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RESEARCH ARTICLE

EVALUATION OF VERMIFILTRATION PROCESS USING ACTIVATED CHARCOAL FOR EFFECTIVE SEWAGE WATER TREATMENT

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ABSTRACT

India is rich in water resources, having a network of as many as 113 rivers and vast alluvial basins to hold plenty of ground water. But due to tremendous increase in the demand of water due to increase in population as well as the deterioration of available water, it has now become the necessity to find ways to reuse the available water. Hence it becomes important to find ways to treat the available polluted water in the simplest way for the benefit of mankind. In this work, evaluation of vermifiltration using different natural ingredients and activated charcoal is done. Activated charcoal is used as natural Ingredient employing *Eisenia Fetida* (Earthworm species) to filter sewage waste water. The whole investigation was carried out for 90 days and the filtrated water was tested for various critical parameters namely, pH, removal efficiency of BOD, COD, Total dissolved solids, Total suspended solids, Turbidity, Odour, Colour, Nitrate, Chlorine. The aim of this review is to evaluate the performance of vermifilter using activated charcoal.

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INTRODUCTION

1.1Overview

India is also blessed with snow-capped peaks in the Himalayan range, which can meet a variety of water requirements of the country. However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, domestic and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated. In India, water pollution comes from three main sources domestic sewage, industrial effluent and run-off from agriculture. Over the years, increasing population, growing industrialisation, expanding agriculture and rising standards of living have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and creating ground water structures such as wells. Recycling and desalination of water are other options but cost involved is very high. However, there is a growing realisation that there are limits to 'finding more water' and in the long run, we need to know the amount of water we can reasonably expect to tap and also learn to use it more efficiently.

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Water is fast becoming one of the most limited resources available to us. We are left with no but to conserve and recycle every drop of water that we use. Due to rapid industrialisation and development, there is an increased opportunity for sewage water reuse in developing countries such as India. Although India occupies only 3.39 million km graphical area, which forms 2.4% of the world's land area, it supports over 15% of world's population, In India alone the International Water Management Institute (IWMI) predicts that by 2025, one person in three will live in condition of absolute water scarcity (IWMI, 2003). It is therefore essential to reduce surface and groundwater use in all sectors of consumption, to substitute fresh water with alternative water resources and to optimise water use efficiency through reuse option.

1.2Sewage Water: Sewage water is wastewater from people living in a community. It is the water released from households after use for various purposes like washing dishes, laundry, flushing the toilet etc. Mostly, sewage water consists of grey water and black water. Grey water is the water from washing either from bathing, dishes or laundry. Black water is the waste water from toilets. It is characterized by debris such as paper wrapping, sanitary products, soap residues and dirt due to the chemical composition of the various waste materials.

Nearly 80% of the water supply used by society returns as municipal wastewater in the system as sewage. Sewage carries hazardous chemicals and very high loadings of organic matters referred as BOD (biological oxygen demand) and COD (chemical oxygen demand) and solids-both dissolved and suspended solids (R.K Sinha et al., 2008). The wastewater generation and its treatment has become an important health issue in the developing countries due to the inadequate treatment facilities. The discharge of the untreated sewage in surface and subsurface water courses is the most important source of contamination of water resources. On the other hand, water is depleting resources all over the world. UNEP has warned that within few decades, 50% of the population would face water scarcity. Reuse of waste water generated by society gives a big hope to civilization to prevent water crisis. It requires very high electricity consumption and many treatment plants do not operate regularly due to a shortage of power supply. Conventional wastewater treatment plants also create sludge which is a highly hazardous waste and another problem for society as they are not being properly disposed in secured landfills but thrown on the open lands (Kumar et al., 2019).
Under all these circumstances, our society needs an automated, self –regulated, no- or low- electricity no-sludge, no-noise pollution, and maintenance-free wastewater treatment plants to get cost-effective clean water for farm irrigation, domestic and industrial uses.

1.3 Vermifilter

Vermifiltration was first advocated by researchers at the University of Chile in 1992 as a low cost sustainable technology suitable for decentralised sewage treatment in rural areas. Vermifilters offer treatment performance similar to conventional decentralised wastewater treatment systems but with potentially higher hydraulic processing capacities. Vermifilters are a type of wastewater treatment biofilter or trickling filter but with the addition of earthworms to improve treatment efficiency. Vermifilters provide an aerobic environment and wet substrate that facilitates microorganism growth as a biofilm. Microorganisms perform biochemical degradation of organic matter present in wastewater. Earthworms regulate microbial biomass and activity by directly or/and indirectly grazing on microorganisms. Biofilm and organic matter consumed by composting earthworms is then digested into biologically inert castings (humus). The vermicast is incorporated into the media substrate, slowly increasing its volume. As this builds up it can be removed and applied to soil as an amendment to improve soil fertility and structure Microorganisms present are heterotrophic and autotrophic. Heterotrophic microorganisms are important in oxidising carbon (decomposition) whereas autotrophic microorganisms are important in nitrification. As a result of oxidation reactions, biodegradation and microbial stimulation by enzymatic action, organic matter decomposition and pathogen destruction occurs in the vermifilter.

2. LITERATURE REVIEW

2.1 What is sewage water?: Sewage water is the type of wastewater that is produced by a community of people. It is characterised by volume or rate of flow, physical condition, chemical and toxic constituent, sand its bacteriologic status. It consist mostly of grey water from (sinks, bathtubs, shower, dishwashers and clothes washers), black water (the water used to flush toilets, combined with human waste that it flushes away); soaps and detergents; Sewage usually travels from buildings plumbing either into a sewer, which will carry it elsewhere, or into an onsite sewage facility (of which there are many kinds). Whether it is combined with a surface runoff in the sewer depends on the sewer design (sanitary sewer or combined sewer).

2.2 Sewage Water Sources

Sewage is generated by residential, institutional, commercial and industrial establishments. It includes household waste liquid from toilets, baths, showers, kitchens, and sinks draining into sewers. In many areas, sewage also includes liquid waste from industry and commerce. The separation and draining of household waste into grey water and black water is becoming more common in the developed world, with treated grey water being permitted for use for watering plants or recycled for flushing toilets. Sewage may include storm water runoff or urban runoff. Sewerage systems capable of handling storm water are known as combined sewer systems. This design was common when urban sewerage systems were first developed, in the late 19th and early 20th centuries. Combined sewers require much larger and more expensive treatment facilities than sanitary sewers. Heavy volumes of storm runoff may overwhelm the sewage treatment system, causing a spill or overflow.

2.VERMICULTURE

Vermiculture is the science of cultivating earthworm which feed on waste material and release digested food material back into the soil, thereby producing composed rich in nutrient. Worms are natural plougher of the soil throughout the day and night, maintain the fertility and porosity of soil. Vermiculture is proven technology for increasing production and productivity of different crops. (Singh Karan et. Al, 2008). Vermiculture biotechnology is an aspect of biotechnology involving the use earthworm as versatile. Nature bioreactor for effective recycling of non toxic organic solid and liquid waste. Vermiculture means culturing of earthworms. The earthworm can effectively employed to maximise the growth of aerobic bacteria for waste processing, this can be achieved by providing proper living condition and feeding them organic waste. This technique does not require expensive laboratories of sophisticated.(Natraj et al, 2010) Some experts recommended the use of surface dwelling epigeic species for vermicomposting. Status report prepared by council for advancement of people action and rural technology, New Delhi (CAPART). The commonly used epigeic species are E.eugeniae, Eisenia fetida and Perionyx Perrier. Worms can tolerate temperature ranges of 5 to 29°C and required moisture content of 50 -60 % of earthworm functions. (Gajalakshmi et al, 2004)

4. MECHANISM OF WORM ACTION IN VERMIFILTER:: The two processes- microbial process simultaneously work in the vermifilteration system. Earthworm further stimulate and accelerate microbial activity by increasing. The population of through improving aeration (by burrowing action) earthworms host million of decomposes microbes in their gut and excrete them in soil along with nutrient nitrogen and phosphorous in their excreta called 'vermicast'. The nutrient N&P are further used by microbes multiplication and enhanced action.

- Vermifilter provide a high specific surface area of soil. Suspended solid are trapped on top of the vermifilter and preceded by earthworm and fed to the soil microbes immobilised in the vermifilter.
- Dissolved and suspended organic solid are trapped by adsorption a stabilised through complex biodegradation process that take place in the living soil inhibited by earthworm and aerobic microbes. Intensification of soil processes and aeration by earthworm enable the soil stabilisation and filtration system to become effective.
- Earthworm increases the hydraulic conductivity and natural aeration by granulation the clay particle. Earthworm prevents choking of the medium and maintain a culture of effective biodegrade microbes to function (Sinha et al.,2007)

5. MECHANISM OF ACTIVATED CHARCOAL IN VERMIFILTER: Activated carbon has been used as water filtering medium for purification of drinking water for many years. It is widely used for the removal contaminants in water due to their high capacity for adsorption of such compound, arising from their large surface area and porosity. Activated carbons have varied surface characteristics and pore sizes distribution, these characteristic of activated carbon play an important role in adsorption of contaminants in water. These contaminants produce bad tastes and odours, and also may constitute a source of infection. Activated carbon can remove the total suspended solids (TSS) and the biological oxygen demand (BOD) effectively over 99%, to 1 mg/l and also improve the tastes and odors of the drinking water. Absorptive properties can be explained by transport pores and adsorption pores of the activated carbon.

Adsorption of activated carbon takes place within the porous network of the particles. Activated carbon adsorption proceeds through three basic steps: (1) Substances adsorb to the exterior of the carbon granules; (2) Substances move into the carbon pores; (3) Substances absorb to the interior walls of the carbon: (4) Activated carbon is surrounded with transport pores which are the macropores on the exterior or surface of the carbon. Whereas, mesopores of the activated carbon are capillary branches off from the macropores toward the micropores. The macropores serve to trap absorbate materials from the external surface. Mesopores serve carry the absorbate materials to the interior of the particles where the finer pores or micropores will trap the absorbate onto the interior walls of the activated carbon. Pores (macropores and micropores) on activated carbon use to trap different sizes of contaminants. Macropores are used to trap larger contaminants and micropores are used to trap the smaller molecules.

Just 4 grams of activated carbon has a surface area the equivalent of a football field (6400 sqm). It's the massive surface area that allows active carbon filters to be very effective in adsorbing (essentially removing) contaminants and other substances .When the wastewater flows through active carbon filters the chemicals stick to the carbon resulting in purer water output. The effectiveness depends on the flow and temperature of the water. Therefore most smaller active carbon filters should be used with low pressure and cold water.In addition to the surface area active carbon filters may have different capabilities in terms of the size of contaminants they remove.

6. MATERIAL AND METHODOLOGY

6.1 EXPERIMENTAL DESIGN

The experimental set up placed for studying hasfive sets of reactor for evaluation purpose. Five different types of media were used as a vermifilter bed material like river bed material, vermicompost and activated charcoal. Each reactor consisted of plastic container having diameter of 200 mm and depth 300 mm. The top layer was 65 mm thick matured vermicompost (worm-bed). The second, third and fourth layers from top were taken as, 2.36 mm sand (70 mm thick), 10 mm gravel (20 mm thick), 20 mm coarse aggregate (40 mm thick) respectively.

Figure 1. Set-up of Vermifilter

Figure 2. Sand

The fifth and bottommost layer was taken as 20 mm activated charcoal (50 mm thick). The specification and arrangement of different layer is illustrated in Table 1. Only fifth layer was changed with different media (Activated charcoal) in all reactors which plays a major role during treatment process. The porosity of different media is represented in Table 2.

Figure 3. Gravel

Figure 4. Coarse Aggregate

Figure 5. Activated Charcoal

The wastewater was applied from the top side of reactors under gravity. To collect the wastewater a 350 litre storage tank was kept at certain height from the reactor that act as an overhead tank. In addition to this for maintaining hydraulic loading rate at constant level a 30 ltr. constant head tank was employed. For uniform distribution of wastewater, a 0.5 in. plastic pipe with 1.5 mm diameter hole was provided as a distributer on the top side of vermifilter bed for uniform distribution. Fig. 1 shows the schematic view of lab-scale vermifilter. Each vermifilter was inoculated with 150 earthworms (Eisenia

Figure 6. Matured Vermi-Compost

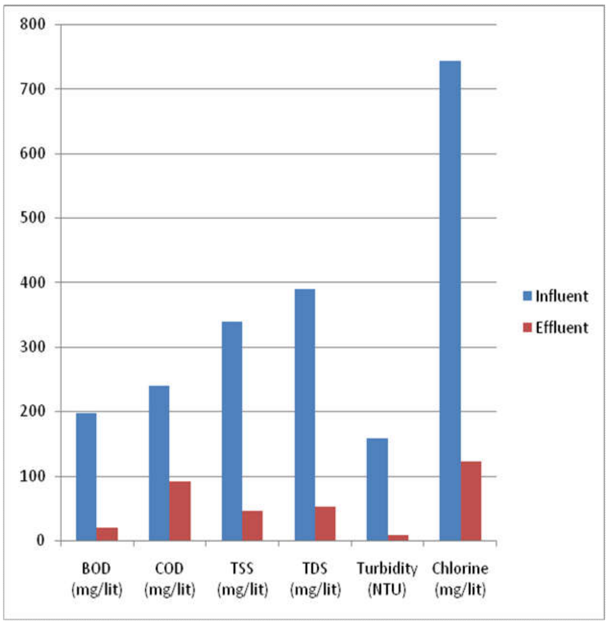

Figure 7. Comparison of Results

fetida) based on the stocking density of 10,000/cum of vermifilter bed. A constant hydraulic loading rate of wastewater, around 1.5 m^3/m^2/day, was maintained in all reactors during study period. The complete study was carried out for 90 days. Prior to analysis a 20 days acclimatization period were provided to the reactors. Description of the filter bed layers for vermifilter; Porosity of different media used in study;

6.2 EARTHWORM SPECIES USED: Long term researches into vermiculture have indicated that the Tiger worm (Eisenia Fetida), Red Tiger Worm (E. Andrei), the Indian blue worm (Perionyx excavatus), the African night crawler (Eudrilus euginae), are best suited for vermin-treatment of variety of solid and liquid organic wastes under all climatic condition (Graff 1981). Our study has indicated that Eisenia Fetida, E. Andrei, and Perionyx excavatus are voracious waste eater and biodegraders. We used the species Eisenia Fetida in our experiment. They are richly available in Maharashtra, India.

Table 1. Filter Bed Layers

Layers from top	Description of layers	Description of material in vermifilter	Size of material	Depth in (mm)
Layer 1	Active layer	Matured vermicompost	600-800µm	65
Layer 2	Supporting layer	Sand	2.36 mm	70
Layer 3	Supporting layer	Gravel	10 mm	20
Layer 4	Supporting layer	Coarse aggregate	20 mm	40
Layer 5	Active layer	Activated charcoal	20 mm	50

Table 2: Porosity of Medias used

Sr. no	Media	Size (mm)	Porosity (%)
1.	Sand	2.36	26
2.	Gravel	10	35
3.	Coarse aggregate	20	45
4.	Activated charcoal	20	43

Table 3. Result of Vermi-trearment

Sr.No.	Parameters	Influent	Effluent	Reduction in %
1.	Odour	Unpleasant	Odourless	-
2.	Colour	Brownish grey	Pale yellow	-
3.	BOD (mg/lit)	197	20.38	89.65
4.	COD (mg/lit)	240	91	62.08
5.	TSS (mg/lit)	340	45	86.76
6.	TDS (mg/lit)	390	53	86.41
7.	Turbidity (NTU)	158	8	94.93
8.	pH	6.58	7.15	-
9.	Nitrate mg/lit)	3.0	10.0	-
10.	Chlorine (mg/lit)	744.25	122.25	83.57

6.3 MATERIAL FOR FILTER MEDIA USED

6.3.1 Sand: Sand is a granular material composed of finely divided rocks and material particles. It is defined by the size being finer than gravel and closer than silt. We used river bed sand passing through 2.36mm I. S. Sieve for the experiment.

6.3.2 Gravel : Gravel is a loose aggregation of rock fragments. Gravel is classified by particle size range and includes size classes from granule- to boulder-sized fragments. In the Udden-Wentworth scale gravel is categorized into granular gravel and pebble gravel. We used gravel of size 10 mm for the experiment.

6.3.3 Coarse Aggregate: Coarse aggregates are a construction component made of rock quarried from ground deposits. Examples of these kinds of ground deposits include river gravel, crushed stone from rock quarries. We used coarse aggregate of size 20 mm size for the experiment.

6.3.4 Activated Charcoal: Activated carbon, also called activated charcoal, is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Activated charcoal sometimes referred to as charcoal filters contain small pieces of carbon, in granular or block form, that have been treated to be extremely porous. We used activated bamboo charcoal of size 20mm for our experiment.

6.3.5 Matured Vermi-Compost: Mature vermicompost bed is prepared for our experiment using black cotton soil of size 600-800µ mixed with powdered form of cow dung in a proportion of 1:3.

6.4 SAMPLING OF SEWAGE WATER

Wastewater sampling involves the collection of water samples and measurement for chemical and biological characteristic to determine its quality. These results are compared against water quality standard in regulation and guidelines to determine its use and the treatment required to make the water suitable for its intended use. The accuracy of water analysis is dependent on the sampling method used, the time elapsed between sampling and analysis, the technique used in laboratory analysis and interpretation of the result. Water samples are used to carry out a number of different test for water quality. The sampling is done by the method of grab sampling from Somalwada Sewage line during Sunday Peak hours and the sample in collected in two containers of 10 litres storage capacity.

6.5 PARAMETER TO BE STUDIED IN SEWAGE VERMIFILTERATION: The untreated sewage (influent) that was fed to the vermifilter and treated sewage (effluent) which was collected at the bottom of the vermifilter kit were analysed to study the BOD, COD, pH, Total dissolved solids, Total suspended solids, Turbidity, Odour, Colour, Nitrate and chlorine.

7. RESULT

Vermifilter kit was constantly observed for symptoms like foul odour, smooth percolation of wastewater through the soil bed, and appearance of the upper layer of soil bed. The vermifilter kit was also observed and monitored for the agility and movement of the earthworm, its growth, and health condition. Any toxicity in the wastewater might adversely affect the earthworm's population in the soil bed. There was very little or no problem of any foul odour with the vermifilter kit throughout the experimental study. However, foul odour was observed emanating from the control kit. Wastewater percolated smoothly into the soil bed in the vermifilter kit throughout the experimental study. The earthworm in the vermifilter bed were agile and healthy and achieved good growth throughout the period of study.

They appeared to be increasing in number and were much developed at the end of the study, about after 6 weeks or so. The influent and effluent wastewater obtained from vermfilter kit which is collected from the bottom of the chamber were analysed into laboratory. The influent was also tested before feeding it into vermifilter kit. The wastewater is then directly applied on the vermifilter bed. The impurities in the wastewater are absorbed in the soil and excess water percolates through vermiculture soil. Earthworm plays major role in removal of impurities in vermifilter kit. The results of various parameters are discussion.

8. CONCLUSION

- The average percentage reduction in concentration of total dissolved solid in vermi filter is found to be 86.41%.
- The average percentage reduction in concentration of total suspended solid in vermi filter is found to be 86.76%.
- The average percentage reduction in concentration of BOD in vermi filter is found to be 89.65%.
- The average percentage reduction in concentration of COD in vermi filter is found to be 62.08%
- The average percentage reduction in concentration of turbidity in vermi filter is found to be 94.93%.
- The average percentage reduction in concentration of chlorine in vermi filter is found to be 83.57%.
- The percentage reduction found in chlorine is due to the addition of activated charcoal which was found efficient in chlorine removal by 83.57%.
- There was a considerable increase in the percentage of nitrate which is desirable for irrigation purpose.
- The result found in the vermifilters containing activated charcoal is more efficient than in the filters without it.
- The reduction found in faecal count particularly with activated charcoal media indicates safer as well as hygienic for agricultural purpose.
- The treated water can be suitably disposed off into the water body after a treatment with a much lesser amount of disinfectant.
- Furthermore, the scientific implications of this research will allow the extension of this methodology to various decentralised/ onsite waste water treatment technologies where conventional sewage system do not exist or cannot be afforded.

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