Vol. 51, No. 1, pp 76-81, 2023
Indian Journal of Soil Conservation
https://www.iaswc.com/ijsc.html

Performance of filter media for improving the irrigation water quality of village pond

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ARTICLE INFO

DOI : 10.59797/ijsc.v51.i1.152

Article history:
Received : January, 2022
Revised : March, 2023
Accepted : March, 2023

Key words:
Activated charcoal
BOD
Column study
Village pond water
Zeolite
Biochar

ABSTRACT

With the increased addition of household wastewater in the village pond, the water quality of the pond was deteriorating rendering it unsuitable for irrigation. Therefore, a study was conducted to treat the pond water for making it suitable for irrigation using different types of filter media. The five types of filter media *viz.,* biochar, activated charcoal, zeolite, fine sand and coarse sand were individually tested for the quality improvement of the pond water for irrigation. The water quality parameters, such as BOD, COD, TDS, TSS, TS, pH, and EC were analysed before and after passing through the filter media. The discharge of treated water for media thickness of 30 and 40 cm and water head of 10, 20 and 30 cm was passed through each filter media and discharge was collected for the water quality analysis. The BOD, COD, and TSS decreased by 12, 9.7 and 28%, respectively due to the combined effect of activated charcoal, zeolite and fine sand, respectively. To further enhance the performance of the filter materials, the study was conducted with the controlled discharge of 5 and 8 l h^{-1} through the same thickness of filter media. The discharge rate of 5 l h^{-1}, materials depth of 40 cm and water head of 10 cm decreased the values of BOD, COD, TSS and TDS more efficiently than the uncontrolled flow of water and discharge rate 8 l h^{-1}. The 40 cm depth of material was found more efficient than the 30 cm depth of material whereas there was an insignificant difference in the efficiency at 10, 20 and 30 cm heads therefore, the 10 cm head along with the 40 cm material depth was selected. Efficient materials based on the removal efficiency were selected (zeolite, activated charcoal, biochar and fine sand) and each selected material having a depth of 40 cm were put in the column one over the other by keeping course material at the bottom and finer at the top and water head 10 cm (Biochar, activated charcoal, zeolite and fine sand at top). Two cycles of 24, 48, 96 and 168 hrs duration were performed and treated water was collected at the outlet of the filter media for determination of quality parameters. For a combination of materials keeping the thickness of each material as 40 cm, the efficiency of 49, 57, 75, and 10% was achieved in terms of BOD, COD, TSS, and TDS.

1. INTRODUCTION

The community ponds in Punjab state had great importance and these were considered as the gift to the mankind. These ponds have been serving the community in more than one way. Presently, the state dwell in approximately 12,500 villages and in these villages about 20,000 ponds are located (Anon, 2019). In the last decades, due to the increase in built up area in the villages; the surface runoff generated got increased. Moreover, the increased household wastewater discharges due to the increase in water use, coupled with concrete channels and roads limiting the space for natural recharge resulted in inundated village ponds. Therefore, the ponds keep on receiving wastewater throughout the year. Because of the physico-chemical and biological quality issue of pond water, villagers have also stopped using this water for animal use as well as irrigation purpose. Moreover, the villagers bathe their animals in the animal sheds, resulting in more discharge of wastewater to the ponds. The greater household wastewater discharge coupled with the discharge of animal waste increases the contamination of the community ponds. The infiltration of water from the bottom of these ponds has decreased due to the non-cleaning of silt from the pond beds. Due to the low infiltration rate from the pond, the water remains inundated in these ponds. The pond water has a very bad smell, and the water source located near the village pond water, either a hand pump or tube well may get contaminated and become non-useful in the future.

Assessment of irrigation water quality for sustainable agriculture is very important (Yadav *et al.,* 2020). Wherever possible, the community pond water can be utilized for irrigation of field crops or forests, by periodical cleaning of these ponds to restore their basic character. Some studies recommend the use of this water as a source of irrigation or for growing timber-yielding plants (Thawale *et al.,* 2006; Minhas *et al.,* 2015). Unless strong evidence of toxicity through heavy metals is available, it may not be proper to prevent the use of this valuable source of water and nutrients. Proper planning for the use of community ponds for irrigation will result in conserving good quality groundwater through natural recharge and the additional water can be used for irrigation as well as other needs. Its use will maintain the community ponds and reduce the problem of the unhygienic conditions in the vicinity of the community pond. Several conventional and innovatory technologies are available for the treatment of community pond water and its use for irrigation such as phytoremediation, adsorbents like biochar, activated charcoal and zeolite (Sulochanan *et al.,* 2022; Assiddieq *et al.,* 2017) Since, the treatments are costly, therefore it is, desirable to develop a low-cost technology to treat the community pond water to make it suitable for irrigation. Therefore, in this study a low-cost effective filter to was developed to treat the community pond water suitable for irrigation purposes.

2. MATERIAL AND METHODS

Construction of Column

The columns were constructed from acrylic pipes of 14.5 cm inner diameter and 0.5 cm thickness joined end to end with the help of adhesive. The height of constructed columns was kept as 60, 120, 180 and 240 cm to study the variable depth of filter media for the improvement of community pond water quality. The bottom of each column was sealed with an acrylic sheet and sealant. An opening of 2.5 cm diameter was provided at the bottom for the collection of treated water. To obtain treated water a filter was placed at the bottom of the column. To maintain the desired depth of water head 10, 20 and 30 cm an overflow pipe was provided.

Selection of Filter Materials

Five types of materials *viz*., zeolite, biochar, activated charcoal (granular), coarse sand and fine sand were selected. The hydraulic conductivity (constant head method) and the size of each material were determined (Table 1). Each material was tested with a material depth of 30 and 40 cm individually. The water head of 10, 20 and 30 cm over each material was maintained as a constant head to check the efficiency of the filter media.

Installation of Column and Testing of Filter Media

The columns were installed in the Field Laboratory, Department of Soil and Water Engineering (Fig. 1). The community pond water was brought from village Gill, district Ludhiana of Punjab. The satellite image of the pond is shown in (Fig. 2) which is located at 30°50'28"N latitudes and 75°51'47"E longitudes. The water quality of the community pond was checked in the laboratory for the BOD, COD,

Table: 1
Properties of materials

S.No.	Media	Hydraulic conductivity (cm sec^{-1})	Size of the aggregate (mm)
1.	Biochar	6.90	10-15
2.	Activated charcoal	2.45	2-5
3.	Zeolite	1.16	1-2
4.	Coarse sand	1.10	1-2
5.	Fine sand	0.70	0.25-0.50

Fig. 1. Installation of combination of filter media

Fig. 2. Location of study site

TDS, TSS, TS, EC and pH. The community pond water was found not fit for irrigation so it was used for the testing of the filter media individually and in combination. In the experimentation, community pond water was filled in the overhead plastic tank of 1000 liter capacity. The water was then put into the column by gravity flow. In the first experiment, the water was allowed to pass through individual filter media without controlling the discharge rate.

The flow rate in each column was adjusted with a regulator to maintain a constant ponding depth of 10, 20 and 30 cm for material depth of 30 and 40 cm. An overflow pipe was provided at the top to remove excess water. A water collecting tank was placed under each column to collect the treated water.

The discharge rate was regulated at the outlet point of the column. The filter materials were tested for outlet discharge of 5 and 8 l h^{-1}. After the testing of the material individually, better-performing materials based on their efficiency were selected and those were placed in columns in layer-wise pattern. While testing the combination of filter layers, 7 day wetting and 7 days drying period was followed. During the first cycle, village pond water was passed continuously for seven days and samples at the outlet were collected at 24 h, 48 h, 96 h and 168 h. Then the column was kept as it is for 7 days and it was considered a drying periods and same cycle was again repeated. The water quality before and after passing the filter media was analysed in the laboratory for the BOD, COD, TDS, TSS, TS, EC and pH.

The Efficiency of the Filter Media

The efficiency of the filter media was determined using the concentration of particular water quality parameters before and after filtration. Based on the efficiency of each filter media, the combination of the filter media was decided.

$$\textit{Media filtration efficiency} = 1 - \frac{C_{AF}}{C_{BF}} \times 100 \qquad ...(1)$$

Where, C_{AF} is the Concentration of a particular parameter after filtration, C_{BF} is the Concentration of particular parameter before filtration.

3. RESULTS AND DISCUSSION

The developed experimental setup was used to evaluate the water quality changes of community pond water. The five filter materials were tested *viz.,* zeolite, activated charcoal, biochar, coarse sand, and fine sand with a depth of 30 and 40 cm and pond water was flooded at the constant head of 10, 20 and 30 cm over these filter media placed separately in the column. The results of the study are presented in the subsequent sections.

Effect of 30 and 40 cm Thickness of Filter Layer

Initially, the BOD of the community pond water was 104.7 mg l^{-1} (Fig. 3) which was more than the permissible limit (100 mg l^{-1}). So, it was passed individually through different filter media. For a filter thickness 30 cm, the BOD decreased by 4.1% for biochar, for activated charcoal by 12%, for zeolite by 3%, for coarse sand by 2.5% whereas for fine sand the reduction was 7.2%. The reduction in BOD due to the adsorption capacity of mainly by biochar, activated charcoal and zeolite which was similar to the study made by Mercado *et al.,* 2018. Similar findings were also reported by Saad and Jlil, 2009 and Assiddieq *et al.,* 2017. The COD (Fig. 4) of the community pond water was 526.7 mg l^{-1} which was more than the permissible limit (500 mg l^{-1}) for irrigation. Therefore, it was passed through each filter material separately at different water heads. In the case of biochar as filter material, COD decreased by 9.6% from the initial value of 526.7 mg l^{-1}, for activated charcoal by 8.6%, for zeolite by 9.7%, for fine sand by 15% of the original value which was found similar as reported by Kaur *et al.,* 1999 and Kim *et al.,* 2018 and for coarse sand it was decreased by 6%. The reduction in BOD and COD is influenced by the adsorbent mass of zeolite, activated charcoal and biochar (Assiddieq *et al.,* 2017). The TSS of the pond water was 350 mg l^{-1}, then it passed through each filter media separately at different water heads. For activated charcoal, TSS decreased by 14.9% from the initial values, for coarse sand, it decreased to 15.8%, for fine sand

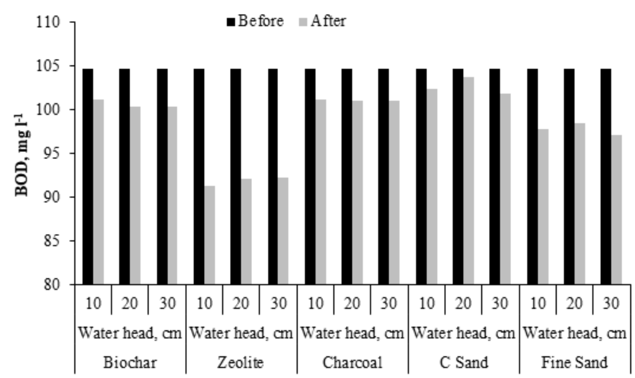

Fig. 3. Effect of filter media and water head on BOD of village pond water

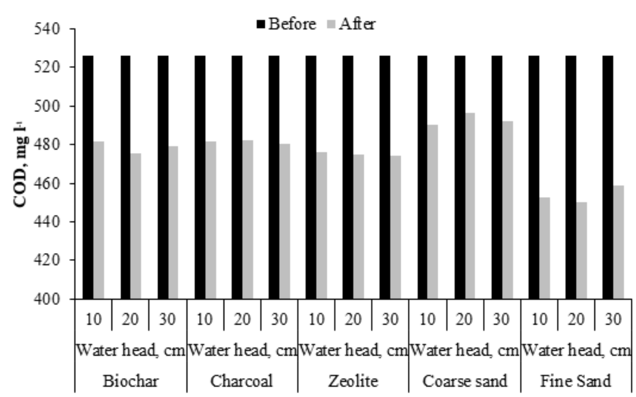

Fig. 4. Effect of filter media and water head on COD of village pond water

by 16.9%, for biochar TSS decreased by 16% and for zeolite TSS decreased by 9.2%. The percent TSS decrease in fine sand was found highest among the filter materials. TSS content decreased because the adsorption power of sand can absorb solids-suspended density in water (Ahmad and El-Dessouky, 2008, Assiddieq *et al.,* 2017). Initially, the TDS of the community pond water was 698 mg l^{-1}, then it was passed through selected materials at different water heads. In the case of activated charcoal, TDS decreased by 8.4%, for coarse sand by 7.6%, for fine sand by 8.2%, for biochar TDS decreased by 11.5% and for zeolite it decreased by 4.5%. Initially, the TDS of the community pond water was 1048 mg l^{-1} then it passed through selected materials at different water heads. For activated charcoal, TS decreased by 11%, for coarse sand by about 10%, for fine sand by about 12%, for biochar TS decreased by 13% and for zeolite it decreased to 6%.

Effect of 5 l h^{-1} Discharge Rate and 30 and 40 cm Depth of Materials

For biochar, the BOD (Fig. 5) decreased by 14%, for activated charcoal by 10.9%, for zeolite by 33%, for coarse sand by 21.4% whereas for fine sand it decreased by 31.6%. The reduction in the COD in the case of biochar, activated charcoal, zeolite, fine sand and coarse sand used as filter material were 22, 26.7, 27.93, 19.11 and 41.7%, respectively (Fig. 6). The reduction in TDS in caser of activated charcoal, coarse sand, fine sand, biochar and zeolite by 5.3, 0.7, 1.3, 3.4 and 5.7%, respectively. For activated charcoal, TSS in the filtrate was reduced by 6.8%, for coarse sand by about 25.8%, for fine sand by about 39.2%, for biochar TDS decreased by 5.7% and for zeolite it decreased by 15%. Further, the community pond water quality improvement was analysed after passing the water through 40 cm depth of material individually. For biochar, the BOD decreased by 22%, for activated charcoal by 24.0%, for zeolite by 14.6%, for coarse sand by 27.5% whereas for fine sand it decreased by 40.5% whereas for biochar, COD decreased by 29.7%, for activated charcoal by 45%, for zeolite by 27%, for fine sand it decreased to 26.5% and for coarse sand it was decreased by 45%. For activated charcoal, TDS decreased by 6.68%, for coarse sand by about 1.0%, for fine sand by about 1.6%, for biochar TDS decreased by 4.3% and for zeolite it decreased to 5.8%. When TSS was compared for different materials, TSS for activated charcoal decreased by 6.6%, for coarse sand by about 27.8%, for fine sand by about 41.4%, for biochar TSS decreased by 7.9 % and for zeolite it decreased to 27%. The total solids when passed through 30 cm of filter media reduced by 3, 7, 6, and 7% in biochar, zeolite, activated charcoal, fine sand and coarse sand, respectively. For a 40 cm depth of material TS decreased by for biochar 5%, for zeolite 8%, for activated charcoal 7.3%, for fine sand 11% and for coarse sand TS decreased by 7%. This is influenced by the mass of zeolite and activated

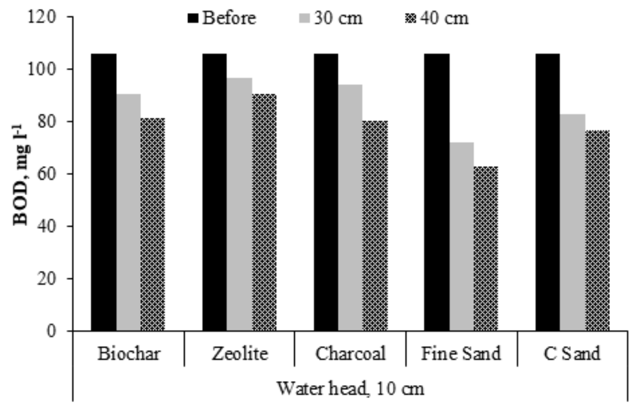

Fig. 5. Effect of 30 and 40 cm filter media depth with 10 cm water head on BOD at 5 l h^{-1} discharge rate

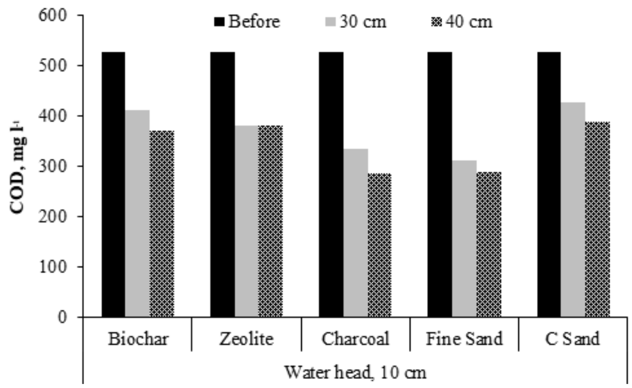

Fig. 6. Effect of 30 and 40 cm filter media depth with water head 10 cm on COD at 5 l h^{-1} discharge rate

charcoal. The above observation shows that the removal efficiency of BOD, COD and TSS increased with the increasing mass of activated charcoal, biochar and zeolite mass. This finding was in line with some previous studies (Karthikeyan *et al.,* 2019; Lap *et al.,* 2021).

Effect of 8 l h^{-1} Discharge Rate and 30 and 40 cm Material Depth

For biochar, BOD (Fig. 7) decreased by 6.9%, activated charcoal by 12%, for zeolite by 3.7%, for coarse sand by 6.2% whereas for fine sand it decreased by 19.6%. For biochar COD (Fig. 8) decreased by 29.4%, for activated charcoal by 24%, for zeolite by 27.4%, for fine sand it decreased to 19.6% and for coarse sand it decreased by 25%. For activated charcoal, TDS decreased by 2.6%, for coarse sand by about 0.89%, for fine sand by about 1.1%, for biochar TDS decreased by 3.1% and for zeolite it decreased by 3.4%. For activated charcoal, TSS decreased by 7.3%, for coarse sand by about 23%, for fine sand by about 33%, for biochar TSS decreased by 4.6% and for zeolite it decreased by 12%.

For biochar, BOD decreased by 13.0%, for activated charcoal by 21.8%, for zeolite by 10.7%, for coarse sand by

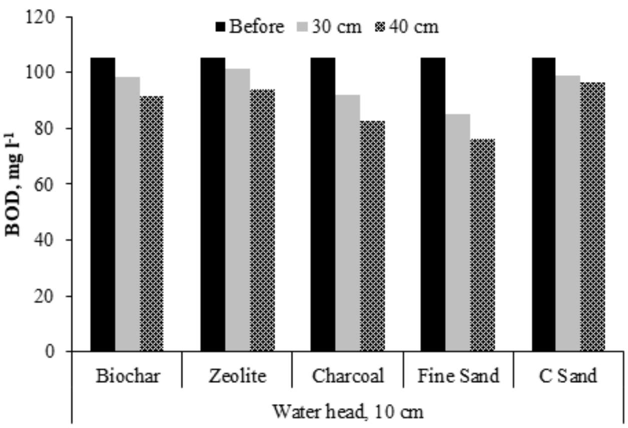

Fig. 7. Effect of 30 and 40 cm filter media depth on BOD at 8 l h^{-1} discharge rate

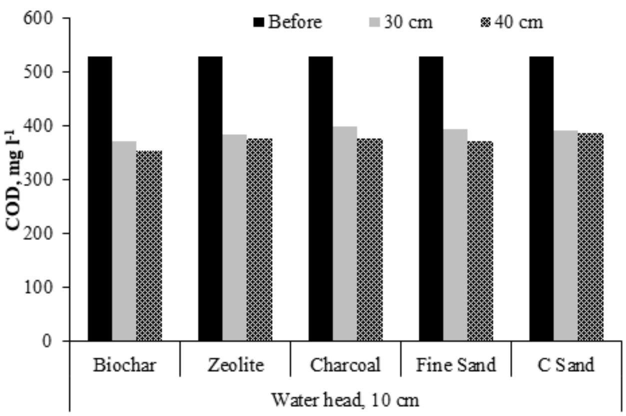

Fig. 8. Relation between COD (mg l^{-1}) and different materials at 8 l h^{-1} discharge rate

8.8% and for fine sand by 27.8%. For biochar, COD decreased by 32%, for activated charcoal by 28%, for zeolite by 37.6%, for fine sand by 26.5% and for coarse sand it decreased by 29.5%. For activated charcoal, TDS decreased by 3.4%, for coarse sand by about 0.7%, for fine sand by about 8.9%, for biochar by 2.8% and for zeolite, it decreased by 3.1%. For activated charcoal, TSS decreased by 10.7%, for coarse sand by about 22%, for fine sand by about 38%, for biochar TSS decreased by 6.5% and for zeolite it decreased by 9.6%. The value of TS before passing the filter media value of total solids are 1149 mg l^{-1} but after infiltration at 30 cm depth of material value decreases for material biochar was 3.39%, zeolite 5.7%, activated charcoal 3.9%, fine sand 8.7% and by coarse sand 6.2%. For 40 cm depth of material TS decreased by for biochar 3.8%, for zeolite 4.8%, for activated charcoal 3.9%, for fine sand 8.7% and for coarse sand TS decreased by 5.9%. As the discharge rate increases, the removal efficiency of the filter media decreases as the water gets less opportunity time to interact with filter media. Similar results were reported by (Kambale *et al.,* 2009; Kumar *et al.,* 2021; Hansra *et al.,* 2022) for composite filters containing activated charcoal and sand.

Effect of Wetting and Drying Cycle-I

For 24 hrs, the BOD (Fig. 9) decreased by 27%, for 48 hrs by 47%, for 96 hrs by 47%, whereas for 168 hrs it decreased by 49%. For 24 hrs, the COD (Fig. 10) decreased by 41.7%, for 48 hrs by 45.8%, for 96 hrs by 50.6%, whereas for 168 hrs, it decreased by 57%. For 24 hrs, the TSS decreased by 67 %, for 48 hrs by 43%, for 96 hrs by 57%, whereas for 168 hrs it decreased by 74%. For 24 hrs, the TDS decreased by 3%, for 48 hrs by 7%, for 96 hrs by 8%, whereas for 168 hrs it decreased by 10%. Change in the value of TS revealed before passing the filter media value of total solids are 1131 mg l^{-1} but after infiltration at 24 hrs value decreases by 3.6%, at 48 hrs value decreases by 7.8%, at 96 hrs value decrease by 8.9% and for 168 hrs decrease in value by10.5%.

Effect of Wetting and Drying Cycle-II

For 24 hrs of the wetting cycle, the BOD (Fig. 11) decreased by 25.5%, for 48 hrs by 39.5%, for 96 hrs by 43.1%, whereas for 168 hrs it decreased by 44%. For 24 hrs, the COD (Fig. 12) decreased by 41.3%, for 48 hrs by 44.8%, for 96 hrs by 55.4%, whereas for 168 hrs it decreased by 63.2%.

For 24 hrs of the wetting cycle, the TSS decreased by 32%, for 48 hrs by 44.6%, for 96 hrs by 55.4%, whereas for 168 hrs it decreased by 63.2%. For 24 hrs, the TDS decreased by 23.8%, for 48 hrs by 2%, for 96 hrs by 4%,

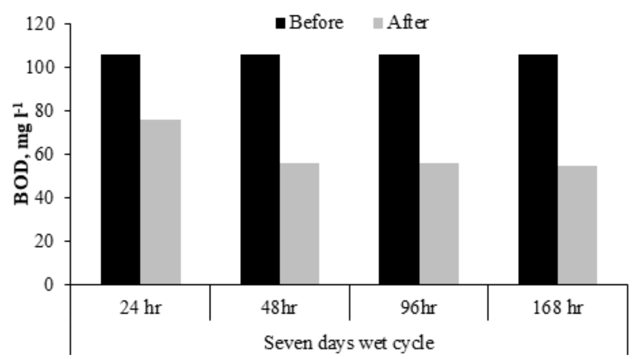

Fig. 9. Effect of BOD on wetting and drying cycle - I

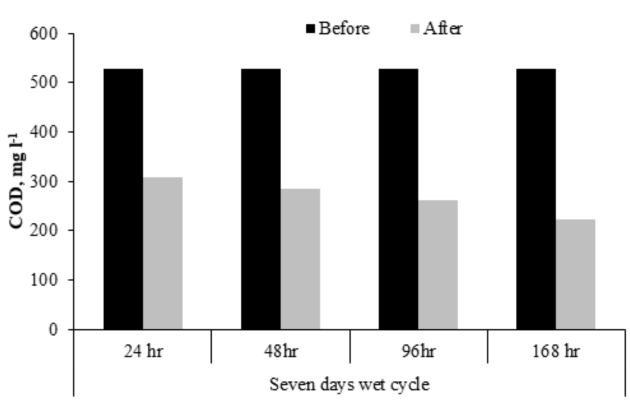

Fig. 10. Effect of COD on wetting and drying cycle - I

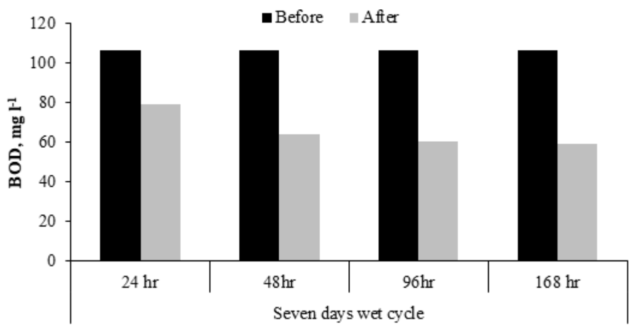

Fig. 11. Effect of BOD wetting and drying cycle - II

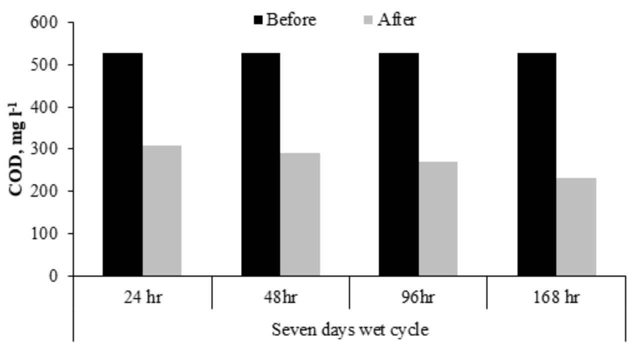

Fig. 12. Effect of COD on wetting and drying cycle - II

whereas for 168 hrs it decreased by 6%. TS revealed in (Fig. 12) before passing the filter media value of total solids are 1131 mg l^{-1} but after infiltration at 24 hrs value decreases to 11.1%, at 48 hrs value decreases to 16.0%, at 96 hrs value decreased by 19.9% and for 168 hrs, the value decreases by 23.8%. The drying and wetting cycle results in recovery in porosity and maintains good porosity of the filter media and helps to enhance the life of the filter media. Similar results were reported by Kaur 1999 and Kumar *et al.,* 2021.

4. CONCLUSIONS

The discharge rate of 5 l h^{-1}, materials depth 40 cm and water head 0f 10 cm reduced the BOD, COD, TSS and TDS more efficiently than the uncontrolled flow of water and discharge rate 8 l h^{-1}. The material thickness of 40 cm was found more efficient than the 30 cm thickness. There was an insignificant difference in the efficiency at 10, 20 and 30 cm head therefore 10 cm head along with 40 cm material thickness can be considered optimum. Based on the filtration efficiency good materials including zeolite, activated charcoal, biochar, and fine sand, with a material thickness of 40 cm each and head of 10 cm were selected and can be recommended. The four materials are arranged one over the other in the column with coarser material at the bottom and the finest at the top was found effective and therefore suggested for upscaling of the filtration system. For the combination and arrangement of material suggested, the filtration efficiency of 49, 57, 75, and 10% was achieved in terms of BOD, COD, TSS, and TDS. However, it was observed that some flushing mechanisms are required for the filter media for the better and long-lasting performance of the filter for irrigation water treatment. The suggested filtration techniques can be adapted and upscaled through a government supported program for effective use of the village pond water to be used in irrigation.

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