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Development of a Bio-reactor septic tank for Domestic waste water treatment

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Abstract : In India 70 percent of households are using septic tank systems for the sewage treatment. The septic tanks in India are not maintained to recommended levels and most of the septic tanks in urban areas are failed due to various reasons and causing severe pollution due to improper disposal of sewage from the septic tank. These types of septic tanks contaminate ground water and create nuisance to the environment.

Present investigation deals to plan, design and develop a low cost new septic tank system namely "Bio-Reactor *Septic Tank"* to solve the pollution problem of effluents from septic tank and also to fulfill the requirement of water demand.

The term "septic" refers to the anaerobic bacterial environment that develops in the tank which decomposes or mineralizes the waste discharged into the tank. In Bio-Reactor Septic tank, instead of soak pit three filter media is used namely Coir filter, Surkhi adsorbent and Sandfilter. The raw sewage directly enters into the filter media which comes out as potable water which can be used for toilet flush, Gardening and other domestic purposes.

Experimental verification and result analysis has been made to prove the improvement of physical, chemical and biological parameters. The recommended project reduced the pollution of sewage and fulfils the needs of future generation.

Key words : Sewage, Septic Tank, Filter Media, Bioreactor Septic Tank.

Introduction

In the present scenario of India, water scarcity is the major problem which involves water stress, water shortage or deficits and water crisis. This may be due to both natural and human factors. Many reports suggest that the scarcity is more due to human factor such as industrialization, irrigation, domestic use etc. Corporation and formers have been guzzling surface water, ground water levels have been reducing and the amount of pollutants in water is increasing rapidly (13).

Water scarcity is the biggest problem prevailing in India. In order to rectify this situation small experiment has been executed. We can reduce the usage of portable water for domestic purpose by replacing it with treated sewage by treatment process, which has been implemented as Bio-reactor septic tank (1). The sewage water is treated and reused for domestic purpose. The main aim is to fulfill the demand of water.

From the review of literature, for the reduction of pollution from waste water many techniques have been followed. One among them is membrane bio-reactor where chemical membrane is used to remove characteristics of waste water and coverts it to potable water. The cost of this process is very high hence, it is not suitable to implement in developing countries like India. So an attempt has been made to design a septic tank with low cost and we are using filter media instead of chemical membrane.

Methodology

Bio-Reactor Septic Tank

The term “septic” refers to the anaerobic bacterial environment that develops in the tank which decomposes or mineralizes the waste discharged into the tank. In Bio-Reactor Septic tank, instead of soak pit three filter media is used (1). The raw sewage directly enters into the filter media which comes out as potable water which can be used for toilet flush, Gardening and other domestic purpose.

Construction Details

The septic tank has been designed for 500 users of residential colony with the capacity of 80000 liters. This tank consist of inlet pipe, outlet pipe, baffle wall and a man hole. One end of the tank is connected to inlet pipe shown in the figure 1 and the other end is connected to filter media, which is the replacement of soak pit (2).

Generally these are interring connections which are made with PVC pipe that allows wastewater to enter and exit without disturbing any crust on the surface.The design of the tank is usually incorporated with one chamber, vent pipe and manhole is provided.

Working process

Sewage enters through the Inlet, Anything that floats rises to the top and forms a layer known as the scum layer. Anything heavier than water sinks to form the sludge layer. In the middle is a fairly clear water layer (2). This body of water contains bacteria and chemicals like nitrogen and phosphorous that act as fertilizers, but it is largely free of solids.

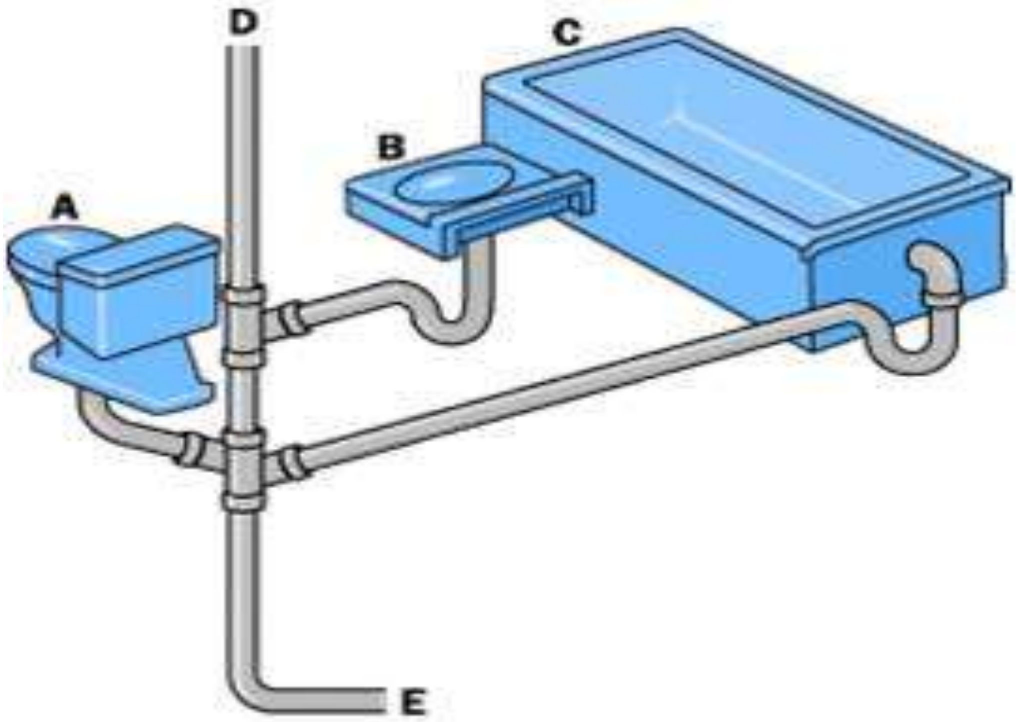

Figure 1 Source of domestic waste water

Organic matter is digested by bacteria. Digestion of settled sludge is carried out byanaerobic decomposition also called sludge digestion.Due to decomposition foul gases are produced thus mass of sludgeis decreased. BOD ofwater also decreased (4).The sewage has to be stored for 5 days and BOD_5 has to be determined. The settleable solids settles down where other solids like suspended solids, colloidal solids and dissolved solids floats on the top.Normally human excreta contain Ammonia and nitrates. These gases when dumped into a closed tank which gets converted into harmful gases like hydrogen sulfide and methane. Since methane is odourless gas, it will not create any impact on human whereas hydrogen sulphide gas has more impact on human and environment.Some amount of hydrogen sulphide gas is passed through vent pipe and remaining comes out as foul gas to the filter media.After 5 days the sewage is passed to filter media.The treatment system consists of three filter media:

- Coir filter
- Surkhi Adsorbent
- Sand filter

Coir filter media

Coir or **coconut fiber** is a natural fiber extracted from the husk of coconutand used in products such as floor mats, doormats, brushes and mattresses (3). Being a good absorbent, coir can remove the floating substances. Screening process is done in this filter where suspended solids can be removed (figure 2).

Figure 2 Coir filter media

The waste water from the septic tank enters into coir filter through PVC pipe. Being a good absorbent, coir can be used as oil absorbent.Screening process is done in this filter where floating solids can be removed.After an hour the filtered water is transferred to next filter media (11).

Surkhi Adsorbent

Surkhi is called as trash or brick dust. Surkhi is used as a substitute for activated carbon in this project. Surkhi has almost the same functions as of activated carbon (6). Surkhi is made by grinding to powder burnt bricks, brick-bats or burnt clay; under burnt or over burnt bricks should not be used, nor bricks containing high proportion of sand (Figure 3). It can absorb inorganic solids and absorb the dissolved solids, odour, and colour.

Figure 3 Surkhi filter media

Bio Reactor septic tank has been designed for 500 users of residential colony.The coconut coir filter media is placed in a rectangular plastic container which is replaced in every 6 months. One end of the tank is connected to inlet pipe and the other end is connected to another filter media (5). These are inter connected with PVC pipe that allows liquid to enter and exit without disturbing any crust on the surface.

The waste water from the coir filter enters into Surkhi filter through PVC pipe. In activated carbon, carbon is activated by the physical and chemical process so that the surface changes into an adsorbent surface. Since Surkhi consists of burnt bricks it has an adsorption capacity as same as of activated carbon. Surkhimedia can remove the dissolved solids, odour and colour.

Normally activated carbon is more efficient than Surkhi in treatment of the waste water. But it consists of high cost. So that it is not suitable for our developing country. Instead of using the activated carbon, we are using Surkhi filter in our project (7). Because Surkhi has the same properties as of activated carbon and it is more economical for our developing country. It is easily available in all the places and it is less in cost.

Sand Filter

Sand, either fine or coarse, is generally used as filter media. The layers of sand may be supported on gravel, which permits the filtered water move freely to under drains, and allows the wash water to move uniformly upward.

Sand

In our project, the fine aggregates are obtained from construction and demolished waste. The size of the sand is measured and expressed by the term called effective size. i.e. D_{10} may be defined as the size of the sieve in mm through which ten percent of the sample of sand will pass. The selection of the correct sieve is very important, because too smaller size will lead to very frequent clogging filters, and will give very low filtration rates (8). Similarly, too large size will permit the suspended particles and bacteria to pass through it, without being removed. The value of D_{10} for sand filter varies from 0.35 to 0.55 mm. It is suited for purifying water with low color, low turbidity’s, low bacterial contents and pathogens.

Gravel

In our project, the course aggregates are obtained from construction and demolished waste. The gravel which may be used below the sand should be hard and durable. It should have a density of about 1600 kg/m^3. Gravel of different sizes are usually placed in 3-4 layers, each of 15-20 cm depth, with the coarsest size (20 to 60 mm) placed in the bottom-layer, and the finest size (3 to 6 mm) in the top most layer. It is suited for purifying water with low colour, low turbidity’s, low bacterial contents and pathogens.

Construction details

Enclosure tank

It consists of an open water-tight rectangular tank, made of plastic. The bed slope is kept at about 1 in 100 towards the central drain. The depth of the tank may be varying from 2.5 to 3.5 m. The plan area of the tank may vary from 100 to 2000 sq.m or more, depending upon the quantity of water to be treated (9).

Filter media

The filtering media consists of sand layers about 90 to 110 cm in depth, and placed over a gravel support. The effective size (D10) of the sand varies from 0.2 to 0.4. The top 15 cm layer of this sand generally kept of finer variety than that of the rest, which is generally of sand are used then the coarsest layer should be placed near the bottom, and the finest towards the top. The filter the sand used, the purer will be the obtained water, as more impurities and bacteria will be removed. Sectional view of sand filter is shown in the figure 4.

Base material

The base material is gravel, and it supports the sand. It consists of 30 to 75 cm thick gravels of different sizes, placed in layers (12). Generally, three to four layers each of 15-20 cm depth are used. The coarsest gravel is used in the bottom most layer. The size of the gravel in the bottom-most layer generally kept 40 to 65 mm; in the intermediate layers, as varying between 20 to 40 mm, and 6 to 20 mm (when two intermediate layers are used); and in the top-most as, 3 to 6 mm.

Inlet and Outlet Arrangements

The waste water from the Surkhi filter enters into Sand filter through PVC pipe. The treated water from the Surkhi filter is allowed to enter the sand filter and get distributed uniformly over the filter bed.The water percolates through the filter media and gets purified during the process of filtration (10).The water enters the gravel layers and comes out as the filtered water.Removal of septic tank wastes by using filter media is shown in figure 5.

The sand filters are best suited for smaller plants and for purifying waters with low colours, low turbidity's, low bacterial contents and pathogens.Materials used in the bio-reactor septic tank isrevealed in figure 6.

The filtered water used for domestic purpose such as flushing, car washing, and gardening purpose.

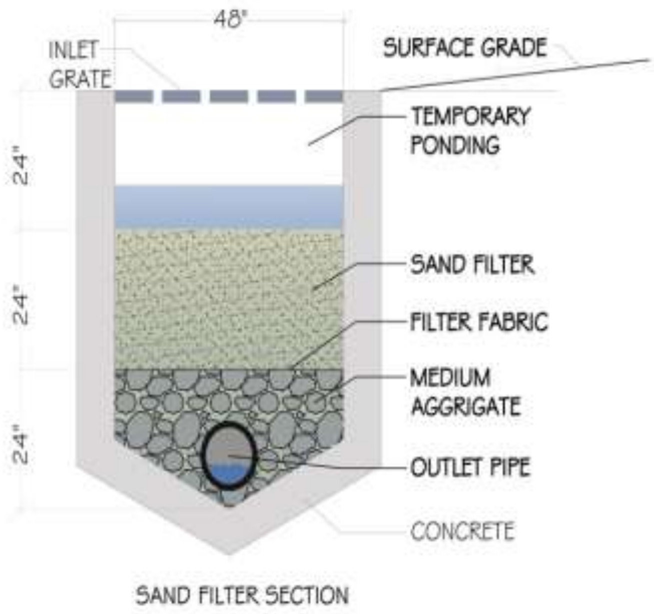

Figure 4 Sand filter sectional view

Flow Chart

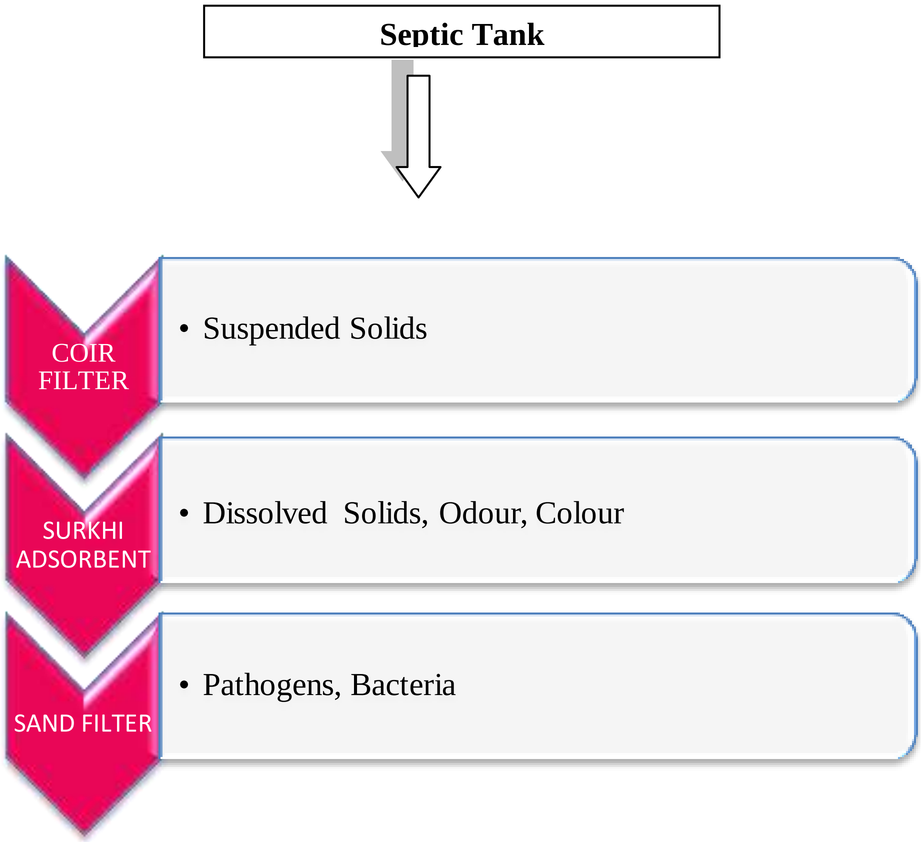

Figure 5 Removal of septic tank wastes by using filter media

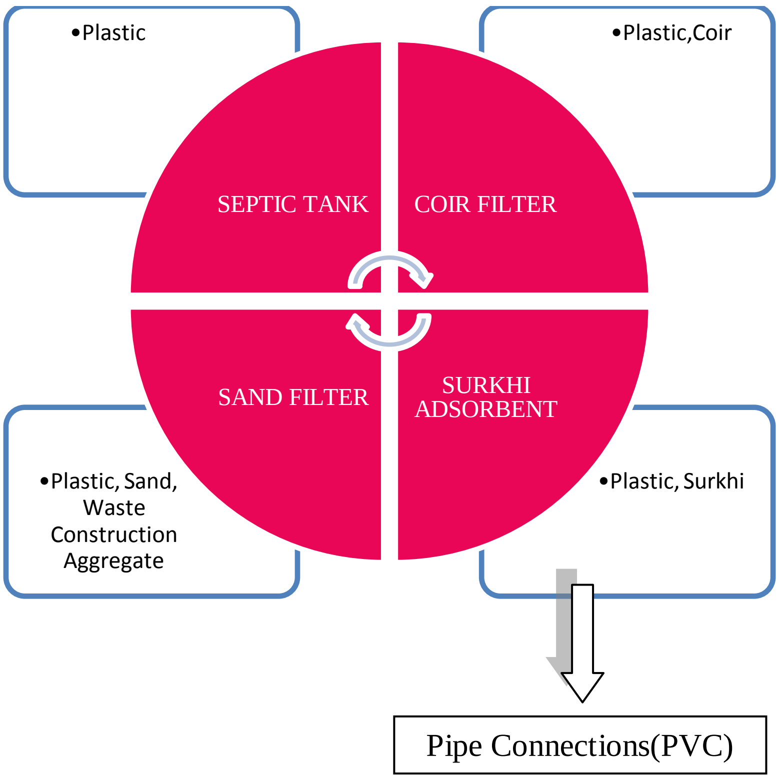

Figure 6 Materials used in the bio-reactor septic tank

Design criteria

Population =500 persons
Rate of water supply =200 l/head/day
The quantity ofWater supply =percapita demand × population
500 × 200 =1,00000 l/day

Assume,

Water supply forSewage =80%
The quantity of sewageProduced =1,00000 × 0.8 =80000 l/day

Assume,

Retention period =5 days
The quantity of sewageProduced =80000 × 24 × 5 / 24=4,00000 litres
Rate of deposited sludge =30 l/c/y
The volume of sludge accumulated =Rate of sludge deposition ×Population × period of cleaning(Assume, cleaning period = 1Year)
=30 × 500 × 1
=15000 litres.
Total capacity of tank =capacity of sludge + capacity of Sewage
=15000 +4, 00000
=415000 litres
=415 m^3
Assuming, depth as =2.7 m
The surface area of tank =Capacity (or) volume of tank/Depth
=415 / 2.7
Surface Area **=153.70 m^2**
The ratio of length to width is taken as 1:2 to 1:4
Assuming, L: B =1:3 (OR) L = 3B
Surface Area =length × width
=L × B
=3B × B
153.70 =$3B^2$
51.23 =B^2
B =7.157 = 7.16 m
B **=7.16 m**
L =3×7.16
L **=21.48 m**
Assume, free board =0.3m
=0.3 + 2.7
D **=3m**
L × B × D =21.48 × 7.16 × 3 m
The size of the septicTank **=21.48 × 7.16 × 3 m**
(As per Code) IS (7): 2470- 1985

Design of Coir Filter Media

Population =500 persons
Percapita demand =200 l/h/day

Assume,

Rate of filtration =180 l/h/m^2
Maximum demand as 1.8 times the average daily demand
Average daily demand =population × percapita demand
=500×200

	=1, 00000 l/day
Maximum daily demand	=1.8 × 1, 00000
	=1.8 × 10^3 l/day
Rate of filtration per day	=(180 ×24) l/m^2/day
Total Surface area ofFilter required	=Maximum daily demand/Rate of filtration per day
	=(180 × 10^3) / (180 × 24)
	=41.666 = 41.67 m^2
Area	**=41.67 m^2**
L	=2B
L × B	=Area
2B × B	=41.67
$2B^2$	=41.67
B^2	=20.835
B	**=4.56 m**
L	=2 × 4.56
L	**=9.12 m**
L × B	=9.12 × 4.56 m
Assume, depth as	=3m
The size of the Coir filterMedia	**=9.12 × 4.56×3 m**
Depth of coir in first filter media	=1 m

Design of Surkhi Adsorbent Media

Population	=500 persons
Percapita demand	=200 l/h/day

Assume,

Rate of filtration	=180 l/h/m^2

Maximum demand as 1.8 times the average daily demand

Average daily demand	=population × percapita demand
	=500×200

=1, 00000 l/day

Maximum daily demand	=1.8 × 1, 00000
	=1.8 × 10^3 l/day
Rate of filtration per day	=(180 ×24) l/m^2/day
Total Surface area ofFilter required	= Maximum daily demand/Rate of filtration per day
	=(180 × 10^3) / (180 × 24)
	=41.666 = 41.67 m^2
Area	**=41.67 m^2**
L	=2B
L × B	=Area
2B × B	=41.67
$2B^2$	=41.67
B^2	=20.835
B	**=4.56 m**
L	=2 × 4.56
L	**=9.12 m**
L × B	=9.12 × 4.56 m
Assume, depth as	=3m
The size of the Surkhi AdsorbentMedia	=**9.12 × 4.56×3 m**

Depth of Surkhi in second filter media = 1 m

Design of Sand Filter Media

Population	=500 persons
Percapita demand	=200 l/h/day

Assume,

Rate of filtration =180 l/h/m^2
Maximum demand as 1.8 times the average daily demand
Average daily demand =population × percaptia demand
=500×200
=1, 00000 l/day
Maximum daily demand =1.8 × 1, 00000
=1.8 × 10^3 l/day
Rate of filtration per day =(180 ×24) l/m^2/day
Total Surface area of
Filter required =Maximum daily demand/Rate of filtration per day
=(180 × 10^3) / (180 × 24)
=41.666 = 41.67 m^2
Area **=41.67 m^2**
L =2B
L × B =Area
2B × B =41.67
$2B^2$ =41.67

B^2 =20.835
B **=4.56 m**
L =2 × 4.56
L **=9.12 m**
L × B =9.12 × 4.56 m
Assume, depth as =3m
The size of the Sand filterMedia **=9.12 × 4.56×3 m**
Depth of sand and coarse aggregate in third filter media = 1 m

Design values for Bio-Reactor Septic Tank

The size of the septic Tank =21.48 × 7.16 × 3 m
The size of the Coir filterMedia =9.12 × 4.56×3 m
The size of the Surkhi adsorption Media=9.12 × 4.56×3
The size of the Sand filterMedia =9.12 × 4.56×3 m

Result and Analysis

Characteristics of sewage have been analyzed at every stage of treatment and the results are shown in the tables 1,2,3,4 and 5.

Sample of raw sewage(Photo)

Sample from coir filter(Photo)

Sample from Surkhi adsorbent(Photo)

Sample from sand filter(Photo)

Table 1 Characteristics of raw sewage

Parameter	Value
Temperature	$40^{o}c$
Total dissolved solids	850 mg/l
Total suspended solids	350 mg/l
Settleable solids	300 mg/l
colour	Black
odour	Foul gas
P^{H}	10
DO	14.6 mg/l
BOD	80 mg/l
Nitrogen	85 mg/l
Chlorides	1000 mg/l
Bacteria	600000 per ml

Table2 Characteristics of the Effluent from Coir Filter

Parameter	Value
Temperature	$40^{0}c$
Total dissolved solids	500 mg/l
Total suspended solids	100 mg/l
Settleable solids	100 mg/l
Colour	Grey
odour	Foul smell
P^{H}	9
DO	20 mg/l
BOD	50 mg/l
Nitrogen	50 mg/l
Chlorides	80 mg/l
Bacteria	<100000 per ml

Table3 Characteristics of the Effluent from Surkhi Adsorbent

Parameter	Value
Temperature	35^0c
Total dissolved solids	<50mg/l
Total suspended solids	<10mg/l
Settleable solids	<10mg/l
colour	Light grey
odour	Odourless
P^H	8
DO	15 mg/l
BOD	23.5 mg/l
Nitrogen	20 mg/l
Chlorides	<20mg/l
Bacteria	<100 per ml

Table4 Characteristics of the Effluent from Sand Filter

Parameter	Value
Temperature	25^0c
Total dissolved solids	10 mg/l
Total suspended solids	3 mg/l
Settleable solids	6 mg/l
colour	White
odour	Odourless
P^H	6.5
DO	10 mg/l
BOD	12 mg/l
Nitrogen	12.5mg/l
Chlorides	<10mg/l
Bacteria	0.30% per ml

Table5 Comparison between Sewage and Filtered Water

Parameter	Value	Value
Temperature	40^0c	25^0c
Total dissolved solids	850 mg/l	10 mg/l
Total suspended solids	350 mg/l	3 mg/l
Settleable solids	300 mg/l	6 mg/l
colour	Black	White
odour	Foul gas	Odourless
P^H	10	6.5
DO	14.6 mg/l	10mg/l
BOD	80 mg/l	12 mg/l
Nitrogen	85 mg/l	12.5mg/l
Chlorides	1000 mg/l	<10mg/l
Bacteria	600000 per ml	0.30% per ml

Advantages & Applications

Advantages

- Ease in construction.

- No maintenance problem(except periodical cleaning)
- Excellently functioning ST can considerably reduce suspended solids &BOD from sewage.
- Due to digestion reduction in volume is about 60% &reduction in weight is about 30%.
- It is suitable for urban and rural societies
- ST is properly functioning; effluent will not have any foul &dark.
- Leakage of gases will not occur.
- Periodical cleaning, removal and disposal of sludge are not required.
- There is no clogging during treatment process
- It will not affect the soil property and ground water table
- Construction and maintenance cost is low.

Applications

- Reused for toilet flushing
- Gardening
- Car washing
- Drains into water bodies

Conclusion

Experimental verification and result analysis has been made to prove the improvement of physical, chemical, and biological characteristics. Thus the implementation of Bio-reactor septic tank will reduce the demand of water. The water from filter media can be used for domestic purpose. The sewage water is treated and reused by people. This type of septic tank can be constructed in an individual house in order to fulfill their requirements. Since the construction of this Bio-reactor septic tank is ease and economic which can be implemented and used in developing countries. This recommended project will reduce the pollution of sewage and fulfilsthe needs of future generation. The standards of treated water are as nearer to the standard range of domestic water.

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