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Waste Water Treatment by Phyto-Remediation Technique

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Abstract: The term "Phyto-remediation Technique" encompasses the life interactions of bacteria, the roots of the wetland plants, soil, air, sun and water. This type of treatment is an engineered method of purifying waste water as it passes through artificially constructed wetland area. It is considered as an effective and reliable secondary and tertiary treatment method. The pollutants are removed by various physical, chemical and biogeochemical processes like sedimentation, absorption, and nitrification as well as through uptake by wetland plants. These systems are reported to be most suitable for schools, hospitals, hotels and for smaller communities. The aim of this project is to study the effectiveness of the wetland plant Typha in the treatment of waste water generated in the SRM University premises. Pilot wetland units were constructed in the campus grounds. Typha species were grown in the pilot scale wetland unit and subjected to treatment using waste water obtained from the hostels and other campus buildings. The raw waste water and treated waste water were collected periodically and tested for quality. It is seen that this pilot unit is reducing the concentrations of various wastewater characteristics like TDS, TN, BOD and COD by 15%, 40%, 65% and 60% (approx.) respectively. There is a cost saving of 80% in O&M by using constructed wetlands. The constructed wetland for an equivalent influent discharge saves 57% over conventional design. Phyto-remediation technique achieves standards for tertiary treatment with no operating costs, low maintenance costs, enhances the landscape, provides a natural habitat for birds, and does not have any odour problem.

Keywords: *Phyto-remediation, Wetland, anthropogenic, BOD, COD, TDS*

1. Introduction

Major environmental pollution occurs due to the outflow of effluents from various domestic and industrial sources. The water of rivers, lakes and oceans is nowadays being polluted on a large scale Water pollution also interferes with the growth of organisms living in the water bodies, thus retarding the natural purification process caused by such organisms.

Some of the suitable wastewater treatment processes for domestic wastewater include biological treatment processes such as activated sludge, trickling filter, and rotating biological contractor systems. However, these treatment systems have high operation, investment costs, difficult to operate and maintain with stable removal efficiencies.

Also, the treated wastewater from these types, might require further treatment with a tertiary treatment process, such as a polishing pond, oxidation pond, or constructed wetland (CW) to improve the treated wastewater quality [1].

Constructed wetland systems are shallow water bodies with wetland vegetation that utilize the plant's uptake processes to remove pollutants from waste water. They also result a rich microbial community that brings about the biochemical transformation of pollutants.

1.1. Constructed Wetland Classification

Flow conditions distinguish the three types of constructed wetland:

1) Surface flow or free water surface constructed wetland.
2) Subsurface horizontal flow constructed wetland
3) Vertical flow constructed wetland.

These types also differ from one another in system layout the removal efficiency of certain pollutants, area requirements, technical complexity, applications and costs. Each type is explained briefly in the sections that follow.

1.1.1 Surface flow Constructed Wetland (SFCW) or free water surface Constructed Wetland (FWSCV)

The surface flow or free water surface wetland technology is strongly related to natural wetlands. Wetlands have been used for wastewater discharge for as long as sewage has been collected. After monitoring of some of the discharges began, an awareness of the potential of water quality purification started to emerge. The "technology" arose in the 1970s in North America with the ecological engineering of natural wetlands for waste water treatment. This type of constructed wetland consists of large, shallow lagoons that contain submerged, emergent or floating plant species. The microorganisms responsible for biological treatment of the wastewater form bio films on the stems and leaves of the plants. These system scan be used for secondary treatment of wastewater, but they are most commonly used as tertiary treatment-that is, to remove nutrients to prevent eutrophication (algae growth) in the receiving water body [2].

1.1.2. Subsurface horizontal flow Constructed Wetland (SSHFCW)

This technology was first investigated in Germany in the 1960s, but it was only about few years ago that constructed wetland systems were applied to the decentralized wastewater treatment of single houses, institutions, and small to medium-size settlements. In the meantime, many industrialized countries developed their OWII national design standards.

This type of constructed wetland essentially consists of shallow basins tilled with coarse sand or gravel as filter material. Locally available wetland plants are grown on the surface of the filter bed, and pre-treated wastewater flows through the bed horizontally below the surface [3-6].

1.1.3. Vertical flow constructed wetland (VFCW)

The vertical flow type of constructed wetland, developed as an alternative to the SSHF constructed wetland consists of shallow sand filter beds. A distribution system on the surface of the constructed wetland allows the wastewater to percolate vertically through the unsaturated filter bed. Plants support the vertical drainage process. An important feature of this type is the intermittent hydraulic loading with resting intervals between the single discharges to the vertical bed. This intermittent loading provides an effective *aeration* mechanism because pores of the filter bed refill with oxygen during the intervals.

As a result, high nitrification rates can be achieved in the filters. De-nitrification can be carried out by recirculating the effluent into the primary treatment unit (septic tank) to eliminate nitrogen. Vertical flow constructed wetlands are also used for sludge dewatering and stabilization ("sludge humification").

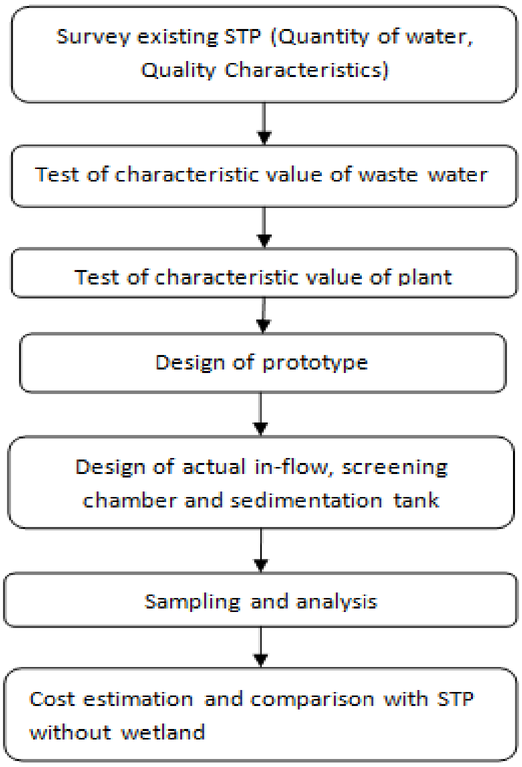
Processes occurring in sludge humification beds differ widely from constructed wetlands for wastewater treatment. Fig.2.2 depicts the vertical flow.

To study the efficiencies of different types of Constructed wetlands, each type namely, Horizontal flow constructed wetland, Vertical flow constructed wetland and integrated flow constructed wetland has been used for the treatment of wastewater.

2. Material and Methodology

Survey of the existing sewage treatment plant was conducted for the quantity of water treated and the quality characteristics. The characteristics of raw wastewater was analyse using Standard methods for analysis of parameters. Native soil of plant was taken for experiments from SRM University where it is unaffected by the anthropogenic activity for a long period of time. Design of prototype is done by using Tennessee Valley Authority (TVA) method.Design of actual inflow using University of New Hampshire' water Centre's design procedure. Design of Screen Chamber and Sedimentation Tank. The characteristics of treated wastewater was analysed using Standard methods for analysis of parameters. Sampling and analysis according to Standard Methods for Water and Wastewater Examination. The cost was estimation and compared with Standard Wastewater treatment plant.

Table 1: *Methodology*



2.1 Site Selection

The horizontal, vertical and integrated type constructed wetland system employed was located in SRM University, Chennai, India. The site is at an altitude of 33 m above mean sea level at latitude 12° 42' N and longitude of 80°02' E. The climate is characterized by a short rain period from mid-July to the end of September, a long rain period from October to mid-January, and a long dry period from mid-January to mid-July. The climate is tropical, with a temperature variation of 19° - 42° C and average annual rainfall of 1330mm [7].

2.2 Method of Sample

2.2.1 Domestic Waste water

Domestic wastewater was collected from a sewage treatment plant from SRM University and then analysed in the experimental setup. Wastewater collected from the inlet chamber of S.T.P. No.1 of SRM University, Kattankulathur as a grab sampling method. The characteristics wastewater was analysed using Standard methods for analysis of parameters [8].

2.2.2 Plant Sample

Native plant was taken for experiments from SRM University where it is unaffected by the anthropogenic activity for a long period of time, Up to 1 feet depth as a grab sampling method. Amount of plant was taken such that the powdered form of plant weighed *5* grams. Sample collection date, time and mode arc given in the table.

Table 2: *Sample collection details*

Sample	Collection Date	Time	Mode of Collection
Soil	15/01/2014	2:30 PM	Grab
Plant	18/01/2014	11 AM	Grab
Raw waste water	20/02/2014	2 PM	As per APHA Guidelines
Treated waste water	22/02/2014	2 PM	As per APHA Guidelines

3. Result and Discussion

3.1 Planning and Preparation

In order to perform the retreat of wastewater by lab scale constructed wetland, proper planning and preparation is required. There are three types of lab scale constructed wetland (prototypes) were used for this purpose namely

1) Integrated constructed wetland
2) Vertical constructed wetlands
3) Horizontal constructed wetland.

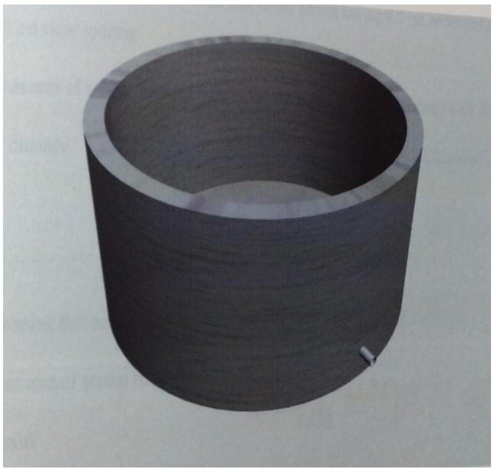
The various stages of preparation of these prototypes are given below:

3.1.1 Integrated Constructed Wetland

A circular shaped lab model made of concretes as prepared for integrated constructed wetland. Three layers of soil, sand and gravel with uniform thickness were used as a filter media. The thickness of these three layers is 10cm. The detail of this wetland is given in the following table.

Table 3: *Dimension Detail of Integrated Constructed Wetland*

Inner Diameter	80 cm
Outer Diameter	90 cm
Thickness of wall	5 cm
Height	48.5cm



3.1.2 Vertical Constructed Wetland

Same as integrated wetland, a circular shaped lab model made of concrete was prepared of vertical constructed wetland. Three layers of soil, sand and gravel with uniform thickness were used as a filter medium. The thickness of these layers was 10 cm. The other detail of this wetland is given in the following table.

Table 4: *Dimension Details of Vertical Constructed Wetland*

Inner Diameter	83 cm
Outer Diameter	92 cm
Thickness of wall	4.5 cm
Height	48.5cm

3.1.3 Horizontal Constructed Wetland

A rectangular lab model made of plastic was prepared for horizontal constructed wetland. Three layers of soil, sand and gravel were used as a filter medium. The thickness of these layers was 7 cm. The other detail of this wetland is given in the following table 5.

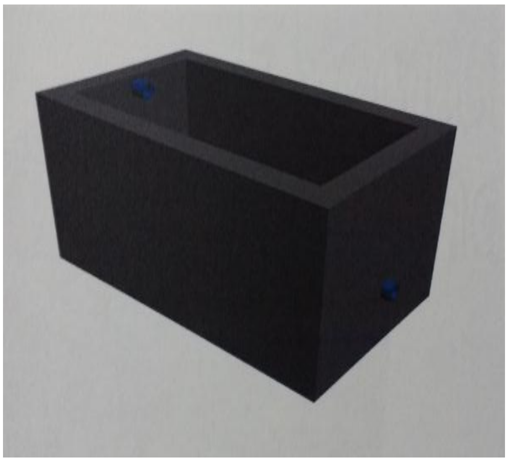


Table 5: *Dimension Details of Horizontal Constructed Wetland*

Length	60 cm
Breath	40 cm
Depth	30 cm

3.2 Design of Constructed Wetland

3.2.1 Prototype Design

Numerous design procedures are in existence for the design of constructed wetland. Some of them are the plug flow method, environmental protection agency (EPA) method and the Tennessee valley authority (TVA) method [9]. The plug flow method considers the design from the view point of pollutant transport, which is not assumed to be necessary for flow In Constructed wetland. The EPA and TVA method among other consider the hydraulic aspects of flow. The TVA method is suited for small flows only as it mainly calculates the cross sectional area based on the organic loading and design flow. When the influential volume is High , this method gives abnormally high methods for the width of the wetland unit. The EPA method has been adopted in many instances and it designs the wetland based on Darcy's law. This method is good for high volume flows as it gives unrealistic design lengths for experimental discharges. In this study, the TVA method was used in the design of the experimental units and the TVA method was adopted in the design of the experimental wetland unit. The TVA method considers the factors controlling the hydraulic performance of a the bed and the organic loading on the entry zone cross sectional area to avoid potential clogging. The specific guidelines involve determination of design flow, daily organic loading and total surface area. This method is suitable for the design of small units and the University of New Hampshire's Storm water Centers design procedure was followed for theoretical design for the actual inflow into conventional selvage treatment plant.

3.2.1.1 Design Calculations

Design flow (Q) = 0.3 m3/day
Organic loading(OL) =0.03BOD5 /person/day
Organic loading Factor(L_o)= 4m^2/kg BOD/day
Hydraulic conductivity (k_s)=259m3/day/m2
Hydraulic gradient(S)=0.01
Cross-sectional area based on organic loading(AL)=(Lo)(OL)=(4)(0.03)=0.12m^2
Cross-sectional area based on design inflow(AS)=(Q)/(KSS)=0.3/(259*0.01)=0.11m^2
Select the larger value for design area 0.12m^2
Assumed depth (d) = 0.3
Bed width (w) = Area/d = 0.12/0.3 = 0.4m
Aspect ratio (L:w) =1.5:1
Length (L) = (1.5)(0.4) = 0.6

The wetland design pet is 0.3m deep, 0.6m long and 0.4m wide. To enable the flow of waste water gravitational from inlet chamber to outlet chamber, a horizontal slope of 1% was made during filter media filling. The empty bed volume of the wetland cell is 0.072m^3. The system is made of plastic and the inside walls were covered with 0.001m thick impermeable plastic liner. It was filled as follows (from bottom to top):

1) The first layer of 0.15m consisted of coarse aggregate gravel 6m size.
2) The second layer of 0.075m consisted of fine aggregate sand 0.3-0.5mm size.
3) 0.075m freeboard

3.2.1.2 Design Results

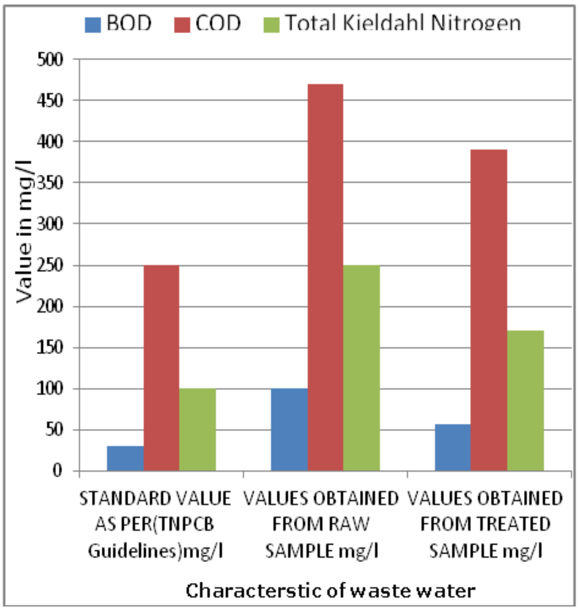
The results obtained from the design program are given in the table 6.

Table 6: *Design Results of Constructed Wetland*

1.	Length of Constructed Wetland	0.6m
2.	Width of Constructed Wetland	0.4m
3.	Depth of Constructed Wetland	0.3m
4.	Longitudinal slope	1%
5.	Empty bed volume of wetland cell	0.072m3
6.	Organic loading rate	0.03kgBOD5/person/day

3.3 Analysis of Wastewater

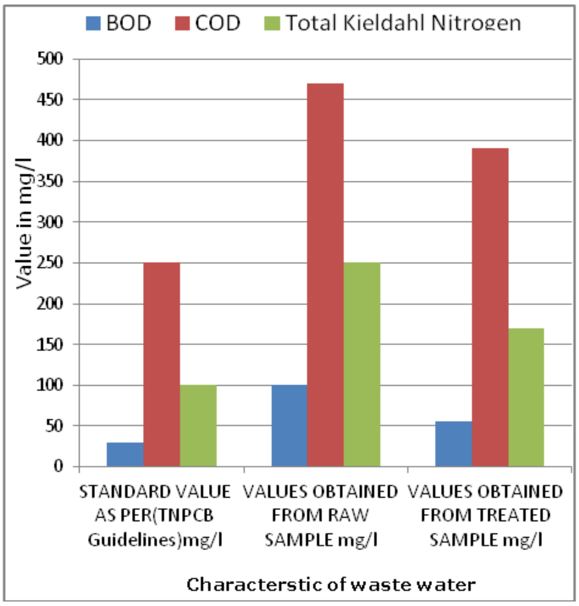
A sample of 500ml of treated waste water is collected and analysed in lab for various characteristic using APHA method. Various code books and standards have been researched to check the standard values. Standard values obtained after analysis are plotted in figures.



The bar graph represents various characteristic of raw waste water and treated waste water in integrated constructed wetland as shown in table below.

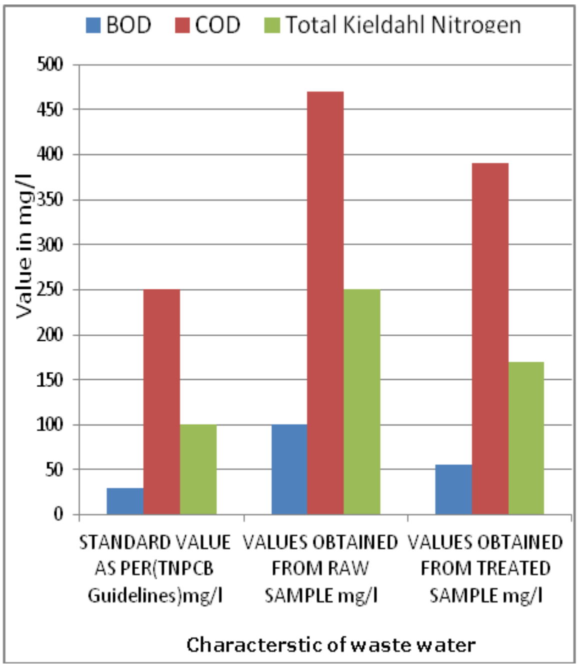
Characteristics	Standard value as per(TNPCB Guidelines) mg/l	Values obtained from Raw Sample mg/l	Values obtained from Treated Sample mg/l
BOD	30	100	36

COD	250	470	280
Total Kjeldahl Nitrogen	100	250	140



The bar graph represents various characteristic of raw waste water and treated waste water in vertical constructed wetland as shown in table below.

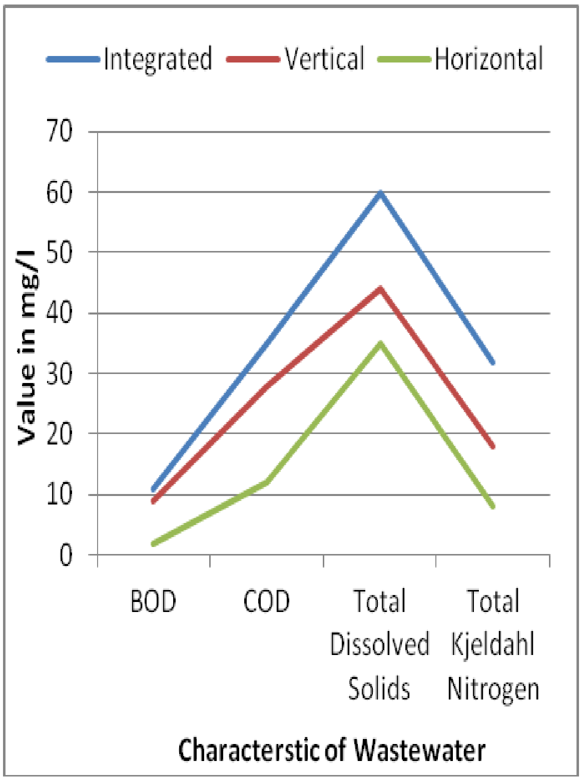
Characteristics	Standard value as per(TNPCB Guidelines) mg/l	Values obtained from Raw Sample mg/l	Values obtained from Treated Sample mg/l
BOD	30	100	48
COD	250	470	325
Total Kjeldahl Nitrogen	100	250	150



The bar graph represents various characteristic of raw waste water and treated waste water in horizontal constructed wetland as shown in table below.

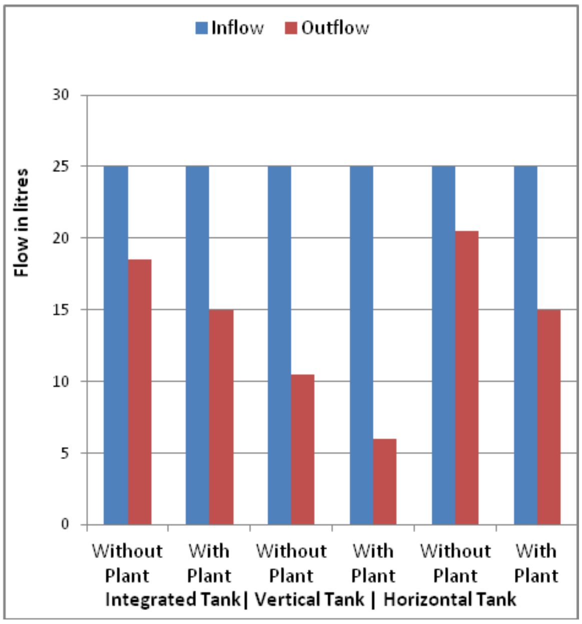
Characteristics	Standard value as per(TNPCB Guidelines) mg/l	Values obtained from Raw Sample mg/l	Values obtained from Treated Sample mg/l
BOD	30	100	56
COD	250	470	390
Total Kjeldahl Nitrogen	100	250	170

Type of wetland	Integrated		Vertical		Horizontal	
	Without plant	With plant	Without plant	With plant	Without plant	With plant
Inflow (litre)	25	25	25	25	25	25
Outflow (litre)	18.5	15	10.5	6	20.5	15



The above bar graph compares average percentage reduction in various characteristics of treated waste water in integrated, vertical and horizontal constructed wetland.

From the above figures it is observed that various characteristics of treated waste water has significantly decreased to its standard value after treatment in constructed wetland and the integrated type of wetland can be most effective for this purpose. Therefore it is concluded to an efficient method when comparing to traditional ternary treatment method.



The above bar graph shows total inflow and outflow in litres for various types of constructed wetland. We observe wetland with plant Typha have a lower outflow rate.

Analysis of plant

The N, P and K content in leaf and root of Typha plant are analysed using Spectrometer. The values obtained after analysis are enlisted in table

Sno.	Test Parameters	Protocol	Results
1.	Nitrogen as N	IS14684:1999 (Reaff:2008)	6094 mg/kg
2.	Phosphorous as P	IS 10158-1982 (Reaff:2009)	72.1 mg/kg
3.	Potassium as K	IS 10158-1982 (Reaff:2009)	11231 mg/kg

Sno.	Test Parameters	Protocol	Results
1.	Nitrogen as N	IS14684:1999 (Reaff:2008)	5899 mg/kg
2.	Phosphorous as P	IS 10158-1982 (Reaff:2009)	33.3 mg/kg
3.	Potassium as K	IS 10158-1982 (Reaff:2009)	1197 mg/kg

From the above table it is concluded that the values of N,P and K absorbed by leaves are considerably higher than those absorbed by roots.

5. Conclusion

In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. The challenge thus is to find such low-cost, low-tech. user friendly methods, which on one hand avoid threatening our substantial wastewater dependent livelihood and on the other hand protect degradation of our valuable natural resources. The use of constructed wetlands is now being recognized as an efficient technology for wastewater treatment, Compared to the conventional treatment systems, constructed wetlands need lesser material and energy, are easily operated, have no sludge disposal problems and can be maintained by untrained personnel. Further these systems have lower construction, maintenance and operation costs as these are driven by natural energies of sun, wind, soil, microorganisms, plants and animals. It is seen that this pilot unit is reducing the concentrations of various wastewater characteristics like TDS. TN. HOD and COD by l5%, 40%, *65%* and 60% (approx.) respectively. There is a cost saving of 80% in O&M by using constructed wetlands. The constructed wetland for an equivalent influent discharge saves *57%* over conventional design.

Hence, for planned, strategic, safe and sustainable use of wastewaters they seem to be a need for policy decisions and coherent programs encompassing low cost decentralized waste water treatment technologies, bio-filters, efficient microbial stains and organic/inorganic amendments, appropriate crops/ cropping system, cultivation of remunerative non edible crops and modern sewage water application methods.

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