Study of Metal Oxide Based Composites for Removal of Heavy Metal Ions

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ABSTRACT

In the modern era, the rise of water contamination has emerged as a prominent global issue, affecting a wide range of habitats, from freshwater reservoirs to expansive oceans. This mounting problem is driven by a multitude of factors, including discharges from industries, agricultural pollutants, and rapid urban growth[1]. The repercussions of water pollution extend well beyond immediate environments, casting profound impacts on both contemporary societies and those of the future. The detrimental outcomes on human well-being, aquatic ecosystems, biodiversity, and socio-economic equilibrium underscore the urgency of addressing this issue. Grasping the interconnectivity of aquatic systems is pivotal as we navigate the intricate consequences and strive for sustainable remedies on a global scale[2].

To identify a suitable method for curbing the effects of water pollution, a comprehensive literature survey was conducted, between metals such as Iron, Zinc, Aluminium, Copper, Silver, and more[3]. It was determined that Aluminium oxide nanoparticles are the most suitable choice due to some of their attractive properties, like high specific surface area, thermal stability, high selectivity, and low toxicity. Furthermore, the methods of synthesizing Aluminium oxide nanoparticles were studied, and it was found that Solution Combustion Synthesis (SCS) is the optimal method, as the particles exhibit high porosity, a crystalline structure, and a near-uniform particle size. The nanoparticles were synthesized using two fuels-glycine and sucrose separately and then combined in a stoichiometric ratio for comparative studies.

INTRODUCTION:

Water is essential for human survival, health, and well-being. It is the cornerstone of life, comprising about 60% of the human body and playing a critical role in maintaining bodily functions such as digestion, circulation, and temperature regulation. Access to clean water is vital for drinking, cooking, and sanitation, directly impacting public health by preventing waterborne diseases. Furthermore, water supports agriculture and food production, ensuring food security and livelihoods. In urban settings, it sustains industries and daily living activities, underpinning economic stability and development. Despite its abundance, millions still lack access to safe water, highlighting the need for sustainable management and equitable distribution to ensure that all communities can thrive.

MATERIALS AND METHODS:

Synthesis of alumina nanoparticles

This section involves the synthesis of nano alumina via solution combustion method using aluminium nitrate and different fuels. The feasibility of obtaining the necessary chemicals, economic advantages, and appropriate properties of the product led to the adoption of this method as shown in Table 3.1. High-efficiency nanoparticles are synthesised as a result. The fuels used in this case were urea, glycine, and dextrose. The amount of fuels estimation is based on stoichiometry.

Aluminium nitrate

Aluminium nitrate is a white, water-soluble salt of aluminium and nitric acid that is most frequently seen as a crystalline hydrate. Aluminium nitrate is a strong oxidizer, and is employed as the source of aluminium in the synthesis.

Dextrose

Dextrose serves as a reducing agent in the green synthesis of nanoparticles, providing an eco-friendly alternative to traditional chemicals or chemical methods. Its use in nanoparticle synthesis facilitates controlled growth and stabilization, making it valuable inbiomedical and environmental applications.

Inductively coupled plasma optical emission spectroscopy

Inductively coupled plasma optical emission spectroscopy is an analytical technique used to measure the concentration of elements in a sample. The process begins by introducing the sample, typically in liquid form, into an inductively coupled plasma, which is generated by a RF coil. The high temperature of the plasma around 10,000 K excites the atoms and ions in the sample, causing them to emit light at characteristic wavelengths.

These emitted wavelengths correspond to specific elements present in the sample. A spectrometer then separates the emitted light into its component wavelengths, and detectors measure the intensity of the light at each wavelength. By comparing these intensities to those from known standards, the concentration of each element in the sample can be determined. ICP-OES is widely used for its high sensitivity, accuracy, and ability to analyse multiple elements simultaneously, making it a valuable tool in environmentalanalysis, material science, and various industrial applications. Spectrogreen ICP-OES was used in this study

SAMPLE PREPARATION:

Procedure for synthesis of alumina

The summary of the process is represented pictorially as shown in Fig. 4.1. The fuel calculations have been made based on 10 g aluminium nitrate salt. The salt was dissolved in 30 ml water in a 500 ml beaker. To this beaker, a calculated amount of fuel from Eqn 3.1 such as dextrose, glycine, or urea was dissolved in a separate beaker and added. The beaker was kept over a hot plate at 90 oC and magnetically stirred at 800 rpm for 45 minto complete the sintering process. The solution went from liquid to a viscous gel-like substance, after which reddish-brown gas off-gassed the material, which then turned into a foamy substance. After cooling to room temperature, the substance was transferred into a silica crucible and placed into a muffle furnace preheated at 450 oC, 550 oC, and 650 oC for 1 hr [52]. The now porous and abrasive nano alumina powder was crushed in a mortar and pestle for 10 min to reduce the size, then weighed and stored for further use.

Procedure for synthesis of composite

10 g Activated carbon granules are weighed and combined with 1% of their mass of synthesized alumina nano powder in a beaker. This mixture is then ultrasonicated for 2 hrto ensure thorough blending and dispersion of the nanoparticles into the pores of the activated carbon. Following ultrasonication [53], the material is placed in a hot air oven at 130 °C for 1 hour to eliminate any trapped moisture. This method is favoured due to its low energy requirements and efficiency in preparing the composite material. The ultrasonication process enhances the interaction between the activated carbon and alumina nanoparticles, while the controlled heating ensures the removal of residual moisture, resulting in a well-prepared adsorbent material as for further applications.

Procedure for testing of removal of heavy metal ions

The 10 g of the synthesised composite was placed in a pipette plugged with cotton as shown in Fig. 4.3. The system was flushed with 1 l distilled water to eliminate any nanoparticles that may not have adsorbed on the surface. A stock solution containing 100 ppm lead, cadmium, andnickel was created by adding a calculated amount of the corresponding metal salt- lead nitrate, cadmium chloride, and nickel sulphate. The stock solution was passed through the bed of composite at a flow rate of 2.5 l h-1

. A small amount of the purified water was collected and characterised using ICP-OES to determine the concentration of heavy metal ion

RESULTS:

Alumina nano powder and composite was synthesised in this project using solution Combustion and ultrasonication. The synthesised samples were characterised using SEM And XRD to note the phase change and morphology. The tested water samples after Passing through the bed was also characterised using ICP-OES. The results and Significance of each of these tests are presented in this section.

CONCLUSION:

Alumina nano-powder was synthesised using solution combustion method of synthesis. The synthesis was done using different based on literature, and trials were done using Certain fuels individually and a combination of fuels to test their effect on the properties Of the nanoparticles.

The average particle size of the synthesised particles, morphology, and crystalline data Was verified by SEM and XRD. The results showed that the particles synthesised at a Temperature of 550 oC and using a combination of fuels showed better properties than the Particles synthesised using individual fuels and at an elevated temperature of 650 c.The alumina powder was used to create a composite using activated carbon granules by Ultrasonication. It could be deduced that for a concentration of 1% and sonication duration Of 1 hour, the alumina had interacted with the pores in the carbon, effectively adhering to It and increasing the surface area of the material. The effectiveness of the composite in removing heavy metal ions such as lead, cadmium, And nickel was tested by creating a stock solution and passing it through a bed of the Synthesised composite. The outflow was collected and characterised using ICP-OES to Determine the concentration of the heavy metal ions. The results were checked against a Control bed without the composite, which indicated that the composite was effective in Removing the stated ions at an efficacy of 99% at a concentration of 100 ppm. Of the three Ions, cadmium was found to be adsorbed to the maximum extent.

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