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Using activated and Nano Silica as Adsorbent Materials for Filtration of Industrial Wastewater

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ABSTRACT

Activated nanosilica was used as an adsorbent and filter media for wastewater treatment in the dairy industry. Wastewater was analyzed for different physicochemical parameters (BOD, COD, Na, Ca, K, P, total nitrogen, and chloride) of dairy industry wastewater before and after treatment. According to the findings, the removal percentages of BOD, COD, Na, Ca, K, P, total nitrogen, and chloride were as follows: 82.612, 84.905, 90.225, 96.25, 66.12, 90.272, 90.78, and 87.013% for activated silica and 90.094, 86.77, 93.33, 66.12, 89.849, 90.66, 90.78, and 87.013% for nano silica, respectively.. Also, activated and nanosilica reduced turbidity with removal percents of 94.07 and 97.525%, respectively. Dissolved oxygen increased after treatment with activated silica and nanosilica, and activated silica increased pH to 9.2, while nanosilica decreased pH to 3.6.

1. Introduction

Today, the issue of the water crisis has led researchers to drastically upgrade wastewater treatment systems to use reclaimed wastewater as a source of water. One of the places that consumes a lot of water is the industrial sector (Kiruba et al., 2014). There are four classes of pollutants in wastewater: organic, inorganic, heavy metals and alkaline earth metals, and pathogens (Huang and Chen, 2009; Singh et al., 2011; Milton et al., 2020). The dairy industry is one of the largest contributors to wastewater. To manufacture milk products, water is the major content used in the dairy industry. All the steps in the dairy industry, including the manufacturing of milk products, packaging and storage of products, effective marketing, and distribution, affect the environment. Wastewater produced at these levels in the dairy industry needs proper disposal; otherwise, it leads to several pollution problems. (Kushwaha et al., 2010). Dairy wastewater and liquid waste arise from different sections of the dairy industry, like cheese and butter plants, ice cream plants, condensed milk plants, and receiving and bottling plants (Britz et al., 2006). The characterization of the dairy wastewater depends on the production process and raw dairy materials. For example, wastewater generated from milk processing and cheese production has a chemical oxygen demand (COD) of 3000 and 50,000 mg/L, respectively (Melchiors et al., 2016). Generally, treatment of dairy wastewaters has some problems with a high level of proteins and lipids, resulting in a change in pH value and high amounts of COD and biochemical oxygen demand (BOD) (Sarkar et al., 2006). Different technologies have been proposed for dairy wastewater treatment, such as coagulation, membrane treatment, electrochemical, and adsorption. (Sarkar et al., 2006; Slavov et al., 2017; Mohebrad et al., 2022).

Silica (SiO_2) has always been considered a raw and available material in various industries such as cement, glass, ceramics, and electronics (Wahyudi et al., 2013). Silica nanoparticles, in addition to being small in size (nanosized), have unique characteristics like stability, robustness, and excellent flexibility, which make them popular for use in many structures (Saleh et al., 2015). It can also be of great interest due to its very low toxicity, excellent rigidity, and very high surface-to-volume ratio in applications where these properties are important (Daud et al., 2019).

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The expression of the surface area primarily describes the high surface area, which is a crucial characteristic of the adsorbents (Guo and Lua, 2003). Hence, due to the suitable properties of silica composites (silica-based materials), they have been used to remove pollutants such as copper, lead, and cadmium (Ren et al., 2013; Wang et al., 2010). Currently, there is a growing trend in interest and demand for nano adsorption technologies in wastewater treatment processes. Due to their large surface area to volume ratio and surface multifunctionality, which enable them to readily react chemically and bind or adsorb a specific target metal ion (s) on their surfaces, nanomaterials have become more popular in the water treatment industry (Kegl et al., 2020; Mohammadifrad and Amiri, 2017). The purpose of these nano-adsorbents is to clean up various kinds of contaminants from industrial effluent.

The aim of the study is to evaluate the effect of using activated and nanosilica for dairy industry wastewater treatment and determine the efficiency of the filtration process using these materials.

2. Material and Methods

Materials

Sodium silicate, hydraulic acid (HCl), and sulfuric acid (H_2SO_4) were purchased from Blutruve company.

Methods

Preparation of activated silica

Activated silica was prepared according to (Mousa et al., 2021) by, firstly, diluting sodium silicate by 50% with distilled water to lower the viscosity and promote ease of handling. The pH of the diluted sodium silicate was approximately 11. While stirring with a magnetic stirrer, gelation was started by adding hydrochloric acid dropwise while stirring. Agitation was stopped approximately 45 seconds after acid addition.

Preparation of nano-Silica

Nanosilica was prepared by the precipitation method, according to (Sabah et al., 2020). Concentrated sulfuric acid with regular addition (dropwise) was used to reduce the pH of the sodium silicate while being stirred magnetically. After the stirring period, pure silica was obtained in gel form. An electric furnace at 200°C for 8 hours was used to dry the gel. The solids were crushed to powder using the mill to get the nanosilica particles (105.4 nm), as shown in Figure 1.

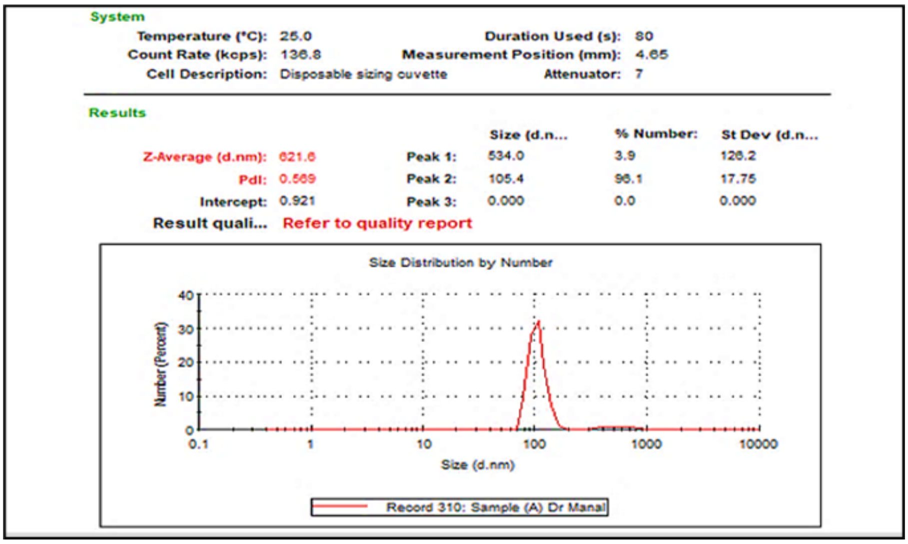

Figure 1. Particle size of nano silica

Wastewater analysis

Different analyses of wastewater before and after treatment were determined using different instruments. BOD was measured using the WTW incubator system, COD was measured using the photolab and the WTW reactor, and turbidity was measured using the WTW turbidity meter. Dissolved oxygen and pH were measured using a WTW multimeter. Total nitrogen, phosphorous, chloride, Na, K, and Ca were measured using a WTW spectrophotometer.

3. Results and discussion

The characteristics of raw wastewater collected from the dairy industry at the Faculty of Agriculture, Cairo University, are shown in Table 1. The wastewater was not within the permissible limits, so it needs to be treated before discharging.

Table 1. Characterization of Dairy industry wastewater

Parameter	Units	Value before treatment
pH	----	5.477
BOD	mg/lit	2450
COD	mg/lit	4240
Turbidity	NTU	493
DO (Dissolved Oxygen)	mg/lit	3.4
Chloride	mg/lit	4.62
Total Nitrogen	mg/lit	14.1
Phosphorus	mg/lit	2.57
Calcium	mg/lit	183
Sodium	mg/lit	330
Potassium	mg/lit	266

Turbidity, dissolved oxygen, pH

Activated silica and nanosilica were used for dairy industry wastewater treatment as filter media for the adsorption process. The pH of the wastewater is one of the key factors governing the adsorption process. The effect of using activated silica and nanosilica as adsorbents on the pH of the wastewater was determined. The results indicated that activated silica increased pH from 5.477 to 10.71 and nano silica decreased pH to 3.6.

Figure 2. shows that using activated and nanosilica as filtration media increased the amount of dissolved oxygen from 3.4 mg/L to 8 and 8.33 mg/L, respectively. The low values of dissolved oxygen are associated with heavy contaminants in organic matter; the increase in dissolved oxygen may be due to the reduced amount of organic matter (Bhutiani et al., 2021) and the simultaneous mixing of atmospheric oxygen during the treatment. Turbidity is an important parameter in wastewater treatment because it shows the growth of pathogens. It is due to the presence of particular organic dissolved matter (Shishaye, 2017). Figure 2. shows the reduction of turbidity from 493 NTU to 29.2 NTU with removal percent (94.07%) and 12.2 NTU with removal percent (97.525%) using activated and nanosilica, respectively.

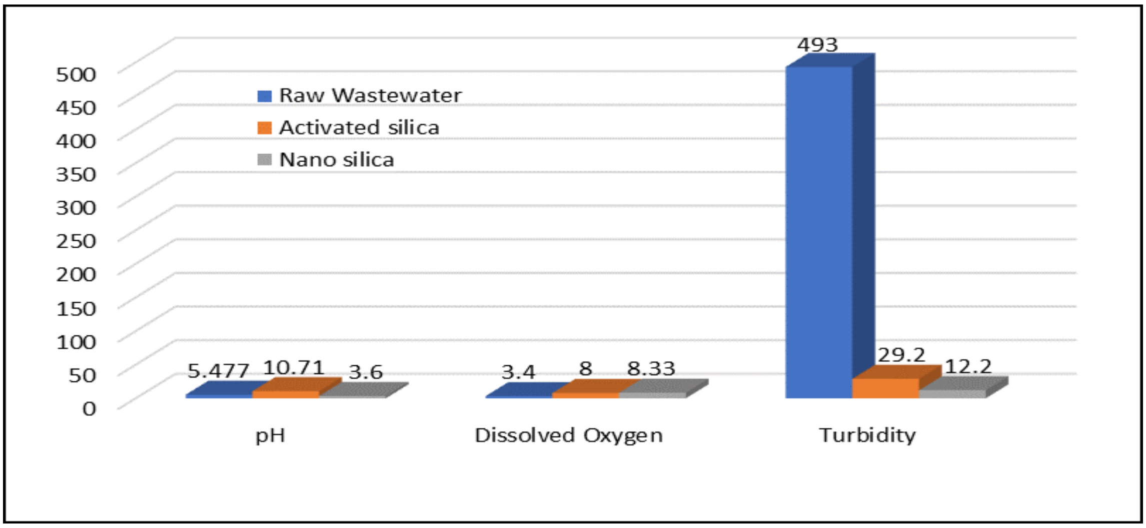

Figure 2. Effect of using activated and nano silica as a filter media on pH, Dissolved oxygen and Turbidity

Reduction of different contaminants using activated and nanosilica

Figure 3. shows the reduction of chloride, phosphorous, and total nitrogen using silica and activated silica as an adsorbent for wastewater treatment in the dairy industry. The results showed that activated silica and nanosilica reduced chloride from 4.62 mg/l to 0.6 mg/l with a removal percent of 87.013 percent and total nitrogen from 14.1 mg/l to 1.3 mg/L with a removal percent of 90.78%. Nanosilica reduced phosphorous from 2.57 to 0.24 mg/l with a removal percent of 90.66 mg/l, and activated silica reduced phosphorous to 0.25 mg/L with a removal percent of 90.272%.

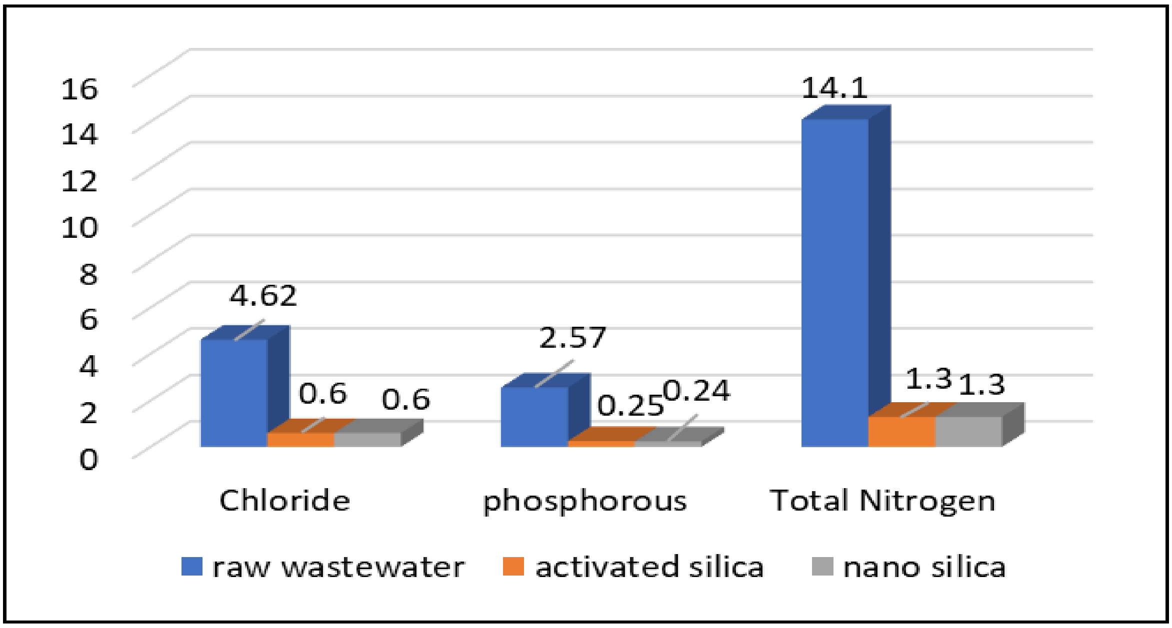

Figure 3. Chloride, Phosphorous and Total Nitrogen of Dairy Industry wastewater

Figure 4. illustrates how activated silica and nano silica are used as adsorbents to reduce BOD and COD in dairy industry wastewater treatment. According to the findings, activated silica decreased BOD from 2450 to 426 mg/L and COD from 4240 to 640 mg/L with a removal percent of 84.95% and 82.612%, respectively. On the other hand, nano silica decreased BOD from 2450 to 324 mg/L and COD from 4240 to 420 mg/L with a removal percent of 90.094%.

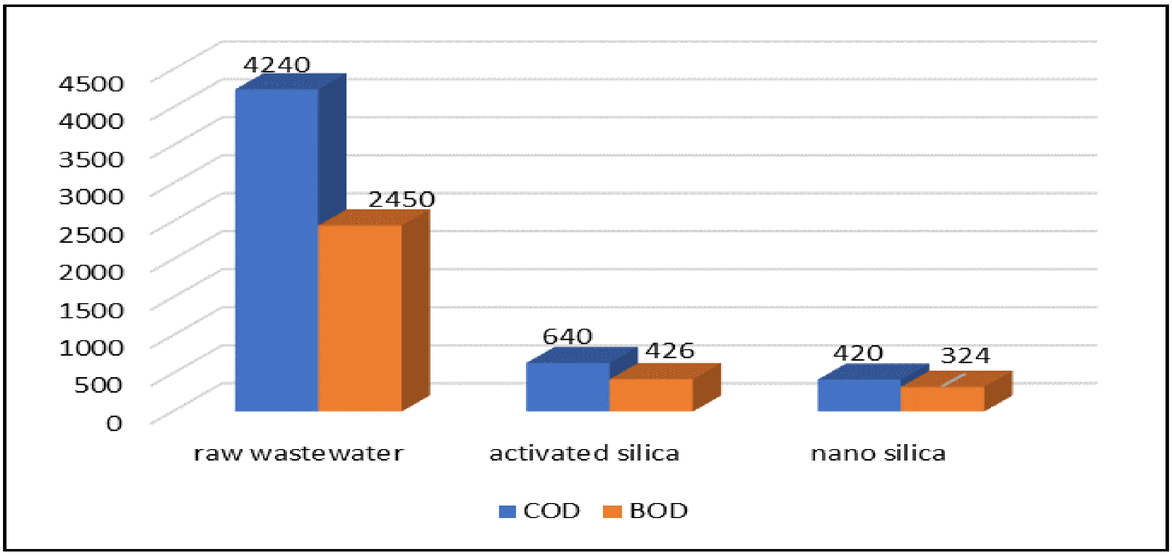

Figure 4. Reduction of BOD and COD in Dairy Industry wastewater

Using activated silica and nano silica as an adsorbent, Figure 5. illustrates the decrease of salt, calcium, and potassium for wastewater treatment in the dairy industry. Based on the findings, it was observed that activated silica and nano silica decreased the following: potassium from 266 to 26, 27 mg/L with percent removal (90.225, 89.849%), calcium from 183 to 62 mg/L with percent removal (66.12%), and sodium from 330 to 22, 23 mg/L with removal percent (96.25, 93.33%).

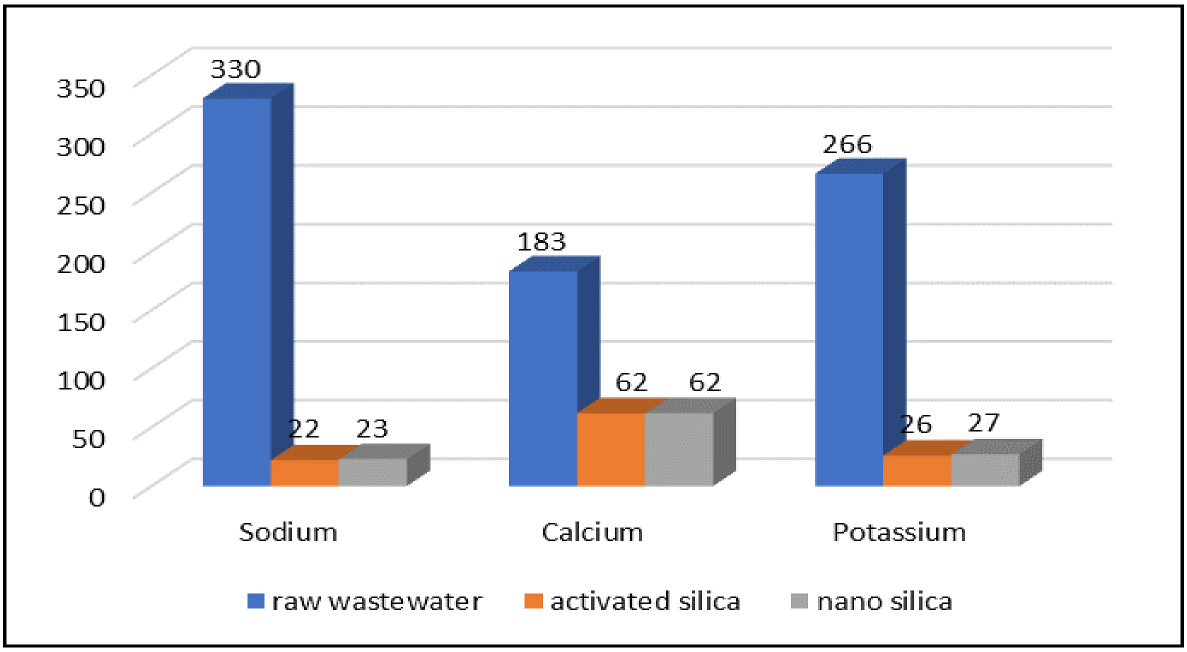

Figure 5. Reduction of Sodium, Calcium and Potassium in Dairy Industry wastewater

4. Conclusion

Nanosilica and activated silica were made for the purpose of treating wastewater from the dairy sector. These materials' effects on pH, dissolved oxygen, and the elimination of BOD, COD, Na, Ca, K, P, total nitrogen, and Cl were investigated when they were used as an adsorbent. According to the results, activated silica had the highest removal percentage of Na, K, and P, whereas nanosilica had the highest removal percentage of total nitrogen, BOD, and COD as well as the greatest reduction in turbidity. Moreover, the removal percentage of Ca and Cl was unaffected by either activated or nanosilica. utilizing nanosilica raised the dissolved oxygen content, and utilizing activated silica raised the pH.

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