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Investigating Studies on Natural Fibrous Materials as Fixed Aerated Beds for Domestic Wastewater Treatment

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ABSTRACT: Water is one of the most important elements involved in the creation and development of healthy life. Since water is such a vital resource for survival of both plants and animals, it is our responsibility to manage this resource. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus wastewater or low quality water is emerging as potential source for demand management after essential treatment. The use of various fixed beds having higher surface area is effective in removing organic matter and nutrients from municipal wastewater. In present study efforts have been made to check the efficiency of two different fibrous material- Agave sisalana fibres and Areca husk fibres at two different packing densities and two different heights as submerged aerated fixed film beds for treating domestic wastewater. The use of agricultural by products in wastewater treatment can necessarily reduce the cost of treatment plant.

KEYWORDS: Wastewater Treatment, Fixed aerated beds, Natural fibrous materials, Agave sisalana fibres, Areca husk fibres

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 and transpiration, condensation, precipitation and runoff, usually reaching the sea. It is one of the most essential thing 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. Wastewater is liquid waste discharged by domestic residences, commercial properties, industry, agriculture, which often contains some contaminants that result from the mixing of wastewater from different sources. Wastewater obtained from various sources need to be treated very effectively in order to create a hygienic environment. If proper arrangements for collection, treatment and disposal of all the waste produce from city or town are not made, they will go on accumulating and create a foul condition that the safety of the structures such that building, roads will be damaged due to accumulation of wastewater in the foundations. In addition to this, disease causing bacteria will breed up in the stagnant water and the health of the public will be in danger. The principal aim of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Therefore in the interest of the community of the town or city it is most essential to collect, treat and dispose of all the wastewater of the city in such a way that it may not cause harm to the people residing in the town. The extent and the type of treatment required, however depends on the character and quality of both sewage and sources of disposal available.

The sewage after treatment may be disposed either into a water body such as lakes, streams, river, estuary and ocean or into land. It may be used for several purposes such as conservation, industrial use or reclaimed sewage effluent in cooling systems, boiler feed, process water, reuse in agriculture, horticulture, sericulture, reuse is becoming increasingly popular, especially in geographies where potable water is in short supply.

Reduction of strength of domestic wastewater using two different bed materials Areca Husk fibre and Agava sisalana fibre as a filter media is one such type of treatment method adopted. The utilization of fixed films for wastewater treatment process has been increasingly considered due to inherent advantages over suspended growth system. The present work is intended to study the application of the comparative study between the fibres ie., Areca fibre and Agava sisalana as a fixed bed for treating domestic wastewater and to know the comparative removal efficiency of COD, BOD ,nitrate, sulphate, chloride with conventional gravel bed in a small volume reactor.

The principal aim of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Therefore in the interest of the community of the town or city it is most essential to collect, treat and dispose of all the wastewater of the city in such a way that it may not cause harm to the people residing in the town. The extent and the type of treatment required, however depends on the character and quality of both sewage and sources of disposal available.

Natural Fibre:

Natural fibres can be defined as bio-based fibres or fibres from vegetable and animal origin. This definition includes all natural cellulosic fibres (cotton, jute, sisal, coir, flax, hemp, abaca, ramie, etc.) and protein based fibres such as wool and silk. Excluded here are mineral fibres such as asbestos that occur naturally but are not bio based. Asbestos containing products are not considered sustainable due to the well known health risk, that resulted in prohibition of its use in many countries. On the other hand there are manmade cellulose fibres (e.g. viscose-rayon and cellulose acetate) that are produced with chemical procedures from pulped wood or other sources (cotton, bamboo). Similarly, regenerated (soybean) protein, polymer fibre (bio-polyester, PHA, PLA) and chitosan fibre are examples of semi-synthetic products that are based on renewable resources.

Objective and scope of the project:

The main objective of the study aims at treating the domestic wastewater in a fixed film reactor filled with Agave sisalana fibres and Areca husk fibres.

The specific objectives are:

1. To study the performance of the Agave sisalana fibres and Areca husk fibres used as filter media at different contact periods.
2. To study the comparative removal efficiency of COD, BOD, sulphate, nitrate using Agave sisalana and Areca husk fibres.

II. LITERATURE REVIEW

Wastewater engineering is that branch of environmental engineering in which the basic principles of science and engineering are applied to solving the issues associated with the treatment and reuse of wastewater. The ultimate goal of wastewater engineering is the protection of public health in a manner commensurate with environmental, economic, social, and political concerns. When untreated wastewater accumulates and is allowed to go septic, the decomposition of the organic matter it contains will lead to nuisance conditions including the production of malodorous gases. In addition, untreated wastewater contains numerous pathogenic microorganisms that dwell in the human intestinal tract. Wastewater also contains nutrients, which can stimulate the growth of aquatic plants, and may contain toxic compounds or compounds that potentially may be mutagenic or carcinogenic. For these reasons, the immediate and nuisance-free removal of wastewater from its sources of generation, followed by treatment, reuse, or dispersal into the environment is necessary to protect public health and the environment.

Besides that, the purpose of wastewater treatment is to remove pollutants that can harm the aquatic environment if they are discharged into it. Because of the deleterious effects of low dissolved oxygen concentrations on aquatics life, wastewater treatment engineers historically focused on the removal of pollutant that would deplete the DO in receiving waters. Biological treatment is an important and integral part of any wastewater treatment plant that treats wastewater from either municipality or industry having soluble organic impurities or a mix of the two types of wastewater sources. The obvious economic advantage, both in terms of capital investment and operating costs, of biological treatment over other treatment processes like chemical oxidation; thermal oxidation etc. has cemented its place in any integrated wastewater treatment plant affected in quality by anthropogenic influence. Itcomprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. Wastewater also known as sewage originates from residential commercial and industrial area. There are several opportunities for improving wastewater irrigation practices via improved policies, institutional dialogue, and financial mechanisms, which would reduce risks in agriculture. Effluent standards combined with incentives or enforcement can motivate improvements in water management by household and industrial sectors discharging wastewater from point sources. Segregation of chemical pollutants from urban wastewater facilitates treatment and reduces risk. Strengthening institutional capacity and establishing links between water delivery and sanitation sectors through inter-institutional coordination leads to more efficient management of wastewater and risk reduction.

India, being an economy in transition from a developing to a developed nation, faces two problems. On the one hand there is a lack of infrastructure and on the other, an ever increasing urban population. The urban population in India has jumped from 25.8 million in 1901 to about 387 million (estimated) in 2011. This has thrown up two self-perpetuating problems, viz. Shortage of water and sewage overload. It is estimated that by 2050, more than 50 per cent of the country's population will live in cities and towns and thus the demand for infrastructure facilities is expected to rise sharply, posing a challenge to urban planners and policymakers. Public services have not been able to keep pace with rapid urbanization. Water supply, sanitation measures, and management of sewage and solid wastes cover only a fraction of the total urban population. There is clear inequity and disparity between the public services received by the inhabitants, depending on their economic strata. Slum dwellers have always received least attention from the civic authorities. The rapid growth of urban population has taken place due to huge migration of population (mostly from rural areas and small towns to big towns) and inclusion of newer rural areas in the nearest urban settings, apart from natural growth of urban population. The majority of towns and cities have no sewerage and sewage treatment services. Many cities have expanded beyond municipalities, but the new urban agglomerations remain under rural administrations, which do not have the capacity to handle the sewage. Management of sewage is worse in smaller towns. The sewage is either directly dumped into rivers or lakes or in open fields.

[1] Kudaligama et al., did a study on " Effect of Bio-brush medium: a coir fibre based biomass retained on treatment efficiency of an anaerobic filter type reactor", which reveals that the efficiency of treatment increased with increase in SSA of the media and proper calibration of OLR in the reactor.

[2] Kevin M. Sherman et al., did a study on "Introducing a new media for fixed film treatment in Decentralied Wastewater systems", which reveals that Quanics .Inc . has patented a product that combines adavantages of both naturally and artificially occuring media. The product has successfully passed NSF Standard 40 certification.

[3] Vinod et al. , did a study on "Studies on natural fibrous material as submerged aerated beds for wastewater treatment", which reveals that the maximum percentage reduction of COD(73%), BOD_5(80%), and Orthophosphate(82%) with increased retention time in both reactors. The used of natural fibrous materials as fixed bed in WWT shows promising removal efficiency of organic and nutrients.

[4] Padmini et al., Surface modified Agava sisalana as an adsorbent for removal of nickel from aqueous solutions-Kinetics and Equilibrium studies. The studies reveals that the Sisal fibre can be considered to be a cheap and viable adsorbent for the removal of nickel from aqueous solution.

[5] Vinod A.R et al., did a study on " Treatability studies of selective fibrous packing medias for sewage treatment", which reveals that the coconut coir packing density 40kg/m^3 showed higher removal efficiency of organic matter and nutrients in comparison to 70kg/m^3. Cost effective and locally available medias such as coconut coir fibres, coffee husk can be used as an alternative option for sewage treatment.

[6] Bharati Sunil et al., did a study on "Coconut coir: A media to treat the wastewater", which reveals that naturally available low cost media proves essentially a best option to industrialists to prevent the environmental pollution. Coconut coir fibre is rich in cellulose and lignin, having a high specific area and wetting ability factor which are essential for bacterial adhesion in fixed film processes.

III. PROBLEMS STATEMENT

Water is one of the most important elements involved in the creation and development of healthy life. Since water is such a vital resource for survival of both plants and animals, it is our responsibility to manage this resource. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus wastewater or low quality water is emerging as potential source for demand management after essential treatment. The use of various fixed beds having higher surface area is effective in removing organic matter and nutrients from municipal wastewater. In present study efforts have been made to check the efficiency of two different fibrous material-coconut coir fibre and areca husk fibre at two different packing densities and two different heights as submerged aerated fixed film beds for treating domestic wastewater. The use of agricultural by products in wastewater treatment can necessarily reduce the cost of treatment plant.

IV. PROPOSED METHODOLOGY

In our present study we have checked the feasibility of Agava sisalana and Areca husk fibres as filter media for wastewater treatment. Wastewater quality analysis have been conducted in the laboratory for parameters such as BOD, COD, chlorides, nitrates, sulphates.

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4.1 MATERIALS USED

1. Agava sisalana as a filter media

Agave sisalana, is a species of Agave native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. The term sisal may refer either to the plant's common name or the fibre, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source for fibre, and other fibre sources were named after it. The sisal fibre is traditionally used for rope and twine, and has many other uses, including paper, cloth, footwear, hats, bags, carpets, and dartboards.Sisal plants, Agave sisalana, consist of a rosette of sword-shaped leaves about 1.5–2 metres (4.9–6.6 ft) tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature. The sisal plant has a 7–10 year life-span and typically produces 200– 250 commercially usable leaves. Each leaf contains an average of around 1000 fibres. The fibres account for only about 4% of the plant by weight. Sisal is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine.Fibre is extracted by a process known as decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain. The production is typically on large scale, the leaves are transported to a central decortication plant, where water is used to wash away the waste parts of the leaf. The fibre is then dried, brushed and baled for export. Proper drying is important as fibre quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fibre than sun drying, but is not always feasible in the developing countries where sisal is produced. Fibre is subsequently cleaned by brushing. Dry fibres are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups.

[Fig.4.1: Agava sisalana]

Traditionally, sisal has been the leading material for agricultural twine (binder twine and baler twine) because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. Sisal has been utilized as an environmentally friendly strengthening agent to replace asbestos and fibreglass in composite materials in various uses including the automobile industry. As extraction of fibre uses only a small percentage of the plant, some attempts to improve economic viability have focused on utilizing the waste material for production of biogas, for stockfeed, or the extraction of pharmaceutical materials.

2. Areca husk fibre as a filter media

Among all the natural fiber-reinforcing materials, areca appears to be a promising material because it is inexpensive, availability is abundant and a very high potential perennial crop. It belongs to the species Areca catechu L., under the family palmecea and originated in the Malaya peninsular, East India. Major industrial cultivation is in East India and other countries in Asia. The husk of the Areca is a hard fibrous portion covering the endosperm. It constitutes 30–45% of the total volume of the fruit. Areca husk fibers are predominantly composed of hemicelluloses and not of cellulose. The chemical composition of Areca fibers is shown along with few known fibers. Areca fibers contain 13 to 24.6% of lignin, 35 to 64.8% of hemicelluloses, 4.4% of ash content and remaining 8 to 25% of water content. The fibers adjoining the inner layer are irregularly lignified group of cells called hard fibers and the portions of the middle layer contain soft fibers.

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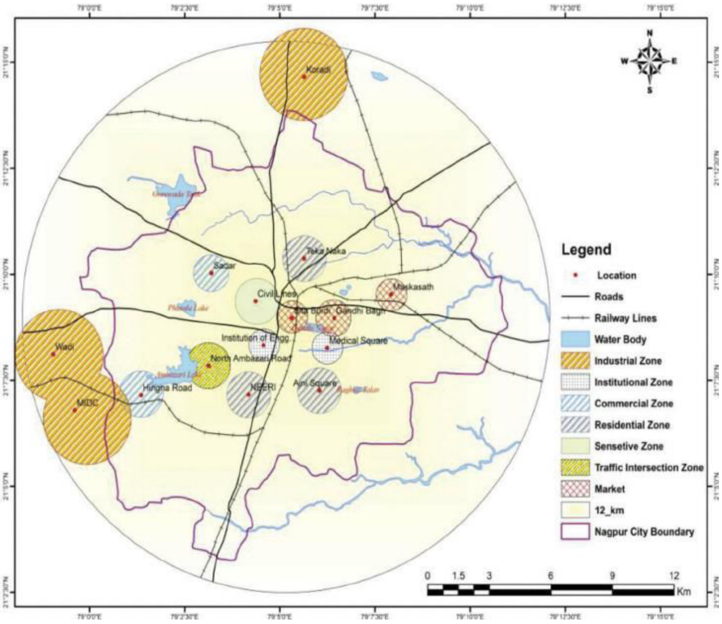
[Fig.4.2: Areca husk]

Selected variety of tender areca was used to study the strength of fiber and to prepare the composites. Green husks of tender areca were soaked in water for about 4 days. The soaking process loosens the fibres and fibres can be extracted out easily. The Areca fibres were separated from the partial dried Areca husk using slow speed hammer mill. Completely dried and thrashed husks were forced through the cyclone separators repeatedly till the neat fibers were separated. The dried Areca husk selected randomly among the stock is considered for the experimentation.

4.2 NAGPUR CITY PROFILE

The Nagpur district consists of Nagpur Municipal Corporation, 10 municipalities, 13 panchayat samitis and 778 gram panchayats. The total area covered is about 9897 sq. km. of which Nagpur city accounts for 217.65 sq. km. (2.2%). The district population (as per Census of India - 2001) was 40.51 lakhs of which 20.52 lakhs (about 50%) were in Nagpur city. The average population density of Nagpur is quite low as compared to other comparable cities of India. The figure was 95 persons per ha in 20015.



[Fig.4.3: Map showing study area in Nagpur]

It is estimated that 36% of the population in the city of Nagpur lives in slums. There are about 427 slum pockets in the city spread over an area of about 17 sq. km. Of the 427 slums, 292 slums are notified slums. In 1997, the slum population of Nagpur was about 6.61 lakhs, which increased to 7.4 lakhs in 2001 and 8.08 lakhs in 2005, thus showing a growth of 22% in the last eight years. Of the 8.08 lakh population, about 20% lives in non-notified slums (Source: Slum department, NMC).

The quantity of wastewater being generated is nearby 500 MLD. The sewage is discharged from individual residential colonies directly into the open drain, since there is no under drainage system for the collection and disposal of sewage.

4.3 SAMPLING LOCATION

Sampling was conducted for every 72 hours for a period of 15 days between 5:30 pm to 6:30 pm. Grab samples were collected in plastic cans rinsed with distilled water. Sample was collected from the open drain channels, in Nandanvan areas, Nagpur City and the treatment process was carried out. Samples were analysed for the following parameters: 1. BOD 2. COD 3. Chloride 4. Sulphate 5. Nitrate 6. pH.

[Fig.4.4: Nag River, Nandanvan Areas, Nagpur]

4.4 PROPOSED METHODOLOGY

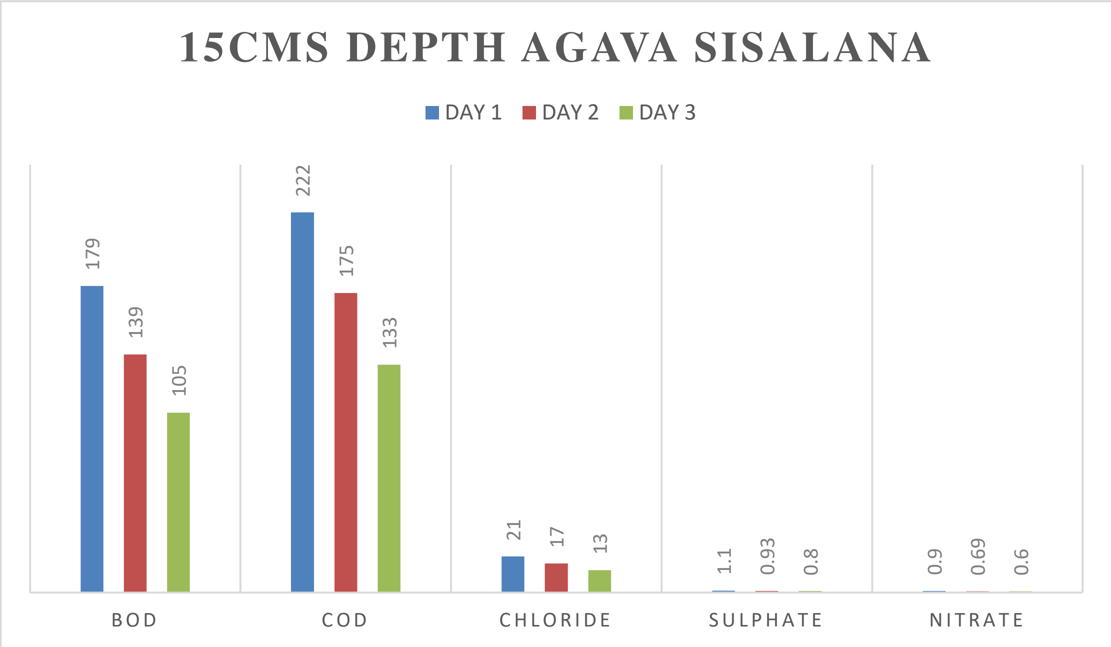
- Two different fibrous packing materials used for the present study, Agave sisalana and Areca husk fibre.
- Two reactors used in this study, are made of 6mm glass, having dimensions 45cm x45cm x60 cm, filled with agave sisalana and areca husk fibres for a known depth of 15 cm.
- Reactors are rectangular in shape and fabricated for downflow mode and for batch operation process.
- Diffused aerators are used to maintain the dissolved oxygen level inside both the reactors.
- Accessories such as mesh, Inlet and outlet pipes and taps are used.
- Initially to start-up the reactor, dairy sludge obtained from Hassan dairy was mixed with AIT girls hostel wastewater of ratio 1:1 for seeding.
- These reactors were then aerated with diffused air pumps continuously for 7 days for acclimatization and development of biomass in both the reactors.
- After the complete growth of biomass on the surface of fixed beds in both reactors,
- known volume (25L) of wastewater is fed through inlet pipe and MLSS is kept constant at an average in both the reactors.
- The initial characteristics of the wastewater used for the study is determined.
- The sampling was done after attaining a DO concentration 2.5mg/L in both reactors at an interval of 24hours up to a contact time of 72 hours.
- The parameters such as pH, COD, BOD5, chloride, sulphate, nitrate are analyzed for the samples coming from the outlet by implementing standard methods for the Examination of Water and Wastewater, (APHA, AWWA,20th Edition).

V. RESULTS AND DISCUSSION

5.1 RESULTS & DISCUSSION

Table 5.1: Removal efficiency using 15cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	240	179	25.4	139	42	105	56.2
COD(mg/L)	305	222	27.2	175	42.6	133	56
Chloride(mg/L)	25	21	16	17	32	13	48
Sulphate(mg/L)	1.5	1.1	26.6	0.93	38	0.8	46.6
Nitrate(mg/L)	1.3	0.9	30.7	0.69	46.92	0.6	53.8
pH	7.5	7.6		7.5		7.5	

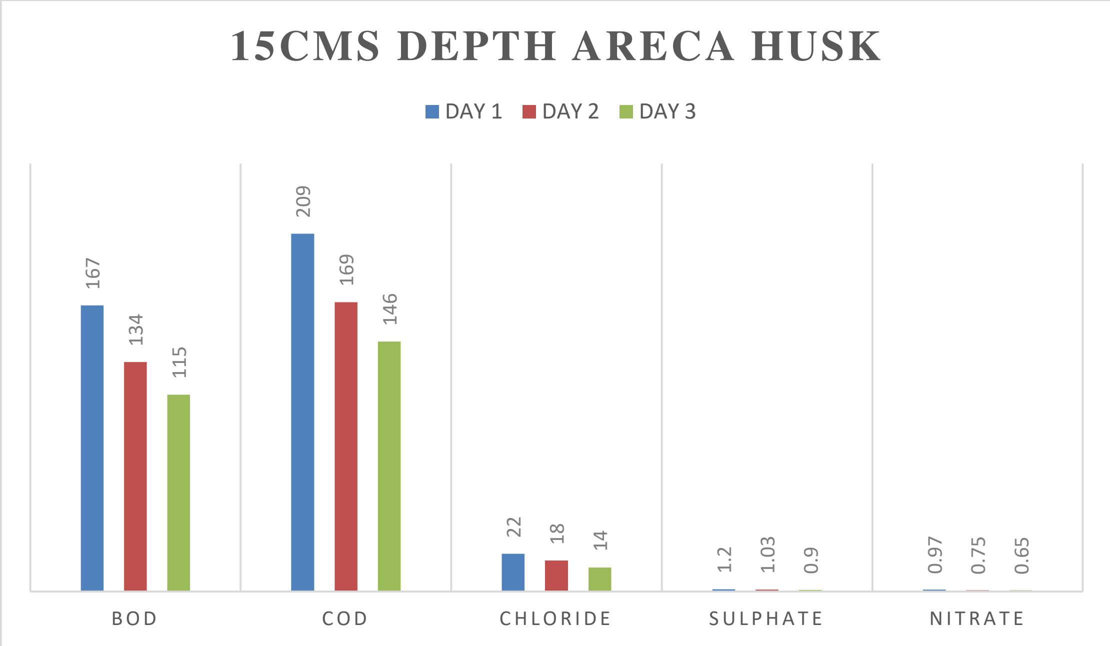


[Fig.5.1: Removal efficiency using 15cm Agava sisalana filter bed]

Table 5.1 and figure 5.1 represents the values of BOD, COD, chloride, sulphate and nitrate as 240, 305, 25, 1.5 and 1.3 mg/l respectively. After 24 hours of contact period their removal efficiency was found to be 25.4%, 27.2%, 16%, 26.6% and 30.7% respectively, similarly after 48 hours it was found to be 42%, 42.6%, 32%, 38% and 46.92% respectively and at the end of 72 hours it was found to be 56.2%, 56%, 48%, 46.6% and 53.8% respectively.

Table 5.2: Removal efficiency using 15cm Areca husk filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	240	167	30.4	134	44.1	115	52.08
COD(mg/L)	305	209	31	169	43	146	52
Chloride(mg/L)	25	22	12	18	28	14	44
Sulphate(mg/L)	1.5	1.2	20	1.03	31.3	0.9	40
Nitrate(mg/L)	1.3	0.97	25.3	0.75	42.3	0.65	50
pH	7.5	7.56		7.6		7.5	

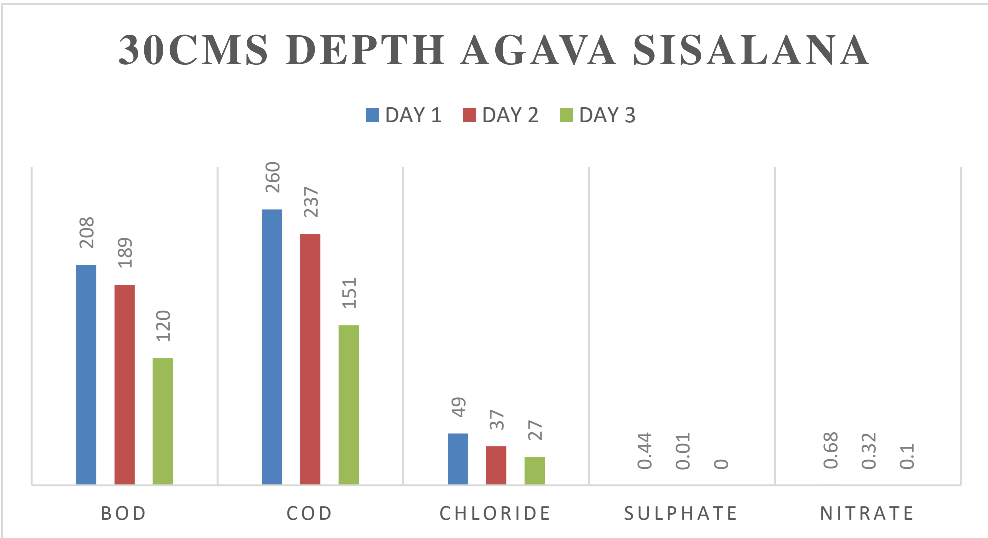


[Fig.5.2: Removal efficiency using 15cm Areca husk filter bed]

Table 5.2 and figure 5.2 represents the values of BOD, COD, chloride, sulphate and nitrate as 240, 305, 25, 1.5 and 1.3 mg/l respectively. After 24 hours of contact period their removal efficiency was found to be 30.4%, 31%, 12%, 20% and 25.3% respectively, similarly after 48 hours it was found to be 44.1%, 43%, 28%, 31.3% and 42.3% respectively and at the end of 72 hours it was found to be 52.08%, 52%, 44%, 40% and 50% respectively.

Table 5.3: Removal efficiency using 30cm Agava sisalana filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	320	208	35	189	40.9	120	62.5
COD(mg/L)	398	260	34.6	237	40.4	151	62
Chloride(mg/L)	70	49	30	37	47.1	27	61.4
Sulphate(mg/L)	1	0.44	56	0.01	99	NIL	100
Nitrate(mg/L)	1	0.68	32	0.32	68	0.1	90
pH	7.7	7.6		7.7		7.5	

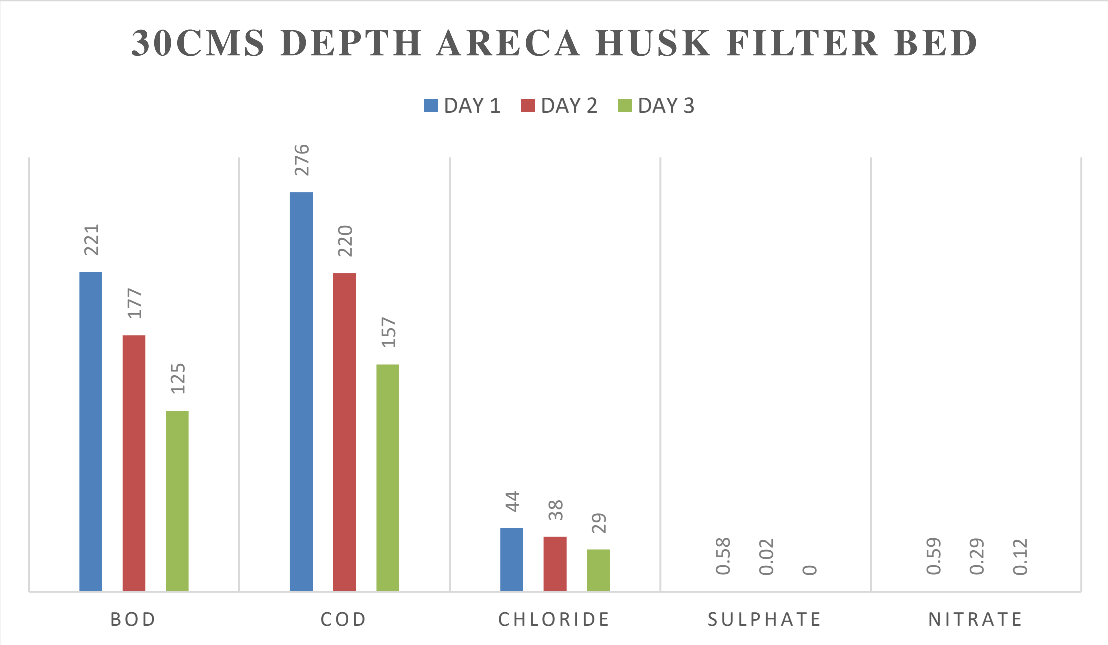


[Fig.5.3: Removal efficiency using 30cm Agava sisalana filter bed]

Table 5.3 and figure 5.3 represents the values of BOD, COD, chloride, sulphate and nitrate as 320, 398, 70, 1 and 1 mg/l respectively. After 24 hours of contact period their removal efficiency was found to be 35%, 34.6%, 30%, 56% and 32% respectively, similarly after 48 hours it was found to be 40.9%, 40.4%, 47.1%, 99% and 68% respectively and at the end of 72 hours it was found to be 62.5%, 62%, 61.4%, 100% and 90% respectively.

Table 5.4: Removal efficiency using 30cm Areca husk filter bed

Parameters	Initial	1st Day	Removal Efficiency (%)	2nd Day	Removal Efficiency (%)	3rd Day	Removal Efficiency (%)
BOD(mg/L)	320	221	30.9	177	44.68	125	61
COD(mg/L)	398	276	30.6	220	44.07	157	60.5
Chloride(mg/L)	70	44	37.1	38	45.7	29	58.5
Sulphate(mg/L)	1	0.58	42	0.02	98	NIL	100
Nitrate(mg/L)	1	0.59	41	0.29	71	0.12	88
pH	7.7	7.7		7.6		7.6	



[Fig.5.4: Removal efficiency using 30cm Areca Husk]

Table 5.4 and figure 5.4 represents the values of BOD, COD, chloride, sulphate and nitrate as 320, 398, 70, 1 and 1 mg/l respectively. After 24 hours of contact period their removal efficiency was found to be 30.9%, 30.6%, 37.1%, 42% and 41% respectively, similarly after 48 hours it was found to be 44.68%, 44.7%, 45.7%, 68% and 71% respectively and at the end of 72 hours it was found to be 61%, 60.5%, 58.5%, 100% and 88% respectively.

VI.CONCLUSION

From this study the following conclusions are drawn:

1. Considerable reduction in BOD, COD, nutrients such as nitrates, sulphates, chlorides were achieved.
2. The removal efficiency of BOD and COD by using Agava as filter media was found to be 56.2% and 56% respectively, for 15 cm depth which was higher than that of Areca which was found to be 52.08% and 52% respectively.
3. The removal efficiency of BOD and COD by using Agava as filter media was found to be 67.1% and 68.3% respectively, for 30 cm depth which was higher than that of Areca which was found to be 61% and 61.5% respectively.
4. The removal efficiency for BOD and COD were found to be 77% and 78% respectively, when both the filter medias were combined.

5. The operation trouble faced during the study was foul odour emission due to the early decomposition of the fibers.
6. The treated wastewater can be used for gardening and other domestic purposes like washing and cleaning purposes.
7. The spent fibres were rich in nutrient values and can be used as a organic manure.

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