OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Performance Evaluation of Bioretention System in Chalakudy River Water

RADHA U M[1], AGNUS[2], ATHULYA[3], SALIH P M[4], NISHAD M M[5]
[1]RADHA UNNIKRISHNAN M, ASSISTANT PROFESSOR, NIRMALA COLLEGE OF ENGG, KERALA, radhau62@gmail.com
[2]AGNUS VARGHESE, B.Tech STUDENT, NIRMALA COLLEGE OF ENGINEERING, KERALA, agnesagivarghese1@gmail.com
[4]ATHULYA JINAN, B.TECH STUDENT, NIRMALA COLLEGE OF ENGINEERING, KERALA, athulyateej@gmail.com
[4]SALIH P M, B.TECH STUDENT, NIRMALA COLLEGE OF ENGINEERING, KERALA, salihpm777@gmail.com
[5]NISHAD M M, B.TECH STUDENT, NIRMALA COLLEGE OF ENGINEERING, KERALA, nishadmm13@gmail.com

Abstract
Bio-retention is a simple bio filtration method. It is a terrestrial based, water quality control practice using the chemical, biological and physical properties of plants, microbes and soil for removal of pollutants from water. In this paper we are evaluating whether this method is suitable for river water. River is the main source of water for several purposes such as drinking water, irrigation etc. However, river is also used as a point where to dump wastes too. Source of pollution in river water is generally categorized to agricultural runoff, industrial effluents and domestic waste from residential areas. Using pesticides and fertilizers in agricultural lands contributes to the pollutant runoff to rivers. Most of the industries are releasing their treated effluents to rivers. Hence it is treated effluent; still it creates pollution problems in some cases. Chalakudy River is the main source of water for several panchayats. However, the presence of agricultural land, residential areas and industrial areas increases the chance of pollution. So, we selected Kathikudam Region, which consists of agricultural lands, residential areas and industries as our source of water. We collect water from near to KCPL Kadavu in Kathikudam village and it is used as raw water for our filtration unit. The quality analysis for raw water and filtered water will be conducted and it will be compared with IS standards and analyze whether the filtration unit is suitable or applicable to river water.
Keywords: *Bioretention; Pollutant Removal; Mechanism; Vegetation*

Date of Submission: 15-05-2024 Date of acceptance: 29-05-2024

I. Introduction

Water is considered as the most important and priceless commodity on planet earth. Water on earth moves continually through the water cycle of evaporation, transpiration, condensation, precipitation, and runoff, usually reaching the sea. It is one of the most essential things that is required for every living being. In order to develop a healthy and hygienic environment, water quality should be monitored such that it lies within the respective standards.

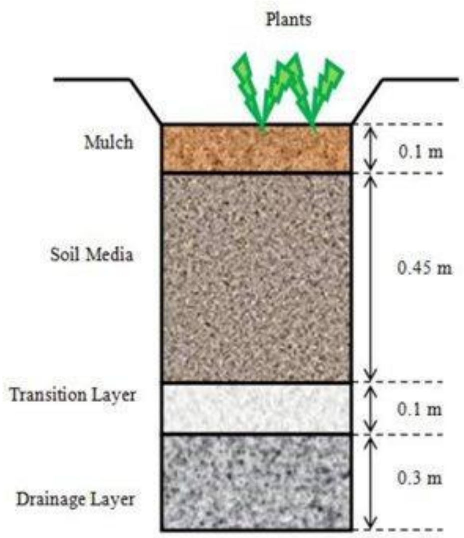
The total water quantity on earth is constant and is recycled by nature in the atmosphere, on the earth surface, below the surface and in the oceans. Population explosion, rapid industrialization and consequent urbanization have increased the demand for the required quantity of water, for different uses. Over recent decades, man has been solely responsible for contaminating the sources of water by neglecting to control the pollution of water. Generally, the pollutants come from three prominent sources- sewage discharged into the river, industrial effluents discharged into the river without any pre-treatment, surface runoff from agricultural land, where chemical fertilizers, pesticides, insecticides and manures are used. Bioretention systems are used to remove a wide range of pollutants, such as suspended solids, nutrients, metals, hydrocarbons, and bacteria from river water. Now the bio retention unit is used to stormwater management and filtrate the stormwater pollutants.

We know previous studies have shown this system is to be effective in stormwater management. If so, through this paper, we check this system is suitable in case of river water.

II. Bioretention System

Bioretention system is a terrestrial based filtration system having a porous filter medium with a drainage facility at the bottom. It is a water quality control practice using the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from water. Bioretention system treat a range of pollutants through physical, chemical and biological processes such as mechanical filtering, sedimentation, adsorption, and plant and microbial uptake. It is a storm water best management practice that uses an engineered runoff reaches the basin through a combination of underground pipes, ditches and overland flow.

fig 2.1 Bioretention System



2.1. **Elements**

Each layer in bioretention system plays vital role in both quantitative and qualitative management of water. Each layer has their own function in the qualitative management process. So materials selecting for each layer should be taken with care and suitable materials should be selected.

2.1.1. Vegetation Layer

It serves multiple roles in water treatment via uptake, transformation to organic forms, carbon provision to microbes, helping to maintain infiltration rates, provides cooling to environment, amenity and aesthetics to land. The microbial community associated with plant roots facilitates uptake, decomposition of pollutants. It helps to remove excess nutrients through the roots of plants.

2.1.2. Mulch

Mulch provides physical filtration and acts as a pre-treatment and anti-scour layer for the media. In addition, the mulch layer protects bio filtration media from occlusion by capturing sediment loads and debris. The mulch also provides water retention for the system's vegetation.

2.1.3 Filter Media

The filter media layer provides the majority of the pollutant treatment function, through fine filtration and also by supporting vegetation. It provides physical filtration of particulates, physiochemical pollutant removal process such as adsorption, fixation, precipitation.

2.1.4. Transition Layer

The purpose of the transition layer is to prevent the filter media from migrating down into the drainage layer (or the saturated zone). It also acts as a buffer between the permanently saturated zone (if required) and the filter media.

2.1.5 Drainage Layer

The drainage layer is used to convey treated flows from the base of the filter media layer (or the saturated zone) into the perforated under-drainage system.

III. Site Details

Water for experimental purpose is collected from the Chalakudy River. Four set of samples were collected from the spot near to KCPL Kadavu and Pulikakadavu in Kathikudam Village by the method of grab sampling. As stated earlier, major sources of pollutants to river is from residential areas, agricultural runoff and industrial effluents. This place which comes as the downstream point of Chalakudy river, is a residential area with agricultural land and consist of industries too. In past, several pollutions related problems were raised in this locality. These were the reasons to select this area for the sample collection.

IV. Materials

A tank of glass material with size 30cm×45cm×60cm is used. Purpose of using glass material is for the easiness to see the process undertaken in the filter media layers. Each layers provided in the tank is clearly seen through the tank glass.

4.1. Coarse Aggregate

Coarse aggregates are arranged in a drainage layer at the bottom of the tank. The size of aggregate varies from 25mm to 4.75 retained. Before filling, material is washed and dried to remove the dust, dirt and presence of other microbes.

Fig 4.1 Coarse Aggregate

4.2. Fine aggregate

The size of aggregate varies from 4.75mm passing to 150 microns retained, the aggregate is collected, sieved through different sieves. Before filling, material is washed and dried in order to remove the dust, dirt and presence of other microbes.

Fig 4.2 River Sand

4.3 Mulch

Mulches can include organic mulches like fresh wood chips or aged composted mulch Organic wood mulch is often a by-product of the lumber industry (typically shredded bark), wood recycling centers (i.e. pallets) or processed yard waste from public landfills.

4.4 Vegetation

Vetiver plant which is found commonly in the nearby area is used. The Vetiver plant is also used in wetland systems which is a good candidate for remediation of waste waters by constructed wetland technology. It also withstands most of the climatic change and also helps to maintain the permeability.

Fig 4.3 Vetiver Plant

V. Methodology

In order to analyze the performance of bioretention system in river water, a sample prototype of conventional bioretention unit is constructed. A tank of glass material is used. Materials needed for each layer is collected, washing if needed in case of aggregates, sieved and filled in the tank. Water for filtering is collected from the Chalakudy River. Four set of samples were collected from the selected site by the method of grab sampling. Various water quality assessing tests such as pH, turbidity, total dissolved solids, total alkalinity, total chloride, biochemical oxygen demand, dissolved oxygen etc. where conducted. Then water is allowed to filter through the unit. The filtered water collected from the unit is again taken for water tests and it is compared with previous test results and IS standards of drinking water.

5.1. Experimental programs

All the water quality assessment tests were performed as per the IS code. The various parameters along with their methods and respective IS codes were tabulated below.

Table No.1 Water Quality Parameters

Sl.No	Parameter	Method	IS Code
1	pH	Electrometric Method	IS 3025-11 (1983)
2	Turbidity	Turbid meter	IS 3025-10 (1984)
3	Total Dissolved Solids	Gravimetric method	IS 3025-16 (1984)
4	Total Alkalinity	Titrimetric method	IS 3025-51 (2001)
5	Total Hardness	EDTA method	IS 3025-21 (2009)
6	Total Chloride	Argentometric method	IS 3025-32 (1988)
7	Dissolved Oxygen	Winkler method	IS 3025-38 (1989)
8	Biochemical Oxygen Demand	--	IS 3025-44 (1993)
9	Chemical Oxygen Demand	--	IS 3025-58 (2006)
10	Nitrate	Chromotropic Acid Method	IS 3025-34 (1988)

VI. Water Quality Analysis

Chalakudy river is the fifth longest river and tributary of Periyar river in Kerala, India. The river flows through Thrissur district, Palakkad district and Ernakulam district of Kerala. The major source of several water supply units, irrigation water projects are Chalakudy River. Several Panchayats in Thrissur district depends on Chalakudy river as their main water source. In past several pollutions related protests were prevailed in related to Chalakudy river. So we collected water samples from Chalakudy river to use as raw water to the filtering. The water quality tests were conducted to raw water and their results are tabulated below.

Table 2. Water Quality Results for River Water

Parameters	IS Limits	Unit	Sample 1	Sample 2	Sample 3	Sample 4
pH	6.5 to 8.5	-	6.42	6.4	6.45	5.93
Turbidity	5	NTU	15.8	0.4	2	4.23
Total Dissolved Solids	500	Mg/L	910	536	678	476
Total Alkalinity	200	Mg/L	118	88.7	81.6	101
Total Hardness	300	Mg/L	432	360	347	222
Total Chloride	250	Mg/L	99	121	132.97	125.71
Dissolved Oxygen	8	Mg/L	3	3.6	3.3	3.6
Biochemical Oxygen Demand	30	Mg/L	6	44	14.5	35
Chemical Oxygen Demand	250	Mg/L	19.8	154	53.2	87.61
Nitrate	45	Mg/L	60	55.1	56.3	65.32

VII. Results and Discussions

River water collected from the selected site is used to filter through the bioretention system. Four set of samples were completed from the site in an interval of 7 days. The filtered water was collected from the bioretention system and their water quality were assessed and compared with IS limits and raw water. The test results of filtered water are tabulated below.

Table 3. Water Quality Results for Filtered Water.

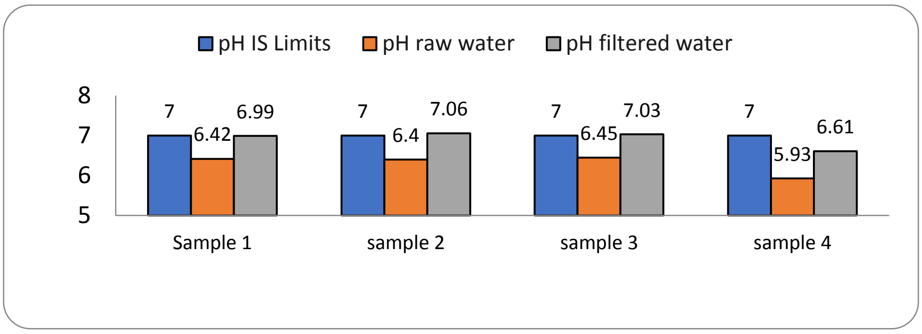
Parameters	IS Limits	Unit	Sample 1	Sample 2	Sample 3	Sample 4
pH	6.5 to 8.5	-	6.99	7.06	7.03	6.61
Turbidity	5	NTU	0.8	<LOQ	<LOQ	0.7
Total Dissolved Solids	500	Mg/L	184	168	174	113
Total Alkalinity	200	Mg/L	13.8	<LOQ	12.3	<LOQ
Total Hardness	300	Mg/L	101	64	52	48
Total Chloride	250	Mg/L	67.9	42.4	80.7	57.8
Dissolved Oxygen	8	Mg/L	2.5	3.5	2.7	2.4
Biochemical Oxygen Demand	30	Mg/L	<LOQ	9.88	3.5	8.67
Chemical Oxygen Demand	250	Mg/L	<LOQ	34.6	30.8	38
Nitrate	45	Mg/L	12.8	2.3	3.13	3.2

Note: LOQ means limit of quantitation

7.1 pH and Total Alkalinity

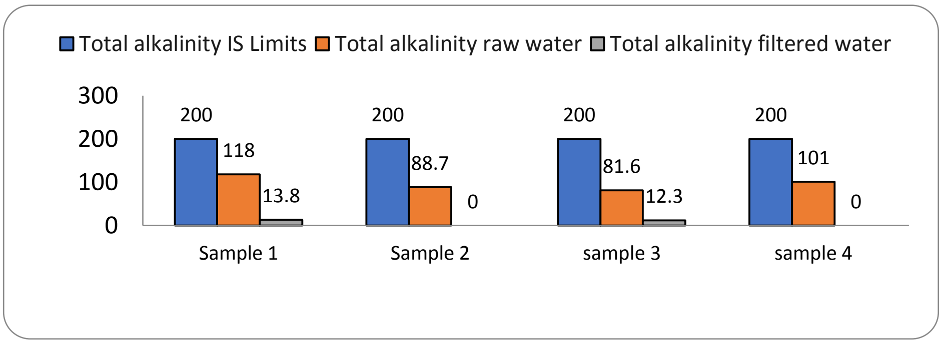
pH is the measure of water, whether it is acidic or basic. The pH of drinking water lies between 6.5 to 8.5. The same range is also applicable to the water which is used for construction purposes too. Alkalinity is the measure of buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or waste water. alkalinity not only helps to regulate the pH of water body, but also the metal content.

Graph 1. pH



From the samples we can say that the raw water collected from the selected site is slightly acidic and the filtered water meets the IS standards.

Graph 2. Total Alkalinity

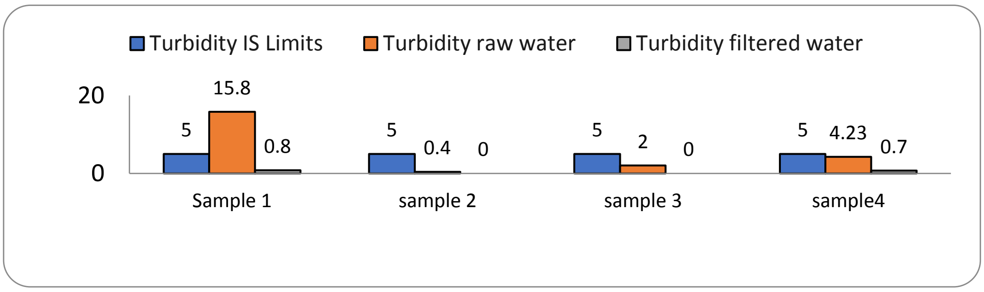


In case of alkalinity, both raw and filtered water lies within the limit. By the filtration of water through bioretention, the amount of alkalinity is decreased when compared to the values of raw river water. if excess amount of alkalinity is present, the bioretention system can decrease its excess content.

7.2 Turbidity and Total Chloride

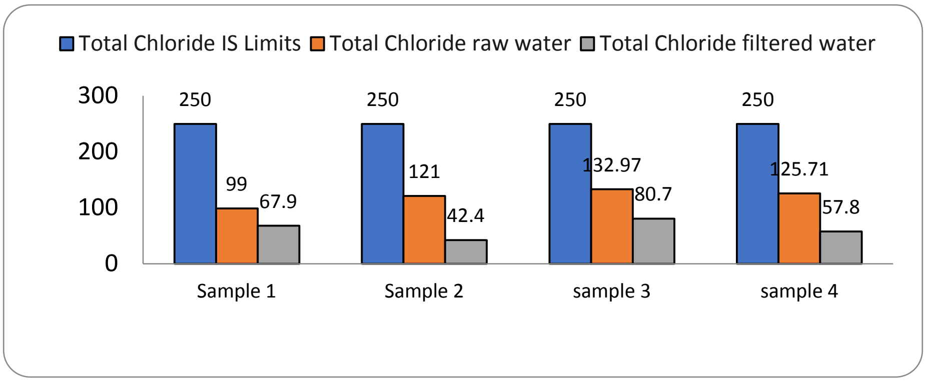
The haziness or cloudiness of water due to various individual particles that can be seen with naked eyes is known as turbidity.

Graph 3. Turbidity



Excessive turbidity on water is aesthetically unappealing and may also represent health concern. Turbidity can provide shelter and food to pathogens. Regrowth of pathogens will be promoted, and lead to waterborne disease outbreaks. Most of the turbidity values in raw water lies within the limit. Filtered water also shows good results. High turbid value is due to the first rainfall. Chlorides are salts resulting from the combination of the gas chlorine with a metal. Chlorine alone as is highly toxic and it is often used as disinfectant. Small amount of chlorides is required for normal cell functions in plant and animal life.

Graph 4. Total Chloride

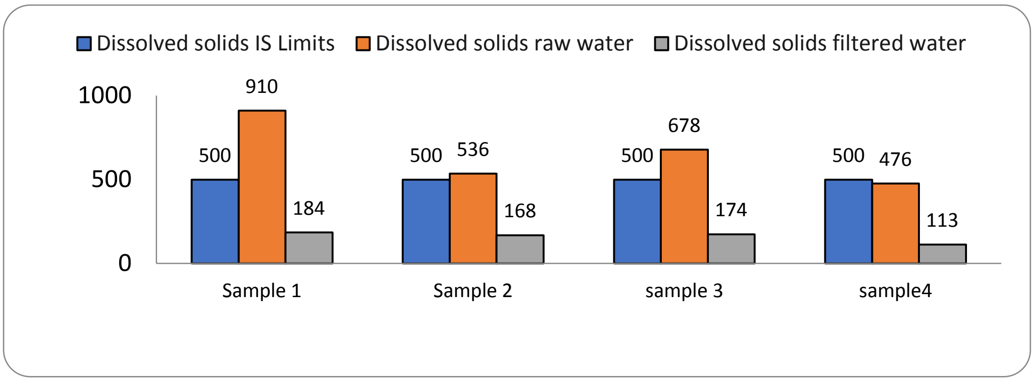


Chlorides may get into surface water from several sources including agricultural runoff, wastewater from industries, effluent waste water from water treatment plants etc. chloride can corrode metal and affect the taste of food products. Chloride content can contaminate fresh water streams and lakes. Here both raw water and filtered water lies within the IS limits.

7.3 Dissolved Solids and Hardness

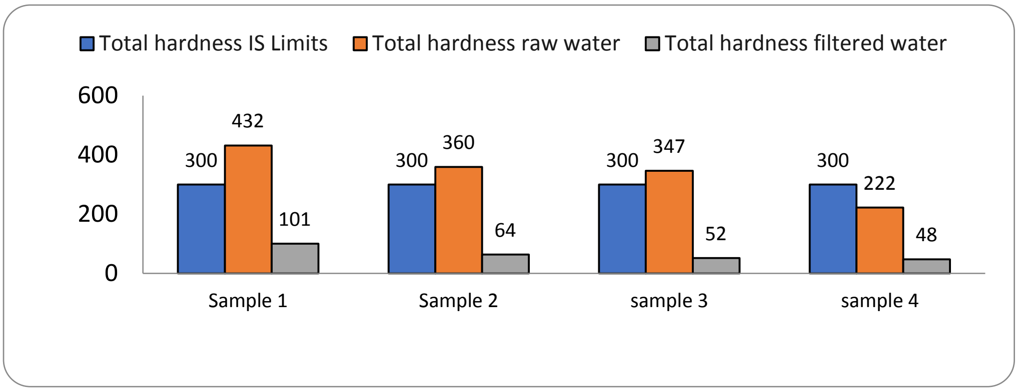
Total Dissolved Solids are the solids in water represents the total concentration of dissolved substances in water. This material can include carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life.

Graph 5. Dissolved Solids



TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high-water hardness, and could result in a laxative effect. Raw water exceeds the limit while the filtered water lies within the limit. Hardness is measure of polyvalent cations (ions with a charge greater than +1) in water. Hardness generally represents the concentration of calcium ($Ca^{2+)}$ and magnesium (Mg) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn), may also contribute to the hardness of water, but are generally present in much lower concentrations

Graph 6. Total hardness

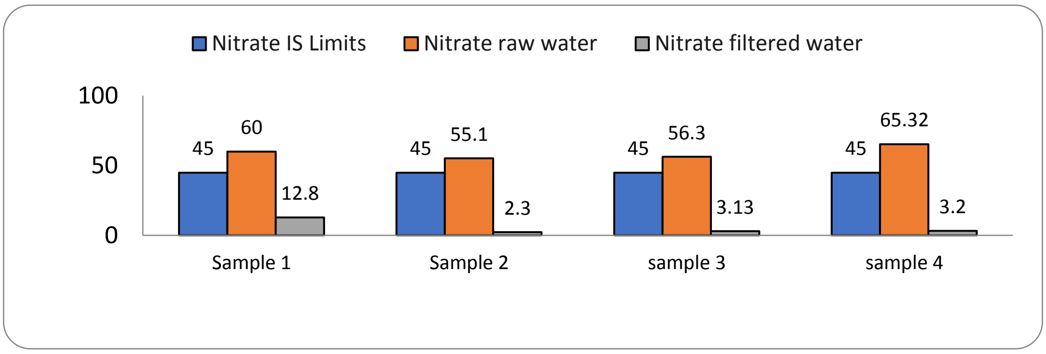


Hardness of the water is very important in industrial uses, because it forms scale in heat exchange equipment, boilers, and pipe lines. Some hardness is needed in plumbing systems to prevent corrosion of pipes. Here raw water exceeds the limit whereas filtered water lies within the limit.

7.4 Nitrate and Dissolved Oxygen

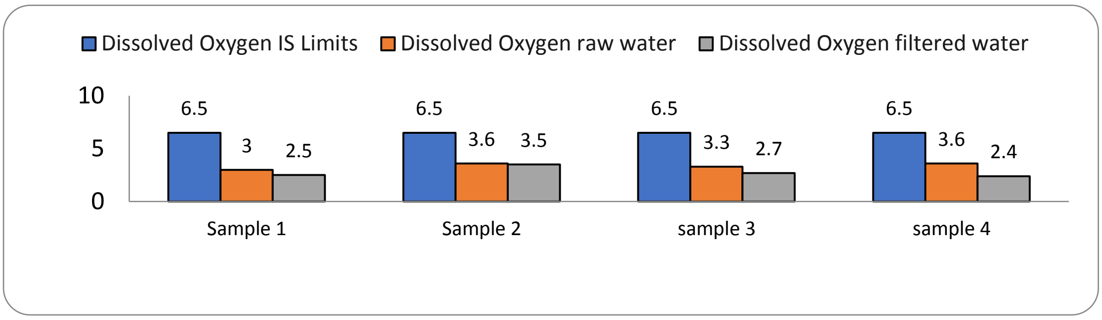
Agricultural fields form the main diffuse sources of the NO3 that is leached to groundwater. However, NO3 is also released from exercise yards and manure storage facilities, which represent important potential point sources of contamination.

Graph 7. Nitrate



If excessive amounts of phosphorus and nitrates are added to the water, algae and aquatic plants can be produced in large quantities. Here nitrate values exceed in raw water while filtered water lies within the limit. Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms. The amount of dissolved oxygen in a stream or lake can tell us a lot about its water quality.

Graph 8. Dissolved Oxygen

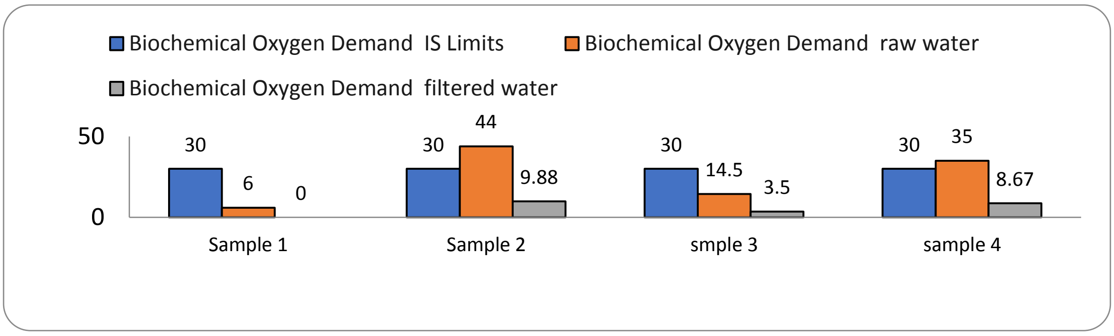


If the amount of dissolved oxygen exceeds the limit, the algae growth promotes. These algae consume the oxygen in water which reduces the amount of dissolved oxygen and it causes destruction to aquatic life. All aquatic animals need DO to breathe. Low levels of oxygen (hypoxia) or no oxygen levels (anoxia) can occur when excess organic materials, such as large algal blooms, are decomposed by microorganisms. During this decomposition process, DO in the water is consumed. Here both raw water and filtered value lies within the limit**.**

7.5 Biochemical Oxygen Demand and Chemical Oxygen Demand

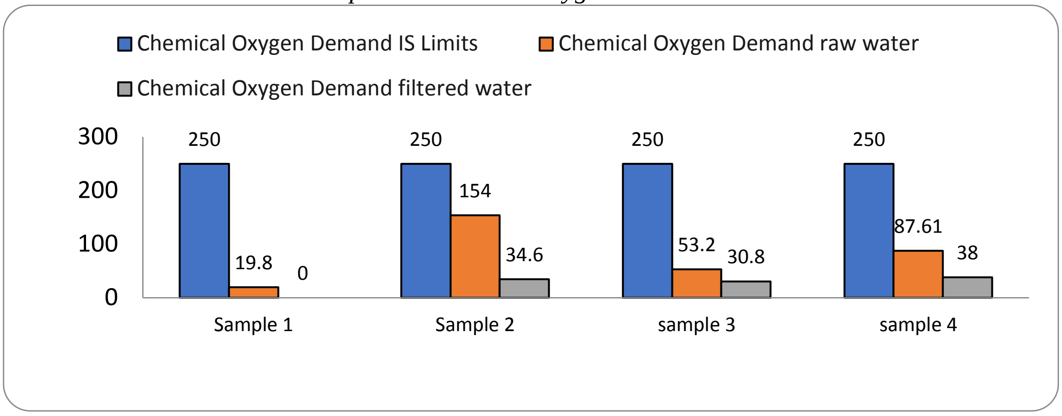
BOD is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria. You can measure biological oxygen demand with the dilution method. if the BOD levels are high, the water is contaminated.

Graph 9. Biochemical Oxygen Demand



Effluents from agricultural area, residential area, industrial area are main sources of BOD in water. Here raw water collected in various days shows variation. Filtered water lies within the limit. Chemical Oxygen Demand (COD) is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant. COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the municipal and industrial wastes.

Graph 10. Chemical Oxygen Demand



A higher COD in a sample indicates that it contains higher levels of oxidizable material. If this is the case, then the water will have reduced dissolved oxygen levels. Both raw water and filtered water lie within the limits.

VIII. Conclusions

Clean water is imperative to maintaining ecological balance and protecting the public's health. The increase in water pollution has contributed to the decrease in aquatic wildlife as well as the increased respiratory illness in neighborhood populations and has contributed to the shortage of clean drinking water. The pollutant removal performance of bioretention system was evaluated and compared with raw water and IS standards. Range of pollutants in river water is reduced to limits by the filtration process through this system. The results show that pH value and hardness could significantly be improved by the filter media of bioretention. Eliminates TSS through sedimentation on the surface, and physical filtration in the mulch. Turbidity decreases due to lower TSS. Total chloride and dissolved solids has decreased. Vegetation takes up nutrients, support biological growth, maintenance and enhance the porosity of soil and continuously break up the filter media to help to prevent clogging. Aerobic decomposition by bacteria in the filter media is vastly improved, facilitating BOD removal. COD is typically removed by adsorption, filtering, microbial breakdown, and plant absorption. Nitrate, alkalinity, dissolved oxygen level of filtered water lies within the limit. This study established the enhanced performance of bioretention system in river water. The results suggest that this system may use to treat the treated effluents from various sources and can be used as a ground water recharging unit.

REFERENCES

[1]. Allen P Davis.et.al (2009)- Bioretention Technology: Overview of Current Practice and Future Needs- "journal of environmental engineering"- vol 135, issue 3

[2]. Rincy Joseph and P.P Tessy –Water Quality and Pollution Status of Chalakudy River at Kathikudam, -Nature Environment and Pollution Technology Vol. 9 No. 1

[3]. Sreelakshmi C D (2018)- Quality Assessment of Sediments in Chalakudy river with special reference to phosphate fractionation and metallic contamination- "international journal of Recent Engineering Research and development"- vol 03, issue 01

[4]. Anil K Dwivedi –Researches in Water Pollution: A Review- International Research Journal of Natural and Applied Sciences Vol. 4, Issue 1

[5]. Danielle Dagenais (2018)-The Role of Plants in Bioretention System; Does The Science Underpin Current Guidance-Ecological Engineering.

[6]. Anton Skorobogatov, Jianxun He, Angus Chu (2020) -The Impact of Media, Plants and Their Interactions On Bioretention Performance: A Review-Science of the total Environment.

[7]. Jia Liu.et.al (2014)-Review and Research Needs of Bioretention Used for the Treatment of Urban Stormwater- Water- Vol.6 issue 4

[8]. S. Sangita Mishra.et.al (2020)- Design of Bio-retention Filter Basin for Conservation and Purification of Storm water runoff in Urban Areas- International Journal of Recent Technology and Engineering (IJRTE)- Vol 9, issue 4