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OPTIMAL DESIGN OF FRAGMENTED SEWAGE PURIFICATION FOR URBAN HOUSEHOLD

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Abstract—Each house can serve as a waste water purifier plant for the domestic waste that is let out from the household drains. And this is economically possible at this growing urban pace. This paper outlines an efficient way of fragmented purification of household waste and its potency in working and the purpose of this approach in every urban household. The experiment aims at the purification and reuse of wastewater from domestic source which is carried out by means of a prototype plant. The waste water collected in the sedimentation tank undergoes anaerobic decomposition which is the existing exorbitant state in the presence of methanogens. This then enters the filter mediums which is a slow sand filter followed by a carbon filter. The continual filtering process of sand and carbon remove particulate matter, pathogenic organisms in addition to the taste and odour. The treated water is then collected in collector tank. The scenario demonstrates a trade-off between social acceptability and operational feasibility. This practice implementation in urban area could be of great benefit in bringing out healthier reciprocity of humans and environment.

Keywords— Slow sand filters, Activated carbon, Sedimentation tank, Methanogens, Screening.

I. INTRODUCTION

Water is a transparent, tasteless and nearly colourless liquid which is the primary constituent of Earth's streams, lakes, seas and a vital fluid for the presence of living beings. Around 71% of Earth's covering is occupied with water of which just 2.5-2.75% is fresh water and 1% among it is effectively open. Safe drinking water is important to all living things on Earth. In spite of the fact that access to it has enhanced in the previous years, still records demonstrate individuals suffering because of unavailability of safe drinking water.

This has stimulated the concept of use of recycled water and this, in turn, has resulted in being a crucial source of water. Water recycling is not an unfamiliar practice and there is persistent study always on the lead to recycle the wastewater to replenish the deprived ecosystem. The sources of water for human utilization include surface water like lakes, hot springs, and geysers, groundwater like aquifers which are extracted artificially in wells and improved ways of tapping frozen water for human consumption. Though there are many freshwater sources available on this planet's crust, there still is prevailing inexorable state where millions of people fall short of safe and pure water on an everyday basis. This is mainly due to the available water being polluted and expended carelessly leaving behind an unbalanced ecology.

There are cities like Beijing, Jakarta, Istanbul, and Cape Town that are marching their way towards “Day Zero”. It’s high time that the individuals living on this planet realize that it is imperative and very vital to preserve this irreplaceable fluid and implement techniques to use the recycled water.

The experiment aims at recycling of household wastewater and making accessibility for non-potable water needs. The wastewater is comprised of 99% of water and relatively small concentrations of suspended and dissolved organic and inorganic solids. Some of the constituents of this wastewater include TDS (Total Dissolved Solids), suspended solids, carbohydrates, lignin, fats, soaps, synthetic detergents, pathogenic viruses, bacteria, etc. The sewage which is carried via sewers apparently increases the load on treatment plant and adding up of its effluent cause evident water pollution.The rapidly inflating population needs purified water to meet its growing day-to-day demands. Even though there are several conventional methods to treat municipal wastewater, the method of fragmented purification aims in decontaminating the household sewage for its reuse at the point of origin itself.

A. Objectives of the study:

1. Fragmentary purification of waste water and thereby achieving recycling of water.
2. Design of a prototype model for integrated approach to purify the sewage from an individual home.
3. Protection of fresh water bodies by preventing the entry of wastewater.

II. STUDY AREA

The study area chosen to setup the prototype plant is M C Sarovar Apartment which is located in the district of Bangalore, Karnataka, India. The study area selected lies in the range of 13° 1' 24.2134" N and 77°43'4.0955" E respectively.The experiment was conducted using a prototype plant at the above mentioned test site. But the design criteria and the dimensions are given for the actual arrangements for the purpose of its water treatment at an individual house. The prototype plant is a smaller unit for the objective of demonstration which is an integrated replica of the real structure.

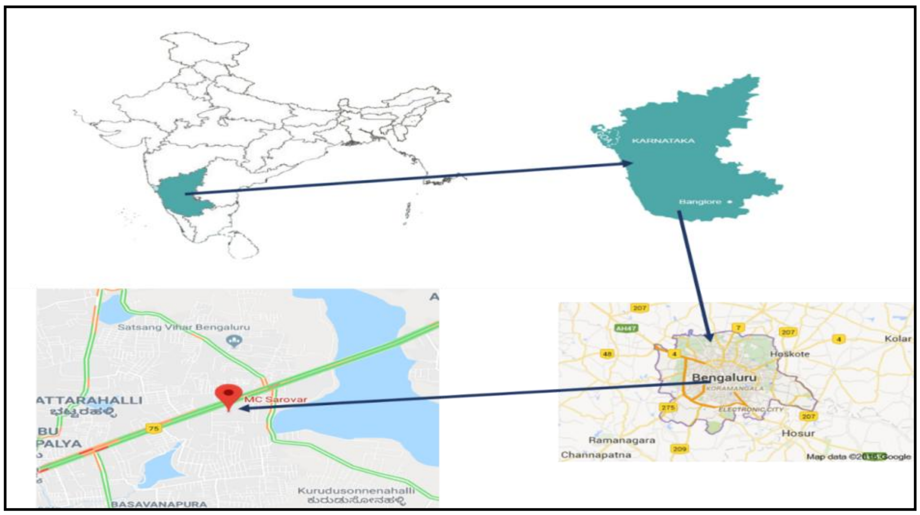

Fig.1Location of the selected Study Area

III. METHODOLOGY

The experiment was conducted for small scale of 25 litres to observe the reactions occurring in the treatment process and to overcome the errors to give cent percent effective treatment plant for urban household. The methodology involved in this process is been described as below:

A. Collection of Sample

The sewage sample was collected from the apartment sewage treatment plant (STP) before purification process. The sample of raw sewage consists of grey water (from sinks, tubs, shower, dishwashers, and clothes washers), black water (the water used to flush toilets, combined with the human waste that it flushes away); soaps and detergents; and toilet paper. For collection of sewage sample a 25-liter water can, a 1-liter plastic bottle and flexible pipe were used. These particulates where carried to the sample collecting site. The sewage water was collected in collecting can and poured into 25-liter water can and is filled up to three quarter of the can and is carried to ray less area. To the sample collected, alum solution (the alum solution is formulated by appending 22 grams of alum to 1 litre of distilled water) and cow dung was added. The addition of methanogens enhances the purification process by reducing the sludge quantity which will further decrease the load on other filtering media. After the addition of cow dung and alum into the collected water, the mix was stirred thoroughly and air tightened by methane trapping bottle where a flexible pipe is being fastened between water can cap and bottle using m-seal.There was a rapid change in turbidity and settlement of heavier metallic particles and biological matter were flocculating on the sewage sample. The collected sample was kept in observation for 7 days.

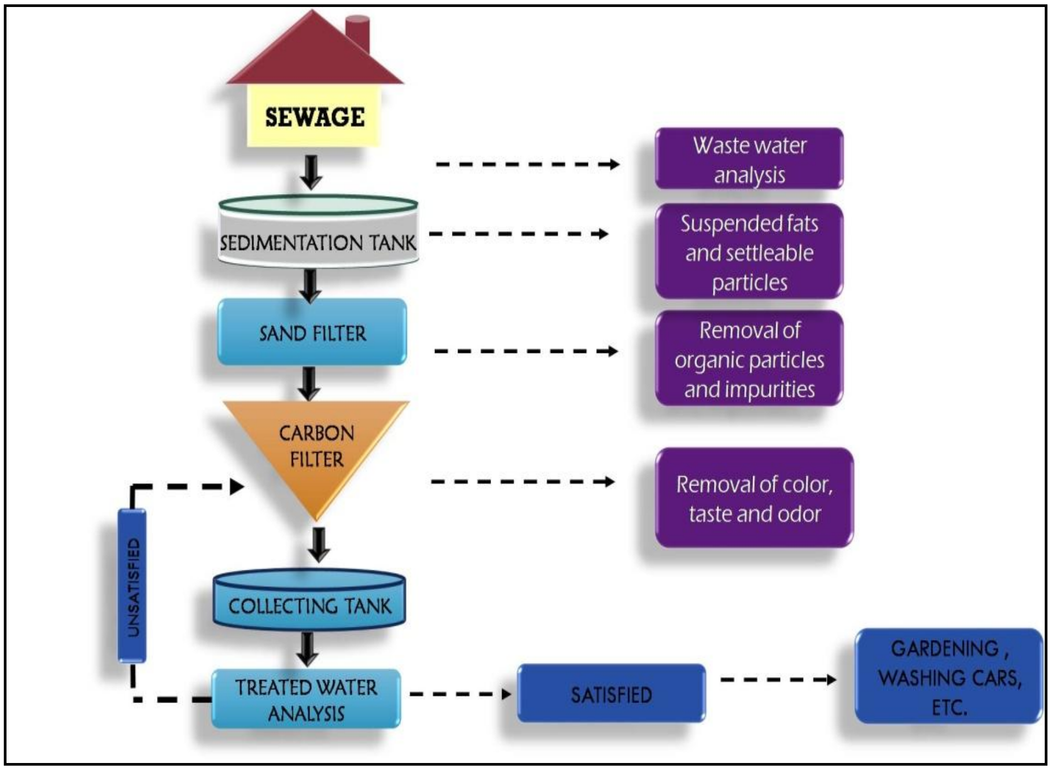

Fig. 2Flow Chart to obtain Fragmented Purification of Sewage water

B. Arrangement of Sand and Carbon filter

The sand filter in our setup was compiled in a plastic can of capacity 25 litre. The sand filter assembly consisted of sand grains of different diameters. The sand layers are placed according to their grain size that constitutes coarse grains at the bottom and fine grains at the top. The smallest diameter being 1mm sand is placed at the topmost of layers which prevails its successive sand beds. This layer is followed by a bed of sand consisting of 4mm diameter sand particles and finally resting upon 8mm diameter sand. The can was filled in this assembly for the sand filter leaving about 10cm depth free space from the brim for the supernatant water to occupy its space.Each layer is physically segregated with a thin sheet of cotton embodied completely in a film of rolled bandage. This cotton and bandage sheet was placed above the top most sand layer which aids in circulating the water throughout its surface dimension.The water from the settling tank is directly let out in to this filter medium which first comes in contact with the cotton sheet and seeks its downward motion through the different grades of sand.

The arrangement of carbon is similar to that of the previously assembled sand filter but a layer of sand in here is replaced with Granular Activated Carbon.The bottom most layer was occupied by 8mm diameter sand grains upon which 4 mm sand grain is placed. On 4mm was the bed of thick, black activated carbon and 1mm diameter sand rests upon the carbon bed respectively. In here too, the layers in the filter medium was separated by a cotton and bandage sheet. One such finely covered sheet was placed above the topmost sand layers which represents itself as a typical distributor for our prototype assembly.

A flexible pipe of 1m was used to connect the filter mediums for its recursive process of purification to occur uninterrupted.The one end of this flexible pipe is fixed firmly to the sand filter outlet and has its other open end encapsulated in the supernatant zone of carbon filter. The outlet of the carbon filter is connected to the collecting tank again by means of a flexible pipe. After all the connections are confirmed to be established firmly, a can of normal water was allowed to pass through the filter. This process enabled to get rid of minute dust and the layers to attain cohesive forces.

Fig. 3Arranged Sand and Carbon Filters

C. Process of Purification

The sewage after the sedimentation from the settling tank is let out into the sand filter by a facile open close tap befitted at the bottom zone of the sedimentation can. The sewage after the detention period of 7 days is allowed to flow into the sand medium for its further purification. The highly contaminated, pale yellowish and brown coloured sewage which comprised high amounts of suspended solids was allowed to discharge into the sand filter.

During the process of filtration, particles of organic origin deposit on the top layer of the sand surface and become biologically active that leads to the establishment of microbial community. This becomes the region of breeding for bacteria and other microbes which form a sticky gelatinous film on the surface known as "Schmutzdecke" or "dirty skin". The majority of organisms present in these communities are predatory bacteria that feed on waterborne microbes passing through the filters. This layer tends to adhere particles to it from raw water leaving behind a sample which is of relatively less bacterial content. The main forces that hold particles in place once they have made contact with the sand grain are: Electrostatic attraction, Van der Waals forces and Adherence. The raw water, in its own pace continues its downward movement, making contact with all possible sand grains along its path in purification operation. But there was presence of colour and odour.

The partly purified water from this medium reaches the inlet of the succeeding medium which is the carbon filter, by Manometric effect. In carbon filter, removal of colour, odour and taste occurs. Here it works on the mechanism of adsorbing nature of carbon and porosity of carbon which further aids in removal of flocs and other biological particles which escaped from sand filter. Activated carbon has substantially large surface area and enormous pores which is why it is the best fit for decolorizing and odour removing.

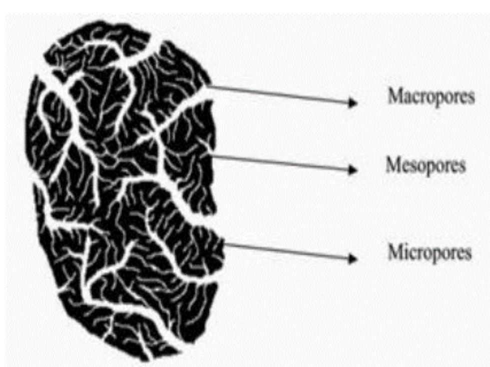

Fig. 4 Pores in activated carbon

The macrospores are large openings that serve as a transport pathway through which the adsorptive materials reach the mesopores and terminate at microspores. This microspore incorporates abundant internal surface area of the activated carbon and has the maximum pore volume. The attractive forces in here are enhanced, thus trapping the adsorptive materials in pores which are filled at low relative pressures. The water percolating through the voids in sand layers hits the carbon bed beneath it and seeps in downward motion uninterrupted across the pores present in the activated carbon. The water exuding out from the carbon layer is devoid of colour, odour, and taste along with organic and inorganic residues.The impregnated carbon layer rests upon a sand bed which receives the clear water and conveys it to a collecting tank through a pipe.

Activated carbon bed is placed amidst the sand layers and is predominantly used for the removal of refractory organic compounds and even residual inorganic compounds such as hydrogen sulphides. Removal of taste and odour from waste water is an additional application as it is for reuse purpose.The water seemed much clearer than the water in the settling tank. Thus, the water from the carbon filter was free from all the above-mentioned pollutants and deemed purified which was manually handled for non-potable domestic purpose.

The water from the carbon filter is collected in the collecting tank by means of tube which is positioned between outlet of the carbon filter and at the aperture of collecting tank. The water in the collecting tank appeared much clear and colourless compared to the sample that made its entrance into the carbon filter medium. Thus, this water was used for the purpose of non-potable human utilization and it was clearly harmless and free from colour, odour and taste. The water from this collecting tank was stored in bottles as shown below which then was sent for the lab for testing.The treated water is finally discharged into the collecting tank which is then used for its desired purposes. The purified water will be free from all kinds of pathogens and hence can be used for domestic purposes such as vehicle washing, gardening etc., or can be let out into the municipal pipes. This treated water reduces the load on the large treatment plant which also reduces the contamination levels in rivers and lakes.The complete setup served its accountable purpose. The clear water from the collecting tank was given for the lab test at BARC (Bangalore analytical research Centre) and the test results are as follows:

TABLE I:TEST RESULTS FROM BARC

No.	Tests	Units	Results	Tolerance Limits	Test Method
	Chemical Test				
1	pH Value		7.7	6.5-9.0	IS3025(Part-11): 1984(Reaff:2012)
2	Biochemical Oxygen Demand 3 days @27^{o}	mg/L	7.0	Not more than 10	IS3025(Part-44): 1993(Reaff:2009)
3	Total Suspended Solids	mg/L	4.0	Not more than 20	IS3025(Part-17):1996(Reaff:2012)
4	Oil&Grease	mg/L	<1.0(BDL)	Not more than 10	IS3025(Part39):1996(Reaff:2009)
5	Turbidity	NTU	3.1	Not more than 2	IS3025(Part-10):1996(Reaff:2012)
6	Residual Free Chlorine as C12	mg/L	1.9	More than 1	IS3025(Part-26):1996(Reaff:2009)
7	Total Dissolved Solids	mg/L	1027.0	Not Specified	IS3025(Part-16): 1984Reaff:2012)
	Microbiological Test				
1	Escherichia coli	MPN/IOO ml		Absent	IS1622-1981RA 1996

(*Report provided by BARC)*

D. Design Details

Since the fragmented purification process met the successful standards, the design step for its installation in individual household is given in brief.

The sedimentation tank is of the dimensions 1.5m*0.75m*1m (L*B*D). The sewage will be collected in the sedimentation tank from the urban household, to which alum is added prior to the Methanogens for capacity of 1125 liters. For this capacity of sewage, 100 grams of alum and 150grams of Methanogens are added initially and are kept for a detention period of 3 days.

Sand filters are a major step in the wastewater treatment unit.The typical dimensions of a Sand Filter for treating household wastewater are 65 cm in diameter and 175 cm height.The basic structure of SSF is very elementary. It is a cylindrical structure made of concrete, coated with waterproofing lining inside which a bed of fine sand is placed over layers of varying grades of coarse sand and pipes to collect the treated water that subsequently conveys it to the next step in the purification process.

The filter media succeeding the sand filter is the carbon filter. It is 175cm depth and 65cm diameter concrete structure. The partly treated water from the sand filter enters this medium through a distributor fitted at its entrance. The tank comprises of thin layers of sand which rests upon the carbon filter and finally 8mm diameter sand granules at the bottom.

The project was successfully completed and was able to optimize the design of a cost effective, yet efficient method of managing available water resources. The treatment plant installed underneath requires a length of 4-4.5m with width of 1-1.5m and depth of 2-2.25m (the dimensions of the plant further depends on the user accessibility and pipe connections which governs the spacing between the filter medias).

IV. RESULTS

From this experiment, the results obtained from the visual sense as well as the lab were satisfied to the desirable limit. The attained outcome was efficient in terms of the tested parameters and it rendered harmless for biotic utilization of non-potable demands.

Fig. 5 Sample before treating

Fig.6Sample after Purification Process

TABLE II:TEST RESULTS OF THE SAMPLE BEFORE AND AFTER PURIFICATION PROCESS

Sl. No.	Tests	Units	Before purification	After purification	Tolerance Limits
Chemical Test					
1	pH Value		8.5	7.7	6.5-9.0
2	Biochemical Oxygen Demand 3 days @27^{o}	mg/L	200	7.0	Not more than 10
3	Total Suspended Solids	mg/L	125	4.0	Not more than 20
4	Oil&Grease	mg/L	50	<1.0(BDL)	Not more than 10
5	Turbidity	NTU	100	3.1	Not more than 2
6	Residual Free Chlorine as $C1_2$	mg/L	-	1.9	More than 1
7	Total Dissolved Solids	mg/L	1500	1027.0	Not Specified
Microbiological Test					
1	Escherichia coli	MPN/IOO ml	Present	Absent	Absent

A. Advantages

1. Convenient to use- Implementation of flexible tools and easy to use contrivances, waste water treatment solution delivers a more convenient way to manage the unnecessary water and generate purified water out of it.
2. Dimensionally small and is easy to install. The possibility of extending the capacity of waste water treatment plant is easy and quick replacement of internals without running.
3. The opportunity to get 600 liter quantity of irrigation water suitable for ornamental gardens, other household washings.
4. No harmful chemicals are being used that may jeopardize biotic organisms. The process of purification is steady and recursive.
5. The outflow is relentless; hence the refined water can be accessed by the users at any time.
6. The fragmentally filtered water can be directly let out into the existing water bodies as it won't agitate the aquatic life.

B. Disadvantages

1. Skilled supervision and constant check on the return sludge is necessary.
2. Large volume of sludge increases in disposal.

V. CONCLUSIONS AND FUTURE SCOPE

It is very evident from the above produced result that the model was able to purify the water for desired level and can be used for non-potable purposes as the treated water met the required standards. From our experiment, it is apparent that sewage treatment plant if constructed for a single house is adequate enough to treat the wastewater coming out of the drains which in turn can serve the needs of car washing, gardening, etc., and can even be sent to construction fields for the curing process. Intrinsically, optimal design of fragmented sewage purification for urban household has considerable potential for offering a balance between the elements of people, prosperity and the planet. The inferences concluded from the project are:

1. The design is currently optimized for fragmented purification, demonstrating 100%efficiency against E-coli.
2. The current system poses no threat of leaks or contamination of filtered water due to the system enclosed design.
3. The water that is let out from the house apparently reduces the load on the treatment plant as it is partly purified.

Scope for future studies

1. Fragmented purification system purifies to domestic usage this can further be purified to portable water by process of electro-coagulation and UV filter.
2. The objective can be improvised as recharging of ground water using rainwater as source.
3. Can treat larger quantity of sewage by increasing the capacity of filters.
4. The objective of sewage as source can be changed for different source and improve purification process.
5. Providing aeration and different coagulants for improving the purification level.

VI. ACKNOWLEDGMENT

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