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Research Journal of Agricultural Sciences
Volume 14; Issue 05 (Sep-Oct 2023); pp 1309–1315

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Full Length Research Article

Use of *Canna indica* Plants in the Aerobic Brickbat Grit Sand (ABGS) Purifier for Domestic Wastewater Treatment

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Abstract

In the developing countries, treatment of domestic wastewater is not a primary objective of development because requirement of huge funds for collection of waste water and to construct centralized treatment facilities as well as need of technical experts for managing the treatment plant. Providing simple, cost effective and eco-friendly wastewater treatment is a challenge in many parts of the world. In the present study *Canna Indica* plants was used in the fourth stage of Aerobic Brickbat Grit Sand (ABGS) purifier and potential of *Canna Indica* plants was observed for the treatment of domestic wastewater. Working model of ABGS purifier was setup for the treatment of grey water at Government College of Engineering, Aurangabad, M.S., India. The variation of physicochemical parameter of the influent and effluent water was shows pH (7.2±0.1 to 7.6±0.1), BOD (189±33 to 11±1 mg/L), COD (354±47 to 26±5 mg/L), TSS (92±6 to 13±3mg/L), TDS (393±51 to 430±43mg/L), Total phosphorus (30±3 to 6±0.6 mg/L), Nitrate (5±1 to 0.5±0.1 mg/L), Ammonia (0.6±0.2 to 0.04±0.1 mg/L), Sulphate (43±1 to 14±3 mg/L), Chloride (86±10 to 78±7 mg/L), Oil and grease (5.1±0.3 to 1.9±0.5 mg/L). In this study it was observed that *Canna indica* flower bed fourth stage of ABGS purifier effectively remove total phosphorus, nitrate as well as helps to remove BOD and COD. ABGS purifier is eco-friendly and cost-effective domestic wastewater treatment system constructed with use of locally available material.

***Key words*:** BOD, COD, Grey water, Turbidity, Total phosphorus, TSS, *Canna indica*

Canna indica, also known as Indian shot or Canna lily, is a perennial flowering plant that belongs to the family Cannaceae. *Canna indica* is a tall plant that can reach heights of 1 to 2.5 meters. It has large, broad leaves that are typically green or variegated in color. The plant produces vibrant, showy flowers in shades of red, orange, yellow, or pink. *Canna indica* is primarily grown as an ornamental plant due to its attractive foliage and flowers. It is commonly used in gardens, landscapes, and as potted plants. The plant adds a tropical touch to outdoor spaces and can create a bold and colorful display. *Canna indica* thrives in moist, well-draining soil and requires full sun to partial shade for optimal growth. It prefers warm temperatures and is not frost-tolerant. The plant can be grown in both terrestrial and aquatic environments, making it adaptable to different conditions.

According to the Environmental Protection Agency in the United States, decentralized wastewater systems may provide a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas [1]. The capital investment for decentralized wastewater systems is generally less than for centralized systems in pre-urban areas, and they are also likely to be cheaper to construct and operate. By tackling wastewater problems close to source, the large capital investment of trunk sewers and pumping costs associated with centralized systems can be reduced, thus increasing the affordability of wastewater management systems [2].

Canna plant is associated with higher growth rate with significantly high biomass production [3] which is directly related to nutrient uptake, and tolerance to water stress and chemical fluctuations, making it a suitable candidate for phytoremediation. Abou-Elela *et al.* [4] also reported a very high dry biomass accumulation by *Canna lily* compared to *Phragmites australis*, an extensively studied potential plant for wastewater treatment in constructed wetlands. Apart from it, the aesthetically pleasing look, and floriculture possibility adds a new dimension to its use in constructed wetlands. A study by Belmont and Metcalfe [5] reported that *Canna*, has limited

Received: 14 July 2023; Revised accepted: 03 Sep 2023; Published online: 20 Sep 2023

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Citation: Agale P, Saner A, Sadgir P, Suryawanshi NS. 2023. Use of *Canna indica* plants in the Aerobic Brickbat Grit Sand (ABGS) purifier for domestic wastewater treatment. *Res. Jr. Agril. Sci.* 14(5): 1309-1315.

growth and cannot survive in cold winter in northern hemisphere and therefore has a limited use of constructed wetlands in such countries.

Denny Patrick [6] reported the fact that decentralized treatment system like constructed wetlands (reedbeds) can provide a low-cost and appropriate technology for the treatment of domestic wastewater and faecal sludge, but will normally require pre-treatment and so can only be considered as a secondary treatment option. Like waste stabilization ponds, they are fairly good at removing pathogens, but facilities have to be designed and operated in a way that controls disease vectors, especially mosquitoes and odour. Because of the problems with mosquitoes, it has been argued that wetlands may not be a suitable form of wastewater treatment for use in areas where malaria occurs [7].

Kujawa [8] distinguished two situations of decentralised wastewater treatment system first system related to treatment of total domestic wastewater and second system is to treatment of separated wastewater streams. In source-separation based wastewater treatment concepts wastewater streams are separated according to their degree and type of pollution and reuse potential of resources. Different degrees of separation can be applied. Generally, three types of wastewater streams are distinguished: black water, grey water and rain water. Grey water is a voluminous stream characterised by lower concentrations of pollutant in comparison with black water.

A recent advance in the technology along with favorable changes in attitudes towards wastewater reuse suggests that there is a potential for grey water reuse in the developing countries [9]. Large volumes of grey water are generated, accounting for 50–80% of domestic wastewater [10-12]. In Australia, the study showed that water saving was in the range of 30–50%when grey water was used for toilet flushing and lawn irrigation [13]. Eric *et al*. [14] conducted the study of current grey water practices globally, with a specific focus on household-level grey water practices in the Middle East and North Africa region, and highlighted the need for cost reduction strategies and epidemiological evidence on the use of household-level grey water and treated grey water. Since 1970's, numerous technologies are developed for treatment and recycling of grey water. Ghaitidak and Yadav [15] reviewed the grey water treatment systems, founded that Coagulation/flocculation systems were found weak in BOD removal but more efficient in pathogen removal. Constructed wetland is efficient compared to other system and feasible for treatment of a large quantity of grey water. Filtration is one of the feasible options but has further scope to study the role of different filtration media. MBRs are found efficient in removal of physicochemical contents and satisfy relevant reuse standards. However, they were not effective in removing microorganisms that were larger than the membrane pore size. Anaerobic followed by aerobic system may be a sustainable option for grey water treatment for reuse.

High COD:BOD ratio, and nitrogen and trace nutrients deficiency in grey water limitstreatment efficiency of biological treatment processesfor grey water [16]. For example, rotating biological contactor (RBC) [17] sequencing batch reactor" [18-19]. Performance of biological treatment can also be affected due to variation in flow and strength of the grey water [20]. A photocatalytic treatment technology under artificial and solar illumination was used for the mineralization of simulated light grey water [21]. Limited data are available in the literature on specific pathogens in grey water [22]. If BOD and microorganism concentration is more in the grey water, biological treatment is necessary to reduce the contamination and its reusability. Disinfection is also essential to eliminate pathogens [23]. Chowdhury [24] investigated grey water reuse in the arid region for Bio-retention system. During the life cycle impact assessment of grey water recycling technologies, Maimon *et al*. [25] observed low environmental impact of natural treatment system. Thus, main objective of study is to design and development of cost-effective and eco-friendly aerobic brickbat-grit sand (ABGS) wastewater purifier and investigate its efficiency for treatment of grey water.

MATERIALS AND METHODS

Aerobic Brickbat Grit Sand (ABGS) purifier system

Self-purification treatment process of river is utilized in the present study. The natural self-purification process is accelerated for removal of contaminants from grey water. AGBS purifier utilizes equalization, aeration, sedimentation, and filtration process. ABGS purifier operates on the principle of gravitational flow, thus avoid pumping and energy cost. The ABGS purifier has five stages in sequence viz. equalization tank, brickbat filter, bio-grit-sand filter, *canna Indica* flower bed, and aeration fountain. ABGS purifier operates under continues flow as per given sequence. The layout of ABGC purifier (5.60 m length, 0.9 m width and 1.2 m average depth) is as shown in (Fig 1), which was designed to treat 9 cum/day of grey water. Dimensions of each unit of ABGS purifier is as given in (Table 1).

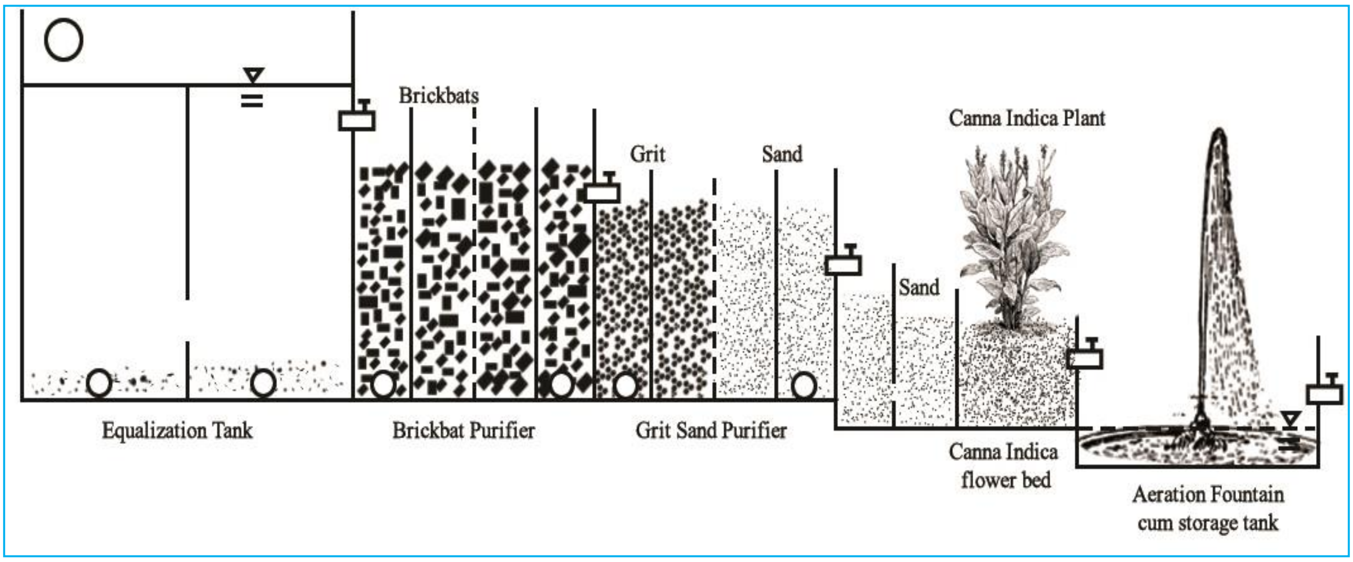

Fig 1 Layout of Aerobic Brickbat Grit Sand (ABGS) purifier

Table 1 Details of ABGS purifier for each stage

BED	1st stage	2nd stage	3rd stage	4th stage	5th stage
Dimensions (m)	1.6 x 0.9. x1.5	1.2 x 0.9 x 1.2	1.2 x 0.9 x 0.9	1.2 x 0.9 x 0.6	1.6 m diameter and 0.45 depth
Surface area (m^2)	1.44	1.08	1.08	1.08	2.073
Filter media	No	Brickbats	sand, grit	Charcoal and flower beds	Aeration with five nozzles
Flow	Horizontal	Zig – Zag	Zig – Zag	Up and down	Vertical

As shown in (Fig 1), the first stage of ABGS purifier is an equalization tank. It is design for equalization of raw grey water properties as well as the settlement of the sludge. The second stage of the ABGS purifier is filled with a brickbat. Three partition walls are provided at closure frequency in the brickbat stage which forms zig-zag flow pattern for proper mixing of grey water. This stage is designed to replenish sudden fall of oxygen demand after organic outfall. It also helps to reduce the concentration of pollutant.

The third stage of ABGS purifier is filled with grit, sand, like the second stage of ABGS purifier, the third stage is designed with three partially opened partition wall which forms zig-zag flow. The first partition wall of the third stage is filled with grit at the bottom and sand at the top. The next two partition wall is filled with sand at the bottom and grit at the top. The designed surface flow, as well as subsurface flow in this part, imparts mechanical straining which helps to remove suspended solids. Moreover, sand and grit present at this stage allows small particle to get adsorbed on the surface of sand and grit particles due to molecular attraction between negatively charged particles and positively charged particles. This also helps bacterial growth in the voids of sand grains. The zoological biofilm forms on the surface of sand grains. The bacteria feed on organic impurities in water. They convert organic impurities into harmless compounds by complex biochemical action. Also, the third stage permits the electrolytic changes. Wherein, opposite electrical charges get neutralized and by doing so, new chemical substances forms. Moreover,backwashing arrangment at this stage helps to reduce organic matters in grey water. The fourth stage consists of two partition walls filled with charcoal layers and grey water flows up and down. The top layer ofthe-the fourth unit has *Canna indica* flower plants for beautification. Flow arrangement of the fourth stage, each down flow compartment consist of charcoal, which also helps in removal of certain organics such as unwanted taste, odor, andmicropollutants. The fifth stage of AGBS facilitates aeration using five nozzles. It elevates dissolved oxygen level in grey water which improves the odor.

Fig 2 Stagewise setup of a working model of ABGS purifier

Instrumentations

Total phosphorus, ammonia, nitrate was measured using spectroscopy method using UV – Vis Spectrometer (Type 117, systronics India Limited) with a resonance line of 220/227,640,880, and 420 nm, respectively. pH,TDS was measured with ESICO international model 1615.COD digester BTI-12 of Biotechnic India Ltd. was utilized. BOD was measured with BOD incubator. Semi micro analytical balance H20 (Mettler) which provides a resolution of 0.01 mg has been used to measure mass of chemicals. Chemical analysis was carried out as per the standard methods [26].

Location

The working model of AGBS is constructed at boy's hostel of Government College of Engineering Aurangabad (M.S.), India which has 130 students (Fig 2).

RESULTS AND DISCUSSION

Poilt model set up of ABGS purifier was constructed and operated for treatment of grey water from boy's hostel of Government College of Engineering, Aurangabad. Grey water from the hostel was allowed to flow through ABGS purifier under gravity without any pretreatment and considering 30 minutes of hydraulic retention time (HRT). The performance of the ABGS is evaluated by measuring removal of pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids(TDS), Total Phosphorus, Nitrate, Ammonia, Sulphate, Chloride, Oil and Grease, and Turbidity, for consecutive 49 days of summer season respectively. Results are expressed as an arithmetical mean. The standard deviations and means for all variables were performed by the Statistical Package for Windows (Version 6.1.7600 Edition7). Physicochemical contaminant removal is given in (Fig 3a–j) describes the respective pattern for physicochemical contaminant removal.

Physicochemical removal performance

Influent and Effluent of pH was found to be 7.1–7.6 showing the buffering capacity of ABGS purifier. Influent Oil and grease concentration in influent were 5.1±0.3 mg/L which was reduced to 1.9±0.4 mg/L. Influent TDS was found to be 393±51 mg/L, and effluent TDS was 429±42 mg/L it is slightly increased. Similarly, Chloride values change marginally from 86 ± 10 to 78 ± 7 mg /l. Sulphate at the influent was 43 ±1 which was 14 ± 1 mg/L at effluent observed with registering 67% removal. Over a period of 49 days operation of ABGS purifier, moreover, effluent was colorless and odorless.

Suspended substances (SS) removal

Suspended substances play an important role in evaluating the performance of treatment and hence the degree of contaminant removal influent. Therefore, removal of TSS is one of the detrimental criteria in wastewater treatment. In this study filtration of TSS is done within the second stage where TSS caught into the rough textures and pores as well as into the voids of brick bates, Further SS matters removed by the filtration through grit and sand media. Moreover, more TSS matter removed in the fourth stage of charcoal media. Table 1shows the media properties and TSS removal is as shown in (Fig 3d). Here, influent contents were 92± 6 mg/L, which reduced to 14±3 mg/L registering 85% removal.

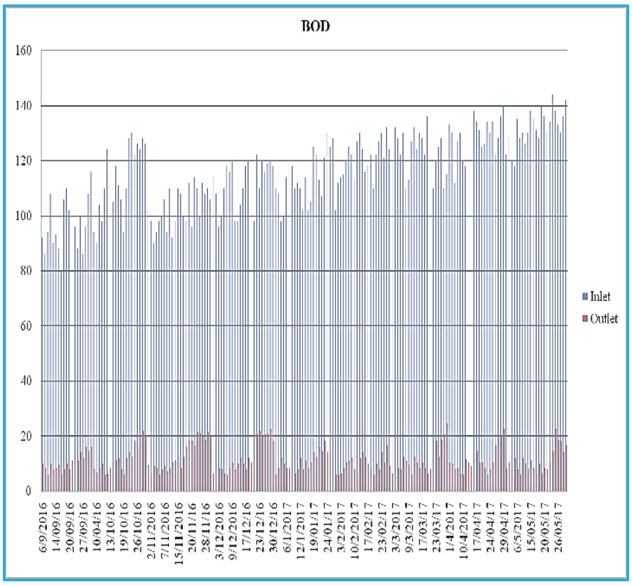

Fig 3a Performance of ABGS purifier for removal BOD from September 2016 to May 2017

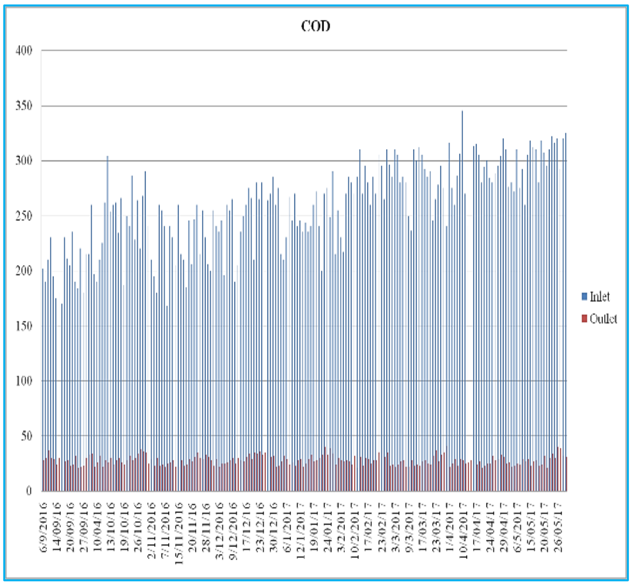

Fig 3b Performance of ABGS purifier for removal COD from September 2016 to May 2017

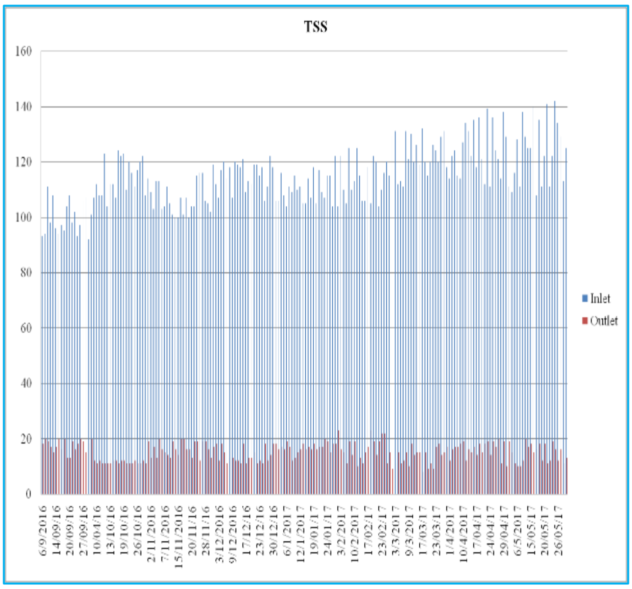

Fig 3c Performance of ABGS purifier for removal TSS from September 2016 to May 2017

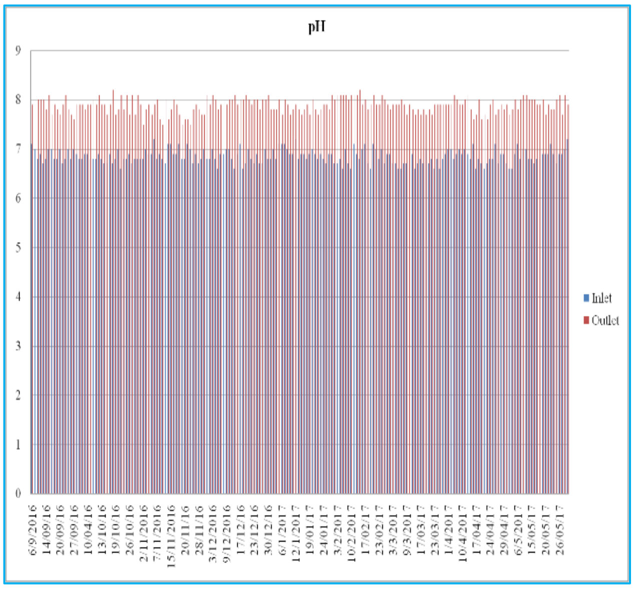

Fig 3d Performance of ABGS purifier for removal pH from September 2016 to May 2017

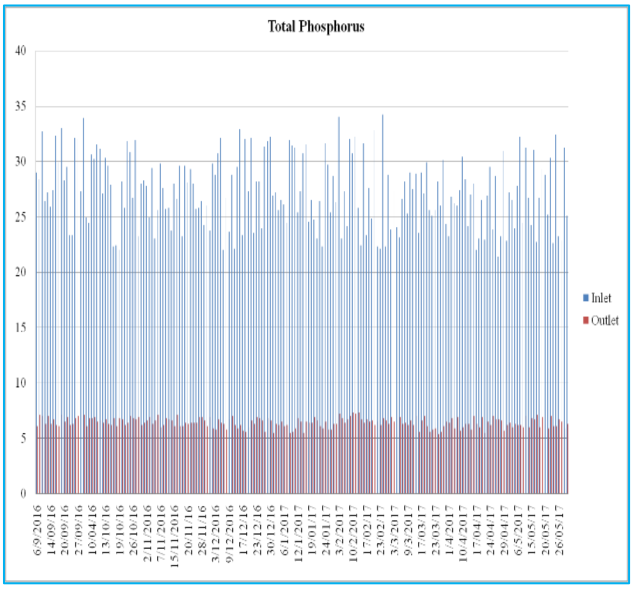

Fig 3e Performance of ABGS purifier for removal total phosphorus from September 2016 to May 2017

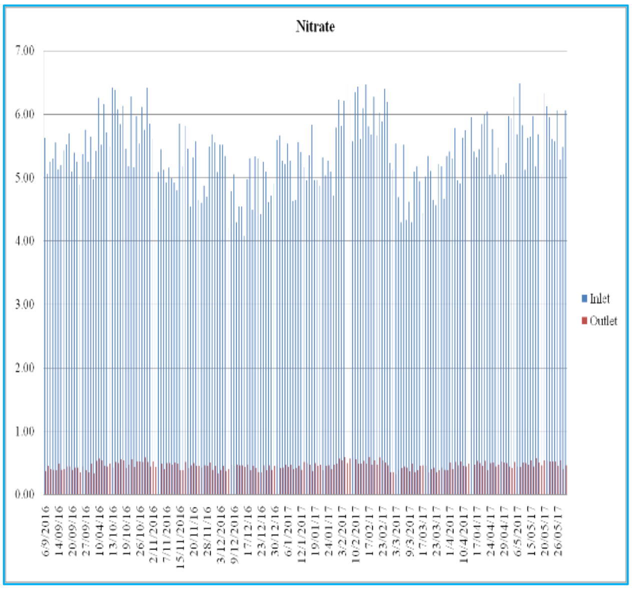

Fig 3f Performance of ABGS purifier for removal TSS from September 2016 to May 2017

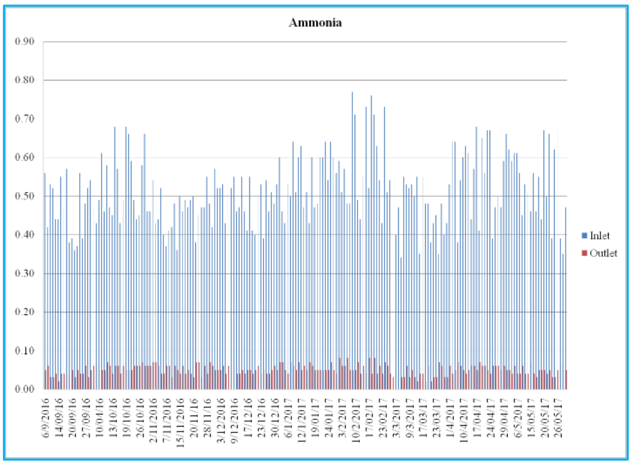

Fig 3g Performance of ABGS purifier for removal ammonia from September 2016 to May 2017

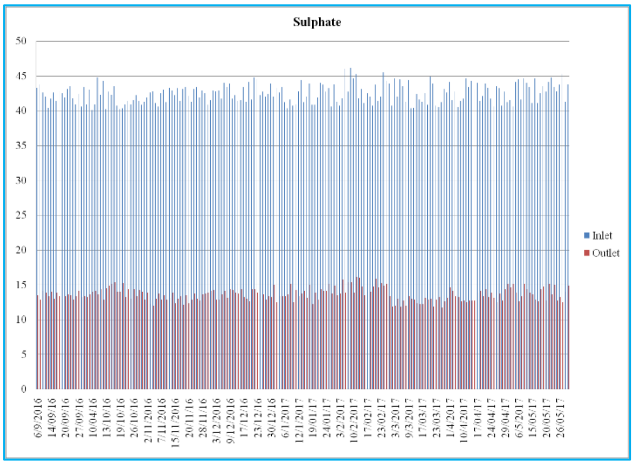

Fig 3h Performance of ABGS purifier for removal sulphate from September 2016 to May 2017

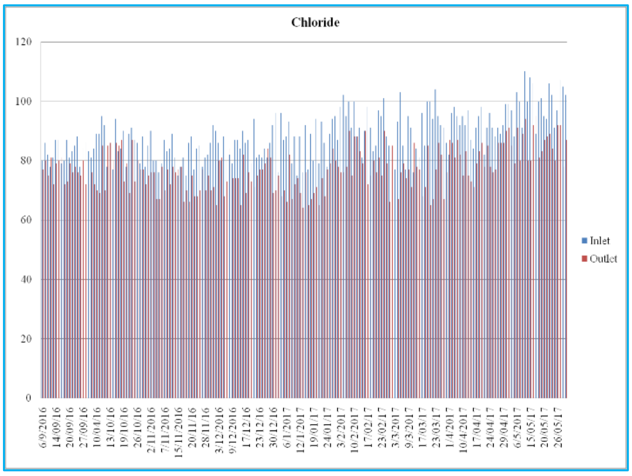

Fig 3i Performance of ABGS purifier for removal chloride from September 2016 to May 2017

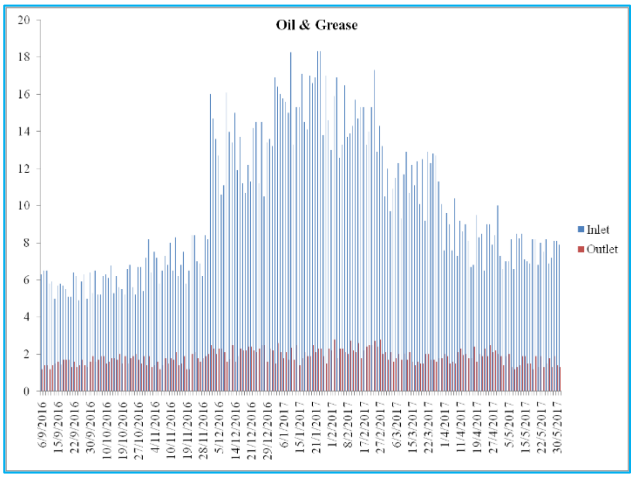

Fig 3j Performance of ABGS purifier for removal oil and grease from September 2016 to May 2017

BOD and COD removal

BOD and COD express removal of organic load in wastewater. To reduce a load of pollution in the natural water bodies, an alternative effective, low-cost treatment method is needed. Therefore, in this study potential of using locally available eco-friendly materials for BOD and COD removal was investigated. (Fig 3 b-c) shows that influent BOD was 189 ± 33 mg/L, and effluent levels reduced to 11 ± 1 mg /L. Similarly, COD at the influent of grey water was found to be 354± 47 mg/L, and effluent COD level was 26 ± 5 mg/L. Most notable removals were 65-70% observed with a fired brickbats filter at stage second of the ABGS purifier system. The same is due to high organic matter adsorption capability of fired bricks bats. Further, stages of ABGS purifier consist of grit, sand and aeration fountain was attributing for BOD and COD removal 90-94% and 85-92 % respectively.

Nutrient removal

The nitrate removal treatment process is relatively expensive. Therefore, waste and natural indigenous materials were utilized for removal of nitrate and ammonium ions [27]. (Fig 3g) shows that concentration of nitrate ions in the influent was 5±1mg/L. The NO_3 ion level of effluent was 0.5 ± 0.1 mg/L registering 90% removal. (Fig 3f) shows that total phosphorus concentrations in the influent were 30 ± 3, mg/L. Total phosphorus levels reduced to 6 ± 0.7 mg/L registering 80% removal. (Fig 3h) illustrated that ammonia concentration in the influent was 0.6 ± 02 mg/Land its level reduced to0.05 ± 0.02 mg/L registering 91% removal. However, at the fourth stage of *Canna indica*, 90-85%, 20-15%, 60-55% of NO_3, total phosphorus, ammonia respectively was removed due to brick bats. Complex ingredient content observed by *Canna indica* plants.

Efficiency chart of pilot model

Pilot scale model efficient in removal of various parameter as shown in (Fig 4). BOD, COD, TSS, nitrate, ammonia removal rate was more than 85% whereas total phosphorus and chloride removal rate was more than 65%. This result shows the capability of ABGS purifier for the treatment of grey water.

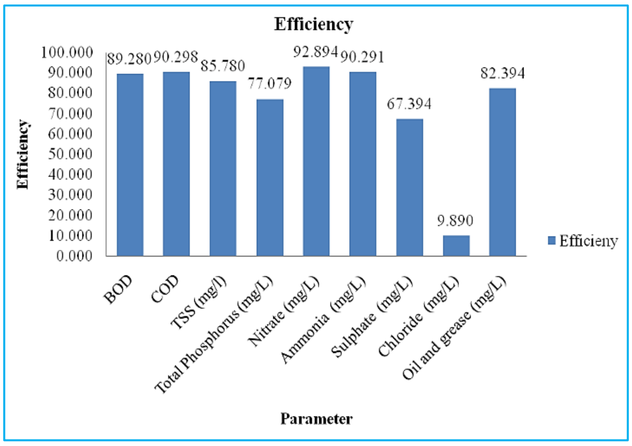

Fig 4 Efficiency chart of pilot model

Treatment mechanism

Fired bricks are burned in a kiln which makes them durable, normally; bricks contain the silica, alumina, lime, iron oxide and magnesia ingredients. Similarly, grit and sand materials occur as silicate, aluminate and calcium substrates in different forms. Therefore, using these naturally available materials the possible basic fundamental mechanisms for treatment are: aeration, filtration, sedimentation, physical adsorption and ion exchange. Suspended substances were mostly removed by mechanical straining, filtration, and sedimentation, while the Nitrate, Total Phosphorus, and Ammonia were removed by ion exchange or by physical adsorption.

Efficient removal of BOD, COD have been attributed due to effective adsorption of organic matters in the large pores space area of fired bricks and charcoal. Aeration fountain accelerates the dissolved oxygen level as well as remove the odor. The horizontal and vertical flow pattern of the system properly mixes the grey water which results in better aeration during the treatment process. However, because of the negligible concentration of magnesia in the bricks pH and TDS levels slightly increase up to ascertain extent as shown in (Fig 3a-e). The construction cost for ABGS Purifier was 500 USD (on 2017), and projected annual maintenance cost is 60 USD for nine cum/day. Abdulrahim [28] noted that the grey water treatment system is not a maintenance-free system. It requires a regular maintenance particularly for the top layer of the sand filter due to the accumulation of grease, food particles, hair, lint and other impurities. In ABGS purifier backwashing of sand is done after 15-20 days that is why there was no need to remove the top layer of sand. In ABGS purifier, food particles, hair, lint link matters are removed in the first stage of equalization. Oil and Grease removed in the pore’s bricks and grit in second and third stage respectively. The efficiency of ABGS purifier system for removal of biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), turbidity, oil and grease, Total Phosphorus, Ammonia, Nitrate, Chloride, and Sulphate, is satisfying the Indian standards for surface water discharge.

CONCLUSION

The present study focuses on use of *Canna indica* plants for domestic wastewater treatment. *Canna indica* plants are used in the fourth stage of ABGS purifier. Results shows that total phosphorus (90%), nitrate (91%), removed in fourth stge wheras these paratmers was not removed in Brickbat stage, Grit and sand stage. It is also observed that Brickbat stage, Grit and sand stage removes BOD (67-75%) COD (70%) whereas when it pass throught Fourth satge of *Canna indica* it was removes BOD (94%), COD (88%). Hence *Canna indica* plants plays important role in ABGS purifer as it enchance the asthatics of wastewater palnt as well as it made ecofirendly and cost effective treatement. ABGS purifier pilot plant model for grey water treatment show high efficiency in removal of BOD (94%), COD (88%), TSS (80%), total phosphorus (90%), nitrate (91%), ammonia (67%), sulphate (67%), oil and grease (67%). Moreover, effluent was colorless and odorless. Summing up, the unique feature of ABGS purifier is it is eco-friendly, simple to construct, requires minimum land, and electrical power as well as costly mechanical equipment for the treatment is not required. ABGS purifier requires low retention time for the treatment of influent it provides green ambiance. It offers the onsite wastewater treatment facility to dwelling, institutions, clusters of housing, rural localities and pre urban areas.

LITERATURE CITED

1. USEPA. 1997. Response to congress on use of decentralized wastewater treatment systems. EPA-832-R-97- 001b, US EPA Office of Water, April 13.
2. Parkinson J, Tayler K. 2003. Decentralized wastewater management in per urban areas in low-income countries. *Environment and Urbanization* 15(1): 75-90.
3. Cui L, Ouyang Y, Lou Q, Yang F, Chen Y, Zhu W, Luo S. 2010. Removal of nutrients from wastewater with *Canna indica* L. under different vertical-flow constructed wetland conditions. *Ecol. Eng*. 36: 1083-1088.
4. Abou-Elela SI, Golinielli G, Abou-Taleb EM, Hellal MS. 2013. Municipal wastewater treatment in horizontal and vertical flows constructed wetlands. *Ecol. Eng*. 61: 460-468.
5. Metcalf, Eddy Inc. 1991. *Wastewater Engineering. Treatment, disposal and reuse.* 3rd Edition. New York (NY): McGraw-Hill Inc. pp 1333.
6. Denny P. 1997. Implementation of constructed wetlands in developing countries. *Water Science and Technology* 35(5): 27-34.
7. Grau P. 1996. Low-cost wastewater treatment. *Water Science and Technology* 33(8): 30-46.
8. Kujawa-Roeleveld K, Grietje Z. 2006. Anaerobic treatment in decentralised and source-separation-based sanitation concepts. *Reviews in Environmental Science and Bio/Technology* 5: 115-139. doi: 10.1007/s11157-005-5789-9
9. Odeh RA. 2003. Grey water reuse: towards sustainable water management. *Desalination* 156: 181-192. doi: 10.1016/S0011-9164(03)00340-0.
10. Li F, Wichmann K, Otterpohl R. 2006. Review of the technological approaches for grey water treatment and reuses. *Science of the Total Environment* 407: 3439-3449. doi:10.1016/j.scitotenv.2009.02.004.
11. Oron G, Adel M, Agmon V, Friedler E, Halperin R, Leshem E, Weinberg D. 2009. Grey water use in Israel and worldwide: standards and prospects. *Water Research* 58: 92-101. doi:10.1016/j.watres.2014.03.032.
12. Yu ZLT, Rahardianto A, DeShazo JR, Stenstrom MK, Cohen Y. 2013. Critical review: Regulatory incentives and impediments for onsite Grey water reuse in the United States. *Water Environ. Res*. 85(7): 650-662. doi: 10.2175/106143013X13698672321580.
13. Jeppesen B. 1996. Domestic grey water re-use: Australia’s challenge for the future. *Desalination* 106: 311-315. doi: 10.1016/S0011-9164(96)00124-5.
14. Eric CL, Dare A, Al-Delaimy WK. 2013. Is grey water the key to unlocking water for resource-poor areas of the Middle East, North Africa, and other arid regions of the world? *AMBIO* 43: 707-717. doi: 10.1007/s13280-013-0462-y.
15. Ghaitidak DM, Yadav KD. 2013. Characteristics and treatment of grey water—A review. *Environmental Science and Pollution Research International* 20: 2795-2809. doi: 10.1007/s11356-013-1533-0.

16. Jefferson B, Burgess JE, Pichon A, Harkness J, Judd S. 2001. Nutrient addition to enhancing biological treatment of grey water. *Journal of Water Resource* 35(11): 2702-2710. doi: 10.1016/S0043-1354(00)00553-4.
17. Friedler E, Kovalio R, Ben-Zvi A. 2006. Comparative study of the microbial quality of grey water treated by three on-site treatment systems. *Environmental Technology* 27: 653-663. doi: 10.1080/09593332708618674.
18. Lamine ML, Bousselmi AG. 2007. Biological treatment of grey water using sequencing batch reactor. *Desalination* 215: 127-132. doi: 10.1016/j.desal.2006.11.017.
19. Krishnan V, Ahmad D, Jeru JB. 2008. Influence of COD: N: P ratio on dark grey water treatment using a sequencing batch. *Jr. Chem. Technol. Biotechnology* 83: 756-762. doi: 10.1002/jctb.1842.
20. Prathapar S, Jamrah A, Ahmed M, Al Adawi S, Al Sidari S, Al Harassi A. 2005. Overcoming constraints in treated grey water reuse in Oman. *Desalination* 186: 177-186. doi: 10.1016/j.desal.2005.01.018.
21. Tsoumachidou S. 2016. Grey water as a sustainable water source: A photocatalytic treatment technology under artificial and solar illumination. *Journal of Environmental Management*. pp 1-10. doi: 10.1016/j.jenvman.2016.08.025.
22. Winward GP, Avery LM, Frazer-Williams R, Pidou M, Jeffrey P, Stephenson T, Jefferson B. 2008. A study of the microbial quality of grey water and an evaluation of treatment technologies for reuse. *Ecological Engineering* 32: 187-197. doi:10.1016/j.ecoleng.2007.11.001.
23. Birks R, Hills S. 2007. Characterization of indicator organisms and pathogens in domestic grey water for recycling. *Environ Monit Assess* 129: 61-69. doi: 10.1007/s10661-006-9427-y.
24. Chowdhury RK. 2015. Grey water reuse through a bioretention system prototype in the arid region. *Water Sci. Technology* 72(12): 2201-2211. doi: 10.2166/wst.2015.442.
25. Maimon A, Tal A, Friedler E, Gross A. 2010. Safe on-site reuse of grey water for irrigation- A critical review of current guidelines. *Environmental Science and Technology* 44: 3213-3220. doi: 10.1021/es902646g.
26. American Public Health Association (APHA). 2015. *Standard Methods for the Examination of Water and Wastewater*. American Water Works Association and Water Pollution Control Federation, Washington, DC.
27. Ahsan S, Kaneco S, Ohta K, Mizuno T, Kani K. 2001. Use of some natural and waste materials for waste water treatment. *Water Research* 35(15): 3738-3742. doi: 10.1016/S0043-1354(01)00047-1.
28. Abdulrahim M, Al-Ismaili, Ahmed M, Al-Busaidi A, Seif Al-Adawi, Tandlich R, Al-Amri M. 2017. Extended use of grey water for irrigating home gardens in an arid Environment. *Environ. Sci. Pollution Research* 24: 13650-13658. doi: 10.1007/s11356-017-8963-z.