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The Use of sawdust and sugarcane bagasse as low cost adsorbent in wastewater treatment

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Abstract
Recently, as a result of water poverty and the economic conditions that the world is experiencing, the world has turned to using low-cost methods to solve the wastewater treatment problems, which are very important for preserving the environment and human health. On one hand, the study is aimed to use natural materials such as sawdust and sugarcane bagasse (SCB), which are environmentally friendly and low cost. In addition to determining the optimum depth for maximizing the qualities of treated wastewater for irrigation purposes, according to the Egyptian Code for the Use of Treated Wastewater in Agriculture and Egyptian law 48, grade A, water will be used to maintain green landscapes at educational institutions, public and private parks, and fresh fruit crops that can be eaten without peeling. At Zenin wastewater treatment plant, low-cost adsorbents were tested in two identical filters. Using different depth of sawdust media layers, biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) were significantly reduced. Using thicknesses of 20 cm, 30 cm, and 40 cm, respectively, BOD decreased by 65.65%, 70.9%, and 73.61%. The COD decreased by 55.07%, 69.96%, and 76.6%. The TSS reduces by 59.4%, 66.6%, and 77.14% respectively. It has been shown that sawdust can effectively remove organic and suspended solids from wastewater when used as an adsorbent in filters. Sugarcane bagasse also demonstrated great result when used as an adsorbent that BOD decreased by 52.25, 56.99%, and 58.82% at depths of 20 cm, 30 cm, and 40 cm, respectively, whereas COD decreased by 51.2%, 56.89%, and 60.64% respectively. The reductions in TSS, 43.93%, and 75% with the respective depths were observed. After selecting the best material and optimum depth for adsorption, sawdust was tested at 40 cm which shows a reduction in BOD by 82.73%, COD by 84.58%, and TSS by 88.235%, there were also reductions in ammonia (NH3), nitrate (NO3), oil, and grease with removal efficiency of 11.6%, 60.27%, and 83.1%, respectively.

Keywords: Low-cost adsorbent; natural adsorbent; depth filtration; Wastewater Treatment; sawdust; Sugarcane bagasse.

Introduction

Over the years, the quality of water has been declining primarily due to human activities, population growth, unplanned urbanization, rapid industrialization, and inefficient use of natural water resources. Additionally, the increased awareness of the importance of addressing the impacts of current environmental strategies has motivated the research community. In develop robust, economically viable, and environmentally friendly processes capable of reducing pollutants from water and at same time to protection the health of pretentious populations, [1]. In the last three decades, numerous approaches using non-conventional adsorbents have been studied for the development of cheaper and more effective adsorbents to eliminate pollutants at trace levels [2]. Essentially, adsorption refers to the accumulation of an element on a surface or boundary. In the context of water treatment, this process occurs at the interface between a solid adsorbent and the polluted water. The pollutant that is adsorbed is referred to as the adsorbing phase as adsorbent [3]. An ideal wastewater treatment process is one that produces

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effluent that meets bacteriological and chemical quality standards, while also being cost-effective and requiring minimal maintenance and operation [4] Sawdust, a lignocellulose material, can be utilized as a viable precursor for producing activated carbon [5][6][7].

Ali et al. [6] mentioned the potential of using low-cost adsorbents in water treatment, specifically for the removal of organic contaminants. These adsorbents, such as fruit wastes, coconut shell, scrap tires, and various other materials, have been found to be effective in removing organic pollutants from water. Adebakin et al. [8] prove that filtration is a mechanical method used to separate solid particles from a fluid phase. The characteristics of the filter material, including its thickness, pore size, and resistance, are crucial factors to consider. Additionally, the properties of the particles being filtered, such as their shape, distribution, and size, can significantly impact the performance of the filtration process.

Djilani et al. [9] found that the cost of removing iron blue with wood was only 1.5% compared with carbon. Also, Gupta et al. [10] showed that the relative cost of hardwood sawdust was 8.4% of the activated carbon content, so there was no need to recycle the sawdust. Therefore, the felled wood can be used as fuel. Also, M. Sćiban et al. [11] proved that the sawdust plays a significant role as an adsorbent for wastewater pollutants. Low-cost adsorbent such as sugarcane bagasse has good performance in removing undesirable pollutants from wastewater [12]. The multimedia filtration process is effective in removing pH, total solids, dissolved solids, suspended solids, biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen. Similarly, Alomá et al [13] indicated that Bagasse, also known as megass, has been employed as a potential biosorbent. Moubarik et al. [14] proved that raw sugarcane bagasse has been extensively studied as a biosorbent for the elimination of contaminants without the requirement of additional physical or chemical treatments. Philani Ncube [15] proved that the removal efficiency of media filter increased as the depth of the filter media increased.

2. Materials and Methodology

In this study, several tests were conducted at the Zenin wastewater treatment plant in Giza, Egypt. The tests were carried out in two identical filters located after the final settling tank, as part of the secondary treatment process. The objective was to investigate the feasibility of using low-cost adsorbents as media filters for wastewater treatment. Additionally, the study aimed to determine the effect of increasing the depth of the media on the reduction of BOD, COD, and TSS, with the goal of reusing the treated water for irrigation purposes, meeting grade A standards.

2.1 The filtration tank

The filtration tank was constructed using galvanized sheet with a thickness of 6 mm, and the interior was painted with an insulating material known as epoxy.

The dimensions of the filtration tank are as follows: length - 0.3 m, width - 0.3 m, and height - 1 m. In order to facilitate the viewing of the media and to easily measure the depth of the media layer, an acrylic part with dimensions of 10 cm width and 80 cm length has been added to the middle of one side of the filter (refer to fig 1).

Located at the bottom of the filter is a tap with a diameter of 1 inch, which is connected to a hose for draining wastewater during the filtration process.

The total capacity of the tank is 90 liters per minute (refer to fig 2). The inlet hose into the filter has a diameter of 0.5 inch, while the tap outlet has a diameter of 1 inch.

Fig.1 Filter model

Fig.2 Acrylic part

2.2. Materials used

2.2.1 – materials of media used

2.2.1.1 Preparation of sawdust as an adsorbent

The process of preparing sawdust as an adsorbent involves obtaining sawdust from carpentry workshops and furniture factories, which is commonly used locally. The sawdust then undergoes a thorough washing process using hot boiled water to ensure the removal of any bacteria, viruses, water-soluble impurities, and surface adhered particles, while simultaneously disinfecting the sawdust.

Following the washing process, the sawdust is subjected to sun drying at a temperature of 40-43°C

for a period of 3 days, until a constant weight is achieved. This drying process leads to the formation of pores in the material, resulting in an increased volume. It is important note that the cost of sawdust is equivalent to 1.5% of activated carbon.

2.2.1.2 Preparation of sugarcane bagasse:

Sugarcane bagasse (SCB) was collected from several sugarcane vendors. It was washed many times with clean water to remove any contaminates or impurities.

After that the SCB was sun dried at 40-43°C for 3 days to remove the moisture present in the sugarcane bagasse. It was cut into small pieces.

2.3 Wastewater Properties

The water utilized in the conducted experiments is wastewater that has undergone secondary treatment and subsequent discharge from the final settling tank.

The properties of the daily incoming water to the facility vary depending on the origin from which the water is derived, taking into account the volume generated from domestic and industrial establishments. The (BOD) exhibits a range of 65.04 to 31 mg/l, the (COD) ranges from 115.5 to 47 mg/l, and the (TSS) vary between 34 to 18 mg/l.

2.4 Filtration Process

The collection of domestic wastewater occurred from the final steeling tank subsequent to the secondary treatment process at the zeinen wastewater treatment plant. The wastewater was then subjected to the filtration process, wherein it flowed from the top to the bottom of the filtration tank. The wastewater flowed in a downward direction. Upon completion of the filtration process, the water was accumulated.

2.5 Samples Collection

Samples were obtained from both filters, specifically from the water outlet of each filter. A layer of 10 centimeters of gravel was placed at the base of the filter after being thoroughly washed. This was done to elevate the medium and prevent any obstruction of the outlet

Initially, a series of tests were conducted on sawdust and sugarcane bagasse: BOD, COD, TSS, and PH, at various depths, specifically 20 cm, 30 cm, and 40 cm, in order to determine the optimum depth. (Refer fig. 3)

As a result of testing sawdust and sugarcane bagasse in order to determine the optimal depth and the best material for both, BOD, COD, TSS, PH, temperature, ammonia, nitrate, oil and gas, and eventually nickel were determined for sawdust.(Refer fig. 4)

Fig.3 Sawdust at different depth

Fig.4 SCB at different depth

3. Result and Discussion

This study was conducted at the Zenin wastewater treatment plant in Giza, Egypt. Its objective was to investigate the use of low-cost adsorbents as media filters for wastewater treatment. Additionally, the study aimed to evaluate the effect of increasing the media depth on the reduction of BOD, COD, and TSS.

3.1 Effect of depth for sawdust

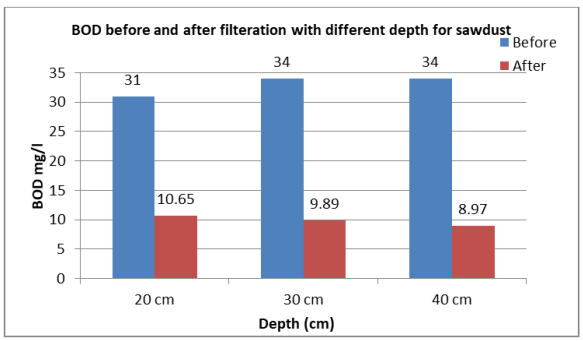


Fig. 5 The relation between the influent and the effluent BOD using sawdust at different depth

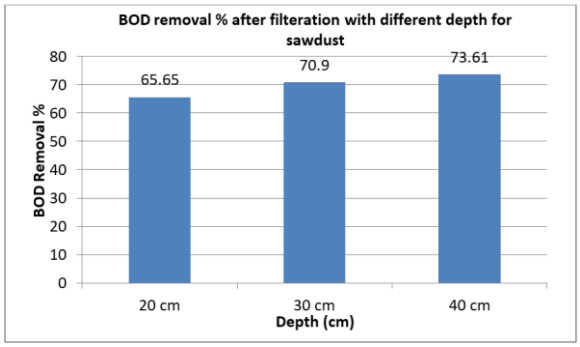


Fig 6 The BOD removal efficiency using sawdust at different depth

Figure 5 illustrates the relation between influent BODs from the final sedimentation tanks before filtration at a Zeinen wastewater treatment plant and effluent BODs after filtration using three different media layers (20 cm, 30 cm, and 40 cm) on the X-axis. The corresponding values are displayed on the Y-axis. The efficiency of BOD removal is depicted in figure 6

Tests were conducted at three different depths of 20 cm, 30 cm, and 40 cm. According to the results of the analysis, the BOD level in the final settling tank is 31 mg/l, 34 mg/l, and 34mg/l before filtration. Using a 20 cm, 30 cm or 40 cm sawdust media layer as filtration media, the effluent BOD is 10, 65 mg/l, 9.89 mg/l and 8.97 mg/l media layer, respectively. According to the Egyptian specification for water intended for irrigation [16] purposes grade A, the removal efficiency of BOD is 65.65%, 70.9% and 73.61%, which reaches the permissible concentration of BOD which is not exceeding 15 mg/l.

It has been found at 2022 by Elanda Fikr et al. [17] that low cost adsorbent reduces phenol levels by 63%, 77%, and 89% after the given treatment at a thickness of 40 cm, 60 cm, and 80 cm, respectively. As shown by B. Ouadie et al [18] at 2020 that sawdust is a low cost adsorbent and filter that can be used to treat wastewater. Approximately 92-97% of biological oxygen demand (BOD) can be achieved by filtering. Before filtration, BOD was 380 mg/l, but now it is 15 mg/l.

Philani Ncube[15] proved that the removal efficiency of the media filter increased as the filter media became deeper. However, the corresponding filter coefficients, which were derived empirically, decreased from 5.6 to 1.8 m-1 as the filter depth increased from 0.02 to 0.42 m for the filters.

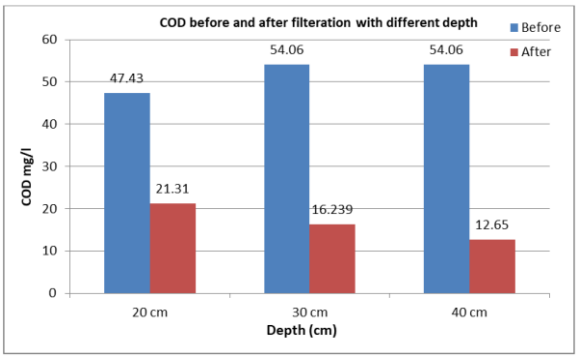


Fig. 7 The relation between influent and the effluent COD using sawdust at different depth

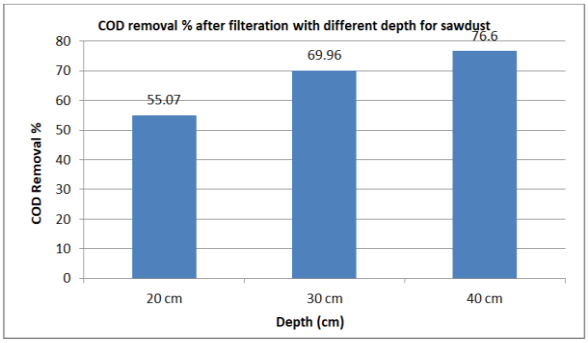


Fig. 8 The COD removal efficiency using sawdust at different depth

Figure 7 shows that influent COD from the final sedimentation tank before filtration from the Zeinen wastewater treatment plant is correlated with the effluent COD after filtration at 3 different depths of the media layer (20 cm, 30 cm, 40 cm on the X axis), based on its values on the Y axis, and its removal efficiency is illustrated in figure 8.

The COD concentration in the effluent from the final settling tank was observed to be 47.43 mg/l, 54.06 mg/l, and 54.06 mg/l. After filtration using sawdust media layers of 20 cm, 30 cm, and 40 cm, the effluent COD concentrations were measured as 21.31 mg/l, 16.239 mg/l, and 12.65 mg/l, respectively. The removal efficiencies of COD at these different depths were found to be 55.07%, 69.96%, and 76.6%, respectively. These values meet the permissible concentration for BOD according to the Egyptian specification for water intended for irrigation [16] purpose grade A, which is not to exceed 50 mg/l.

Elanda Fikr et al.[17] were discovered in 2022 when used a low-cost adsorbent that the average phenol levels after the treatment were measured at different thicknesses: 40 cm, 60 cm, and 80 cm. The treatment resulted in a percentage reduction of 63%, 77%, and 89%, respectively.

In 2020, B. Ouadi et al. [18] demonstrated, when use sawdust as a low-cost adsorbent for filtering wastewater, that the filtration process achieved an

efficiency yield of approximately 85-94% for biological oxygen demand (COD). The initial COD level before filtration was 718 mg/l, which was reduced to 64 mg/l.

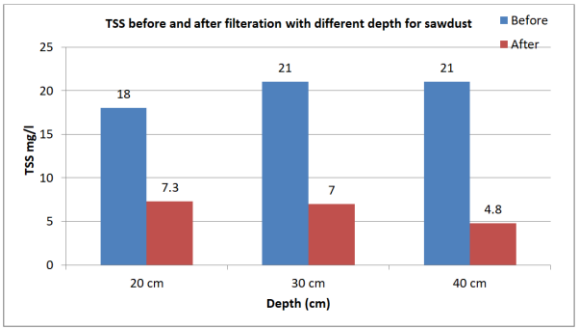


Fig. 9 The relation between influent and the effluent TSS using sawdust at different depth

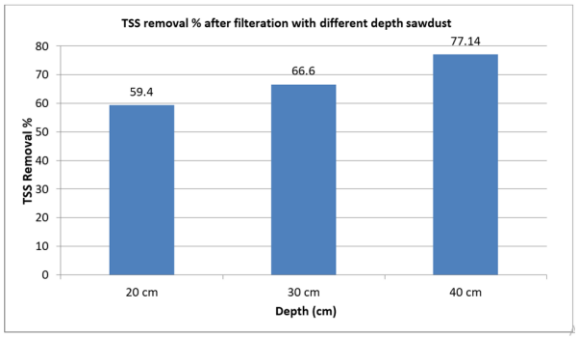


Fig 10 The TSS removal efficiency using sawdust at different depth

Figure 9 illustrates the correlation between the influent TSS of wastewater exiting the final sedimentation tank before filtration at the zeinen wastewater treatment plant and the effluent TSS after filtration at three different depths of the media layer (20 cm, 30 cm, and 40 cm) on the X-axis. The values are represented on the Y-axis, with the removal efficiency indicated in figure 10.

It was observed that using adsorbent materials with different depths such as sawdust media may prove to be more efficient in improving the effluent quality in terms of its physiochemical content. It was also observed that the experimental filter model will significantly assist in the removal of TSS quality of the effluent. Hence, the results of present investigation that this filter will be found to be an effective adsorbent filter by using 3 different depths for the removal of impurities from the domestic waste water and the treated waste water.

It was observed that TSS levels before filtration from the final settling tank at three different depths were 18 mg/l, 21 mg/l, and 21 mg/l. The effluent TSS levels after filtration using 20 cm, 30 cm, and 40 cm of sawdust media layer were 7.3 mg/l, 7 mg/l, and 4.8 mg/l, respectively. The removal efficiency of TSS at different depths was found to be 59.4%, 66.6%, and 77.14%, respectively. These levels meet the permissible concentration for TSS according to the Egyptian specification for water intended for irrigation purpose grade A.

Elanda Fikr et al. [17] were discovered in 2022 when used a low-cost adsorbent that the average phenol levels has a great reduction after the treatment when measured at different thicknesses: 40 cm, 60 cm, and 80 cm.

In 2008, Mohamed S. Azab [19] demonstrated the effectiveness of using sawdust as a bio-mixture in waste treatment technology and environmental management. The TSS) were reduced from 5225 mg/l to 2200 mg/l, with a removal efficiency of 87.7%.

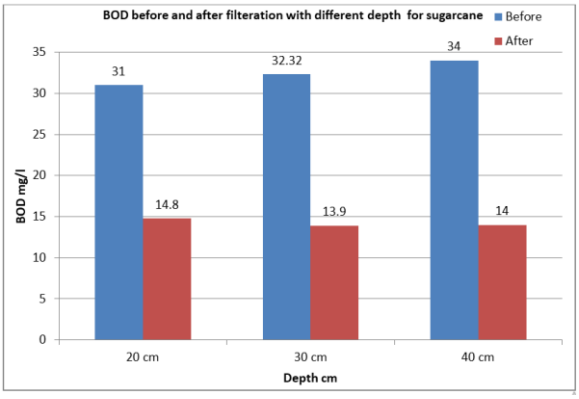
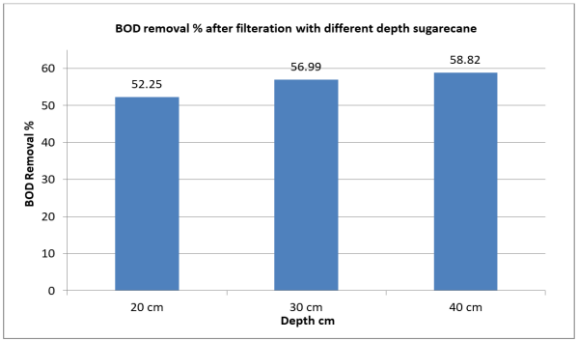


Fig.11 The influent BOD and the effluent BOD using SCB at different depth



Fig, 12 The BOD removal efficiency using SCB at different depth

Figure 11 illustrates the relationship between the influent BOD of wastewater from the final sedimentation tank before filtration at the Zeinen wastewater treatment plant and the effluent BOD after filtration at three different depths of media layer: 20 cm, 30 cm, and 40 cm on the X-axis. The values are represented on the Y-axis, indicating the removal efficiency shown at figure 12.

The test was done on three different depth 20 cm, 30 cm and 40cm. It was observed that the BOD before

filtration out from the final settling tank is 31 mg/l, 32.32mg/l and 34 mg/l, the effluent BOD after filtration are respectively 14.8mg/l,13.9 mg/l and 14 mg/l and removal efficiency of BOD at different depths are respectively 52.25 %, 56.99% and 58.82% which reach the permissible concentration for BOD according to the Egyptian specification for water intended for irrigation purpose [16] grade A which does not exceed 15 mg/ l.

In 2017, V. Anusuya et al. [12] are found that by using sugarcane bagasse as low cost adsorbent as a media in a filter the BOD of domestic wastewater before filtration was 400 mg/l and after filtration became 115 mg/l.
In 2022, Elanda Fikr et al. [17] are found that by using low cost adsorbent that average phenol levels after the given treatment at a thickness of 40 cm, 60 cm, and 80 with a percentage reduction of 63%, 77%, and 89% respectively.

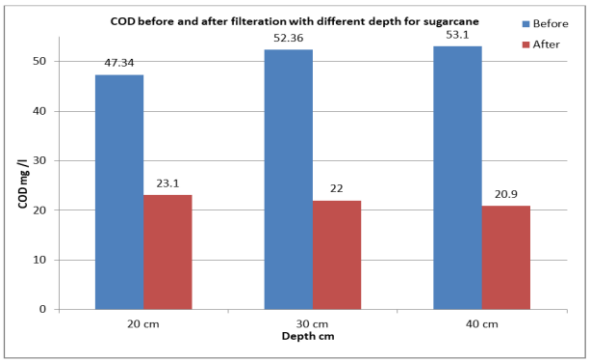


Fig.13 The relation between the influent COD and the effluent COD using SCB at different depth

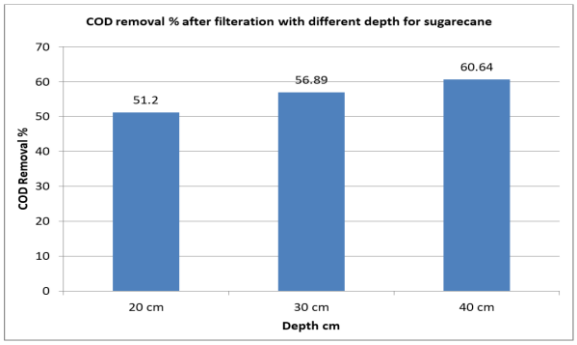


Fig. 14 The COD removal efficiency using sawdust at different depth

Figure 13 shows the relation between influent COD for wastewater out from the final sedimentation tank before filtration from zeinen wastewater treatment plant and the effluent COD after filtration at 3 different depths of media layer 20 cm ,30 cm and 40 cm on X – axis , and its values , on Y- axis ,noting its removal efficiency at figure 14.

It was observed that the COD before filtration out from the final settling tank is respectively 47.34mg/l, 52.36mg/l, 53.1mg/l, the effluent COD after filtration using 20 cm, 30 cm and 40 cm of SCB media layer are respectively 23.1 mg/l ,22 mg/l , 20.9 mg/l and removal efficiency of COD at different depths are respectively 51.2%, 56.89% and 60.64% which reach the permissible concentration for BOD according to the Egyptian specification for water intended for irrigation purpose grade A which does not exceed 50 mg/ l.

In 2017, V. Anusuya et al. [12] are found that by using sugarcane bagasse as low cost adsorbent as a media in a filter the COD of domestic wastewater before filtration was 500 mg/l and after filtration became 276 mg/l.
In 2022 , Elanda Fikr et al.[17] are found that by using low cost adsorbent that average phenol levels after treatment at a thickness of 40 cm, 60 cm, and 80 has a great percentage of reduction.

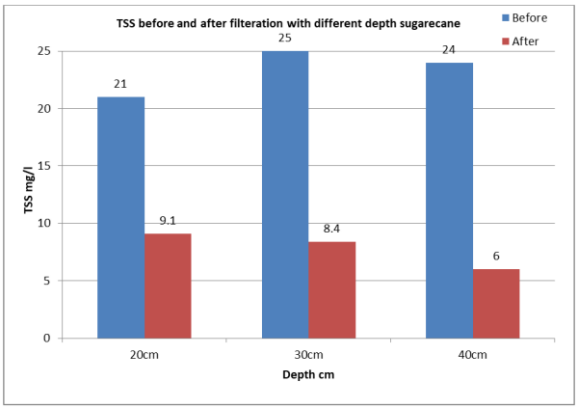


Fig. 15 The relation between the influent TSS and the effluent TSS using sawdust at different depth

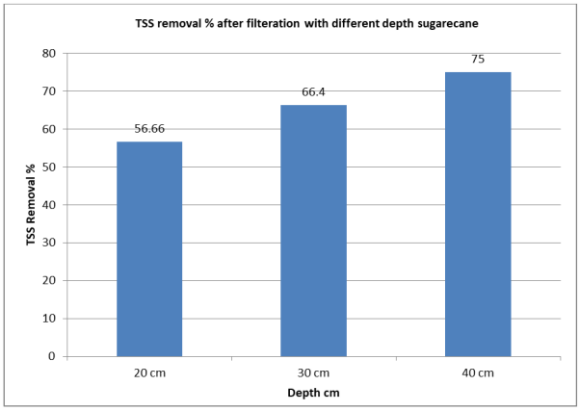


Fig. 16 The TSS removal efficiency using sawdust at different depth

Figure 15 shows the relationship between the influent TSS in wastewater coming out of the final sedimentation tank before filtration at the Zeinen wastewater treatment plant and the effluent TSS after

filtration at three different depths of the media layer (20 cm, 30 cm, and 40 cm) is plotted on the X-axis. The values are plotted on the Y-axis, representing the removal efficiency shown at Figure 16.

It was observed that the TSS before filtration out from the final settling tank were respectively 21 mg/l, 25 mg/l, 24 mg/l , the effluent TSS after filtration became respectively 9.1 mg/l ,8.4 mg/l ,6 mg/l and removal efficiency of TSS at different depths are respectively 17.27%,43.93% and 75% which reach the permissible concentration for TSS according to the Egyptian specification for water intended for irrigation purpose grade A. which not exceed 15 mg/l.

V. Anusuya et al., 2017, [12] found that by using sugarcane bagasse as low cost adsorbent as a media in a filter the TSS of domestic wastewater before filtration was 420 mg/l and after filtration became 245 mg/l.
Elanda Fikr et al. , 2022,[17] found ,by using cost adsorbent at thickness 40 cm, 60 cm, and 80 ,a great effect in wastewater properties.

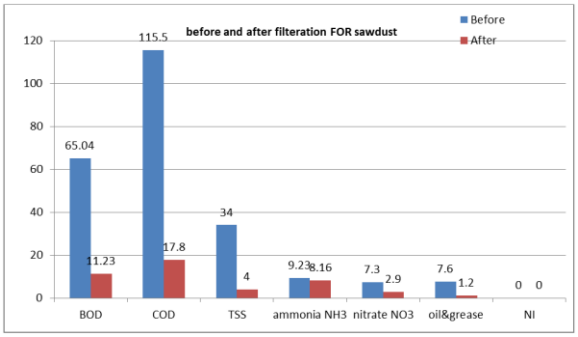


Fig. 17 The relation between the influent and effluent BOD, COD, TSS, Ammonia (NH3), Nitrate (NO_3), oil and grease, Nickel (NI) using sawdust as low cost adsorbent.

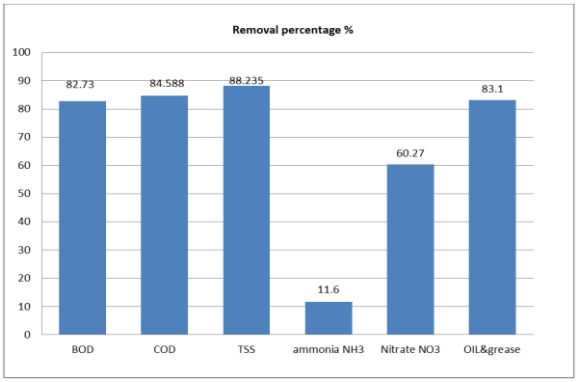


Fig. 18 Removal percentage of BOD, COD, TSS, Ammonia (NH3), Nitrate (NO_3), oil and grease using sawdust as low cost adsorbent.

Figure 17 shows the relationship between the influent wastewater from Zeinen wastewater treatment plant and the influential BOD, COD, TSS, Ammonia (NH_3), Nitrate (NO_3), oil and grease, Nickel (NI), along with the influent effluent BOD, COD, TSS, Ammonia (NH_3), Nitrate (NO_3), oil and grease, Nickel (NI) after filtration by using sawdust as a low cost adsorbent and removal percentage in figure 18.

Based on the results of the study, the use of adsorbent materials, such as sawdust media, may prove more effective in improving effluent quality in terms of physiochemical properties. The experimental filter model was also observed to significantly assist in the removal of BOD, COD, TSS, ammonia (NH_3), nitrate (NO_3), oil and grease, which significantly enhanced the effluent quality. Thus, the results of the present investigation suggest that this filter is an effective adsorbent filter for the removal of impurities from domestic waste water and treated wastewater.

It was observed that the BOD before filtration out from the final settling tank was 65.04 mg/l and after filtration by using sawdust as adsorbent media the BOD became 11.25 mg/l with removal efficiency 82.73 % which reach the permissible concentration for BOD according to the Egyptian specification for water intended for irrigation purpose grade A which does not exceed 15 mg/ l.
In 2020 B. Ouadi et al [17] show that by using sawdust as low cost adsorbent a as filter in the treatment of wastewater. Filtration efficiency yield is around 92–97% for biological oxygen demand (BOD).the BOD before filtration was 380 mg/l and reduces to 15 mg/l.

Also, the COD before filtration out from the final settling tank was 115.5 mg/l and after filtration by using sawdust as adsorbent media the COD reduce to 17.86 mg/l with removal efficiency 84.58 % which reach the permissible concentration for COD according to the Egyptian specification for water intended for irrigation purpose grade A which does not exceed 50 mg/ l. B. Ouadi et al [17] show that by using sawdust as low cost adsorbent a as filter in the treatment of wastewater. Filtration efficiency yield is around 85–94% for biological oxygen demand COD. The COD before filtration was 718 mg/l and reduces to 64 mg/l.

The test prove that the influent TSS was 34 mg/l and the effluent TSS after filtration was 4 mg/l with removal 88.235%.Which reach the permissible concentration for TSS according to the Egyptian specification for water intended for irrigation purpose grade A which does not exceed 15mg/ l and the removal the efficiency of low-cost adsorbents increase with time until the filter is clogged. Mohamed S. Azab et al. [19] proves at 2008 by using sawdust as bio-mixture in Waste-waste treatment technology and environmental management that the

TSS reduces from 5225 mg/l to 2200 mg/l with removal efficiency 87.7%.

At the other hand, there was a reduction at Ammonia (NH3), Nitrate (NO_3), oil and grease respectively from 9.23 mg/l, 7.3 mg/l and7.6 mg/l to 8.16 mg/l, 2.9 mg/l and 1.2 mg/l with removal efficiency respectively 11.6%, 60.27 % and 83.1 %. Ammonia is undefined at the Egyptian specification for water intended for irrigation because it's important at the nutrition of plants. For oil and grease according to the Egyptian law 48 for irrigation purpose
[20]which does not exceed 3 mg/ l. Mohamed S. Azab et al. [19] shows at 2008 by using sawdust in Waste-waste treatment technology and environmental management that oil and grease reduces from 160 mg/l to 110 mg/l with removal efficiency 82.7%.

4. Conclusions

Based on the experimental program executed in this research and limited on both the tested materials and the testing procedures employed, the following conclusions have been reached.

Using sawdust and sugarcane bagasse as filter's media with different depths as follows 20 cm, 30 cm, and 40 cm the removal efficiency increased with the increase of the depth of media. The optimum depth was 40 cm for both sawdust and sugarcane bagasse.

The removal efficiency of BOD, COD and TSS were 73.61%, 76.6% 77.14% respectively for sawdust. On the other hand, the removal efficiency of BOD, COD and TSS were 58.82%, 60.64% % 75% for sugarcane bagasse filter's media at the same depth.

Sawdust is more effective than sugarcane in reducing BOD, COD, TSS.

By using a 40 cm sawdust media layer as filtration media, the BOD reduce from 34 mg/l to 8.97 mg/l which reaches the permissible concentration of BOD which is within the permissible concentration 15 mg/l, the COD 54.06 mg/l decrease to 12.65 mg/l which is not to exceed 50 mg/l and the TSS levels reduce from 21 mg/l to 4.8 mg/l, These levels meet the permissible concentration according to the Egyptian specification for water intended for irrigation purpose grade A.

5. Recommendation

1. The promotion of advanced treatment technologies that are sustainable.
2. As a result, the most sustainable technologies to remove toxic pollutants from wastewater will be those that are high-efficiency, energy-efficient, and environmentally friendly.
3. A further kinetic study for the used adsorbent materials is recommended to assure to obtained rates and optimize the applocation of the study results on large scale .
4. The third step is to build a database of local research and application work in order to select the most appropriate technology for implementing advanced wastewater treatment technologies in developing countries.

6. Conflicts of interest

There are no conflicts to declare

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