Probing of the Aerobic Bio-Reactor for Treating Sugar Wastewater with the Support of Nanoparticles

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Abstract

The lucrative treatment of sugar industry wastewater is a tricky mission. In the current study, an effort was made for the management of sugar industry wastewater. The synthetic sugar wastewater is primed in the laboratory and used for the experimentation. A laboratory scale Aerobic Bio-Reactor was planned and fabricated for the treatment of Industrial wastewater to observe the intensity changes of Chemical Oxygen Demand. The Aerobic Bio-Reactor was accomplished with both suspended as well as an attached growth process. The effect of OLR on the recital of an ABR reactor depends on a integer factors which sometimes have a disparate outcome, mostly conflicting, on the performance of ABR reactor. Researchers have accounted an increase in the effectiveness of high rate aerobic reactors with mounting OLR. The COD reduction was conquered at less in the early stage and increased and achieved a steady state. The utmost COD deduction effectiveness was attained at 91.42% with an organic loading rate of 1.591 Kg COD/m^3.day. Apart from the different technologies the Aerobic Bio-reactor proves the healthier one for treating industrial wastewater which can be considered as a trustworthy, secure and cost efficient method in favor of the treatment of sugar industry wastewater. To achieve the goal of reusing the wastewater, again the treated effluent was analyzed by the technology of adsorption process using Silver nanopowder as a chemisorbent and the maximum COD removal efficiency was 100% with the dosage of 0.25 g at a pH of 6 with a at the contact time of 120 minutes were obtained.

Keywords: Aerobic Bio-Reactor, Chemical Oxygen Demand, Chemisorbent, Hydraulic Retention Time and Nanopowder

Introduction

Water is our most valuable resource, and because we are more concerned about future water supplies, we are required to use new, changed technology to protect these water bodies from contamination. Industrial effluents that include large amounts of solids, COD, and have a high unstable pH are difficult to treat. As a result, sewage is frequently discharged into nearby bodies of water without even a basic treatment. In order to treat wastewater, a number of traditional procedures have been used. However, they are not efficient in their effectiveness. The biggest challenge of sago sector is getting rid of effluent that doesn't match the standards. Due to constraints in present water and wastewater treatment technologies, it is no longer viable to provide a sufficient amount of high-quality water that fulfils human and environmental demands (Grupta and Sharma 1996) and (Hirata et al., 2001). As the effluent from the sago business restrains significant amounts of whole materials, proper treatment before discharge is crucial (Banu et al., 2006). Sugar synthetic wastewater has been generated in response to the problems, and an effort has been made to break down the greater quantities of organic debris. With the awareness of the affordable technologies of aerobic therapy, attention in the aerobic reactors has quickly improved (Murphy 2002).

In this situation, technologies that filter water without endangering people or the environment are required to produce clean, affordable water. Technological breakthroughs in nanotechnology provide up new possibilities for the creation of devices that might help ease water-related challenges. In order to create a sustainable water supply, it is crucial to repurpose treated wastewater effluents. In the current study, an Aerobic Bio-Reactor (ABR) investigational model was created to conduct experiments on replicated, man-made waste streams of sugar to evaluate the behavior of treatment efficacy under changing experimental settings. Sorbents are frequently used in batch processes to remove excess organic and inorganic impurities.

Although nanoparticle water treatment has the potential to be used, its cost should be managed to withstand the market's current competitiveness. They convey size-dependent features such as strong reactivity, increased adsorption capability, and elevated dissolving action and can be employed in wastewater treatment because of their larger surface to volume ratio. Additionally, several distinctive qualities like super paramagnetism, semiconductivity, and the quantum confinement effect have added benefits to treatment methods. The effectiveness of common sorbents used in adsorption practice, such as activated carbon, ion-exchange resins, and others endure from a lack of active sites or high accessible face area, as well as from a be deficient in selectivity and specificity and adsorption kinetics. Due to the much better surface area of nanoparticles, their higher specificity and selectivity, as well as their tunable pore size and surface chemistry on a mass source the use of nanomaterials (also known as "Nanosorbents") may have advantages over conventional materials (also known as "Sorbents") in order to overcome difficulties. A few nanoparticles can also be very effective adsorbents due to their distinct structure and electrical characteristics.

The intention of this study is to assess the performance of ABR at different HRT and the treated effluent was again treated with the support of nanotechnology in the ambient condition with a goal of reusing the effluent.

Materials and Methods

Reactor Fabrication

A working volume of 13.30 litres with the Plexiglass was used to create the experimental model. The suspended growth process and the attached growth process were successfully placed in a single reactor by making the appropriate separations. A suspended growth process is used to complete the first half of the reactor, and an attached growth process is used to complete the second half. The Bio carriers were sporadically filled in the subsequent half of the reactor to confess the attached growing process. In **Figure 1**, you can see the photographic outlook of an experimental setup. The carrier was 15 x 22 mm in size and had a black finish. The carrier's specific surface area was 400 sqm/cum and its specific gravity ranged from 0.90 to 95 gms/sqcm.

Wastewater Characteristics

The influent chemical oxygen demand (COD) sort from 2800 to 3720 mg/L. Commercially obtainable edible glucose, sugar powder, urea, KH_2PO_4 and K_2HPO_4 were used to create this synthetic wastewater. The pH of the inlet wastewater is maintained in the neutral array of 7-8 to provide the best circumstances for bacterial growth. To facilitate supply the necessary nutrients for biological intensification, edible sugar was added to around 30% of the inflow COD in all different organic loads. The complete operation was conceded out in the room temperature.

Figure 1. Photographic outlook of the Reactor

Composition and Analysis of Wastewater

The components recommended by Guiot and Berg (1984) were used to create artificial sugar industry wastewater, which was then used in this study. Periodically, samples taken from the feednosh tank and from the reactor's outlet were examined using the procedures outlined in Standard techniques by the American Public Health Association and the American Water Works Association (Standard Methods for Examination of Water and Wastewater 2017).

Experimental Conditions

Throughout the study period, the average room temperature ranged from 29 to 37°C. Daily records were kept of the flow rate, the pH of the influent and effluent, and the MLSS and DO in the reactor. Initial flow rate settings were made to achieve a HRT of 42 hours, and they were let to stabilize. When there was little to no distinction between two consecutive COD levels, HRT was altered (i.e. after attaining steady state).

Preparation of Silver nanopowder

To prepare Silver nanopowder, all the ingredients of reacting materials were prepared in double distilled water (Pham Van Dong et al., 2005). In typical experiment, 50 ml of 0.001 M $AgNO_3$ was heated to boiling. To this solution, 5 ml of 1% trisodium citrate was included drop by drop. Solution was mixed vigorously during this process and heated until the colour change was noticeable (greenish yellow). Finally, it was removed from the heating element and stirred until cooled to room temperature. Keep the test tube undisturbed for 20 minutes, so that the precipitate will settle down at the base. The precipitate was then collected and stored for the further study. The product specification is as offered in the **Table 1**.

Table 1. Specification of Silver Nanoparticles

Purity	99.9%
Molecular Formula	Ag
Form	Powder
Density	10.5 g/cm^3
Boiling Point	2162 °C
APS	60-80 nm
Molecular Weight	107.87 g/mol
Color	Dark Gray
Melting Point	960.8 °C
Solubility	Insoluble in water

Characterization of Synthesized Nanoparticles

Sem Analysis

The prepared nanoparticles were characterized using high-resolution SEM analysis. Structural analysis for the surface morphology of Ag was inspected using HRSEM. **Figure 2** shows the HRSEM images of AgNPs which revealed the good morphologies of the as-prepared AgNPs. It also reveals the spherical shape without any impurities (range from 60 to 100nm).

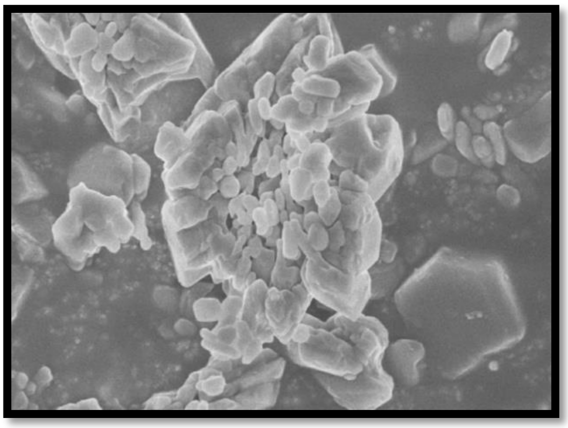

Figure 2. HRSEM Analysis of Silver nanoparticles

UV-Vis Spectroscopy

UV-Vis absorption spectroscopy technique is widely being used to examine the optical properties of nanosized particles. The absorption spectrum of Ag nanopowder was shown in the **Figure 4**. It exhibits a strong absorption band at about 420nm for Ag and it evidences that there is a significant sharp absorption indicates clearly that it have a unique crystalline structure, which is different from other AgNPs.

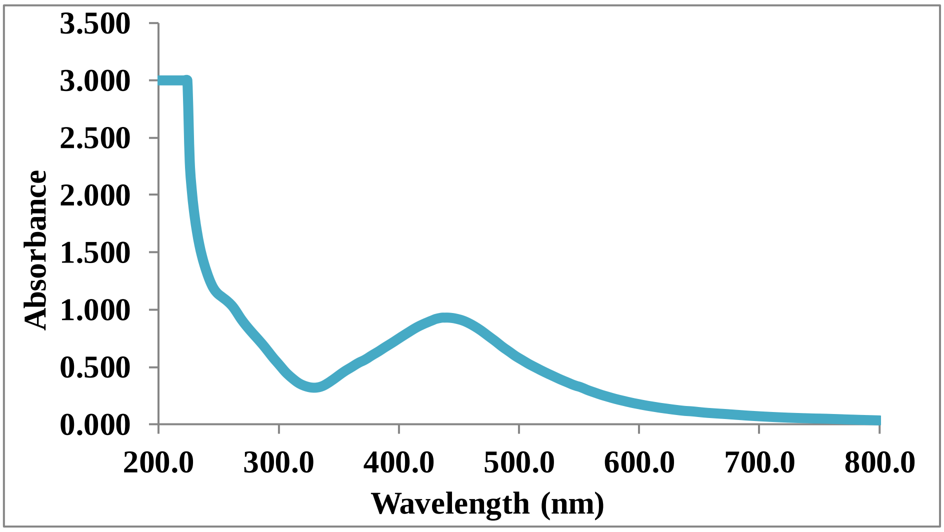

Figure 4. UV-Vis Spectroscopy of Silver nanoparticles

Results and Discussion

Initially, the wastewater from the Chidambaram Municipality was combined with seeding sludge from the M R K Sugar Mill in Sethiathoppe, Cuddalore, Tamil Nadu used for the start-up process. Cow dung was mingled with water to speed up startup time, and the resulting filtrate was deployed as the reactor's seed after being sieved to eliminate big debris. Microorganisms received the bare minimum in the way of nutrients and carbon sources. The technology was used for a week in batch mode to adjust the microbes. In order to accomplish this, the ventilation was stopped up each 8 hours, and set of time offered for the sludge to settle—roughly 1 hour. The reactor was decanted to about half its contents and nosh with synthetic wastewater. Owing to the development of biofilm resting on the carriers, the procedure changed from batch mode to continuous mode after that. Peristaltic pump was used in this stage to feed the structure, and the sludge was beginning to settle. The biofilm was readily visible after a month, and the experiments then proceeded. However, the reactor's treatment time was just 15 days long, making it practically impossible to apply the reactor in the field. The original measurement of the MLSS was 2100 mg/l. Although there was little raise in MLSS concentration over the earliest various days, there was a progressive rise in concentration that was eventually documented, reaching 3700 mg/l.

Throughout the first two days of the reactor start-up, merely frothing was viewed on the facade of the wastewater body. This may designate a few respiratory activities inside the reactor, but it did not consequence in perceptible COD reduction. Based on the treatment situation and the modification of effluent standard of wastewater there is an inclination and declination in the parameters. The reactor has been incessantly operated at mesosphilic series with an organic load pace of 0.735 kg COD/m^3.day. The outcome evidenced that the aerobic bio-reactor conquered a steady state from 15^{th} to 18^{th} day. All through the start up episode the pH plays an imperative responsibility for the putrefaction of unrefined essence in the reactor. The COD diminution was arrived at 7% in the preliminary stage and was augmented up to 12^{th} day and turn down from 12^{th} to 15^{th} day and then reached a steady state from 15^{th} to 18^{th} day. The maximum COD deduction effectiveness was achieve at 96.45% at a hydraulic retention time of 24 hours amid organic loading rate of 0.735 kg COD/m^3 .day.

The reactor was functioned with enhanced OLR after reaching steady-state during the startup procedure so as to obtain the maximum positive loading rate possible. In this investigation, three sets of synthetically prepared sugar wastewater with Influent COD values of 2800, 3400, and 3720 mg/l were used. Acclimatization is required for biological treatment if the BOD/COD proportion of the sugar wastewater is superior than 0.6; otherwise, biological treatment may not be required. If the ratio is between 0.3 and less than 0.3, acclimatization is not required. The BOD/COD ratio for synthesized sugar wastewater is 0.57, thus acclimation is required for biological treatment.

Behind achieving a firm state, the synthetic sugar wastewater was feeded to the reactor gradually at the pace of 20%, 40%, 60%, 80% and 100%. After allowing 100% concentration of unreal sugar wastewater, the COD exclusion is monitored to achieve a stabilized removal of COD. The reactor has been incessantly operated at mesosphilic range with the Hydraulic Retention Time of 11, 14, 17, 21, 28, 42, 84, 141 hours. The initial loading rates were kept modest in sort to ensure the success of the ABR reactor. Because it promotes the development of aerobic active sludge and the stumpy organic loading rate that ultimately led to the low up-flow velocity, this was done. **Figure 4** shows the effectiveness of HRT and HRT in terms of % COD elimination efficiency. **Figure 5** shows the routine of HRT and HRT in relation to pH. Due to biomass edition to the fresh environment, the deduction efficiency was poor at the beginning of the operation.

In aerobic reactors, MLSS and DO continue to be a key controlling component during the whole process. Additionally, a key factor in the digesting process is pH. The MLSS must be between 2000 to 2500 mg/l as well as the DO must be between 4 to 5 mg/l for aerobic microbes to thrive. The scenario showed an abrupt rise in MLSS concentration, with the beginning attentiveness of 2000 mg/l and a peak attentiveness of 4800 mg/l. This was the reason the reactor was capable to remove such a lofty percentage of COD (Mise & Biradar 1997). Due to its unique characteristics, an aerobic approach is used for wastewater management in the Indian industrial sector (Yeole & Gadre 1996) and maximum MLSS concentration of 5000 mg/l was allegedly reached. This shows a considerable rise in the microbial population in the tank, which in turn led to a notable decrease in BOD/COD (Schmidt & Ahring 1977, Sutton & Mishra 1991). An ideal pH series in effluent is between 7.12 and 8.75, which aids in the breakdown of organic contaminants. The COD deletion effectiveness of experiment was achieved 91.42% with an Influent COD of 2800 mg/l decreased to 240 mg/l. The highest COD deduction effectiveness of 91.42% was reached in 42 hours at an OLR of 1.591 Kg COD/m3.day and a pH of 7.45.

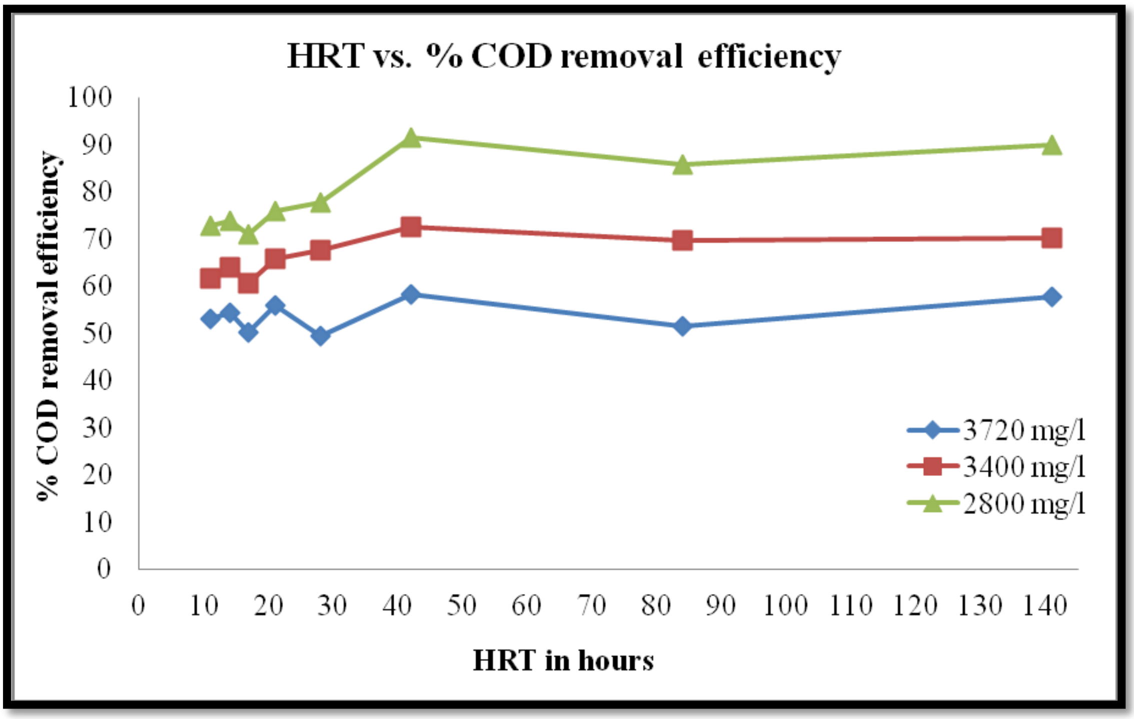

Figure 4. HRT (hours) relating to % COD removal efficiency through an average influent COD of 3720, 3400 and 2800 mg/l

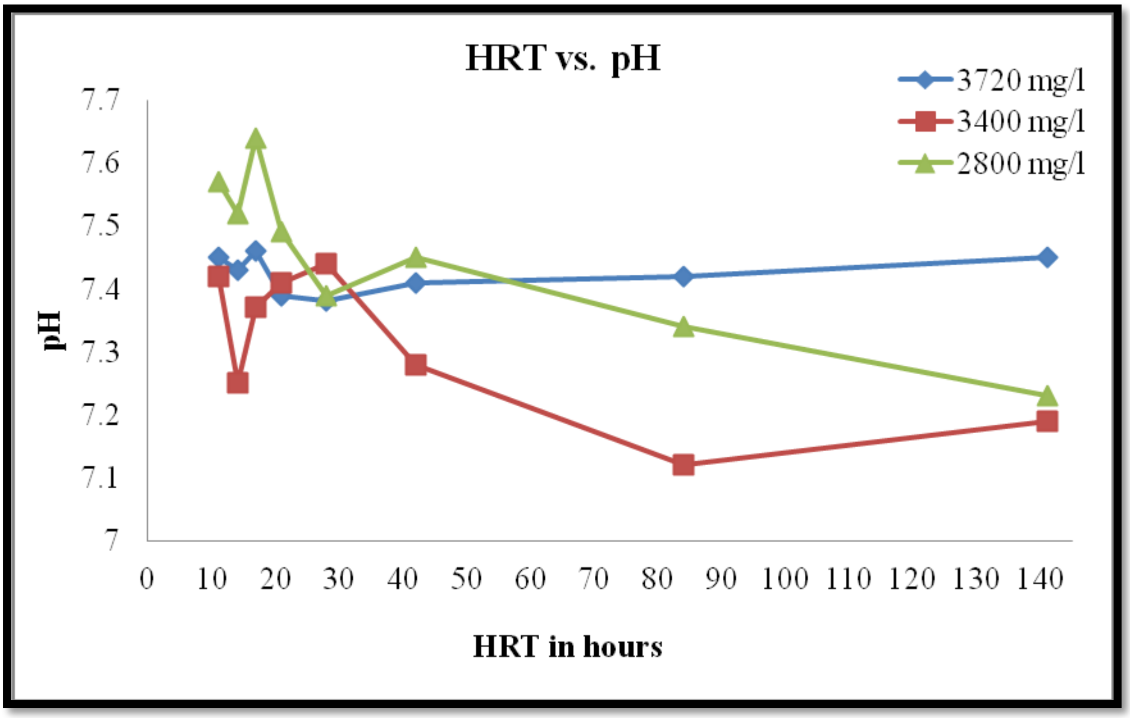

Figure 5. HRT (hours) relating to Effluent pH through an average influent COD of 3720, 3400 and 2800 mg/l

Tertiary Treatment

The usage of nanoparticles for wastewater treatment results in a high reduction rate in the suspension present in wastewater (Kullu Sai Kumar et al., 2022). The analysis was conducted based on the three criteria of effluent pH level, dosage content, and contact time. To determine the absorption capacities, the test was conducted in a batch mode. A 500 ml glass conical flask was filled with 100 ml of treated wastewater and various adsorbent dosages for chemisorbents were 0.25g, 0.5g, 0.75g and 1g. By adding a few drops of 0.1M HCl or 0.1M NaOH aqueous solutions, the original pH of the treated effluent was modified to correspond with the working values (pH levels of 1 to 14). The glass flask was shaken for a predetermined period at room temperature in an orbital shaker for a time span of 60, 90, 120, 180, 240 and 360 minutes at 300 rpm.

For the experimental investigation, chemisorbent doses as Silver of 0.25, 0.5, 0.75, and 1.0g were utilized. The percentage removal effectiveness of COD at a various dosage levels with the changes in relation to various effluent pH values was analyzed. The experiment was examined using different dosage levels and a pH range of 1 to 14. The impact of adjusting the dosage from 0.25 to 3.0 g on the elimination of COD while maintaining the contact time of 60 to 360 minutes was examined.

Effect of pH on percentage COD removal efficiency by Silver nanopowder (chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l

The effect of variation in pH of the treated sugar wastewater with a COD concentration of 320 mg/l in the removal of organic pollutants by varying the dosage of Silver nanopowder from 0.25 to 1.0 g by keeping the contact time 60 minutes as constant was analysed. Generally the pH level from 1 to 3 the reduction of COD was low and negligible. Increasing the dosage at higher pH levels, the percentage removal efficiency was also high.

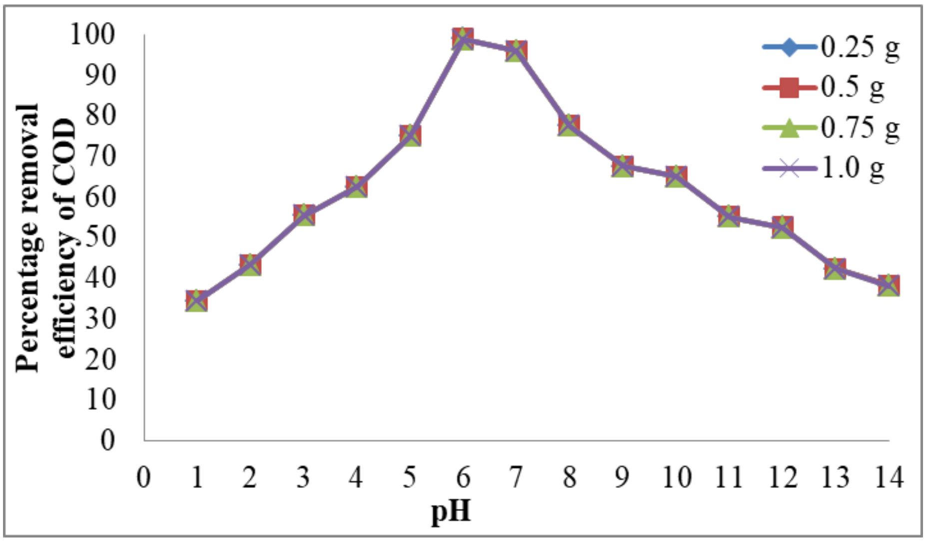

Figure 6. Effect of pH on percentage COD removal efficiency by Silver nanopowder (chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l.

The effect of pH on the sugar wastewater showed that the pH level from 1 to 7 was increased slowly. By further increasing the pH level from 8 to 14 the percentage COD removal efficiency was dropped down slowly. For pH 1, the percentage COD removal efficiency was 34.36 at 0.25g of silver nanopowder. In this case at the same dosage of 0.25g of silver nanopowder with the pH level of 6, maximum percentage removal efficiency was attained at 100. For the dosage 0.25g with increasing the pH level, the removal efficiency was started to decrease (**Figure 6**). When increasing the dosage level to 0.75g, the percentage removal efficiency was started to decrease. Hence more than 0.25g of silver nanopowder the percentage removal efficiency was attained an equilibrium conditions.

Effect of Dosage content on percentage COD removal efficiency by Silver nanopowder (Chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l.

The dosages of silver nanopowder used for the experimental study are 0.25, 0.5, 0.75 and 1.0g. The percentage COD removal efficiency was low and negligible at the pH from 1 to 5 and 8 to 14. Hence the percentage COD removal efficiency at the pH of 6 and 7 was analysed by varying the dosage from 0.25 to 1.0g.

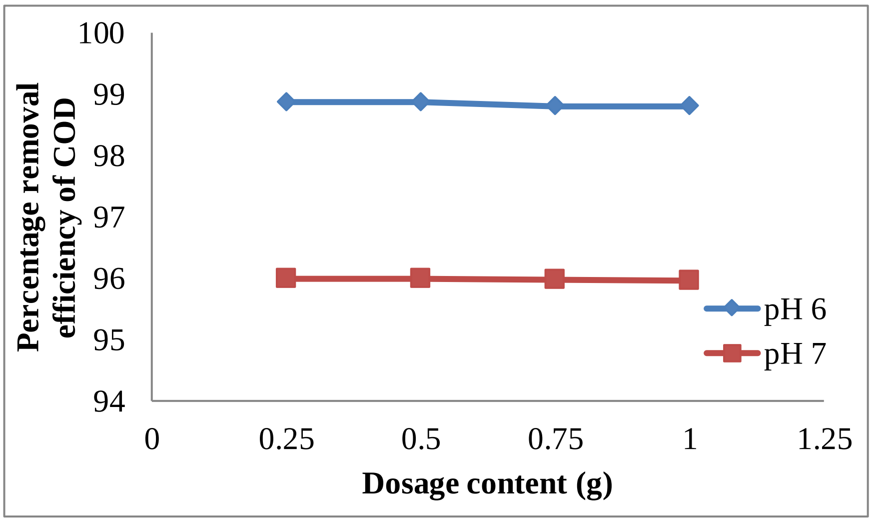

Figure 7. Effect of Dosage content on percentage COD removal efficiency by Silver nanopowder (Chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l at pH 6 and 7

The percentage COD removal efficiency was increased sharply from 98.87 at dosage of 0.25g and decreased to 95.99 at dosage of 0.75g. Also, there was no increment in the percentage COD removal efficiency with the pH (**Figure 7**). After 0.75g dosage content of Silver nanopowder at pH level of 6 the percentage removal efficiency was attained in equilibrium conditions.

Effect of variation in contact time on percentage COD removal efficiency by Silver nanopowder (Chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l.

Contact time is also one of the most effective factors in batch chemisorption process. The contact time increases the ability of chemisorbents in the removal of organic pollutants. For pH level 6 and 7 with 0.25g of Silver nanopowder, the contact time was varied from 60 to 360 minutes and the percentage COD removal efficiency was analysed to find the optimum contact time.

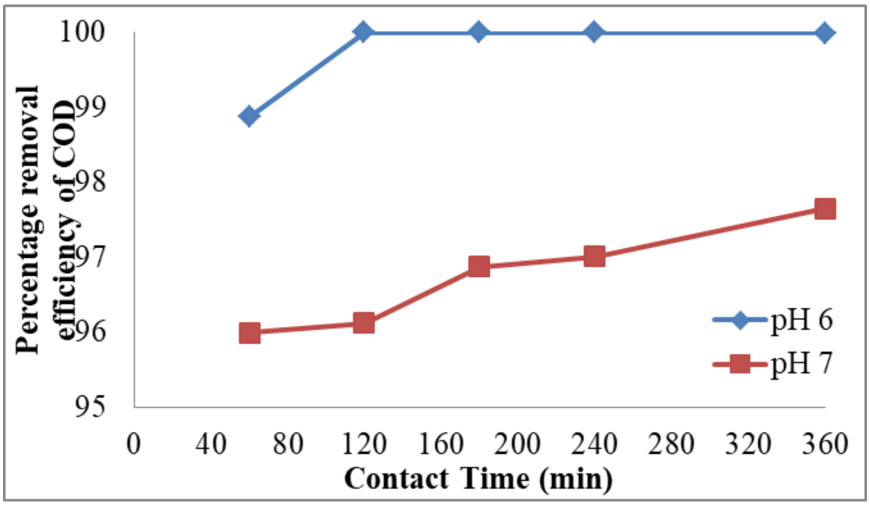

Figure 8. Effect of variation in contact time on percentage COD removal efficiency by Silver nanopowder (Chemi-sorbent) in treated synthetic sugar wastewater with a COD concentration of 320 mg/l at pH 6 and 7.

The rate of chemisorption was rapid in the initial stages because of the adequate surface area of the chemisorbent was available. After increased contact time, more extent of pollutants got adsorbed onto the surface of the chemisorbent due to Vander Waal's force attraction and the results were decreased in the available surface area (Varma D et al., 2010). The maximum COD removal efficiency was 100% for sugar wastewater with the dosage of 0.25 g of Silver nanopowder at a pH of 6 with a at the contact time of 120 minutes were obtained. After further increasing the contact time, the percentage removal efficiency did not show significant change in the equilibrium concentration, i.e., the chemisorption phase reached equilibrium conditions.

Conclusion

The study finds that the ABR, with its great performance, can manage any kind of high strength wastewater and was able to handle the high organic load. Within 15 to 18 days following the day's instigation, the reactor reached steady-state conditions. The sample of wastewater containing synthetic sugar was prepared and scrutinized in the laboratory. Within a short start-up time, the ABR reactor was effectively used to achieve high COD removal efficiency. The optimal operating settings formed an utmost COD removal of 91.42% in 42 hours at an OLR of 1.591 Kg COD/m^3.day, according to the assessment data. At the top COD reduction, the pH was 7.45. As a result, it may be claimed that this approach emerges to be a doable alternate for treating wastewater from the sugar industry. As a result, it is a rapid, easy, and economical process for treating effluent from the sugar industry that uses little space and equipment. Further, the technology of adsorption process using Silver nanopowder as a chemisorbent gives the maximum COD removal efficiency was 100% with the dosage of 0.25 g at a pH of 6 with a at the contact time of 120 minutes. Therefore, it is suggested that sugar wastewater can be treated efficiently by chemisorption of silver nanopowder followed by Aerobic Bio-Reactor.

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