DEWATS IN AUROVILLE

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The use of horizontal planted filters for decentralised wastewater treatment in Auroville, an overview and description.

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Abstract

The Auroville community, situated in South India near Pondicherry, has been experimenting with wastewater recycling systems for over fifteen years. During that time pilot systems were built, experience was gathered and the operating skills with such plants improved.

From 1995 to 1998 Auroville participated in a European Union funded project on Decentralised Wastewater Systems (DEWATS) through which we were able to receive expertise and upgrade our knowledge on planted filters or root zone treatment systems. Four specially designed research plants were constructed and tested under the project. At present Auroville operates more than 35 DEWAT systems for recycling both 'grey' and 'black' domestic wastewater from small individual households, community plants and small industrial type systems producing effluent with similar characteristics to domestic wastewater.

In this paper four wastewater plants are described, one is a small individual household plant for four persons, two are community plants for 20 and 200 persons and one is a recycling plant from an industrial unit specialized in silk painting.

Keywords

Septic tank, Imhoff tank, Baffled septic tank reactor, Planted gravel filter.

I. INTRODUCTION.

Auroville is situated on a large plateau, about 65 metres above sea level sloping gently towards the Bay of Bengal. The absence of rivers or major lakes makes it necessary to draw water needs from underground for its present population of 1500 members. If the projected growth rate towards a small city of 50.000 people is to be achieved and sustained, wastewater treatment will be an essential part of the overall city water use.

After having successfully carried out the reforestation of 3500 acres of wasteland with the planting of nearly 3 million trees, a next step was researching and developing natural techniques for wastewater recycling and rainwater harvesting.

During the mid eighties the first experiments with recycling of wastewater took place. Absence of specialised literature and proper guidance made the small household pioneer plants more of an exercise in trial and error learning. A dedicated group maintained the interest in the subject and relied for expert advice and information mainly on visiting experts from western countries. During the nineties the preferred choice for recycling domestic wastewater shifted towards systems called planted gravel filters, because with such natural functioning systems one could obtain a high quality effluent. The large land space requirements for these kind of systems was not viewed as a disadvantage since these kind of treatment systems can be beautifully landscaped into any environment, even urban, as is shown by urban treatment plants situated all around the world.
Through a European Union project executed by BORDA (Bremen Overseas Research and Development Association), Auroville was given the opportunity to research and develop horizontal planted filters for a wide variety of domestic wastewater treatment. Access to experts in the technology proved extremely beneficial for further growth and development.

II. HORIZONTAL PLANTED FILTER FOR INDIVIDUAL HOUSEHOLDS.

Most Auroville households dispose of their wastewater with a septic tank connected to a soak pit. The most frequent complaint concerns the overflowing of the soak pit. No matter how big, after a while the soak pit gets lined with a thin impermeable layer, which prevents the draining of the incoming wastewater. Water stagnation, clogging and ultimately overflow with a foul smell is the result. Emptying or even making a new soak pit is often necessary.

Small recycling systems designed for households from four to eight persons based on a primary treatment with a settling tank or septic tank, a secondary treatment consisting of a horizontal planted filter and an optional tertiary treatment with several polishing tanks have the major advantage that all the wastewater is **reusable** e.g., for irrigation, at the end of the process. A well functioning planted filter has a subsurface flow and is covered with a top layer of sand to eliminate the smell completely. The effluent from the planted filter can further be improved through a series of open water bodies called polishing tanks. A well-designed plant for continuous daily operation can operate on a minimal maintenance routine.

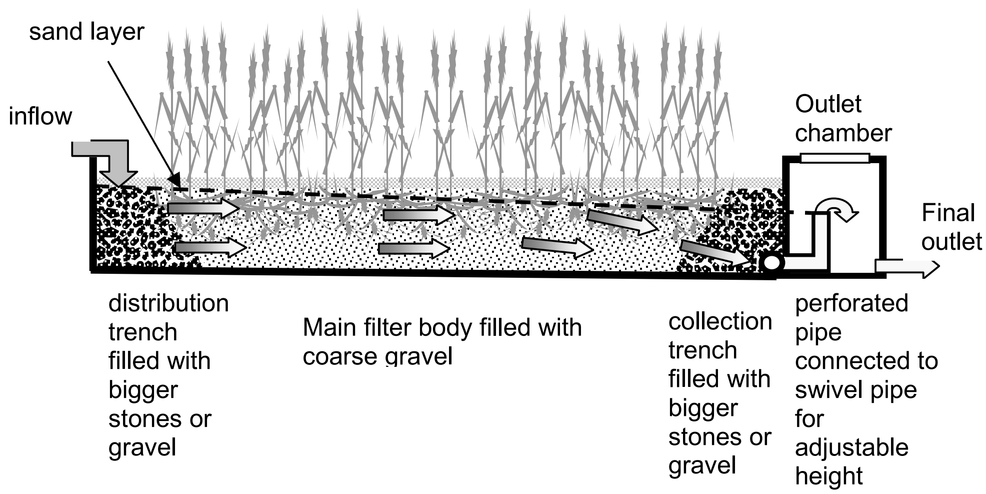
About ten small-scale individual household plants have been functioning within Auroville for several years now. All of them are built next to the houses. Recycled wastewater is used for irrigation of gardens, fruit trees or is allowed to recharge the groundwater table.

1. Centre Field planted filter for household of 4 persons.

The treatment plant is incorporated right next the house and blends fully into the garden landscape. Being one of the first pilot plants, several improvements were introduced over the years, especially in the composition of the filter material.
The initial filter material, consisting of limestone blocks, pebbles and a fine sand layer was subsequently changed to a full pebble filter bed. This removed the problems of clogging observed at the inlet with the limestone layer and the slow filtration rate of the sand layer during increased water use from the washing machine.
The major requirement from the household members was for an odour free operating **planted filter**, which, despite initial drawbacks, has been achieved during the entire five-year operating period. The presence of fish, frogs and dragonflies in the polishing pond is beneficial for the whole aquatic eco-system and keeps a firm control on the mosquitoes. The presence of duckweed, water hyacinths, lotus plants and water lilies replicates a natural functioning system and is also aesthetically pleasing.

Principle of the Horizontal Planted Filters

1. Continuous oxygen supply to the upper layers only.
2. Anaerobic conditions in the lower parts of the filter.
3. Roots of plants provide favorable environment for bacteria diversity.



Planted horizontal gravel filters are also referred to as Subsurface Flow Wetlands (SSF), Constructed Wetlands or Root Zone Treatment Plants. The horizontal planted filter is simple by principle and requires almost no maintenance. However, design and construction requires a thoroughly understanding of the treatment process and knowledge of the filter medium.

Planted filters are suitable for pre-treated (pre-settled) domestic or industrial wastewater of a COD content not higher than 500 mg/l. Wastewater must be pre-treated especially in respect to suspended solids, given the fact that the biggest problem in ground filters is **clogging** of the filter media.

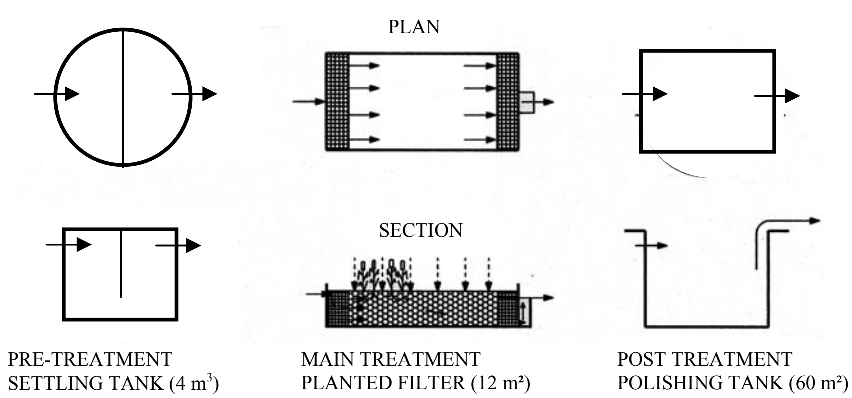
The filter bed should not be deeper than the depth to which plant roots can grow (30 – 60 cm), as water will tend to flow faster below the dense bed of roots. Shallow filters are more effective compared to deeper beds of the same volume. To prevent percolation of wastewater into the ground, the bottom of the filter must be sealed. While the top part of the filter media in a planted filter is kept horizontal, the constructed bottom slopes down from inlet to outlet by preferably 1%.

Planted filters are covered by suitable plantation, using any plant, which can grow on wastewater and whose roots go deep and spread wide. Phragmites australis (reed) is considered to be the best plant because its roots form horizontal rhizomes that guarantee a perfect root zone filter bed.

2. Plant overview.

Start of operation	1995
Retaining structure	Ferrocement
Users (Person Equivalent)	4 Persons
Estimated water use	700 ltrs. / day
Wastewater type	Domestic
Total plan area of the system	82 m²
Pre-treatment	Settling tank of 4 m^3, separation baffle for solids and liquid
Main treatment	Horizontal planted filter of 12 m² / depth of 60 cm
Post treatment	Polishing tank (60 m²) divided in three sections, ending with collection tank (4 m^3)
Filter media	Pebbles / top layer of sand
Plant-Cover	Canna Indica and Arundo Donax
Mode of disposal	Irrigation of fruit trees, orchard and flower garden

3. Schematic plant lay out.



4. Water analyses

Parametres	Outflow planted filter	Outflow polishing tank
COD	66 mg/l	56 mg/l
E Coli	2400 / 100 ml	23 / 100 ml

5. Observations

- The small difference in COD between the outlet of the planted filter and the polishing tank can be due to the production of algae (phytoplankton), one of the vital elements in the aquatic life chain.
- The efficiency of the polishing tank is evidenced by a 99% reduction in the bacteriological count (E. Coli), which makes the effluent fit for any water utilization in the bio-system (landscaping, aquaculture, irrigation).
- The sludge from the settling tank was removed twice during a 5 year period with a sludge tanker and brought for further treatment through composting. This is a **last** and **necessary** link in the long chain of procedures for achieving a **full recycling cycle** of man-made waste.

II. HORIZONTAL PLANTED FILTERS FOR COMMUNITY USE.

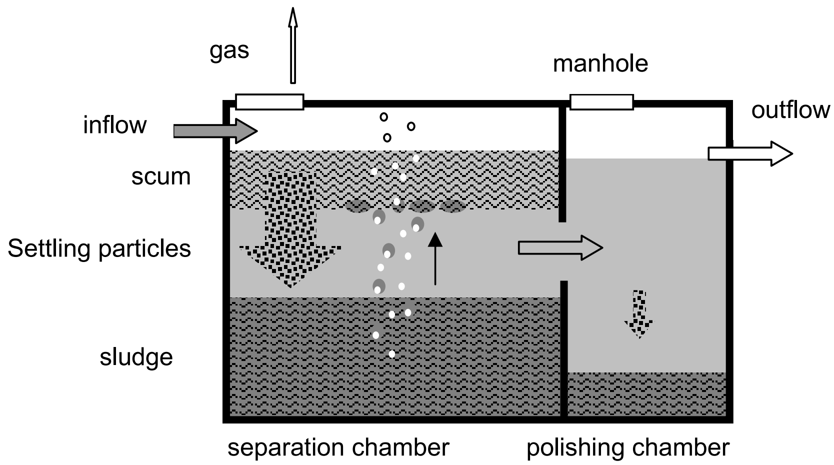
A. 1. Samasti planted filter for 20 persons.

Samasti community comprises 7 residential houses with a present population of 20 persons. The normal practice of individual septic tanks was abandoned for a common wastewater purification plant, situated right in the middle of the housing complex. Being one of the earlier pilot plants, the architect opted for a lagooning type purification system. Space problems reduced the treatment system to rather minimal operational dimensions. All wastewater was collected in a common settling tank and discharged through a single outlet in a series of four long shallow open water channels, on which water hyacinths were growing. Using data from an expert it was assumed that from the second channel onwards the wastewater would be sufficiently purified to allow fish to thrive. The whole experiment proved difficult to sustain and ultimately the residents opted for a planted filter system, which was implemented and improved upon in a later phase.
At present wastewater is pre-treated with a **septic tank** and a horizontal planted filter. A large collection tank is placed at the end and functions also as a storage tank, from which the recycled wastewater is pumped out for garden use.

The use of a planted filter solved the earlier persistent problems of foul smell and mosquito infestation.

Principle of the Septic Tank

1. Sedimentation and floatation
2. Fermentation of bottom sludge



The septic tank is the world's most common, small-scale decentralised treatment plant. It is compact, robust and in comparison to the cost of its construction, extremely efficient. It is basically a sedimentation tank in which settled sludge is stabilised by anaerobic digestion. Dissolved and suspended matter leaves the tank more or less untreated.

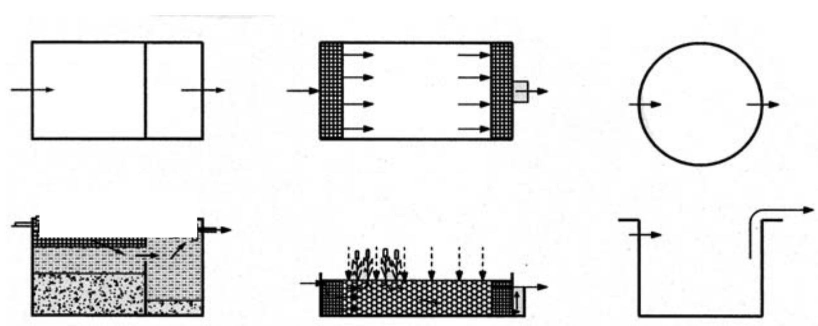
Two treatment principles, a mechanical treatment by sedimentation and a biological treatment by contact between fresh wastewater and active sludge compete with each other in the septic tank. Optimal sedimentation takes place when the flow is smooth and undisturbed. Biological treatment is optimised by quick and intensive contact between new inflow and old sludge, particularly when the flow is turbulent. The way the new influent flows through the tank decide which treatment effect predominates.

A septic tank consists minimum of 2, or 3 compartments. The first compartment occupies about half the total volume because most of the sludge and scum accumulates here. The following chamber(s) are provided to calm down the turbulent liquid. They are of equal size and occupy the other half of the total volume. Scum accumulates and must be removed regularly every two years. Scum does not harm the treatment process as such, but it does occupy tank volume.

2. Overview of plant.

Start of operation	1998
Retaining structure	Concrete and brick walls
Design Capacity	4 m^3 / day
Users (Person Equivalent)	20 Nos.
Wastewater type	Domestic
Total plan area of the system	35 m^2.
Pre-treatment	Septic tank (9,6 m^3)
Main treatment	Horizontal planted filter of 21,75 m^2, depth of 60 cm and 40 cm
Post treatment	Water tight collection tank of 10 m^3 with water hyacinths
Filter media	Pebbles, granite stones
Plant species	Arundo donax
Mode of disposal	Reuse for irrigation purposes

3. Schematic plant lay out.



SEPTIC TANK (9,6 m^3) PLANTED FILTER (21,15 m^2) OPEN TANK (10 m^3)

SEC

4. Water analyses

	Parametres	Inflow planted filter	Outflow planted filter
1	pH	-	7.5
2	EC	-	870
3	COD	340	37
4	BOD	75	21
5	Total Kjeldahl Nitrogen	72	53
6	E. Coli.		75x10^2

(EC - µS. COD, BOD_5 at 20°C, TKN – mg/l. TC, EC - number/100 ml)

5. Observations

- The treatment plant is interesting given the available area for filter purification of $1m^2$ per person, which is minimal. Despite this disadvantage the effluent produced is odourless and foam formation at the outlet of the treatment system has reduced considerable, a feature observed when the plant cover became fully established.
- The 10 cm thick sand layer placed on top of the filter media, used to prevent smell, has the tendency to shift downwards into the pebble layer and over time hampers the smooth flow of wastewater. By placing an intermediary thin layer of fine granite chips as a buffer, this problem was solved completely.
- The high COD/BOD5 ratio could be due to the content of non-biodegradable substances like detergents used for washing clothes.

B. 1. Invocation planted filter, designed for 200 persons.

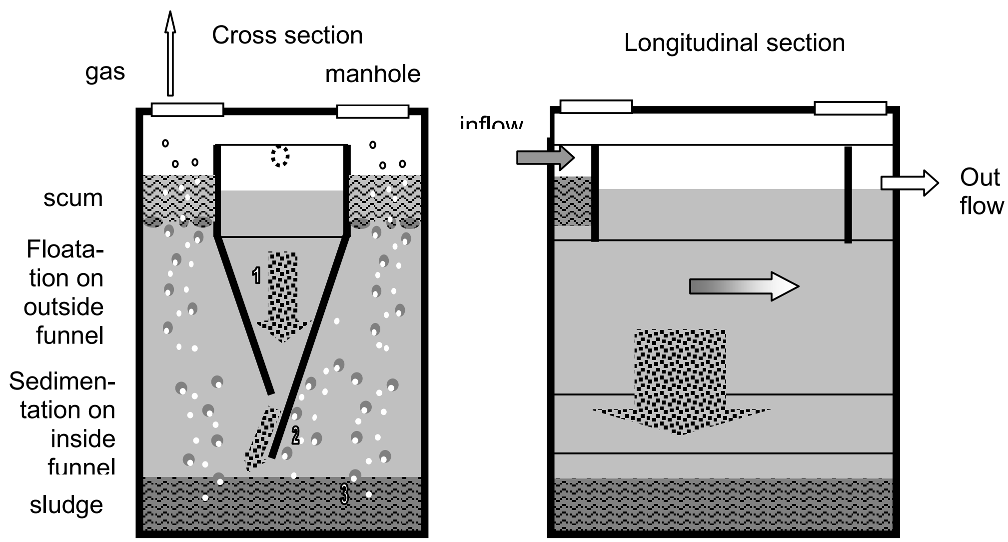
This treatment plant serves three new communities, with a present population of 57, who opted to invest in a common wastewater treatment plant. Further expansion plans can accommodate up to 200 residents.
All three communities are equipped with an **Imhoff tank** for pre-treatment. Such a tank is been considered useful for loads above 3 m^3/day. The three Imhoff tanks connect to a single inlet box for feeding the planted filter, which is divided into two separate operating parts. Each has a middle-feeding lane, from where wastewater travels towards the sides, where it is collected on both ends and further canalised towards a huge polishing tank. Two fountains are installed for oxygenation purpose.

2. Plant Overview

Start of operation	1998
Retaining structure	Bottom: concrete, walls: bricks
Design Capacity	10 m^3 / day
Users (Person Equivalent)	57 Nos.
Wastewater type	Domestic
Total Plan area of the system	614 m^2
Pre-treatment	3 Imhoff tanks combined capacity of 84 m^3
Main treatment	Horizontal planted filter of 400 m^2, depth of 60 cm
Post treatment	Polishing tank of 190 m^2,171 m^3
Filter media	Granite stones, pebbles, sand
Plant species	Arundo donax
Mode of disposal	Reuse for irrigation purposes

Principle of the Imhoff – Tank

1. Sedimentation
2. Protection against up flow of sludge particles
3. Fermentation of bottom sludge

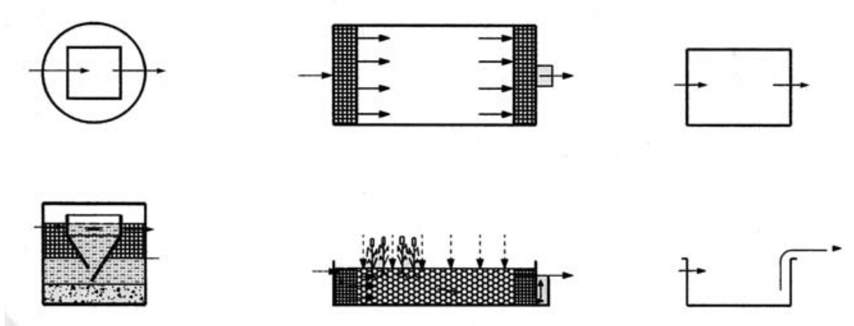


Imhoff or Emscher tanks are typically used for domestic or mixed wastewater flows above 3 m^3/d. The tank consists of a settling compartment above the digestion chamber. Funnel-like baffle walls prevent up-flowing sludge particles from getting mixed with the effluent and from causing turbulence.

The effluent remains fresh and odourless because the suspended and dissolved solids do not have an opportunity to get in contact with the active sludge to become foul and bad smelling. Tanks are designed with a retention period of less than two hours during peak loads in order to ensure this effect. Additional baffles to reduce velocity at the inlet and to retain suspended matter at the outlet are also used as design features.

Desludging is necessary at regular intervals. Leaving some bottom sludge behind in the tank helps the starting up process i.e., decomposition of settled sludge.

3. Schematic plant lay out



IMHOFF TANK (33 m^3) | PLANTED FILTER (400 m^2) | POLISHING TANK 190 m^2)

4. Water analyses

	Parametres	Inflow planted filter	Outflow planted filter
1	pH	-	7.2
2	EC	-	530
3	COD	162	63
4	BOD	96	25
5	Total Kjeldahl Nitrogen	31	20
6	E. Coli.	$46x10^8$	$24x10^2$
(EC - µS. COD, BOD_5 at 20°C, TKN – mg/l. TC, EC - number/100 ml)			

5. Observations

- The treatment plant operates next to the apartment block and is free from any smell and mosquitoes.
- Imhoff tanks have to be emptied at more regular intervals than septic tanks. Due to the reduced user number in comparison with the original design this has only been done once since the plant began operating.
- Clogging problems occurred once with the wastewater outflow devices in the feeding lane due to the excessive deposit of human hair.
- Twice a year the reed plants are cut and used for composting purposes.
- The excellent results in COD/BOD reduction show that the plant is functioning well and eliminates most of the incoming chemicals.

III. HORIZONTAL PLANTED FILTER FOR SMALL SCALE INDUSTRIAL UNIT.

1. Auromode planted filter

Auromode is one of the larger tailoring export units in Auroville. Continuous expansion has taken place since the operation started in 1986. The increased workforce taxed the initial existing septic tank recycling system to the maximum and proved insufficient on many accounts.
The main reason for switching to a natural wastewater treatment system was the possibility to use the recycled water for the surrounding lawn and garden irrigation, thereby saving on a scarce resource, while also reducing the electricity costs.
The first conversion was an open type lagooning system, which was dysfunctional because of restricted space and wrongly applied operation principles. The smell of wastewater was all pervading, especially during lawn watering with the treated water.
The second attempt converted the existing lagooning basin into a modified covered baffled reactor. The effluent quality improved drastically but the smell remained, due to the anaerobic digestion. It was decided to add a planted filter to get rid or at least reduce the smell. The experiment proved successful.

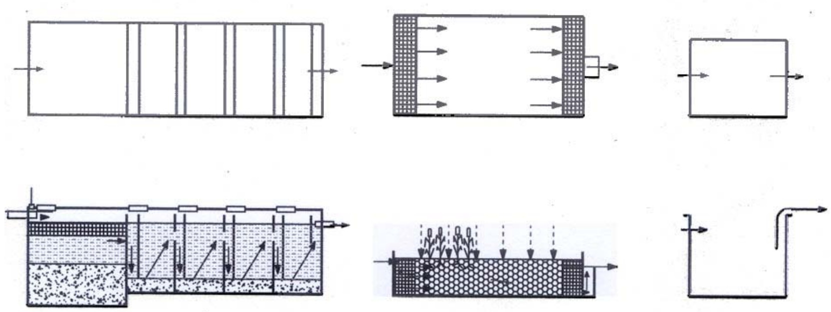
At present three **baffled reactors** are operating in the compound: one for the toilet blocks serving the labour force, another for an administrative building, and one for a new unit housing the silk painting production, which necessitates the use of chemicals for painting and the rinsing and washing of cloth.

All three baffled reactor systems connect to a common planted filter situated prominently next to the administrative building and built above ground. The effluent is collected in an open underground water tank from where it is emptied daily for irrigation.

2. Auromode plant overview

Start of operation	1998 - 2000
Retaining structure	Concrete and brick walls
Design capacity	6 m^3 / day
Users (Person Equivalent)	Total labour force of 130 persons
Wastewater type	Domestic, Industrial
Total plan area of the system	130 m^2
Pre-treatment	3 baffled reactors of combined 72 m^3
Main treatment	Horizontal planted filter of 77m^2, depth of 40 cm
Filter media	Pebbles, top layer of sand
Plant-species	Canna Indica
Mode of disposal	Reuse for irrigation purposes

3. Schematic plant lay out



BAFFLED REACTOR (20 m³) PLANTED FILTER (77 m²) OPEN TANK (12 m3)

4. Water analyses

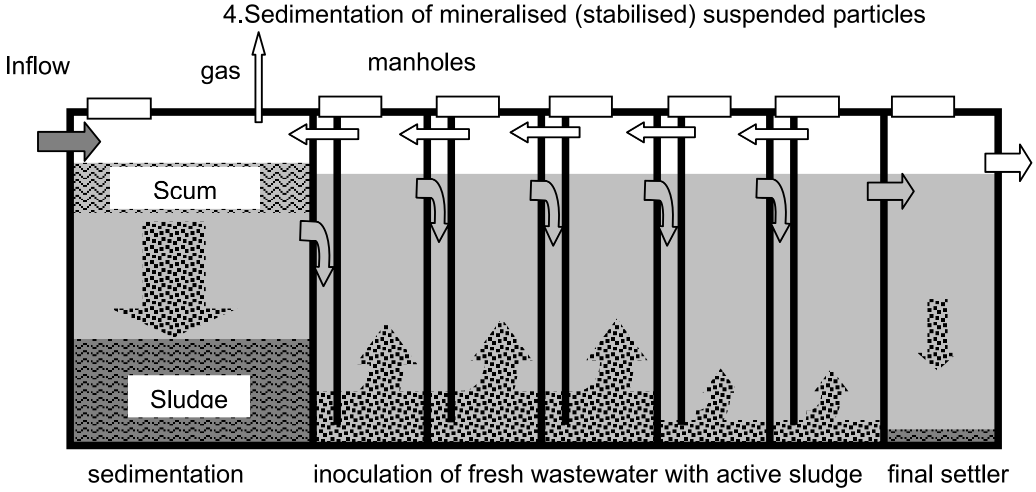
	Parametres	Inflow planted filter	Outflow planted filter
1	pH		7.7
2	EC		1960
3	COD	97	75
4	BOD	29	11
5	Total Kjeldahl Nitrogen	0	45
6	E. Coli.	$24x10^3$	$46x10^2$
(EC - µS. COD, BOD_5 at 20°C, TKN – mg/l. TC, EC - number/100 ml)			

5. Observations

- The Auromode experiment has a twofold long-term aim: to test a relative unknown treatment design, the baffled reactor, and to verify the potential of smell reduction through the use of a smaller designed planted filter. The absence of any smell was achieved soon after the wastewater got channelled through the planted filter.
- The results at the outlet of the baffled reactor are excellent.
- The planted filter shows a reduction of 60% BOD, while the COD shows only a reduction of 20% which could be explained by the fact that the unit is still using some non-biodegradable substances.

Principle of Anaerobic Baffled Reactor

1. Sedimentation / floatation of solids
2. Anaerobic digestion of suspended and dissolved solids through contact with sludge
3. Anaerobic digestion (fermentation) of bottom sludge
4. Sedimentation of mineralised (stabilised) suspended particles



A baffled reactor or baffled septic tank is a design incorporating an initial settling tank followed by at least four and upto ten, narrow chambers or compartments all of them fitted with a baffle wall to force the wastewater in every chamber **to flow downwards**. The active sludge that is washed out from one chamber is trapped in the next. The compartments placed in series help to digest difficult and slow degradable substances.

The up-flow velocity should never be more than 2m/h. Equal distribution of inflow and widespread contact between the fresh incoming influent with the active sludge present in the reactor in order to ensure quick inoculation for digestion are important process features.

The baffled reactor is suitable for all kinds of wastewaters, including domestic. Its efficiency increases with higher organic load. It is the high efficiency answer to the low efficiency septic tank, because simple and efficient operation goes along with easy construction and low cost. Treatment performance are in the range of 65% to 90% COD removal (70% to 90% for BOD).

IV. FUTURE DIRECTIONS.

The first phase of Auroville's quest for managing its wastewater, consisting of information gathering, system familiarization and training of competent personnel seems to move towards its successful end.
A second phase is announcing itself where system optimisation will be the main criteria. Although space is not yet an important factor, costs of construction becomes an increasingly dominant aspect. With increasing growth some treatment systems will have to make do with restricted space. In this case the long-term observation of relatively "under designed" systems like the Samasti plant becomes interesting, not only for Auroville, but also for outside urban situations.
Trying to optimise space requirements for acquiring maximum efficiency in organic and bacteriological reduction will be a top priority in our further research and development.

The exploration of novel or less-known treatment systems, like the baffled reactor and Effective Micro-organisms (EM), or access to new technologies, or the possibilities and eagerness towards implementation, are some of the areas where Auroville's creative joy and love for experimentation can be used for the benefit of all who aspire towards a more sustainable future.

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