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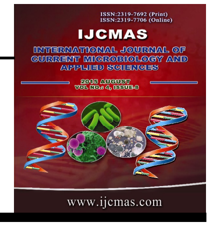

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Original Research Article

Design and Treatability Studies of Low Cost Grey Water Treatment with Respect to Recycle and Reuse in Rural Areas

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A B S T R A C T

In India, the 'water shortage' is one of the major issues coming from the rural areas area which necessitates grey water treatment options generated from domestic sources in rural areas and need for conceptualizing a treatment scheme to reduce cost. This paper present the design of laboratory scale grey water treatment system, which is restricted to five stages of physical operations such as raw grey water unit, sedimentation, first filtration unit of sand and gravel, second dual filtration and storing unit for treated grey water . The sample was collected from the Ashram School in rural area, Taluk Tivsa of Amravati District. The research work is related to the physico-chemical characterization of grey water samples, treatability studies were carried out for the treatment of grey water by using low cost technological options and to minimize the pollutant load from grey water. The results showed that nylon rope filter showed better performance in the filtration stage as compared to dual filters, and individually used activated carbon filter and zea maize fodder filter. Hence, this treatment technology could be considered as a viable alternative to conventional treatment systems in rural areas.

Keywords

Grey water, Low cost treatment system, Recycling, Reuse, Low cost materials

Introduction

Water is a fundamental source to our existence. As cities expand and population grows, the demand for water is rising. With increase in population, there will be an increase in stress on sanitation and wastewater disposal system. The concept of three R's, i.e. Reduce, Reuse and Recycle is a part of cleaner production that concentrates on pollution prevention at source rather than the end of pipe treatment. In other words, it is vitally important to treat wastewater in order to save water as a precious source and protect the environment from pollution (Jamil Ahmad and Hisham El. Dessouky, 2008). Throughout the world, supply of water to the rural population has been a challenging risk. By reusing water, it is possible to benefit from water that would otherwise be lost to us after a single use. Using domestic grey water is one way of contributing to the achievement of this reuse target (Greywater Use, October 2007). In India, the 'water shortage' is one of the major issues coming from the rural area (Vijayaraghavan Krishnan *et al.,* 2008). Grey water is slowly gaining importance in the management of water resources. The benefits of well organized grey water management is that it offers a tool for coping with water scarcity and reduces the amount of pollution to enter the hydrological cycle. Grey water can be defined as the wastewater generated from baths, showers, hand basins, washing machines and dishwashers, laundries and kitchen sinks. This means that the wastewater from toilets is excluded when considering the sources of wastewater of a household. The characteristics of the grey water depend on the facts such as the cultural habits, living standards, household demography type of household chemicals used etc. Grey water contains micro-organisms, chemical contaminants (e.g. nutrients and salts) and physical contaminants (dirt and sand) (Morel and Diener, 2006). The present study is made to assess the grey water produced at domestic sources of Ashram schools and need for conceptualizing a treatment scheme to conserve water. In general, design principles were based on the need to reduce cost. As a result of simplicity, readily available materials and low maintenance become key principles for rural area. The pollutants of grey water are reduced by a laboratory scale grey water treatment system was the aim of this study.

Materials and methods

Location

Shree Saint Satyadevbaba Primary and Middle Ashram School is situated in Mohjri, Taluk Tivsa of Amravati District. Amravati district is a district of Maharashtra state in central India. Amravati is the administrative headquarters of the district. The district is situated between 20°32' and 21°46' north latitudes and 76°37' and 78°27' east longitudes.

Sampling technique

Direct method i.e. Bucket Method was used for collection of grey water from Ashram School, wherein a bucket of 40-60 liter capacity was used. Screen was put at the inlet of pipe collecting grey water from the outlet of the pipe where the bucket was kept for the collection of grey water. The sample of grey water was collected from combined outlet of flowing water from bathrooms, washings and sinks from Ashram school.

Sample collection and analysis

Laboratory scale grey water treatment system was designed for 5 liters capacity, restricted to five stages of physical operations such as raw grey water unit of 10 liters capacity, sedimentation unit of 10 liters capacity, first filtration unit of sand and gravel of 5 liters capacity, second dual filtration unit of 5 liters capacity containing granular activated carbon and zea maize fodder and storing unit for treated grey water of 5 liters capacity as shown in figure 1. The easily available and natural materials were used as filter media in the filtration unit such as fine particles of sand 0-2 mm, gravel of 8-10mm and 18–20mm size, granular activated carbon, zea maize fodder which is the waste material used for the experiment. The bed height of each material was determined and finalized by the experimentation. The gravitational flow was used for the flow of water from raw grey water unit to the storing unit of treated grey water. The flow rate was adjusted at 20ml/min. The samples were collected from raw water and from each stage for the analysis. These samples were analyzed by standard method at laboratory (Aery, 2010; WHO, 2004; OECD, 2003; APHA, AWWA and WEF, 2005; Clair *et al.*, 2003). The parameter such as Turbidity, Total suspended solid (TSS),Total dissolved solids (TDS), Total hardness (TH), Chemical oxygen demand (COD) and Biochemical oxygen demand (BOD) and were determined of raw and treated water sample for the performance study of the grey water treatment system.

Statistical analysis

All analyses were performed in triplicates. The data were recorded as means ± standard deviation and analyzed using Microsoft excel.

Result and Discussion

Four experimental setups were performed by using low cost materials and their performances were evaluated. The low cost material such as sand, gravels, zea maize fodder, granular activated carbon and nylon rope were used in the filtration unit. The sample of water was taken before and after filtration with varying bed height of each filter bed at 20ml/min of water flow rate. The samples were analyzed for the physical and chemical parameters to check the quality of wastewater (raw grey water) and subsequently used the data for the selection of treatment process.

Experimental setup-I, using combination of zea maize and activated carbon (dual filter)

Table 1 shows the concentration of various selected parameters to remove load of pollutants of each stage of the Grey water treatment system. The levels of total dissolved solids (TDS) and Total suspended solids (TSS) of wastewater were 688 mg/l and 155mg/l respectively which are high and it was due to soap and dirt contaminations (organics). The high content of Total dissolved solids and Total suspended solids were also responsible for higher chemical oxygen demand (COD) and Biochemical oxygen demand (BOD). The pH and turbidity of wastewater were 8.39 and 145NTU respectively. Grey water is typically alkaline due to the use of soap and detergents (Katell Chaillou *et al.*, 2002). The data showed that sedimentation and filtration was decreased the quality of wastewater to be used for the filtration of sand and gravel filter and then through dual filter of zea maize fodder and activated carbon. Total suspended solids was reduced from 155mg/l to 10mg/l, total dissolved solids from 688mg/l to 645mg/l, turbidity from 145 to 13.86 NTU, total hardness reduced from 522mg/l to 273mg/l. Additionally the organic load in the form of Chemical oxygen demand (COD) reduced from 176.7mg/l to 98.23mg/l and Biochemical oxygen demand (BOD) from 56.65 to 31.74 mg/l. The applied treatment system has reduced the organic load nearly 50% 0f the original organic load.

Efficiency and performance of each stage of the treatment system of dual filter

The data showed that in sedimentation and filtration, there was maximum decrease in the total suspended solids (TSS) and turbidity levels. Due to sedimentation, the course size and fine solid particles were settled down by gravitational force and only clear water flew towards sand and gravel filter of treatment system and found that 87% of TSS was removed in the sedimentation unit, 37% by sand and gravel filter and 18% by dual media filter, (filter contain zea maize fodder and activated carbon).77% turbidity was removed by sedimentation unit, 42% was removed by sand and gravel and 27% was removed by dual media filter. In efficiency and performance at each stage of the treatment system, the results showed that, dual media filter which was combination of zea maize fodder and activated carbon filter beds did not give much better performance to remove the pollutants. Figure 2 explains the removal of pollutants from grey water in each stage of the grey water treatment system

Experimental setup-II, using activated carbon

The Total dissolved solids (TDS) and Total suspended solids (TSS) of waste water were found to be 752.31mg/l and 163.20mg/l respectively. Large quantity of suspended solids in wastewater could affect wastewater treatment processes in several ways. Suspended solids can interfere with the flow of water in transport pipes, distribution components, and soil pores. The pH and turbidity of wastewater was 8.31 and 160.49NTU respectively. The natural materials such as sand, gravels and activated carbon were used as medium in the filtration unit. Grey water was passed through a sedimentation tank. The sedimentation tank was designed to stabilize the flowing water or water is allowed to flow at a very low velocity. The heavier inorganic impurities settled at the bottom of tank and the lighter inorganic impurities float on the surface of liquid. It was observed that plain sedimentation tank removed about 60% of suspended matter and about 75% of bacterial load from water (Eriksson *et al.*, 2002). Table 2 shows the concentration of various selected parameters to remove load of pollutants from each stage of the treatment system. The data has showed that sedimentation and filtration improved the quality of wastewater after passing through sand and gravel filter media and then through activated carbon. pH was reduced from 8.38 to 7.65. TSS from 163.20mg/l to 14.31mg/l, TDS from 752.31mg/l to 611mg/l, turbidity from 160.49 to 29.30 NTU.TH reduced from 562.60 to 265.6mg/l. Additional parameters like COD reduced from 183.7mg/l to 74.60mg/l with BOD from 59.24mg/l to 20.56 mg/l.

Efficiency and performance of each stage of the treatment system of activated carbon filter

Figure 3 indicates the removal of pollutants in each stage of the grey water treatment system. Due to sedimentation, the course size and fine solid particles are settled down by gravitational force and only clear water flew towards sand and gravel filters removing 82% of TSS in the sedimentation unit, 38% was removed by sand and gravel filter and 22% was removed by activated carbon filter. 66% turbidity was removed by sedimentation unit, 37% was removed by sand and gravel and 13% was removed by activated carbon filter. The result showed that activated carbon filter beds which were used instead of dual media filter did not give better performance to remove the selected parameters of grey water.

Experimental setup-III, using Zea maize fodder

The data revealed that the water is alkaline in nature. The average conductivity value was 1240 µS/cm. The TDS and TSS of wastewater were also high and it was due to soap and dirt contaminations. The turbidity of grey water was 167.58 NTU. Table 3 shows the reduction in concentration levels of various selected parameters in each stage of the treatment system of activated carbon. The data showed that filtration through zea maize fodder did not much improve the quality of waste water. pH was reduced from 8.10 to 7.89. TSS from 132.20mg/l to 12.02mg/l, TDS from 868mg/l to 854.20mg/l, turbidity from 167.58 to 20.20

NTU. Total hardness reduced from 576.86mg/l to 311.01mg/l. The parameters like COD, reduced from 165.47mg/l to 58.52mg/l, whereas BOD from 48.27mg/l to 18.71mg/l. Total nitrogen was reduced from 53.44mg/l to 18.22mg/l.

Efficiency and Performance of each stage of the treatment system of Zea maize fodder filter

Figure 4 presents the removal of pollutants in each stage of the grey water treatment system. Due to sedimentation, the course size and fine solid particles were settled down by gravitational force and only clear water did flow towards sand and gravel filter of treatment system and found 68% of TSS reduction in the sedimentation unit, 51% in sand and gravel filter and 51% in zea maize fodder filter.68% turbidity was removed in sedimentation unit, 29% in sand and gravel and 51% by activated carbon filter media. The result showed that activated carbon filter beds which were used instead of dual media filter did not give better performance to remove the selected parameters of grey water.

Experimental setup-IV, using Nylon rope

The data revealed that the pH of grey water was alkaline in nature. The average conductivity value was 1011µS/cm. The TDS and TSS were 705.16mg/l and 165.29 mg/l respectively which were high due to soap and dirt contaminations. The turbidity of grey water was 159.88 NTU. The average value of Total hardness was found to be 445.67mg/l. Table 4 shows the concentration levels of various selected parameters to remove pollutants at each stage of the treatment system of nylon rope filter. The data showed that filtration through Nylon rope improve the quality of wastewater. pH did not vary much. Total suspended solids were reduced from 165.29mg/l to 1.2mg/l, TDS from 705.16 mg/l to 95.64mg/l, turbidity from 159.88NTU to 3.1 NTU. Total hardness reduced from 415.97mg/l to 43.12 mg/l. Additional parameters like COD reduced from 166.25mg/l to 19.1mg/l, BOD from 52.41mg/l to 5.36mg/l. Total nitrogen was reduced from 35.23mg/l to 10.32mg/l.

Efficiency and Performance at each stage of the treatment system of Nylon rope filter

Figure 5 presents the removal of pollutants at each stage of the grey water treatment system. Due to sedimentation, the course size and fine solid particles are settled down by gravitational force and only clear water did flow towards sand filter and then through Nylon rope filter. Removal was found to be 90% for TSS level in the sedimentation unit, 81% in sand and gravel filter and 63% by nylon rope filter. 78% removal was observed in turbidity level in sedimentation unit, 72% in sand and gravel and 68% by nylon rope filter. The result showed that nylon filter beds which were used instead of dual media filter and activated carbon showed better performance to remove the selected parameters of grey water.

Evaluation of Grey water Treatment system

For all pollutants removal efficiency was increased in the filtration stage. This stage was only to control the total treatment system. Hence the filtration stage was studied and performance evaluation for removal of load pollutants in grey water at each filter bed was investigated and is depicted in figures 6 and 7. The results showed that nylon rope filter media showed better performance in the filtration stage as compared to dual media filters (combination of zea maize fodder and activated carbon), and individually used as activated carbon filter and zea maize fodder.

The results presented in this study are to establish the potential applicability of the developed low cost technological treatment system especially for the rural areas in which economics is the major constraint. This laboratory scale grey water treatment system is a combination of natural and physical operations which could be applied easily without any maintenance. All the natural and easily available low cost materials were used for the treatment process. Economically the unit could be easily made available, the power supply, which is an important part of the operating cost of the conventional system and it is a today's major issue in India, is required minimum, because system works on the natural force for flowing of water from first stage to last stage.

The laboratory treatment system showed the better and effective performance with balances advantages and disadvantages at rural level. As per the Indian standard, the treated water could be used for toilet flushing. The benefits found are the easily applicable operation; less maintenance of the plant hence does not require the highly skilled personnel. After the investigations, it could be impressed upon that due to negligible energy demand, low operation and maintenance cost, lesser time consuming operation, this treatment system may be applied as a significant and efficient treatment system for rural communities for treatment and reuse of grey water.

Table.1 Concentration of various parameters at each stage of treatment system of Dual filter

Sr. No.	Parameters	wastewater	Sedimentation tank (unit 1)	Sand and gravel filter (unit 2)	Dual filter (unit 3)
1	Turbidity(NTU)	145.16±0.30	34.1±0.17	19.08±0.02	13.86±0.01
2	TSS(mg/l)	155.33±0.01	19.53±0.01	12.32±0.01	10.12±0.01
3	TDS(mg/l)	688.50±0.01	649.1±0.17	638.03±0.06	645.32±0.01
4	TH(mg/l)	522.37±0.54	396.96±0.99	285.5±0.61	273.5±0.06
5	COD(mg/l)	176.37±0.32	153.22±0.01	152.39±0.05	98.23±0.01
6	BOD(mg/l)	56.65±0.01	49.76±0.01	47.53±0.06	31.73±0.01

(Concentration is reported as Average values ± Std. deviation)

Table.2 Concentration of various parameters at each stage of treatment system of Activated carbon

Sr. No.	Parameters	wastewater	Sedimentation tank (unit 1)	Sand and gravel filter(unit 2)	Activated carbon filter (unit 3)
1	Turbidity(NTU)	160.49 ±0.49	54.32±0.56	34.17±0.06	29.30±0.26
2	TSS(mg/l)	163.20±0.18	29.31±0.02	18.31±0.01	14.31±0.01
3	TDS(mg/l)	752.31±0.10	721.31±0.01	672.60±0.01	611.60±0.01
4	TH(mg/l)	562.60±0.79	311.55±0.11	279.13±0.12	265.48±0.10
5	TN(mg/l)	30.53±0.15	21.24±0.07	18.19±0.08	15.14±0.04
6	COD(mg/l)	183.25±0.06	160.25±0.22	101.16±0.11	76.54±0.01
7	BOD(mg/l)	59.24±0.12	50.43±0.06	48.50±0.01	20.56±0.39

(Concentration is reported as Average values ± Std. deviation)

Table.3 Concentration of various parameters at each stage of treatment system of zea maize fodder

Sr. No.	Parameters	wastewater	Sedimentation tank (unit 1)	Sand and gravel filter(unit 2)	Zea maize fodder filter (unit 3)
1	Turbidity(NTU)	167.58±0.50	54.06±0.04	35.2±0.01	20.2±0.02
2	TSS(mg/l)	132.2±0.01	42.29±0.03	30.12±0.01	12.02±0.01
3	TDS(mg/l)	868±0.01	861.17±0.09	858.9±0.09	854.2±0.05
4	TH(mg/l)	576.86±0.02	389.82±0.03	324.21±0.18	311.01±0.01
5	TN(mg/l)	53.44±0.05	48.47±0.25	19.25±0.03	18.22±0.01
6	COD(mg/l)	165.47±0.20	142.4±0.07	139.17±0.05	58.52±0.03
7	BOD(mg/l)	48.27±0.10	45.46±0.04	45.12±0.46	18.71±0.13

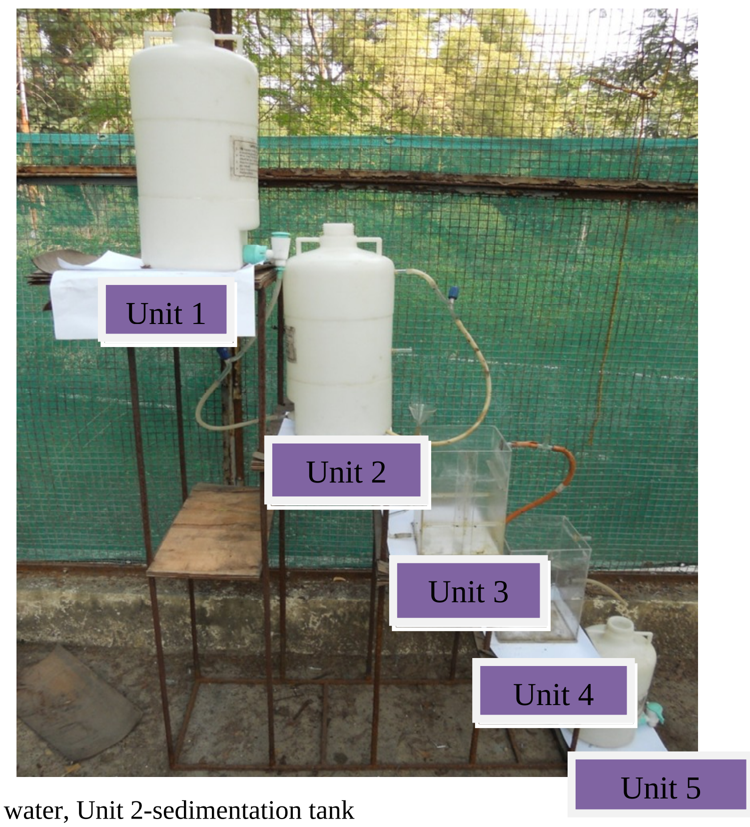
(Concentration is reported as Average values ± Std. deviation)

Table.4 Concentration of various parameters at each stage of treatment system of nylon rope filter

Sr. No.	Parameters	wastewater	Sedimentation tank (unit 1)	Sand and gravel filter (unit 2)	Nylon rope filter (unit 3)
1	Turbidity(NTU)	159.88±0.12	35.4±0.26	9.7±0.06	3.1±0.01
2	TSS(mg/l)	165.29±0.29	17.16±0.01	3.33±0.15	1.2±0.01
3	TDS(mg/l)	705.16±0.42	526.73±0.15	205.55±0.01	`95.64±0.01
4	TH(mg/l)	445.67±0.12	415.97±0.06	122.34±0.01	43.12±0.01
5	TN(mg/l)	35.23±0.04	21.2±0.06	15.94±0.02	10.32±0.02
6	COD(mg/l)	166.25±0.03	144.65±0.02	44.65±0.02	19.1±0.06
7	BOD(mg/l)	52.41±0.01	46.02±0.01	12.88±0.02	5.33±0.03

(Concentration is reported as Average values ± Std. deviation)

Figure.1 Experimental set up



Unit 1-raw grey water, Unit 2-sedimentation tank
Unit 3-sand and gravel filter, Unit 4- filtration unit
Unit 5-treated grey water

Figure.2 % Removal efficiency of various parameters in each stage of treatment system of Dual filter

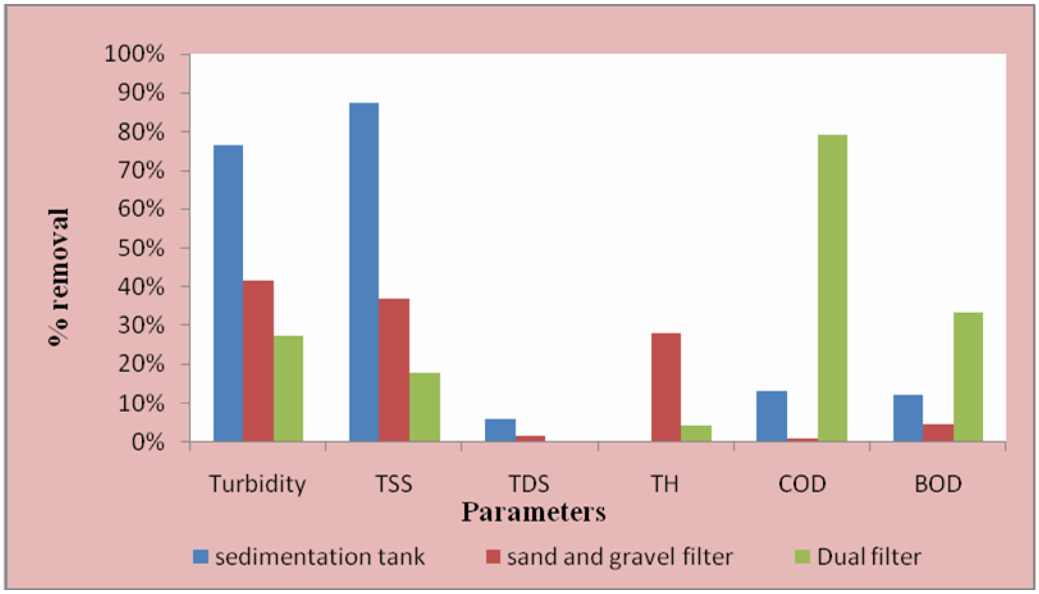


Figure.3 % Removal efficiency of various parameters in each stage of treatment System of activated carbon

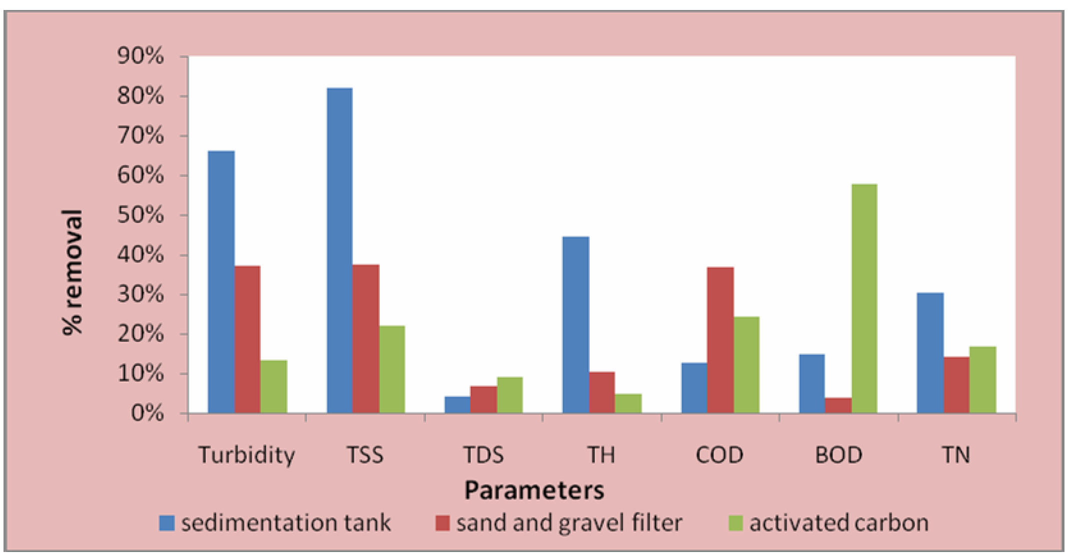


Figure.4 % Removal efficiency of various parameters in each stage of treatment system of activated carbon

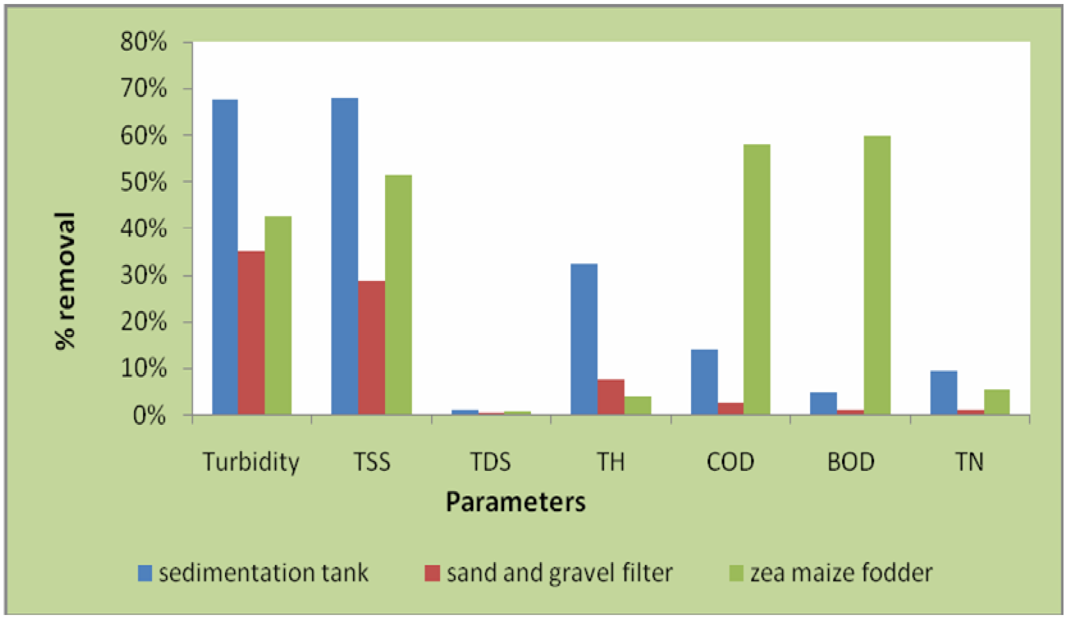


Figure.5 % Removal efficiency of various parameters in each stage of treatment system of nylon rope filter

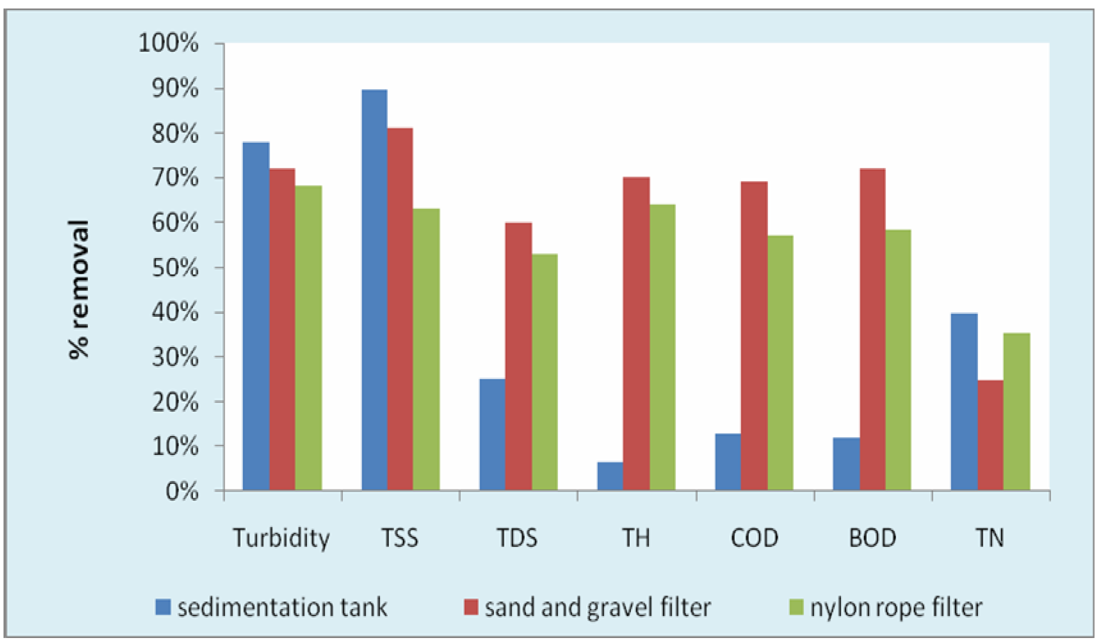


Figure.6 % Removal of pollutants (TH, TDS, TSS, and Turbidity) by each filter bed in the filtration operation

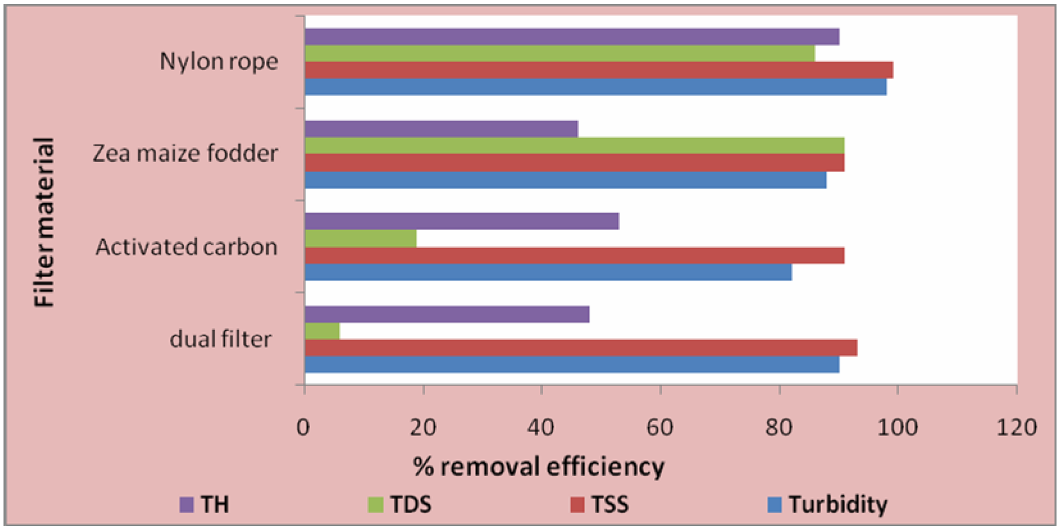
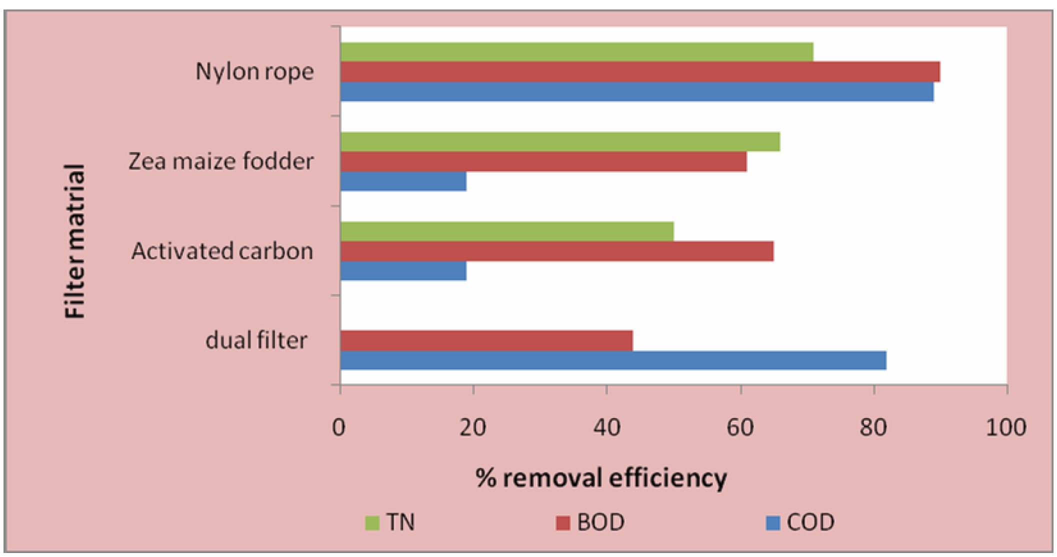


Figure.7 % Removal of pollutants (TN, COD and BOD) by each filter bed in the filtration operation



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