, Vellore (about 30 km from the site) up to 1 Jan 2000. From January 2000 onwards the CETP staff collected the same, till Dec 2000.

Rainfall

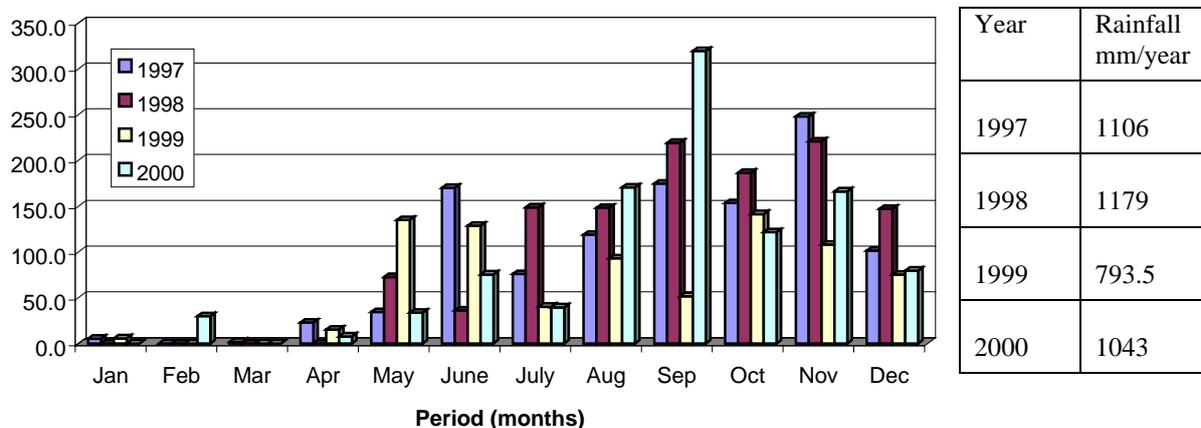


Figure 7 Average rain fall in Ranipet (mm)

Note: Since the mass balance preparation of miniforest project was done using data only upto December 2000, the data related to rainwater too was collected only until then.

6.2.6 Interpretation of results

6.2.6.1 Growth rate of trees

In general, the growth rate of trees in the flood irrigation plot was a little more than that in the ridges & furrows area. This difference had been mainly explained by the fact that the saplings planted in these locations were of different varieties but of the same species.

The growth rate of *Acacia mangium* in general was better than the normal growth rate reported for the species viz. 10-15% as against the normal growth of 8-10% in a month.

The improvement in the girth of the tree was remarkable, doubling in nearly two months between December 1998 & January 1999.

6.2.6.2 Ground water quality

From the analytical reports the following inference could be made:

The ground water contamination with respect to TDS was found to be more in the flood irrigation area than in the ridges and furrows area. While in the flood irrigation area at 1.8 m the TDS increase was due to an increase in sulphates, at 0.3 m the increase in TDS was due to an increase in chlorides.

6.2.6.3 Soil quality

There had been no appreciable change in the quality of soil due to the irrigation by treated effluent.

6.2.7 Status and future

6.2.7.1 Present status

With reference to the original specific objectives, the current status is as follows:

Objectives	Present status
To test and confirm the survival and growth of the selected plant species (<i>Acacia mangium</i>) irrigated by treated tannery effluent.	The survival and growth have been confirmed.
To test and verify the volume of effluent admissible to the field with respect to density of tree plantation.	This has been tested and the volume verified. (Figure 6)
To test and confirm the absence of or the extent of ground water and soil contamination due to continuous irrigation with treated tannery effluent.	Data collected so far established the trend and relatively low level of contamination of ground water and soil. It was observed that soon after rains, the level of TDS, Cl & SO ₄ declined but started building up in summer months. However, continued monitoring for a longer period is desirable.
To compare the two modes of irrigation (flood irrigation and ridges and furrows) with respect to water uptake by the plant and ground water contamination.	Based on the data collected, the flood irrigation was found to be better.

6.2.8 Future

The CETP management continues monitoring this plot. Incidentally, this plot has been now merged in the mini forest described hereafter.

6.3 Mini forest project at CETP-SIDCO

6.3.1 Rationale

Encouraged by the positive results of its two experiments, the CETP-SIDCO sought technical assistance of UNIDO for development of a low lying, degraded land, adjacent to its premises, measuring 3.55 hectares, into a mini forest, using treated effluent for irrigation. SIPCOT, a state government industrial promotion organisation and owner of the land, also expressed its willingness to provide the land, free of rental, for use by the project. UNIDO agreed to join hands with CETP-SIDCO in taking up the project.

Specific objectives of the project are:

- ❖ To rehabilitate the apparently degraded land by converting it into a mini forest.
- ❖ To utilise the treated effluent as much as possible to minimise environmental impact outside the irrigated plot.
- ❖ To test and confirm the survival of the different varieties of plants irrigated by the treated tannery effluent and compare their growth rates.
- ❖ To test and confirm the extent of ground water and soil contamination due to continuous irrigation by treated tannery effluent.
- ❖ To achieve progressively zero discharge status for the CETP.
- ❖ To recover revenue from the land considered degraded and unusable.

6.3.2. Events prior to project implementation

The approval of the Tamil Nadu Pollution control Board for use of treated effluent was obtained during the month of September 1998. Subsequently SIPCOT gave permission by mid October 1998 to use their land for the project. After obtaining these permissions, the CETP-SIDCO approached UNIDO vide its letter dated 28 October 1998 for assistance. Based on a proposal of the CETP management, in accordance with the ToR prepared by its RePO, UNIDO awarded the subcontract for development of a mini forest using treated effluent for irrigation to the management of CETP-SIDCO.

6.3.3. Project design

M/s. Archana Agrotech Pvt. Ltd, Chennai was entrusted by the CETP with the job of surveying the proposed area and preparing a detailed design for irrigation of the area. After surveying the entire area for contour levels etc. The company made a design of the project site, which included the contour map, scheme of plantation and piping details.

The basic design consisted of dividing the entire plot into 11 sections and planting of different varieties of trees, intermingled. Plantation of different varieties of trees had been planned in such a way that the low-lying areas were planted with those varieties, which could withstand comparatively high salinity. The area was to be developed into ridges and furrows.

In the middle of the site, a central park of about 0.5 acre had been envisaged. This park was to be planted with grass and flowering shrubs.

A pond of about 10 m diameter at the end of the irrigation plot was planned, mainly to collect surface run-offs. Lotus was to be planted in the pond.

A road was to be formed from the entrance till the end of the plot cutting through the forest in the middle. Avenue trees were to be planted on either side of the road.

The condition of the area which is today a mini forest and where the untreated effluent used to accumulate earlier is shown in pic.6. The front side of the mini forest after the development is shown in pic. 7.



Pic.6: Degraded land



Pic.7: A view of the mini forest in June 2001

The following arrangement was made for transport and distribution of treated effluent:

A collection sump of 5.0 m x 5.0 m x 2.5 m was constructed for collection of treated effluent by gravity. The treated effluent collected was pumped to the irrigation plot using a centrifugal pump of 3.75 kW capacity through 90 mm distribution lines. The collection tank was provided with suitable arrangement to let out the effluent through the normal discharge line, if the collected treated effluent was not needed for irrigation.

The earthwork and levelling was started by the third week of December 1998 and plantation began by the third week of January 1999. Some very low lying areas were filled up with fresh soil.

Regular irrigation of the plants was started in some sections by the beginning of February 1999. Initially around 250 m³/d of treated effluent was utilised for irrigation and the volume was increased steadily as more sections were planted with saplings.

6.3.4. Monitoring

Before developing the area samples of ground water and soil were collected for obtaining baseline data. Treated effluent was analysed on a daily basis. A detailed monitoring schedule followed by the subcontractor is given below:

- ❖ The treated effluent used for irrigation was analysed for all the parameters specified by the TNPCB viz., pH, Total dissolved solids, Chlorides, Sulphates, EC, BOD @ 20° C, COD,

(on a daily basis) Total chromium, Percent sodium, Total Kjeldahl Nitrogen, Nitrates as NO₃, Phosphates as PO₄ (on a weekly basis)

- ❖ Soil samples inside and outside the mini forest, once in three months, at 6 points & at the surface, 0.3 m & 0.6 m in each point, total 18 samples, for parameters such as pH, N kg/ac, P₂O₅ kg/ac, K₂ O kg/ac and Cr kg/ac.
- ❖ Ground water samples, twice a month, at two depths (6 ft and 40 ft, Number of sampling points: 4 – 8 samples). Parameters checked in ground water samples were pH, TDS, Chlorides, Sulphates, BOD₅, Total chromium and Percent sodium
- ❖ Other parameters such as the volume of treated effluent admitted, growth factors such as height and girth of trees, meteorological data such as humidity, rainfall, temperature etc. were regularly monitored & recorded.

The sampling points of soil and ground is shown in Annex 5.

The chronology of project implementation is given in Annex 2.

6.3.5. Number of saplings planted

As the area available for plantation was less than 3.6 hectares, the distance between saplings was kept low. Altogether around 25,000 saplings were planted in the area.

6.3.6 Irrigation pattern

Originally the entire effluent admitted to the mini forest was fed through pumping from the treated effluent collection sump. The valves in the branches were opened to admit treated effluent into each bay for about 45 minutes every day. Control valves were kept open and closed in such a way that any time during the day, at least 35% of the lines were open.

Later, to increase the feed, a separate earthenware pipeline (200 mm) was laid to admit effluent through gravity. This line has been operational since January 2001.

6.3.7 Effluent used for irrigation

The volume of treated effluent used for irrigation is given in figure 8:

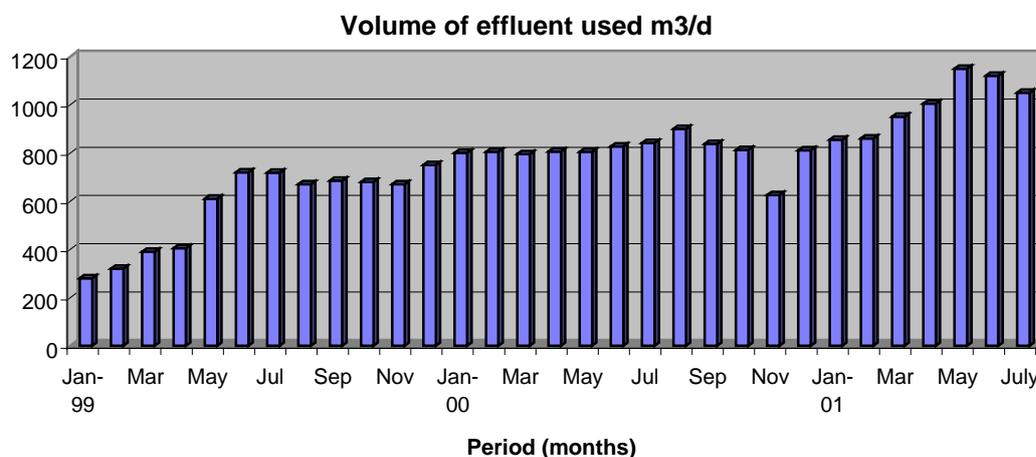


Fig.8: Volume of effluent used in miniforest m³/d

6.3.8 Survival of plants

All plants survived & grew well except for *Eucalyptus* and *Casuarina* in the early stages. This was because these saplings were procured as naked seedlings. Replanting these varieties was carried out with saplings of average height of (30 cms) in poly bags. The survival rate, as of June 2001, is given in Table 6:

Table 6: Survival of plants as of June 2001

Tree variety	Nos. originally planted	Nos. replanted	Nos. survived and grown as on 31 June 2001
<i>Mangium</i>	5914	2210	5420
<i>Pungam</i>	803	155	710
<i>Neem</i>	1200	360	1025
<i>Casuarina</i>	9230	6200	5825
<i>Eucalyptus</i>	5446	2200	4610
<i>Terminalia arjuna</i>	500	220	530
<i>Bamboo</i>	1030	50	894
	24123	11395	21046

Note: Additionally 504 numbers of teak were planted along the boundary and approximately 420 numbers were replanted and the number of trees surviving as of 1 June 2001 was 705.

6.3.9 Results obtained

6.3.9.1 Growth of plants

The height (cm) of plants, planted during January 1999, as in June 2001 is given in table 7.

Table 7: Height (cm) of plants : Mar 1999- June 2001

Months	<i>Mangium</i>	<i>Eucalyptus</i>	<i>Casuarina</i>	<i>Neem</i>	<i>Pungam</i>	<i>Terminalia</i>	<i>Bamboo</i>
Mar-99	142	72.7	41	43.3	37.9	40.3	36
April	146	99	53.9	68.9	56	45.6	48.5
May	153	101.4	60.9	86.2	59	61.1	51
June	156	108.8	65	97.3	59.8	79	52
July	163	122	73.3	175	60.4	107	71
August	173	144.9	78.7	201	64.6	136	109
September	184.8	157.5	102.2	211	73.7	156	129
October	202	167.1	129.4	216	87.9	190	166
November	229	184	151.8	227	97	198	199
December	230	205	162	231	98.9	199	208
Jan-00	238	234	187	233	99.2	203	215
February	276	298	252	240	100.8	211	221
March	315	301	317	246	118	218	227
April	354	358	384	262	123	232	232
May	393	416	443	277	126	246	236
June	432	474	512	298	128	259	250

July	471	531	577	308	130	262	282
August	510	589	600	323	133	274	305
September	522	595	612	332	138	275	309
October	527	599	618	332	141	282	312
November	535	611	632	339	152	294	325
December	538	614	639	341	156	299	329
January-01	541	617	643	345	162	301	333
February	544	616	648	348	163	302	336
March	546	621	652	349	167	304	334
April	547	623	655	355	169	308	337
May	552	626	662	352	171	311	338
June	558	627	663	358	174	313	341

The girth (cms) of these plants in June 2001 is given in Table 8:

Table 8: Girth (cm) of plants: Mar 1999- June 2001

Months	<i>Mangium</i>	<i>Eucalyptus</i>	<i>Casuarina</i>	<i>Neem</i>	<i>Pungam</i>	<i>Terminalia</i>	<i>Bamboo</i>
Mar-99	3.2	1.8	1.2	2.7	2	1.3	2.6
April	3.3	2.8	2.1	4.3	2.6	2.7	4.3
May	4	3.1	2.4	4.4	3	3.4	5
June	4.2	3.3	3.7	5.3	3.7	4	7.4
July	5.3	3.6	3.8	7.1	3.8	5.6	9.8
August	6.5	5	3.9	8.3	3.9	7.3	11
September	7.9	6.2	4	9.1	4	9	16
October	9.5	7.3	4.8	9.7	4.6	11.5	16.2
November	10.9	8.3	5.6	10.1	4.9	12.2	16.5
December	12.1	9.3	6.5	11.2	5.2	12.7	18
Jan-00	13.3	10.3	7.4	11.7	5.8	13	19.5
February	14.6	12.3	8.5	12.3	6.2	13.8	20
March	15.7	12.7	9.9	14.2	6.7	14.1	22.5
April	16.7	12.9	10.4	14.6	7.2	14.5	23
May	17.5	13.7	11	14.8	7.6	15	24
June	18.2	15	11.5	15.3	8	15.5	25
July	18.7	15.6	12.3	16	8.4	16.4	26.5
August	19.2	15.8	13	17.5	8.8	17	27.5
September	19.8	16.1	13.2	17.9	8.9	17.3	29
October	20.4	16.9	13.6	18.3	9.1	18.4	29.8
November	21.1	17.8	14.2	19.3	9.9	19.1	30.3
December	21.7	18.1	14.9	19.9	10.2	19.7	30.9
January-01	21.8	18.2	14.9	19.8	10.4	19.8	31.2
February	21.9	18.4	15.0	20.1	10.7	19.8	31.4
March	22.1	18.7	15.1	20.2	10.8	20.2	31.4
April	22.3	18.9	15.3	20.5	11.2	20.6	31.8
May	22.6	19.1	15.5	20.8	11.2	20.9	32.1
June	23.4	19.3	15.7	21.3	11.2	21.3	32.3

The height of plants planted in January 2000 as of June 2001 is in table 9:

Table 9: Height (cm) of trees April 2000 – June 2001

Months	<i>Mangium</i>	<i>Eucalyptus</i>	<i>Casuarina</i>	<i>Neem</i>	<i>Pungam</i>	<i>Terminalia</i>	<i>Bamboo</i>
April	219	144	254	161	102	172	232
May	224	148	265	174	104	176	268
June	227	152	275	179	108	183	277
July	240	157	284	184	112	190	284
August	256	164	296	189	117	195	296
September	265	167	301	191	119	199	298
October	267	171	302	192	121	201	301
November	269	173	303	196	123	204	305
December	271	178	311	205	128	212	311
January-01	273	179	312	206	130	214	315
February	275	182	314	211	133	218	319
March	277	185	316	215	138	219	324
April	282	189	323	218	142	222	326
May	289	191	324	221	145	225	331
June	291	195	329	223	149	227	336

The girth of these plants is in table 10:

Table 10: Girth (cm) of trees April 2000-June 2001

Months	<i>Mangium</i>	<i>Eucalyptus</i>	<i>Casuarina</i>	<i>Neem</i>	<i>Pungam</i>	<i>Terminalia</i>	<i>Bamboo</i>
April	9.5	5.9	13.7	10.4	6.5	19.9	7.2
May	9.7	6.4	14.1	11	6.9	20.3	7.6
June	10.2	6.8	15	11.5	7.2	22.1	8.2
July	11.3	7.1	16	12.2	8.4	23.5	8.6
August	11.9	7.8	16.4	12.6	9	24	9
September	12.1	7.9	16.9	12.8	9.2	24.2	9.3
October	12.3	8.1	17.4	13.5	9.9	25.3	10.1
November	12.9	8.8	17.9	14.1	10.2	25.9	10.3
December	13.1	9	18.1	14.2	10.3	26.1	10.6
January 01	13.4	9.2	18.2	14.3	10.7	26.2	10.7
February	13.7	9.3	18.3	14.5	11.1	26.4	10.8
March	13.9	9.3	18.5	14.6	11.2	26.5	10.9
April	14.1	9.5	18.7	14.9	11.3	26.9	11.1
May	14.3	9.8	18.7	15.1	11.5	27	11.2
June	15.1	9.9	18.9	15.1	11.5	27.1	11.3

6.3.9.2 Ground water analysis

The variation in the values of TDS, chlorides & sulphates observed in the ground water in the mini forest project (4 sampling points, at two depths at each point) are presented schematically in the figures 9, 10 & 11:

TDS (mg/l)

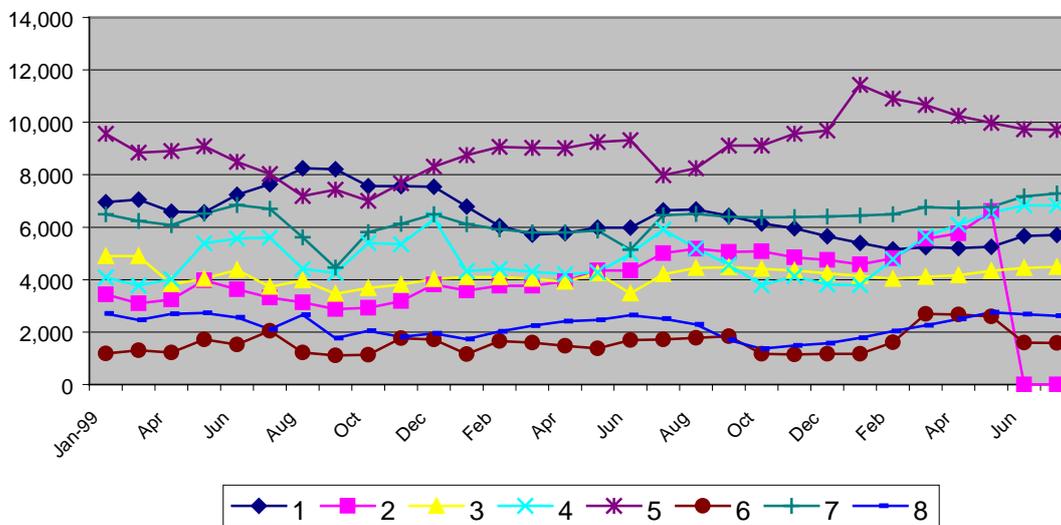


Figure 9: TDS variations in the ground water

Chlorides (mg/l)

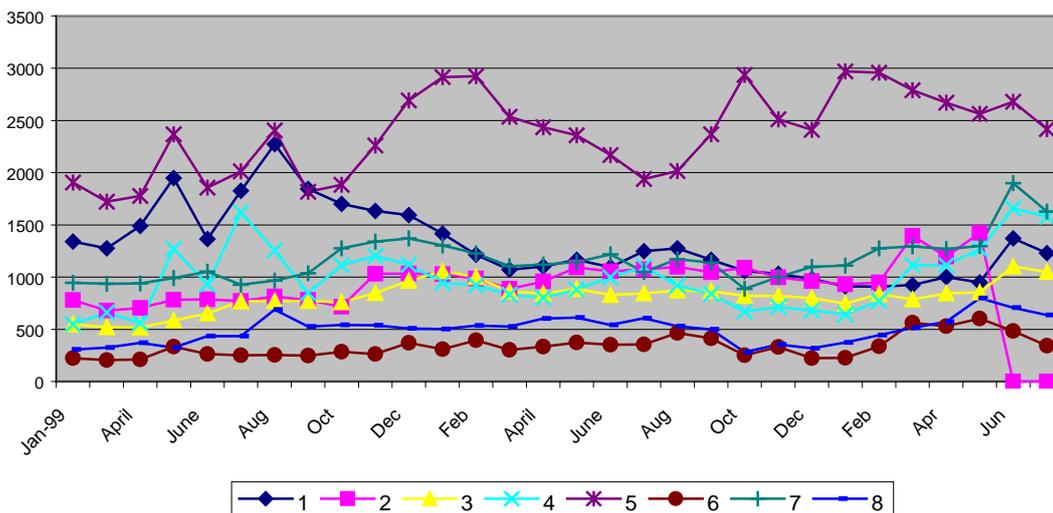


Figure 10: Variation of Chlorides in the ground water

Sulphates (mg/l)

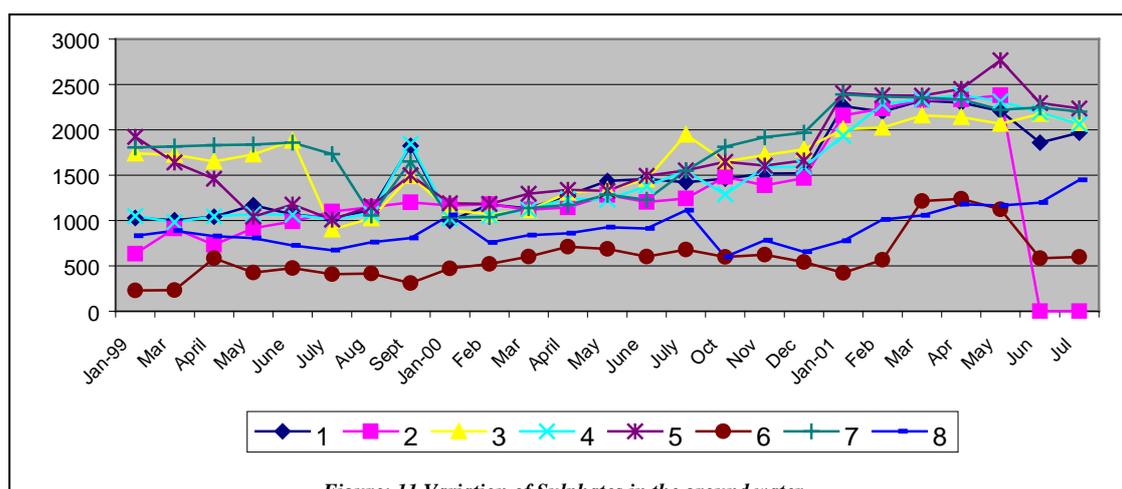


Figure: 11 Variation of Sulphates in the ground water

6.3.9.3 Soil analysis

The soil analysis values obtained from various sections of the mini forest during the beginning (Feb 99) and during May 2001 are given in table 11:

Table 11: Soil analysis value

Block (Inside the irrigation plot)	February 1999			May 2001			
	Sample collection point	Electrical conductivity micro- siemens/sec	Soil organic matter	Nitrogen kg/acre	Electrical conductivity micro- siemens/sec	Soil organic matter	Nitrogen kg/ acre
A Block	a. Surface	0.98	0.97%	70	0.48	0.06%	55
	b. 0.3 m	0.53	0.09%	126	0.52	0.19%	108
	c. 0.6 m	0.86	0.31%	84	0.55	0.22%	48
B Block	a. Surface	0.87	0.56%	168	1.1	0.51%	41
	b. 0.3 m	1.08	0.20%	112	0.49	0.48%	114
	c. 0.6 m	0.86	0.26%	98	0.67	0.29%	59
C Block	a. Surface	2.51	0.67%	224	0.98	0.38%	61
	b. 0.3 m	0.91	0.08%	154	0.79	0.26%	102
	c. 0.6 m	1.65	0.10%	126	0.64	0.28%	162
I Block	a. Surface	1.07	0.33%	252	1.85	0.24%	59
	b. 0.3 m	0.88	0.44%	196	1.16	0.08%	104
	c. 0.6 m	1.81	0.13%	140	0.98	0.05%	101
Just outside the irrigation plot	a. Surface	0.35	0.51%	238	0.33	0.22%	154
	b. 0.3 m	0.27	0.32%	182	0.46	0.19%	142
	c. 0.6 m	0.72	0.24%	140	0.48	0.17%	99
50 m away from the plot	a. Surface	0.45	0.63%	266	0.52	0.45%	72
	b. 0.3 m	0.38	0.13%	196	0.43	0.11%	125
	c. 0.6 m	0.25	0.04%	182	0.38	0.18%	89

Evaluation of results

6.3.9.4 General observations

During the 2 years of continued monitoring of the mini forest irrigated by treated effluent, the following observations are made:

- ❖ The growth rate of trees generally seemed to be good indicating that there was no adverse effect on their growth due to irrigation by treated effluent. However, in certain pockets where the soil was in a much degraded state (particularly with respect to soil salinity), the growth rate was not satisfactory.
- ❖ The variation of ground water characteristics indicated that no significant addition to contaminants in ground water had occurred during this period. However, continued monitoring is called for.
- ❖ No adverse change in the soil characteristics was observed.

6.3.10 Mass balance

A complete mass balance of the TDS let into the mini forest in terms of TDS, chlorides and sulphates using the data obtained till Dec 2000 is given in Annex 4. As may be seen from this, even when rainfall is below normal, a slight reduction of the volume of effluent let into the mini forest would keep the TDS in the ground water unchanged.

6.3.11 Status and future

Present status

With reference to the original specific objectives, the current status is as follows:

Specific objectives	Present status
To rehabilitate the degraded & unused land by converting it into a mini forest	The mini forest has been successfully established in the degraded & unused land.
To utilise the treated effluent as much as possible to minimise environmental impacts outside the irrigated plot	This objective has been achieved. About 70% of the effluent treated by the CETP is used for irrigation.
To test and confirm the survival of the various plants irrigated by the treated tannery effluent and compare their growth rates.	The survival and growth of selected inedible plant species have been confirmed. Reasonably reliable figures of rates of growth of different species obtained.
To test and confirm the extent of ground water and soil contamination due to the irrigation by treated tannery effluent.	Data collected so far indicates no such danger, but to establish the same, continued monitoring for a longer period is recommended.
To recover some revenue from the land previously considered as waste land	Though the actual realisation of commercial benefits is yet to take place, the commercial potential of the mini forest is well recognized.

6.3.12 Future

Future action by the CETP management will involve optimising the volume of effluent used for irrigation based on the mass balance and continued monitoring for a longer period.

7. COST AND BENEFITS

Since the cost at PKL is not known (no estimation was made during the early stage of the project), cost-benefit analysis of the mini forest project in SIDCO is provided.

7.1 Investment cost

The total investment cost of the mini forest project was INR 0.55 million (US \$ 12,500) the break up of which is given below:

Item	Cost (INR)	Cost (US \$)
Land levelling filling etc.	150,000	3,409.09
Plantation including cost of plants	90,000	2,045.45
Piping	125,000	2,840.91
Collection sump and pump	85,000	1,931.82
Monitoring instruments	100,000	2,272.73
Total	550,000	12500.00

Note: Land cost excluded

7.2. Operational cost

Labour	
No. of workers employed for the maintenance of the mini forest	14
Daily wage provided to the labour	INR 60/head
Total labour cost	INR 840/d = INR 25,200/month (30 days)
Power	
Total working hours	7 h/d, 26.25 kWh/d
Total power cost	26.25 kWh/day = INR105/d (INR 3150/month)
Others	
Miscellaneous including manure for trees	INR 100/d or INR 3000/month
Monitoring cost (30 effluent samples, 36 ground water samples and 9 soil samples)	INR 5,850 / month
Total cost	INR 37,200 / month.

7.3 Reported benefits

7.3.1 Greening of the area

With over 20000 fairly well grown trees in the area, the CETP premises now appear quite green. This has considerably improved the overall appearance of the CETP and the image of the industry.

7.3.2 Timber value:

It has been reported that some of the trees, particularly the *Acacia mangium*, have good commercial potential. The assumptions made by the supplier of the mangium saplings for cost-benefit calculations are given in Annex 3.

8. CONCLUSION

- ❖ The pilot demonstrations at PKL and CETP-SIDCO have clearly established that effluent generated by tanneries processing semi processed hides and skins to finished leather can be profitably used for irrigation of inedible plants with positive results.
- ❖ The saline resistant species identified include 1. *Pongamia pinnata*, 2. *Azadirachta indica*, 3. *Casuarina equisetifolia*, 4. *Tectona grandis*, 5. *Acacia arabica*, 6. *Eucalyptus tereticornis*, 7. *Dendrocalamus strictus* and 8. *Acacia mangium*
- ❖ Even assuming some possible ground water contamination, the project has got its positive attraction, as the total magnitude of environmental damage will be certainly less when the effluent discharge is confined to a limited area with the possibility of getting a substantial amount of pollution absorbed by the plants.
- ❖ The possibility to achieve zero discharge in this manner will be important for many tanneries having vacant land.
- ❖ The advantages of the project are: (a) containing ill effects from low saline tannery effluent (b) greening the otherwise arid lands (c) converting the waste water into a valuable resource and thus saving good water normally used for irrigation (d) rehabilitation of degraded land and (e) generating revenue for tanneries and ETP.
- ❖ The obvious limitations are: (a) this practice is currently recommended only for effluent from semi processed to finished leather processing units (b) potential of ground water/soil contamination in case of overloading (c) requirement of sufficient vacant land and (d) inadequate information on optimum feeding rate.
- ❖ It is yet not possible to conclusively define the volume of wastewater that can be used to irrigate one hectare of land, with a given plant density. However, based on the observations made so far, it may be tentatively stated that with a plant density of 2500 per acre, it is safe to use about 90 m³ per acre for irrigation, without any adverse impact on soil or groundwater. However, it must be stated that continuous monitoring should be done of soil & groundwater & if any increasing trend in TDS or chlorides were seen, the volume of effluent used for irrigation should be suitably modulated.

9. FUTURE

The volume of effluent used for irrigating the mini forest in CETP-SIDCO will be progressively increased by the CETP management with strict monitoring of ground water and soil, mainly to find out the threshold limit of absorption. Establishing the maximum volume of effluent that can be used for irrigation, both in hydraulic and pollutant loading, will be of immense value to plan such systems in future for other tanneries.

The rate of irrigation must be modulated, keeping in view the area irrigated, density and variety of plants & total rainfall. If rainfall is low in a year, in that case, the rate of irrigation may be reduced. Annex 4 provides some tentative calculations in this regard.

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3. CETP-SIDCO, Ranipet
4. Presidency Kid Leather (P) Ltd., Kannivakkam
5. Archana Agrotech Co. Ltd., Chennai

Annex 1

Baseline data in CETP-SIDCO irrigation area

(a) Ground water samples drawn from nearby wells during July 1998

Parameter	CETP tank on 13.7.98	CETP tap on 13.7.98	Sri Leathers on 9.7.98	Sri Selva Vinayagar on 22.7.98	Sri Lakshmi Industries on 22.7.98	Chinnappa Leathers on 23.7.98
pH	7.0	7.0	6.9	7.1	7.1	7.1
TDS	3240	2880	7160	1180	3160	2200
Chlorides	507	460	1,959	118	503	613
Calcium	481	441	1,046	188	433	480
Magnesium	58	29	268	24	170	231
Total hardness	1201	1101	3710	570	1780	2150
Calcium hardness	960	980	2612	469	1080	1198
Magnesium hardness	241	121	1,098	99	701	952

All values except pH are expressed in mg/l.

(b) Ground water samples from experimental plot 27 July 1998

Parameter	SIPCOT land bore 1.8 m	Flood irrigation bore 1.8 m	Flood irrigation bore 0.9 m	Ridges & furrows bore 1.8 m	Ridges & furrows bore 0.9 m
pH	6.81	7.47	7.41	7.87	7.89
TDS	1920	1900	2320	5000	4900
Chlorides	384	341	700	887	503
Sulphides	BDL	BDL	BDL	BDL	BDL
Calcium	325	284	472	405	372
Magnesium	78	119	141	49	29
Total hardness	1130	1200	1760	1210	1050
Calcium hardness	811	709	1178	1011	929
Magnesium hardness	320	490	582	201	119
EC (μ mhos/cm)	2.95	2.92	3.56	7.69	7.53
Colour	Clear	Clear	Turbid yellow	Light brown	Light brown

All values except pH and EC are expressed in mg/l

(c) Soil characteristics

Sample point + depth of sample taken	pH	TDS (mg/l)	Chlorides (mg/l)	Sulphates (mg/l)
Near secondary clarifier 30 cm	6.83	720	124	251
Near secondary clarifier 60 cm	6.72	1440	93	234
Near secondary clarifier 100 cm	6.14	820	112	246
Near sludge drying beds 30 cm	6.24	1560	81	197

Near sludge drying beds 60 cm	6.21	1040	56	226
Near sludge drying beds 100 cm	6.54	1600	87	222
SIDCO land - near sludge heap 30 cm	6.09	1640	124	205
SIDCO land - near sludge heap 60 cm	5.92	1040	112	205
SIDCO land - near sludge heap 100 cm	5.74	1080	74	242
SIDCO land - middle of the pond 30 cm	6.09	760	105	193
SIDCO land - middle of the pond 60 cm	6.60	1160	93	214
SIDCO land - middle of the pond 100 cm	6.72	1300	136	284
Flood irrigation land (Mangium) 30 cm	6.14	1000	112	237
Flood irrigation land (Mangium) 60 cm	6.23	1380	93	238
Flood irrigation land (Mangium) 100 cm	6.22	1380	99	230
Ridges & furrows land (Mangium) 30 cm	6.99	1120	99	259
Ridges & furrows land (Mangium) 60 cm	7.02	720	81	
Ridges & furrows land (Mangium) 100 cm	6.77	1360	99	
Land behind fire office 30 cm	6.29	980	99	
Land behind Fire office 60 cm	6.49	1040	112	
Land behind fire office 100 cm	6.22	820	99	

Note 1: Chromium could not be detected using a qualitative test in any sample.

Annex 2

Chronology implementation of miniforest project at CETP-SIDCO

10 December 98	Initial meeting was conducted in RePO, UNIDO. The CETP representatives were briefed on the terms and conditions of the contract.
15 December 98	Signing of the contract for the “Mini Forest” Project
16 - 19 December 98	Forming a trench to drain the treated effluent discharged from the neighbouring area and to prevent the cattle grazing.
19 - 21 December 98	Levelling of A and B Blocks.
22 - 25 December 98	Forming of ridges and furrows in A & B Blocks.
26 December 98 to 01 January 99	Forming a trench on the other side to prevent cattle grazing.
29 & 31 December 98	Fixing of the peizometers at four different locations. i. On the ridges and furrows ii. Near the trench iii. Near the park area iv. Near the pond area Two different depths (i.e.) 0.9 m and 1.8 m respectively.
01 - 02 January 99	Ploughing and levelling of C, G & H blocks.
04 January 99	A low lying area on the road had been filled with 5 truck loads of soil.
05 January 99	Levelling of C, G & H blocks.
06 - 08 January 99	Levelling of land, J, D & E blocks.
09 - 11 January 99	Ridges and furrows were taken in G & H blocks, digging of pit for building sump.
12 - 13 January 99	Ridges and furrows were taken in C & D blocks.
14 January 99	No work has been carried out in the field due to rains.
15 - 17 January 99	Holidays due to Pongal festival.
18 January 99	Building of a sump to store water and pump for the Mini Forest area.
19 - 20 January 99	Levelling of K block and pulling out reeds in the F block.
21 - 23 January 99	Laying of pipelines.
24 - 25 January 99	Laying of roads.
26 - 27 January 99	Closing the pipeline trenches.
28 - 29 January 99	Planting of G, H & I blocks.
30 - 31 January 99	Planting of C & D blocks.
01 - 03 February 99	Planting of <i>Casuarina</i> and <i>Eucalyptus</i> in A, B, C, G & H blocks.
04 & 05 February 99	“A” block planting
08 & 09 February 99	Replanting of dried up plants.
10 - 13 February 99	Planting in E block after forming ridges and furrows.
15 - 16 February 99	Planting of K block after forming ridges and furrows.

Annex 3

Cost-benefit calculations for *Acacia mangium* in 1600 m² experimental plot at CETP-SIDCO, Ranipet

1. Cost of operation

No. of labours deployed in the 1600 m² plot: 1

Labour cost @ INR 60/d: INR 1800 (30 days) per month.

Power cost: INR 600 per month.

Miscellaneous including manure and monitoring charges: INR 600 per month

Total cost: INR 3000 per month

Cumulative cost for 10 years: INR 360,000.

2. Benefits

This can be divided into two parts: Number of trees planted 835, cost of each sapling INR 9. Based on extrapolation of growth rates of *Acacia mangium* at CETP-SIDCO the following values have been given by M/s Archana under the condition that: Tree density is 1.5 m x 1.5 m; and the number of pits equals the number of trees (835) with each pit size 0.6 m x 0.6 m.

The assumption is that thinning (removal of weakest trees starts at the end of year 2) will be done between year 2 and year 6. M/s Archana consider the values indicated below as conservative compared with current market price for timber. Also the specific gravity of *Acacia mangium* as a 14 year old tree is 0.55 to 0.6 at 10 % moisture, the weight is around 550 kg per m³ of timber (35 ft³), however in the calculation only 25 ft³ has been considered.

Age of the plant (years)	Height (m)	Weight (kg)	Girth (cm)	Timber (m ³)	Rate (INR)/m ³	Total price per tree
2	3.6-4.5	25 to 30	-	Not yielding any timber	Rs.3 /kg (Pulp)	INR 75
3	6.1	50	50	Not yielding any timber	Rs.3 /kg (Pulp)	INR 150
4	7.6	80 to 100	60	0.03	Rs.3 /kg (Pulp) or INR 7000/m ³ (timber)	INR 240 / tree or INR 225/tree
5	9.1	120 to 150	80	0.08	Rs.3 /kg (Pulp) or INR 7/m ³ (timber)	INR 360/tree or INR 750 / tree
6	10.6-12	200 to 210	88 to 100	0.17	INR 275/tree	INR 1650/tree
7	10.6-12	220 to 230	100	0.22	INR 300/tree	INR 2400/tree
8	12.2	280 to	100	0.34	INR 9200/m ³	INR 3900/tree

		300				
9	13.7	300 to 350	110	0.34	INR 9900/m ³	INR 4200/tree
10	15.2	350	120	0.42	INR 17000/m ³	INR 9000/tree
14	18.3	400 to 420	120	0.71	INR 17000/m ³	INR 15000/tree

Calculated income after 2 years is 83 trees x INR 75 = INR 6,225
 Calculated income after 3 years is 83 trees x INR 150 = INR 12,450
 Calculated income after 4 years is 83 trees x INR 225 = INR 18,675
 Calculated income after 5 years is 83 trees x INR 750 = INR 62,250
 Calculated income after 6 years is 83 trees x INR 1850 = INR 153,550
 Calculated income after 10 years is 420 trees x INR 9000 = INR 3,780,000

Total (cumulative after 10 years) = INR 4,033,150
 Effective savings (cumulative after 10 years) = 4,033,150-360,000
 = 3,673,150

Note 1: Thinning is only between year 2 and 6. It is assumed that all trees will be axed at the end of year 10 and none dies during the first two years.

Note 2: These figures have been calculated on the basis of information provided by the supplier of saplings and should be interpreted with caution.

Annex: 4

Mass balance in the mini forest of CETP-SIDCO (Prepared by Mr. Michel Aloy, CTC, France)

1. General

Comparison of the results of ground water samples available for 1999 and 2000, (figures are annexed in Excel format) indicates that there is a slight decrease of 4.4 % in the first level of the ground water at 6 feet, but also an increase of 7.6 % of the parameters in the deep level of the ground water at 40 feet. These points can be seen on the mean values for each month at eight different piezometer points, four at 6 feet depth and four at 40 feet depth.

Parameter	TDS mg/l		Chloride mg/l		Sulphate mg/l		Total hardness mg/l		EC mmhos/cm	
	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft
Mean value	6401	3065	1389	658	1420	923	2372	1640	9.8	4.7
Variation 2000/1999	-1.5%	3.8%	2.0%	6.8%	-1.9%	20.5%	-19.3%	3.0%	-1.5%	3.8%
Mean variation	1.2%		4.4%		9.3%		-8.1%		1.2%	

Average effluent coming from SIDCO CETP and sent to the site:

#Sl. No.	Parameter	Concentration	Pollution load	
			In kilograms/day	In tonnes/year
1	TSS	118 mg/l	81	30
2	TDS	4225 mg/l	2916	1064
3	BOD ₅	22 mg/l	15	6
4	COD	281 mg/l	194	71
5	Chloride	568 mg/l	392	143
6	Sulphate	1745 mg/l	1204	440

This represents 236 tonnes of sodium chloride and 650 tonnes of sodium sulphate every year.

- Effluent received: 690 m³ per day or 252,000 m³/year with 143,136 kg of chloride (568 mg/l)
- Rain received on the site: 850 mm/year on 37,000 m² = 31,450 m³/year
- Total effluent + rain: 283,450 m³/year with 143 tonnes of chloride (505 mg/l)

Absorption and evaporation rate of 20 % is assumed, taking into account the observation made on reed beds in Melvisharam.

The effluent and rain evaporated will be: 56,690 m³/year.

Effluent and rain sent to the ground water will amount: 226,760 m³/year with 143 tonnes of chlorides (644 mg/l) (assuming no absorption of chlorides by the plants/soil).

2. Mitigation of effects of salt load

It has been noted that there is some slight increase in salt concentration, particularly in the samples collected at 40 feet. In order to maintain the concentration of salts in groundwater at the same level, some mitigation measures need to be adopted. This can be done by either by increasing the area being irrigated without increasing the volume of effluent or by decreasing the volume of effluent admitted to the field. Two assessments, one theoretical and the other, based on the analytical values, have been made to assess these requirements.

2.1 Theoretical assessment

This theoretical assessment has been made on the assumption that no quantity of salt is absorbed by the plants/soil.

Additional surface needed for irrigation

To maintain the same level of chloride in the ground water, the volume of extra water required shall be:

$252,000 \text{ m}^3/\text{year}$ (total volume of effluent) – $226,760 \text{ m}^3/\text{year}$ (total volume of effluent after evaporation + rain sent to ground water) = $25,240 \text{ m}^3/\text{year}$.

At the average rainfall reported, this extra rainwater will be collected on an increased surface of:

$25,240 \text{ m}^3/\text{year}$: 0.85 m (850 mm/year) = $29,700 \text{ m}^2$ or 7.4 acres

Hence the theoretical additional area requirement will be about $30,000 \text{ m}^2$

By increasing the area, the total surface will be $37,000 + 30,000 = 67,000 \text{ m}^2$

Reduction of effluent to be sent for irrigation:

To maintain the same level of concentration, rainwater must compensate the evaporation.

- Rain water: $31,450 \text{ m}^3/\text{year}$
- At this rate of rainwater, total water (effluent and rain water) that can be sent:
 $31,450/0.20 = 157,250 \text{ m}^3/\text{year}$

This quantity represents an average volume of:

- $157,250 / 365 = 430 \text{ m}^3/\text{day}$ out of the daily effluent 690 m^3 , that is to say, only $430/690 = 62 \%$ of the present loading rate.

2.2 Practical assessment

Taking into account the real values observed on site, it is possible to see that the highest impact is for sulphate at the depth of 40 ft with an increase of 20.5 % of this parameter.

The required reduction of volume of effluent and/or the additional area required is calculated as follows:

Decrease of effluent volume

Increase of area

(a) Based on TDS values

	Based on the ground water sample at	
	both levels	at low level
Average effluent	690.16	690.16
TDS mg/l	4225	4225
TDS kg/d	2916	2916
Excess TDS	1.20%	3.80%
Excess TDS kg/d	35	111
Required effluent decrease	8	26
Final volume	682	664

	Based on the ground water sample at	
	both levels	low level
Average effluent	690.16	690.16
TDS mg/l	4225	4225
Area m ²	37000	37000
TDS g/m ²	78.8	78.8
Excess TDS kg/d	35	111
Required additional area m ²	444	1406

(b) Based on value of chlorides

Average effluent	690.16	690.16
Cl mg/l	568	568
Cl kg/d	392	392
Excess Cl	4.40%	6.80%
Excess Cl kg/d	17	27
Required effluent decrease	30	47
Final volume	660	643

Average effluent	690.16	690.16
Cl mg/l	568	568
Area m ²	37000	37000
Cl g/m ²	10.6	10.6
Excess Cl kg/d	17	27
Required additional area m ²	1628	2516

(c) Based on values of sulphates

Average effluent	690.16	690.16
SO4 mg/l	1745	1745
SO4 kg/d	1204	1204
Excess SO4	9.30%	20.50%
Excess SO4 kg/d	112	247
Required effluent decrease	64	141
Final volume	626	549

Average effluent	690.16	690.16
SO4 mg/l	1745	1745
Area m ²	37000	37000
SO4 g/m ²	32.5	32.5
Excess SO4 kg/d	112	247
Required additional area m ²	3441	7585

Considering the worst scenario from above, i.e., increase of sulphate at low level, it is suggested to reduce the volume admitted to the irrigation area by 20.5% i.e., to reduce the average volume to 549 m³/d. Alternatively, an additional area of 7585 m² may be provided with irrigation, without increasing the volume of effluent fed into the field.

TDS mg/l

	Piezometer location								Mean values		Variation		Proportion
	1	2	3	4	5	6	7	8	Val 6 ft	Val 40 ft	6 ft	40 ft	40ft/6ft
Jan-99	6,960	3440	4900	4080	9560	1180	6500	2700	6,980	2,850			40.8%
Feb													
Mar	7060	3100	4900	3780	8840	1300	6240	2460	6,760	2,660			39.3%
April	6593	3246	3820	4026	8906	1213	6086	2693	6,351	2,795			44.0%
May	6565	3975	4030	5380	9090	1720	6522	2725	6,552	3,450			52.7%
June	7240	3630	4375	5570	8490	1522	6850	2560	6,739	3,321			49.3%
July	7645	3315	3730	5605	8025	2045	6705	2105	6,526	3,268			50.1%
Aug	8245	3128	3973	4408	7187	1224	5620	2655	6,256	2,854			45.6%
Sept	8207	2873	3455	4253	7428	<i>1112</i>	<i>4454</i>	1772	5,886	2,503			42.5%
Oct	7568	2920	3685	5400	<i>7005</i>	1133	5810	2047	6,017	2,875			47.8%
Nov	7568	3184	3819	5343	7673	1761	6126	1817	6,297	3,026			48.1%
Dec	7546	3812	4020	6308	8315	1714	6498	1951	6,595	3,446			52.3%
Jan-00	6781	3583	4096	4324	8744	1152	6120	1731	6,435	2,698	-8.5%	-5.7%	41.9%
Feb	6047	3769	4093	4416	9060	1663	5917	2021	6,279	2,967			47.3%
Mar	5710	3768	4028	4298	9033	1594	5803	2237	6,144	2,974	-10.0%	10.6%	48.4%
Apr	<i>5778</i>	3937	3918	4208	9017	1475	5798	2409	6,128	3,007	-3.6%	7.1%	49.1%
May	5986	4353	4240	4280	9253	1373	5873	2466	6,338	3,118	-3.4%	-10.6%	49.2%
June	5979	4351	3478	4995	9327	1697	5143	2643	5,982	3,422	-12.7%	3.0%	57.2%
July	6641	5009	4200	5914	7985	1722	6460	2515	6,322	3,790	-3.2%	13.8%	60.0%
Aug	6683	5182	4448	5188	8245	1779	6502	2287	6,470	3,609	3.3%	20.9%	55.8%
Sept	6433	5056	4476	4566	9113	1845	6397	1697	6,605	3,291	10.9%	24.0%	49.8%
Oct	6142	5078	4406	3784	9109	1175	6374	<i>1368</i>	6,508	2,851	7.5%	-0.8%	43.8%
Nov	5957	4844	4345	4125	9562	1148	6379	1485	6,561	2,901	4.0%	-4.3%	44.2%
Dec	<i>5651</i>	4747	4236	3814	9687	1173	6413	1569	6,497	2,826	-1.5%	-22.0%	43.5%
Mean value	6,738	3,926	4,116	4,698	8,637	1,466	6,113	2,170	6,401	3,065	-1.5%	3.7%	00/99

Maximum	8,245	5,182	4,900	6,308	9,687	2,045	6,850	2,725	6,980	3,790
Minimum	5,651	2,873	3,455	3,780	7,005	1,112	4,454	1,368	5,886	2,503
max variat.	2,594	2,309	1,445	2,528	2,682	933	2,396	1,357	1,094	1,288
in %	38%	59%	35%	54%	31%	64%	39%	63%	17%	42%

Sample collection point:

1. Near Trench	: 6 Feet	2. Near Trench	: 40 Feet
3. Ridges & Furrows	: 6 Feet	4. Ridges & Furrows	: 40 Feet
5. Park Area	: 6 Feet	6. Park Area	: 40 Feet
7. Pond Area	: 6 Feet	8. Pond Area	: 40 Feet

Chlorides mg/l

	Piezometer location								Mean values	Variation m/m		Proportion	
	1	2	3	4	5	6	7	8	Val 6 ft	Val 40 ft	6 ft	40 ft	40ft/6ft
Jan-99	1340	780	549	549	1906	223	946	307	1,185	465			39.2%
Feb													
Mar	1275	680	519	662	1721	206	936	323	1,113	468			42.0%
April	1491	703	518	560	1778	212	939	370	1,182	461			39.0%
May	1949	784	583	1271	2369	332	992	324	1,473	678			46.0%
June	1364	786	653	931	1857	263	1051	433	1,231	603			49.0%
July	1826	770	768	1617	2013	252	927	435	1,384	769			55.5%
Aug	2272	814	770	1255	2404	253	966	689	1,603	753			47.0%
Sept	1846	779	770	846	1818	249	1036	526	1,368	600			43.9%
Oct	1702	717	760	1114	1886	285	1276	541	1,406	664			47.2%
Nov	1633	1030	846	1201	2262	263	1339	537	1,520	758			49.9%
Dec	1595	1034	963	1119	2692	371	1371	509	1,655	758			45.8%
Jan-00	1415	1028	1056	945	2915	310	1302	501	1,672	696	29.1%	33.2%	41.6%
Feb	1215	986	1001	920	2924	395	1226	534	1,592	709			44.5%
Mar	1070	888	862	832	2536	304	1103	526	1,393	638	20.1%	26.6%	45.8%
April	1100	959	840	803	2436	335	1120	603	1,374	675	14.0%	31.7%	49.1%

May	1167	1093	887	881	2359	373	1145	613	1,390	740	-6.0%	8.4%	53.3%
June	1096	1056	830	996	2170	353	1219	542	1,329	737	7.3%	18.1%	55.4%
July	1247	1075	845	1101	1939	355	1050	606	1,270	784	-8.9%	2.0%	61.7%
Aug	1276	1097	873	920	2015	466	1171	530	1,334	753	-20.2%	0.1%	56.5%
Sept	1166	1046	865	839	2367	412	1139	499	1,384	699	1.2%	14.2%	50.5%
Oct	1058	1089	821	671	2937	250	888	282	1,426	573	1.4%	-15.9%	40.2%
Nov	1030	998	821	713	2512	329	1001	356	1,341	599	-13.3%	-26.5%	44.7%
Dec	982	961	797	680	2412	222	1099	318	1,323	545	-25.2%	-39.1%	41.2%
Mean value	1,396	920	791	932	2,271	305	1,097	474	1,389	658	2.0%	6.6%	00/99
Maximum	2,272	1,097	1,056	1,617	2,937	466	1,371	689	1,672	784			
Minimum	982	680	518	549	1,721	206	888	282	1,113	461			
max variat.	1,290	417	538	1,068	1,216	260	483	407	559	323			
in %	92%	45%	68%	115%	54%	85%	44%	86%	40%	49%			

Sample collection point :

1. Near Trench	: 6 Feet	2. Near Trench	: 40 Feet
3. Ridges & Furrows	: 6 Feet	4. Ridges & Furrows	: 40 Feet
5. Park Area	: 6 Feet	6. Park Area	: 40 Feet
7. Pond Area	: 6 Feet	8. Pond Area	: 40 Feet

Sulphates mg/l

	Piezometer location								Mean values		Variation		Proportion	
	1	2	3	4	5	6	7	8	Val 6 ft	Val 40 ft	m/m	6 ft	40 ft	40ft/6ft
Jan-99	1028	633	1740	1050	1922	230	1806	831	1,624	686	-	-	-	42.2%
Feb											-	-	-	
Mar	1004	912	1724	981	1641	234	1816	889	1,546	754	-	-	-	48.8%
April	1042	733	1653	1047	1462	586	1831	828	1,497	799	-	-	-	53.3%
May	1168	916	1728	1071	1043	425	1837	805	1,444	804	-	-	-	55.7%
June	1068	989	1881	1064	1175	477	1858	724	1,496	814	-	-	-	54.4%
July	1025	1098	903	1014	1009	407	1733	671	1,168	798	-	-	-	68.3%
Aug	1120	1148	1025	1075	1157	416	1056	759	1,090	850	-	-	-	78.0%
Sept	1825	1202	1491	1845	1501	309	1651	806	1,617	1,041	-	-	-	64.3%
Oct	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jan-00	995	1164	1111	1024	1189	473	1036	1061	1,083	931	-50.0%	26.3%	-	85.9%
Feb	1176	1180	1069	1053	1183	520	1040	757	1,117	878				78.6%
Mar	1135	1121	1111	1121	1297	601	1138	839	1,170	921	-32.1%	18.1%	-	78.7%
April	1277	1143	1306	1238	1337	712	1173	859	1,273	988	-17.6%	19.2%	-	77.6%
May	1438	1282	1339	1230	1327	687	1285	925	1,347	1,031	-7.2%	22.0%	-	76.5%
June	1456	1205	1454	1380	1493	603	1230	913	1,408	1,025	-6.2%	20.7%	-	72.8%
July	1423	1242	1946	1545	1552	680	1551	1111	1,618	1,145	27.8%	30.3%	-	70.7%
Aug														
Sept														
Oct	1460	1484	1651	1289	1647	598	1812	600	1,643	993				60.4%
Nov	1517	1388	1721	1587	1607	624	1919	780	1,691	1,095				64.7%
Dec	1522	1467	1786	1593	1661	543	1969	654	1,735	1,064				61.4%

Mean value	1,260	1,128	1,480	1,234	1,400	507	1,541	823	1,420	923	-1.9%	18.8%	00/99
Maximum	1,825	1,484	1,946	1,845	1,922	712	1,969	1,111	1,735	1,145			
Minimum	995	633	903	981	1,009	230	1,036	600	1,083	686			
max variat.	830	851	1,043	864	913	482	933	511	652	459			
in %	66%	75%	70%	70%	65%	95%	61%	62%	46%	50%			

Sample collection point :

1. Near Trench	: 6 Feet	2. Near Trench	: 40 Feet
3. Ridges & Furrows	: 6 Feet	4. Ridges & Furrows	: 40 Feet
5. Park Area	: 6 Feet	6. Park Area	: 40 Feet
7. Pond Area	: 6 Feet	8. Pond Area	: 40 Feet

Total hardness mg/l

	Piezometer location								Mean values		Variation m/m		Proportion
	1	2	3	4	5	6	7	8	Val 6 ft	Val 40 ft	6 ft	40 ft	
Jan-99	700	2130	2900	2940	7400	870	1960	1400	3,240	1,835			56.6%
Mar	590	1640	2100	2800	6400	880	1812	1384	2,726	1,676			61.5%
April	754	1683	2136	2643	7466	883	1696	1276	3,013	1,621			53.8%
May	950	1605	2052	2700	6800	877	1675	1012	2,869	1,549			54.0%
June	1025	1702	2435	2025	6925	910	1740	1187	3,031	1,456			48.0%
July	1425	1715	1935	1825	6650	950	1332	1267	2,836	1,439			50.8%
Aug	1930	1730	2123	2360	3803	933	1200	1326	2,264	1,587			70.1%
Sept	1446	1780	2070	1796	2773	983	1713	1346	2,001	1,476			73.8%
Oct	1706	1773	2183	2340	3290	953	2036	1206	2,304	1,568			68.1%
Nov	1360	2203	2323	2476	3120	803	1933	1300	2,184	1,696			77.6%
Dec	1160	2822	2662	2260	3362	929	1842	1395	2,257	1,852			82.1%
Jan-00	1083	2900	2560	1866	3303	1036	2013	1296	2,240	1,775	-44.7%	-3.4%	79.2%
Feb	1056	2700	2520	1550	3073	856	1556	1076	2,051	1,546			75.3%

Mar	957	2560	2270	1432	2715	917	1585	1282	1,882	1,548	-44.8%	-8.3%	82.3%
April	1643	2870	3293	2023	3310	1186	2293	2440	2,635	2,130	-14.4%	23.9%	80.8%
May	1350	2663	2220	1811	3343	966	2260	1746	2,293	1,797	-25.1%	13.8%	78.3%
June	1371	2894	2080	1816	2904	930	1990	1560	2,086	1,800	-45.3%	19.1%	86.3%
July	1350	2897	2220	1812	2905	975	1900	1685	2,094	1,842	-35.4%	21.9%	88.0%
Aug	1525	2967	2272	1545	2992	1095	1872	1632	2,165	1,810	-4.6%	12.3%	83.6%
Sept	1462	2675	2242	1262	3265	1025	1777	1237	2,187	1,550	8.5%	4.7%	70.9%
Oct	1165	2610	2015	880	3600	765	1557	885	2,084	1,285	-10.5%	-22.0%	61.7%
Nov	1127	2792	1960	1075	3655	767	1657	1095	2,100	1,432	-4.0%	-18.4%	68.2%
Dec	1164	2854	1974	1012	3336	938	1598	1002	2,018	1,452	-11.8%	-27.6%	71.9%
Mean value	1,230	2,355	2,285	1,924	4,191	932	1,782	1,349	2,372	1,640	-21.3%	3.0%	00/99
Maximum	1,930	2,967	3,293	2,940	7,466	1,186	2,293	2,440	3,240	2,130			
Minimum	590	1,605	1,935	880	2,715	765	1,200	885	1,882	1,285			
max variat.	1,340	1,362	1,358	2,060	4,751	421	1,093	1,555	1,358	845			
in %	109%	58%	59%	107%	113%	45%	61%	115%	57%	52%			

Sample collection point :

1. Near Trench	: 6 Feet	2. Near Trench	: 40 Feet
3. Ridges & Furrows	: 6 Feet	4. Ridges & Furrows	: 40 Feet
5. Park Area	: 6 Feet	6. Park Area	: 40 Feet
7. Pond Area	: 6 Feet	8. Pond Area	: 40 Feet

EC mmhos/cm

	Piezometer location								Mean values		variation		Proportion	
	1	2	3	4	5	6	7	8	Val 6 ft	Val 40 ft	m/m	6 ft	40 ft	40ft/6ft
Jan-99	10.7	5.3	7.5	6.3	14.7	1.8	10.0	4.2	10.7	4.4				40.8%
Mar	10.9	4.8	7.5	5.8	13.6	2.0	9.6	3.8	10.4	4.1				39.3%
April	10.1	5.0	5.9	6.2	13.7	1.9	9.4	4.1	9.8	4.3				44.0%
May	10.1	6.1	6.2	8.3	14.0	2.6	10.0	4.2	10.1	5.3				52.7%
June	11.1	5.6	6.7	8.6	13.1	2.3	10.5	3.9	10.4	5.1				49.3%
July	11.8	5.1	5.7	8.6	12.3	3.1	10.3	3.2	10.0	5.0				50.1%
Aug	12.7	4.8	6.1	6.8	11.1	1.9	8.6	4.1	9.6	4.4				45.6%
Sept	12.6	4.4	5.3	6.5	11.4	1.7	6.9	2.7	9.1	3.9				42.5%
Oct	11.6	4.5	5.7	8.3	10.8	1.7	8.9	3.1	9.3	4.4				47.8%
Nov	11.6	4.9	5.9	8.2	11.8	2.7	9.4	2.8	9.7	4.7				48.1%
Dec	11.6	5.9	6.2	9.7	12.8	2.6	10.0	3.0	10.1	5.3				52.3%
Jan-00	10.4	5.5	6.3	6.7	13.5	1.8	9.4	2.7	9.9	4.2	-8.5%	-5.7%		41.9%
Feb	9.3	5.8	6.3	6.8	13.9	2.6	9.1	3.1	9.7	4.6				47.3%
Mar	8.8	5.8	6.2	6.6	13.9	2.5	8.9	3.4	9.5	4.6	-10.0%	10.6%		48.4%
Apr	8.9	6.1	6.0	6.5	13.9	2.3	8.9	3.7	9.4	4.6	-3.6%	7.1%		49.1%
May	9.2	6.7	6.5	6.6	14.2	2.1	9.0	3.8	9.8	4.8	-3.4%	-10.6%		49.2%
June	9.2	6.7	5.4	7.7	14.3	2.6	7.9	4.1	9.2	5.3	-12.7%	3.0%		57.2%
July	10.2	7.7	6.5	9.1	12.3	2.6	9.9	3.9	9.7	5.8	-3.2%	13.8%		60.0%
Aug	10.3	8.0	6.8	8.0	12.7	2.7	10.0	3.5	10.0	5.6	3.3%	20.9%		55.8%
Sept	9.9	7.8	6.9	7.0	14.0	2.8	9.8	2.6	10.2	5.1	10.9%	24.0%		49.8%
Oct	9.4	7.8	6.8	5.8	14.0	1.8	9.8	2.1	10.0	4.4	7.5%	-0.8%		43.8%
Nov	9.2	7.5	6.7	6.3	14.7	1.8	9.8	2.3	10.1	4.5	4.0%	-4.3%		44.2%
Dec	8.7	7.3	6.5	5.9	14.9	1.8	9.9	2.4	10.0	4.3	-1.5%	-22.0%		43.5%
Mean value	10.4	6.0	6.3	7.2	13.3	2.3	9.4	3.3	9.8	4.7	-1.5%	3.7%		00/99

Maximum	12.7	8.0	7.5	9.7	14.9	3.1	10.5	4.2	10.7	5.8
Minimum	8.7	4.4	5.3	5.8	10.8	1.7	6.9	2.1	9.1	3.9
max variat.	4.0	3.6	2.2	3.9	4.1	1.4	3.7	2.1	1.7	2.0
In %	38%	59%	35%	54%	31%	64%	39%	63%	17%	42%

Sample collection point :

1. Near Trench	: 6 Feet	2. Near Trench	: 40 Feet
3. Ridges & Furrows	: 6 Feet	4. Ridges & Furrows	: 40 Feet
5. Park Area	: 6 Feet	6. Park Area	: 40 Feet
7. Pond Area	: 6 Feet	8. Pond Area	: 40 Feet

Mean values of analytical parameters

	TDS		Chloride		Sulphate		Total hardness		EC mmhos/cm	
	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft	6 ft	40 ft
Jan-99	6,980	2,850	1,185	465	1,624	686	3,240	1,835	10.7	4.4
Fev										
Mar	6,760	2,660	1,113	468	1,546	754	2,726	1,676	10.4	4.1
April	6,351	2,795	1,182	461	1,497	799	3,013	1,621	9.8	4.3
May	6,552	3,450	1,473	678	1,444	804	2,869	1,549	10.1	5.3
June	6,739	3,321	1,231	603	1,496	814	3,031	1,456	10.4	5.1
July	6,526	3,268	1,384	769	1,168	798	2,836	1,439	10.0	5.0
Aug	6,256	2,854	1,603	753	1,090	850	2,264	1,587	9.6	4.4
Sept	5,886	2,503	1,368	600	1,617	1,041	2,001	1,476	9.1	3.9
Oct	6,017	2,875	1,406	664			2,304	1,568	9.3	4.4
Nov	6,297	3,026	1,520	758			2,184	1,696	9.7	4.7
Dec	6,595	3,446	1,655	758			2,257	1,852	10.1	5.3
Mean 1999	6,451	3,004	1,374	634	1,435	818	2,611	1,614	9.9	4.6
Maximum 99	6,980	3,450	1,655	769	1,624	1,041	3,240	1,852	10.7	5.3
Minimum 99	5,886	2,503	1,113	461	1,090	686	2,001	1,439	9.1	3.9

max variat.	1,094	948	543	307	535	355	1,240	412	1.7	1.5		
in %	17%	32%	39%	48%	37%	43%	47%	26%	17%	32%		
Jan-00	6,435	2,698	1,672	696	1,083	931	2,240	1,775	9.9	4.2		
Feb	6,279	2,967	1,592	709	1,117	878	2,051	1,546	9.7	4.6		
Mar	6,144	2,974	1,393	638	1,170	921	1,882	1,548	9.5	4.6		
Apr	6,128	3,007	1,374	675	1,273	988	2,635	2,130	9.4	4.6		
May	6,338	3,118	1,390	740	1,347	1,031	2,293	1,797	9.8	4.8		
June	5,982	3,422	1,329	737	1,408	1,025	2,086	1,800	9.2	5.3		
July	6,322	3,790	1,270	784	1,618	1,145	2,094	1,842	9.7	5.8		
Aug	6,470	3,609	1,334	753			2,165	1,810	10.0	5.6		
Sept	6,605	3,291	1,384	699			2,187	1,550	10.2	5.1		
Oct	6,508	2,851	1,426	573	1,643	993	2,084	1,285	10.0	4.4		
Nov	6,561	2,901	1,341	599	1,691	1,095	2,100	1,432	10.1	4.5		
Dec	6,497	2,826	1,323	545	1,735	1,064	2,018	1,452	10.0	4.3		
Mean 2000	6,356	3,121	1,402	679	1,408	1,007	2,153	1,664	9.8	4.8		
Maximum	6,605	3,790	1,672	784	1,735	1,145	2,635	2,130	10.2	5.8		
Minimum	5,982	2,698	1,270	545	1,083	878	1,882	1,285	9.2	4.2		
max variat.	623	1,093	402	239	652	267	753	845	1.0	1.7	Global	
in %	10%	35%	29%	35%	46%	27%	35%	51%	10%	35%	variation	
Mean value	6,401	3,065	1,389	658	1,420	923	2,372	1,640	9.8	4.7	6 ft	40 ft
Var.00/99	-1.5%	3.8%	2.0%	6.8%	-1.9%	20.5%	-19.3%	3.0%	-1.5%	3.8%	-4.4%	7.6%
Total 00/99	1.2%		4.4%		9.3%		-8.1%		1.2%		1.6%	