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Shrankhla Mishra
Department of Soil and Water Engineering, Punjab Agricultural University Ludhiana Punjab, India

Sanjay Satpute
Department of Soil and Water Engineering, Punjab Agricultural University Ludhiana Punjab, India

Corresponding Author:
Shrankhla Mishra
Department of Soil and Water Engineering, Punjab Agricultural University Ludhiana Punjab, India

Review paper on study of different filter media for quality improvement of village pond water for irrigation

Shrankhla Mishra and Sanjay Satpute

Abstract
Due to the increasing influx of household wastewater into the village pond, the pond's water quality began to deteriorate, making it unsuitable for irrigation. Consequently, a study was conducted to improve the pond water's suitability for irrigation using various filter media. Five types of filter media, namely biochar, activated charcoal, zeolite, fine sand, and coarse sand, were individually tested to enhance the quality of the pond water for irrigation. Water quality parameters including BOD, COD, TDS, TSS, TS, pH, and EC were assessed before and after passing through the filter media. The treated water was discharged through each filter media with varying thicknesses (30 and 40 cm) and water levels (10, 20, and 30 cm), and the discharged water was collected for water quality analysis. The combination of activated charcoal, zeolite, and fine sand led to a 12% reduction in BOD, a 9.7% reduction in COD, and a substantial 28% decrease in TSS. The combined impact of activated charcoal, zeolite, and fine sand was examined to enhance the performance of filter materials. The study involved controlled discharges of 5 and 8 liters per hour (l/h) through the same thickness of filter media. Comparatively, a discharge rate of 5 l/h, a material depth of 40 cm, and a water head of 10 cm exhibited more effective reduction in BOD, COD, TSS, and TDS compared to uncontrolled water flow and an 8 l/h discharge rate. The 40 cm material depth proved more efficient than a 30 cm depth, with insignificant differences observed at 10, 20, and 30 cm heads. Consequently, a 10 cm head paired with a 40 cm material depth was selected. Based on removal efficiency, zeolite, activated charcoal, biochar, and fine sand were chosen as efficient materials. Each material, with a depth of 40 cm, was layered in a column, with coarser material at the bottom and finer material at the top, maintaining a water head of 10 cm (Biochar, activated charcoal, zeolite, and fine sand at the top). Two cycles of 24, 48, 96, and 168 hours were conducted, and treated water was collected at the filter media outlet for assessing quality parameters. The combination of materials, each with a thickness of 40 cm, achieved efficiencies of 49%, 57%, 75%, and 10% for BOD, COD, TSS, and TDS, respectively.

Keywords: BOD, COD, village, pond water

Introduction

Village ponds in the Punjab state hold significant importance and are considered a valuable gift to the community. These ponds have served various essential purposes, historically acting as a lifeline for the people in Punjab. Approximately three decades ago, rainwater and runoff were stored in these ponds, serving as a vital source of drinking water and a place for bathing animals. Currently, with around 12,500 villages in the state, there are approximately 20,000 ponds (Anon 2018). However, in recent decades, the expansion of built-up areas in villages has led to an increase in surface runoff. Additionally, the rise in household wastewater discharge due to increased water use, along with the development of concrete channels and roads, has left little space for natural recharge, leading to the inundation of village ponds.

Many households in these villages have installed family toilets with septic tanks, and the discharge from these septic tanks also flows into the channels and, ultimately, into the village ponds. As a result, the ponds receive wastewater throughout the year. Due to concerns about water quality in village ponds, villagers have ceased using this water for both animals and irrigation. Furthermore, villagers now bathe their animals in separate sheds, contributing to an increase in wastewater discharge into the ponds. The combination of increased household wastewater and animal waste has led to higher contamination of the village ponds.

The decreased water infiltration, caused by the accumulation of silt in the pond beds, has further exacerbated the problem. This reduced infiltration rate results in the water stagnating in the ponds, leading to foul odours and potential contamination of nearby water sources such as hand pumps or tube wells. These water sources should ideally be eco-friendly and safe for use, but without proper management, they risk becoming problematic.

To utilize village pond wastewater for irrigation, an effective filtration system is necessary. Various techniques are available to treat this wastewater to mitigate its adverse effects on human health, crops, and soil. In this chapter, we will delve into the current status of available options and discuss relevant studies in this regard.

Kaur (1999) A study was undertaken to assess the potential of a Soil Aquifer Treatment (SAT) system with varying soil depths and types for enhancing the quality of sewage water, with the aim of making it suitable for irrigation. The study involved passing treated effluents through the SAT and analyzing various water quality parameters, including COD, BOD, TSS, pH, EC, TDS, TH, NO3-N, and fluoride.

The results indicated that SAT effectively enhances the quality of primary treated effluents, making them suitable for unrestricted irrigation. Consequently, the SAT system emerges as a more practical and cost-effective alternative for sewage water quality improvement.

Chawala *et al.* (2001) [9] An investigation was conducted to assess the water quality of a village pond in Ludhiana district, Punjab. Water samples were subjected to analysis for various parameters, including carbonate (CO3), bicarbonates (HCO3), chloride (Cl), calcium (Ca), magnesium (Mg), RSC (Residual Sodium Carbonate), electrical conductivity (EC), turbidity, pH, alkalinity, dissolved oxygen (DO), carbon monoxide (CO), and total nitrogen (N). The findings led to the conclusion that the water in the village pond is deemed suitable for both irrigation and fisheries purposes.

Shrivastava and Kanungo (2003) [25] The research was conducted on pond water in the Surguja district of Chhattisgarh, India. In this investigation, water samples were examined for temperature, pH, electrical conductivity, total dissolved solids (TDS), alkalinity, free carbon dioxide (CO2), chloride, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness, calcium, and magnesium. The findings indicated that the parameters measured were found to be within acceptable pollution levels for groundwater, making it suitable for various purposes such as domestic use, agricultural irrigation, and industrial applications. However, the water quality in the case of surface water, particularly in a small community pond, exceeded the recommended values.

Prasad *et al.* (2006) [19] conducted the study for treatments of domestic sewage water. Research included sand intermittent filtration beds of mixture of sand and soil at different ratio i.e. 1:1; 1:3; 3:1 and one set of 100% of each sand and soil were also taken. The filtration system was found to have good potential in reducing BOD by 72.5%, COD by 69.9%, total alkalinity by 37.9%, total solids by 88.5%, total dissolved solids by 86.1%, total suspended solids by 91.2%. Minimum reduction ability with respect to above mentioned parameter was found in 100% sand and soil bed without mixture.

The low cost activated carbons from agricultural waste materials *viz*., coconut shell, coconut shell fibers and rice husk was prepared and used for removal of COD, heavy metals, anions, etc. from industrial wastewater (Mohan *et al.* 2007) [18]. This study was carried out at different temperatures and particle sizes to study the effect of temperatures and surface areas. The result was found that the removal of chloride and fluoride increased with rise in temperature while COD and metal ions removal decreased with increase in temperature, The COD removal was 47–72% by coconut shell fiber carbon (ATFAC), 50–74% by coconut shell carbon (ATSAC) and 45–73% by rice husk carbon (ATRHC).

Hami *et al.* (2007) [20] The study aimed to assess how the introduction of powdered activated carbon (PAC) impacted the functioning of a pilot-scale dissolved air flotation (DAF) system. Wastewater sourced from a refinery, with varying concentrations, was treated, and the influence of different operational factors on the effectiveness of pollutant removal, specifically in terms of BOD and COD, was examined. The operational parameters under investigation encompassed the flow rate, recycle ratio, saturation pressure, and the PAC concentration added. The results revealed that when PAC dosages fell within the range of 50–150 mg/l, removal efficiencies for BOD increased from 27–70% to 76–94%, while those for COD increased from 16–64% to 72–92.5%, depending on initial inlet values of 45–95 mg/l for BOD and 110–200 mg/l for COD. These findings shed light on the performance of the dissolved air flotation unit.

Janveja *et al.* (2008) [15] An experiment was conducted to eliminate red dye from textile wastewater by utilizing activated rice husk charcoal as an adsorbent. The study explored the impact of factors such as the quantity of adsorbent and the duration of contact on the adsorption of the dye. The quantity of rice husk charcoal was varied from 0.2 g/l to 2.0 g/l, and the contact time ranged from 30 to 360 minutes. While maintaining all other conditions constant, it was observed that as the quantity of rice husk charcoal increased, the adsorption also increased from 0.2 g/l to 1.2 g/l, after which it reached a plateau. Similarly, as the contact time was extended, adsorption increased from 30 to 210 minutes, beyond which it remained constant.

Waleska *et al*. (2008) employed untreated coffee husks as adsorbents in a batch system to remove heavy metal ions such as Cd (II), Cu (II), and Zn (II) from aqueous solutions. The results indicated that the highest adsorption capacity was achieved at specific pH levels for each metal ion.

Ghazanfary (2009) investigated the reduction of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) in domestic wastewater using processes such as sedimentation, aeration, activated sludge, sand filtration, and activated carbon. The study observed that the mean maximum reduction in COD and BOD was 92.17% and 97.66%, respectively. Other water quality parameters such as TSS, TDS showed significant reduction. These materials showed the excellent potential for COD and BOD removal from domestic wastewater. Study revealed that the concentration level of COD and BOD in the treated water was within the permissible limits for industrial cooling and agriculture use especially for landscape irrigation.

Azouaou *et al.* (2010) [4] studied the effect of various parameters on adsorption capacity of cadmium using untreated coffee grounds collected from cafeterias as adsorbent. The results revealed that the coffee ground have high possibility to be used as effective and economical adsorbent for cadmium removal.

Patel and Vashi (2010) [20] A study was conducted to investigate the removal of chemical oxygen demand (COD) and biological oxygen demand (BOD) from textile wastewater using various natural materials, including bentonite, fuller's earth, china clay, and zeolite. The study examined the impact of different factors such as the dosage of adsorbents, contact time, and temperature on the removal of COD and BOD. Both Langmuir and Freundlich models of adsorption were applied to describe the equilibrium isotherms and determine their constants, with experimental data fitting well to the Freundlich isotherm. The results indicated that the highest removal rates for COD (92.5%) and BOD (95.5%) were achieved at a temperature of 350 K, a contact duration of 4 hours, and a dosage of 50 g/l of zeolite.

Toor *et al*. (2011) [26] conducted a study to assess the water quality of village ponds in Ludhiana district. Samples from the village ponds were analyzed for total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity (EC), and residual sodium carbonate (RSC). The results indicated that only 18% of the total samples met the standards for irrigation.

In a study by Clark *et al*. (2012) [11], the focus was on the design, implementation, accessibility, and sustainability of slow sand water filters in developing countries. The authors found that by implementing slow sand water filters and making use of microfinancing services, developing countries could not only gain access to clean and potable water but also break free from the cycle of poverty.

Berger (2012) conducted a study involving the use of activated carbon for treating greywater. The objective of this research was to assess and compare the effectiveness of biochar and activated carbon in reducing various chemical parameters (pH, EC, NH4-N, NO3-N, Tot-N, PO4-P, Tot-P, MBAS, and COD). The water was passed through a column for treatment. The results revealed that both materials effectively purified the greywater from organic substances, achieving a 99% efficiency in COD and MBAS removal. Biochar proved more effective than activated carbon in removing Tot-P and PO4-P, with average removal rates of 89% for Tot-P and 86% for PO4-P. Water quality parameters such as TSS, TDS showed significant reduction. These materials showed the excellent potential for COD and BOD removal from domestic wastewater. Study revealed that the concentration level of COD and BOD in the treated water was within the permissible limits for industrial cooling and agriculture use especially for landscape irrigation.

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Salmani *et al.* (2012) [22] the laboratory experiment involved the use of activated carbon to remove copper ions from drinking water through a sorption method. A 20 mg/l copper ion solution was prepared and passed through a 5×10cm column. The average output rate was 1.85 ml/min, and samples were taken from the column every 30 minutes. The results indicated that the highest copper ion removal efficiency reached 99.7% at 127 minutes and remained constant over time.

In a study by Afiffi *et al*. in 2013, a reed bed system was employed for wastewater treatment and reuse in urban and semi-urban communities in Gaza, Palestine. The research demonstrated that reed bed units proved to be a cost-effective system for wastewater disposal and treatment, offering the possibility of reusing the treated effluent. The biological complexity within the reed bed's root zone contributed to its effective water cleansing capabilities, often surpassing those of many chemical or mechanical treatment methods. The system achieved an 80% removal efficiency for Biological Oxygen Demand (BOD).

Sayed's 2013 study focused on a common effluent treatment plant (CETP) in Koperkhairne, Navi Mumbai, Maharashtra. Various filters, including activated carbon, dual media, and sand filters, were used to treat effluents received from approximately 3056 industries, ranging from large to small scale. These industries encompassed a wide range, including textiles, leather, paints, pharmaceuticals, and more, with effluents carrying high levels of COD, TSS, TDS, and other contaminants. The study aimed to determine which of the mentioned filters provided the best colour and odour removal, COD reduction, and TSS removal. After conducting the study for seven days using effluent from the clariflocculator, it was found that activated carbon was the most effective in removing colour and odour and reducing COD.

Choudhury *et al*. (2013) [10] conducted a study on effluent characterization and assessed physical and chemical treatment using filtration and coagulation processes with sand-stone. The filtered effluents were treated with various doses of FeCl3. The results showed that the effluents were yellowish-brown in colour, had a basic pH, high levels of BOD5, COD, TDS, TSS, TS, and significant concentrations of Cr, Na, SO2−, as well as other organic and inorganic constituents. The study concluded that a coagulant dose of 150 mg/L of FeCl3 at a near-neutral pH exhibited the best removal efficiencies for major physico-chemical parameters. The analysis indicated that most physical and chemical parameters fell well below the prescribed permissible limits for effluent discharge.

Gawad (2014) [13] performed the study to investigate oil and grease pollution that may pollute fresh water and influence aquatic environment. Enzyme and adsorption units were selected to assess the water quality and humiliation prospective of oil and grease from wastewater. Several components and environmental variables that were dissolved oxygen, bacteriology measure, flow rate and adsorption material amount studied to assess the removal performance of oil and grease. The result concluded that declining develop biological treatment process reached to 72%. These conditions were closer spacing and high length of adsorbing unit that led to increase oil and grease contact period with adsorbent and added to increase performance removal reached to 99%.

Chavda and Pandya (2014) [8] A batch experiment was carried out by PARAPHRASE IT to examine the adsorption capabilities of biochar and activated carbon. The findings revealed that activated carbon was ineffective in removing TDS and heavy metals, while biochar proved to be a suitable option for their removal. The primary mode of removal with biochar was determined to be surface precipitation, as observed in the batch absorption experiments. Key variables such as biochar dosage and contact time were considered in the batch adsorption study, resulting in varying removal efficiencies for TDS, COD, and heavy metals. Overall, the results indicated that the use of biochar for adsorption in wastewater demonstrated excellent efficiency.

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In a study conducted by Ratnoji and Singh in 2014, an experiment was performed to enhance the quality of raw water. The study compared the performance of activated carbon filters and sand filters. Activated carbons were collected at various depths, both individually and in combination. This research aimed to assess the reduction and removal of iron, turbidity, biochemical oxygen demand

(BOD), and chemical oxygen demand (COD) in river water.

In another study conducted by Biswas and Mishra in 2015, chemically carbonized rubber wood sawdust (CRSD) columns were employed to remove lead ions from a lead-contaminated waste stream. The results revealed a maximum lead ion removal of 38.56 mg/g in the column process. It was observed that the adsorption capacity increased with higher inlet concentrations and bed depths, but decreased with increasing flow rates.

Shahmoradi *et al.* (2015) [23] An experiment was conducted to eliminate nitrate from groundwater. In this investigation, a comparison was made between the adsorption capabilities of activated carbon derived from rice husk through the pyrolysis process and the sludge obtained from wastewater treatment in the paper industry for nitrate removal. The findings indicated that the highest level of adsorption occurred at a pH level of up to 4, after which it reached equilibrium. The efficiency of nitrate removal from rice husk was approximately 93.5 mg/g, while the removal efficiency from paper industry sludge was around 79.5 mg/g. Consequently, the study concluded that activated carbon derived from rice husk was more effective in removing nitrate.

In a study by Sountherajah *et al*. (2015), a batch experiment was conducted to eliminate suspended solids (turbidity), dissolved organic carbon (DOC), and heavy metals from storm water using granular activated carbon (GAC) in both batch and fixed-bed column experiments. The results revealed that turbidity and DOC in storm water were effectively reduced when using a 100 cm high GAC filter column at filtration velocities of 5, 10, and 11.5 m/h. Adsorption experiments conducted at pH levels of 6.5–7.2 using GAC showed that the order of efficiency in removing metals from solutions, both single and mixed, was as follows: Pb, Cu > Zn > Ni, Cd. This study concluded that a GAC filter is efficient in eliminating turbidity, DOC, and heavy metals from storm water.

Razvantalab and Bhadori (2015) [21] conducted a study to experimentally investigate the reduction of sodium adsorption ratio (SAR) and total dissolved solids (TDS) in reverse osmosis concentrate using two different types of natural zeolites. Experiments were carried out to reduce the salinity of wastewater by varying the type of zeolite, zeolite concentration, and residence time. The results demonstrated that both zeolites could lower the SAR and TDS of wastewater; however, Rhyolitic tuff was more effective than clinoptilolite.

Manyuchi *et al.* (2016) [17] The research was conducted within a paper mill, where sludge was transformed into biochar through pyrolysis technology, intended for application in wastewater treatment. The paper mill sludge underwent pyrolysis at temperatures ranging from 400 °C to 1000 °C, with a heating rate of 10 °C per minute, and a carbonization duration of 45 minutes in a laboratory-scale pyrolysis reactor. Following this, the biochar was finely ground to a particle size of 1.8 mm and possessed a surface area of 500 m2/g. Subsequently, the paper mill biochar was loaded into a custom-made adsorption column in the laboratory, featuring a radius of 1.5 cm and a length of 20 cm. It was loaded at a rate of 0.02 g/cm3 and employed as a bio-adsorbent for treating textile wastewater. This treatment aimed to bring about changes in the levels of total dissolved solids (TDS), total suspended solids (TSS), and chemical oxygen demand (COD) in the textile wastewater.

The study identified that the optimal adsorption time was 15 seconds, which resulted in an increased level of absorbance and transmittance in the treated effluent. Furthermore, the results indicated that the use of paper mill biochar as an adsorbent led to a remarkable reduction of over 97% in TDS, TSS, and COD in the treated effluent.

Ibrahim (2016) [22] An experiment was carried out to explore the utility of dried brown alga Sargassum latifolium (SAP) and its activated carbon (SAC) in adsorbing Pb+2, Cd+2, and Cu+2 ions from contaminated water. The assessment involved studying various factors, including the initial concentration of metal ions, contact duration, the quantity of adsorbent used, and the pH level. It was determined that the most effective adsorption of these ions occurred at a contact time of 60 minutes, a pH value of 5.0, an adsorbent dose of 8.0 g/l, and an initial concentration of 80 mg/l. SAC exhibited a maximum removal capacity of 167 mg/g for Cd+2, 147 mg/g for Cu+2, and 141 mg/g for Pb+2. Furthermore, SAC emerged as the most efficient medium for removing 100% of heavy metals from samples of drinking water.

Conclusion

A discharge rate of 5 liters per hour, a material depth of 40 cm, and a water head of 10 cm exhibited greater efficiency in reducing BOD, COD, TSS, and TDS compared to uncontrolled water flow and an 8 liters per hour discharge rate. A material thickness of 40 cm proved more effective than 30 cm. In terms of efficiency, there was negligible difference at 10, 20, and 30 cm heads, thus suggesting that a 10 cm head with a 40 cm material thickness is optimal. Materials with high filtration efficiency, including zeolite, activated charcoal, biochar, and fine sand, each with a 40 cm thickness and a 10 cm head, were selected and recommended.

Arranging these four materials in a column with coarser material at the bottom and the finest at the top was found to be effective, supporting the suggestion for upscaling the filtration system. The combination and arrangement achieved filtration efficiencies of 49%, 57%, 75%, and 10% for BOD, COD, TSS, and TDS, respectively. However, it was noted that implementing flushing mechanisms for the filter media is essential for improved and prolonged performance in irrigation water treatment. The proposed filtration techniques can be adopted and expanded through government-supported programs for the efficient utilization of village pond water in irrigation.

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