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Original articles

SYNTHESIS OF COCONUT SHELL–DERIVED CHARCOAL NANOPARTICLES FOR THE REDUCTION OF HYDROGEN SULFIDE AND AMMONIA IN ODOROUS LIQUID WASTE

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ABSTRACT

CSCNP synthesis is an innovation in making activated charcoal nanoparticles with the main ingredient of coconut shells, which can reduce odors in liquid waste. Ammonia (NH_3) and hydrogen sulfide (H_2S) are indicators of the cause of odor pollution (such as rotten eggs and urine odor) and are found in liquid waste in Indonesia. This study has two objectives, namely to obtain the right method of making (synthesis) of CSCNP, and to analyze the addition of the most effective concentration of CSCNPs in reducing *liquid waste* odors with H_2S and NH_3 parameters. The method in the synthesis of CSCNPs is the hydrothermal method, while the method of analysis of the effectiveness of CSCNPs in reducing H_2S is the methylene blue method based on UV-Vis spectrophotometry and in reducing NH_3 is the phenol method based on UV-Vis spectrophotometry. Effectiveness data analysis was carried out in a quantitative descriptive manner by calculating the mean value and standard absorption deviation. The results showed that CSCNPs with hydrothermal had the highest effectiveness in reducing H2s at a concentration 0.07 g with an initial absorbance value of 1.173 mg/L to 0.145 mg/L and effectiveness in reducing ammonia at a concentration 0.05 g with an initial absorbance value of 1.963 mg/L to 0.000 mg/L. CSCNPs were also able to normalize the acidity level of the waste with pH 8 to 7 (neutral). These results show that CSCNPs have the potential to provide solutions to environmental problems, especially in reducing the unpleasant odor of liquid waste.

Keywords: coconut shell, nanoparticles, hydrogen sulfide, ammonia, liquid waste

INTRODUCTION

Environmental issues, particularly sanitation and clean water, have become an urgent global concern in the sustainable development agenda. The availability of water that is free from pollution is a vital indicator of community welfare as stated in the *Sustainable Development Goals* (SDGs), especially the 6th goal regarding Clean Water and Proper Sanitation [1]. In addition, effective waste management is also closely related to the 12th SDG on Responsible Consumption and Production [2]. However, major challenges are still faced in urban areas and educational institutions, where domestic liquid waste is often disposed of without adequate treatment, contaminating ecosystems [3].
Environmental problems in Indonesia's urban areas are currently dominated by poor management of domestic liquid waste which has a high burden of organic pollutants, so that it has the potential to damage aquatic ecosystems and become a source of disease [3]. This condition is exacerbated by the activities of the restaurant industry that produce waste with excess levels of ammonia and organic

matter, which triggers the occurrence of a pungent odor due to an incomplete anaerobic decomposition process [4]. Specifically, this sanitation problem was identified in the Food Court of the State University of Surabaya (UNESA) Ketintang Campus. Based on field observations, the drainage channels at the location showed indications of heavy pollution with blackish cloudy water conditions. This black color indicates an anaerobic condition (lack of oxygen) due to the high load of organic matter, triggering the emission of strong-smelling gases that greatly disturb the comfort of the academic community [5, 6].

To overcome these complex problems, the use of local materials as adsorbents is a promising solution. Current research trends highlight the great potential of local biomass-based activated carbon due to its abundant availability as well as its extensive pore structure (500–3000 m^2/g) that is effective for pollutant adsorption [7]. However, the effectiveness of this material depends heavily on its physical characteristics. Pratama & Paradise asserts that reducing the size of adsorbent particles to be finer is scientifically proven to be able to expand the external contact surface and accelerate the kinetics of diffusion of the intraparticle for more optimal absorption [7]. Jenar et al. revealed that local technological innovations have now shifted to nanotechnology engineering, where the modification of materials into nanoparticles or composites has been proven to be able to overcome the limitations of conventional organic materials and significantly improve performance [8].

Based on this technological transition, this research offers novelty through the synthesis and application of Coconut Shell–Derived Charcoal Nanoparticles (CSCNPs). CSCNPs are defined as coconut shell-based activated carbon materials that are structurally engineered to reach the nanometer scale (1–1000 nm). In contrast to conventional activated carbon, the nanostructures in CSCNPs offer a much higher surface area to volume ratio, allowing for faster and more powerful interactions in capturing harmful gas molecules such as Hydrogen Sulfide (H_2S) and Ammonia (NH_3). This innovation also supports the use of low-cost advanced materials (less than Rp 35,000/kg) that have potential for tropical environmental applications [8].

The main chemical indicators that are targeted for CSCNPs reduction at these locations are Hydrogen Sulfide (H_2S) and Ammonia (NH_3). H_2S is formed naturally from the anaerobic decomposition of sulfur-containing organic matter and has toxic, flammable, and annoying "rotten egg" odors. Meanwhile, NH3 comes from the degradation of organic nitrogen compounds that cause a pungent aroma. The handling of these gases dissolved in water requires a material with precise micropores, where the effectiveness of CSCNPs is expected to be able to absorb these molecules completely and more efficiently than conventional filters [4].

Furthermore, the presence of H_2S in liquid waste needs to be watched out for not only because of its smell, but also its chemical properties. Hydrogen sulfide is a colorless, toxic, flammable, and volatile (volatile) gas [5]. The detection of pungent odors in the air around sewers is scientific evidence of the release of harmful gases from the liquid phase into the air, which demands immediate handling so as not to have a negative impact on environmental health. In addition to H_2S, another chemical parameter that contributes significantly to odor pollution is Ammonia (NH_3). These compounds generally come from the degradation of organic nitrogen compounds, such as high-protein food scraps or urine, which gives rise to a pungent aroma known as a "pee smell". The handling of ammonia in wastewater is very crucial, where the effectiveness of its reduction is highly dependent on the interaction between the ammonia molecules and the surface area of the filter material used [4].

In addition to odor parameters, physical-chemical aspects such as acidity (pH) and Total Suspended Solids (TSS) play a crucial role in determining wastewater quality. Domestic liquid waste from restaurant activities often has unstable pH conditions and high turbidity which are harmful to the ecosystem, whereas ideal water treatment should be able to return the pH to neutral (± 7) and minimize suspended solids. Therefore, this study aims to prove the effectiveness of the application of Coconut Shell-Derived Charcoal Nanoparticles (CSCNPs) in normalizing pH and reducing organic pollutants simultaneously, offering a low-cost and environmentally friendly advanced material-based sanitation solution[3, 6].

In order to overcome the complex problem of organic and inorganic pollutants, the absorption method using activated carbon is considered an effective solution. The utilization of coconut shell waste as a base material for activated carbon is very potential due to its abundant availability and rich structure of microscopic pores[9]. Activated carbon has high absorbency that is specifically effective at removing odors, tastes, and colors in water, making it an ideal material for environmental sanitation[10].

MATERIALS AND METHODS

Research Materials

The main material used in this study is coconut shells obtained from household waste in the Surabaya area and used as a basic material for making activated carbon. The chemicals used include 1 M sodium hydroxide solution, phenol reagents, blue methylene reagents, and ethanol with pro analysis purity level (Merck, Germany) obtained through distributor PT Brataco, Indonesia. Standard ammonia solutions with a pro analysis purity level (Merck, Germany) were obtained from Smart Lab Indonesia as well as aqueducts and deionized water (WaterOne, Onemed–OneLab, Indonesia). All chemicals are used without advanced purification according to the manufacturer's specifications. Liquid waste samples were obtained from the drainage channel of the *food court* area of the State University of Surabaya, Ketintang Campus. Samples were collected using clean polyethylene bottles, then analyzed as a research object with no preliminary treatment other than initial screening to remove coarse particles.

Research Instruments

The instruments used in this study include a Genesys 50 type dual-beam UV-Vis spectrophotometer (Thermo Scientific, USA), a high-speed centrifuge (Eppendorf, Germany), a polytetrafluoroethylene or Teflon-lined polytetrafluoroethylene hydrothermal autoclave (Parr Instrument Company, USA), a digital pH meter (Eutech Instruments, Singapore), an analytical scale (Ohaus Corporation, USA), a hotplate stirrer (Thermo Scientific Cimarec, USA), and ultrasonic cleaner (Elma Schmidbauer GmbH, Germany). The sample drying process is carried out using a drying oven (Memmert GmbH, Germany) and a laboratory oven (Labtech, Thailand). All instruments are used in accordance with the standard operating procedures applicable in the faculty laboratory.

Coconut Shell–Derived Charcoal Nanoparticles Synthesis Method

The synthesis of coconut shell activated charcoal nanoparticles is carried out through a hydrothermal approach to obtain a smaller particle size and a larger surface area, as has been reported in previous studies on the use of biomass-based activated charcoal nanoparticles for liquid waste treatment [5, 11]. Coconut shells are converted into charcoal, then crushed until a fine powder is obtained and sifted using a 100–200 mesh sieve. A total of 0.1 g of carbon powder is dispersed into 50 mL of acuples and processed using an ultrasonicator for 30 minutes until a homogeneous suspension is formed. The pH value of the suspension is set to pH 10 with the addition of a 1 M sodium hydroxide solution gradually, then the mixture is stirred for 15 minutes at room temperature.

The suspension is then fed into a polytetrafluoroethylene-coated autoclave and heated to 180 °C for 3 hours using the hydrothermal method [11]. After the process is complete, the mixture is cooled to room temperature before the separation of the solid and liquid phases. The resulting deposits are centrifugated at a speed of 7000 rpm for 10 minutes, then washed using aqueducts until the rinse pH is close to neutral. The drying stage is carried out using an oven at 80°C for 12 hours until coconut shell activated charcoal nanoparticles are obtained.

Liquid Waste Absorption Procedure

A total of 25 mL of liquid waste samples were put into a beak, then coconut shell activated charcoal nanoparticles were added with mass variations of 0.03 g, 0.05 g, and 0.07 g. The mixture is stirred slowly until the absorbent is evenly dispersed, then filtered to obtain a filtrate used in subsequent analysis.

Water Quality Parameter Analysis

The pH value of liquid waste is determined semi-quantitatively using universal pH indicator paper as the initial stage of water quality screening. Ammonia concentrations were analyzed using the ultraviolet-visible spectrophotometry-based phenote method according to *the Standard Methods for the Examination of Water and Wastewater* [12]. Hydrogen sulfide analysis was carried out as a supporting parameter for liquid waste odor through the formation of colored complexes using the methylene blue method [4 13]. All measurements were carried out three times and the results were declared as average values along with standard deviations.

Data Analysis

The measurement data were analyzed in a quantitative descriptive manner by calculating the mean value and standard deviation to evaluate the effect of absorbent mass variation on changes in wastewater quality parameters. Statistical calculations are carried out using Microsoft Excel software. No inferential statistical significance test was carried out because this study aimed to evaluate the tendency of changes in water quality parameters descriptively. The calculated concentrations obtained from calibration curve equations serve as the quantitative basis for evaluating the adsorption performance of the synthesized CSCNPs.

Ethical Approval

This research does not involve human or animal subjects, so it does not require ethical approval.

RESULTS AND DISCUSSION

Morphology of Coconut Shell Activated Charcoal Nanoparticles (CSCNPs)

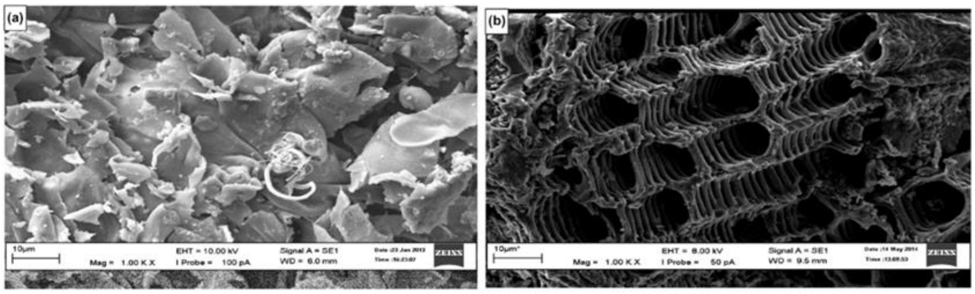

Figure 1. SEM images of coconut shell based activated carbon reported by Mohammed et al. (2015). (a) Morphology of raw coconut shell (CS), showing a dense and compact surface with no evident pore development. (b) Morphology of KOH activated coconut shell carbon produced under microwave irradiation (PHAC), exhibiting a well developed porous structure with open cavities and an interconnected pore network formed through carbonization and chemical activation.

The adsorption performance of activated carbon is strongly influenced by its surface morphology and pore structure. Although scanning electron microscopy (SEM) characterization was not directly performed in this study, the morphological features of coconut shell based activated carbon nanoparticles have been widely reported in previous literature and are discussed here as a supporting reference to interpret the adsorption behavior. Scanning Electron Microscopy (SEM) images reported by Mohammed et al. (2015) reveal pronounced morphological differences between raw coconut shell and chemically activated carbon [14]. The raw coconut shell displays a dense and compact surface morphology with no significant pore formation. In contrast, coconut shell activated carbon produced via carbonization followed by KOH activation under microwave irradiation exhibits abundant open cavities and a highly interconnected porous network. These structural transformations are attributed to the thermochemical degradation of lignocellulosic components and the reaction between KOH and the carbon matrix, which promotes pore formation and surface etching. As a result, chemical activation significantly enhances the specific surface area up to 1,354 m^2/g, with micropores as the dominant pore structure. This finding highlights the critical role of pore development in improving the adsorptive properties of coconut shell based activated carbon. Based on these reported characteristics, the coconut shell–derived charcoal nanoparticles synthesized in this study are expected to exhibit similar porous features that support their effectiveness in adsorbing odor causing compounds such as hydrogen sulfide and ammonia.

Effect of Coconut Shell–Derived Charcoal Nanoparticles on H_2S Concentration

The concentration of hydrogen sulfide (H_2S) in wastewater was determined indirectly using the methylene blue method through absorbance measurements with a UV–Vis spectrophotometer. In this method, dissolved H_2S reacts to form a colored complex, allowing its concentration to be quantitatively evaluated based on absorbance values. Because absorbance values do not directly represent concentration, a calibration curve was required to convert absorbance into quantitative concentration values.

The calibration curve was constructed using standard H_2S solutions with concentrations ranging from 0.5 to 2.5 mg L^{-1} and showed a linear relationship described by the regression equation:

$y = mx + c$

$y = 0.0506x + 0.2867$ (1)

This equation was rearranged to calculate H_2S concentration from measured absorbance values:

$x = (y - c) / m$

$x = (y - 0.2867) / 0.0506$ (2)

All H_2S concentrations reported in this study were calculated using this regression equation. Thus, the calibration based mathematical conversion serves as the quantitative basis for evaluating the effectiveness of CSCNPs in reducing H_2S concentration in liquid waste. The calculated H_2S concentrations before and after CSCNPs treatment are presented in Table 1.

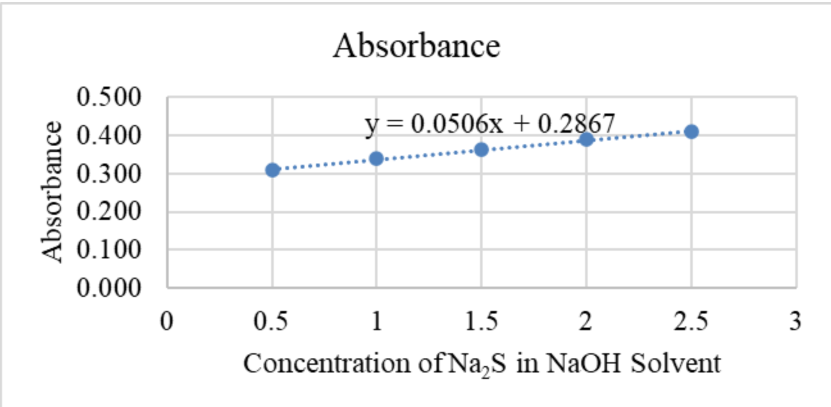

Figure 2. H_2S Concentration Absorbance Curve Graph

Table 1. Effect of CSCNPs Mass on H_2S Concentration in Liquid Waste

Treatment	**H_2S Concentration (mg/L)**
Liquid Waste (control)	1.173
LW + 0,03 g CSCNPs	0.777

LW + 0,05 g CSCNPs	0.599
LW + 0,07 g CSCNPs	0.145

The data in Table 1 show that the highest concentration of H_2S was found in untreated sewer water samples. The addition of CSCNPs causes a gradual decrease in H_2S concentration as the absorbent mass increases, with the lowest concentration obtained at the addition of 0.07 g of CSCNPs. This trend suggests that an increase in absorbent mass has a direct effect on the effectiveness of removing sulfide compounds from liquid waste.

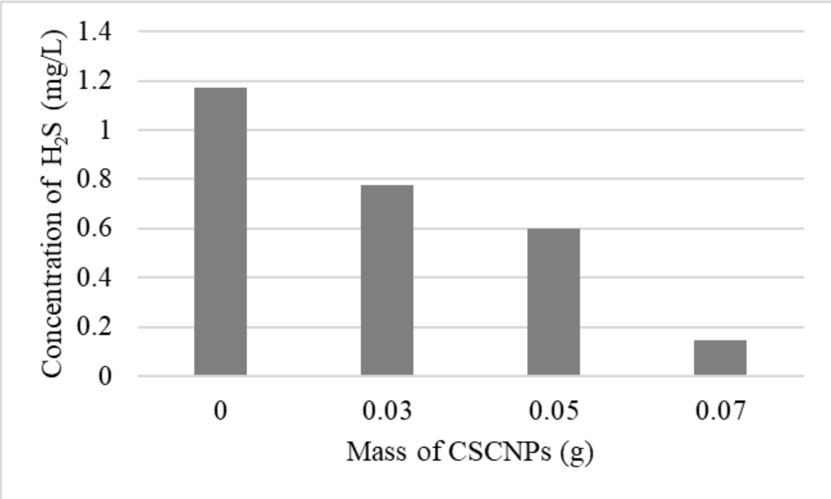

Figure 3. CSCNPs Mass Relationship to H_2S Concentration in Liquid Waste

This trend indicates a clear negative correlation between CSCNPs mass and H_2S concentration, demonstrating that increasing adsorbent dosage enhances sulfide removal efficiency. This behavior is governed by the adsorption mechanism of porous activated carbon with a high surface area, which is further amplified at the nanoparticle scale due to the substantial increase in specific surface area, thereby enhancing adsorbent–H_2S interactions [10] [11]. Consistently, higher adsorbent loading improves H_2S removal efficiency by expanding the effective surface area available for adsorption [15]. The presence of nano sized carbon crystallites within the pore structure intensifies molecular contact with sulfide species, promoting adsorption efficiency [16] In addition, chemical activation produces a more homogeneous pore distribution that facilitates pore filling mechanisms and surface chemical interactions [17]. Nevertheless, alkali impregnation exhibits an optimal threshold, as excessive sulfur reaction products may block pores and reduce adsorption performance [18]. Overall, H_2S adsorption onto activated carbon is governed by the synergistic effects of micro and mesoporous structures, molecular diffusion, and the combined contributions of physical adsorption and surface chemical interactions [19]. The significant reduction in H_2S concentration observed after CSCNPs treatment confirms that the coconut shell–derived charcoal nanoparticles synthesized via the hydrothermal method possess effective adsorption capability toward sulfide based odor compounds. This result directly demonstrates the success of the synthesis process in producing a functional adsorbent for H_2S removal in odorous liquid waste.

Effect of Coconut Shell–Derived Charcoal Nanoparticles on NH_3 Concentration

Ammonia concentration (NH_3) analysis was carried out using the phenote method based on UV–Vis spectrophotometry. This method is based on the formation of colored complexes resulting from the reaction between ammonia and phenate reagents, where the color intensity is proportional to the NH_3 concentration. Similar to H_2S analysis, a calibration curve was required to convert absorbance values into concentration values.

The calibration curve for NH_3 was constructed using standard solutions with concentrations ranging from 0.5 to 2.5 mg L^{-1}, yielding the regression equation:

$y = mx + c$

$y = 0.054x + 0.104$ (3)

This equation was rearranged as follows:

$x = (y - c)/m$

$x = (y - 0.104) / 0.054$ (4)

All NH_3 concentrations reported in this study were calculated using this regression equation. Thus, the calculated concentrations serve as the quantitative basis for assessing the ammonia adsorption performance of the synthesized CSCNPs. Based on these equations, the values of NH_3 concentration in the sample and the CSCNPs treatment are presented in Table 2.

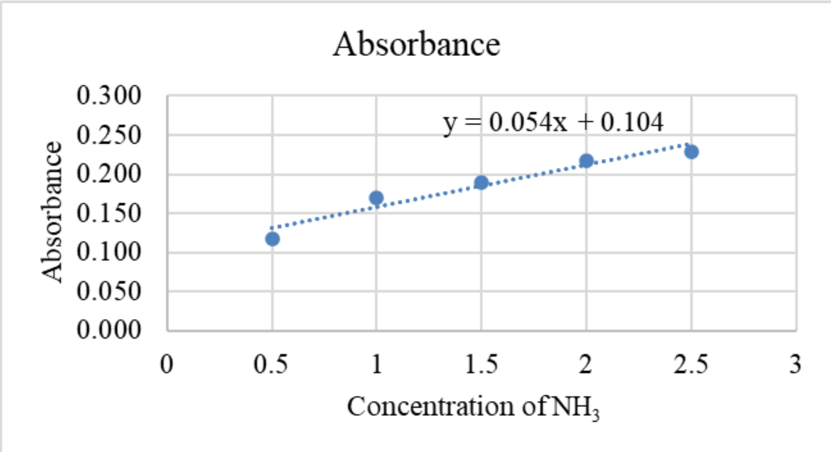

Figure 4. NH_3 Concentration Absorbance Curve Graph

Table 2. Effect of CSCNPs Mass on NH3 Concentration in Liquid Waste

Treatment	NH_3 Concentration (mg/L)
Liquid Waste (control)	1.963
LW + 0,03 g CSCNPs	0.000
LW + 0,05 g CSCNPs	0.056
LW + 0,07 g CSCNPs	0.241

The NH_3 concentration in untreated drainage water samples was relatively high. Following CSCNPs treatment, a marked reduction in NH_3 concentration was observed across all adsorbent mass variations. At a CSCNPs dosage of 0.03 g, the NH_3 concentration fell below the instrumental detection limit, indicating near complete removal. At dosages of 0.05 g and 0.07 g, residual NH_3 concentrations of 0.056 mg L^{-1} and 0.241 mg L^{-1} were observed, respectively. The pronounced decrease in NH_3 concentration at the lowest adsorbent mass indicates the high adsorption capacity of CSCNPs. This behavior is primarily governed by the dominance of microporous structures in coconut shell based activated carbon, which facilitate effective surface interactions between NH_3 molecules and active adsorption sites [20]. Minor fluctuations in NH_3 concentration at higher adsorbent masses suggest the attainment of adsorption equilibrium in the batch system, as well as the possible occurrence of partial desorption and nonhomogeneous adsorbent dispersion [21, 22]. Nevertheless, the final NH_3 concentrations remained substantially lower than the initial levels, owing to the synergistic contribution of micropores and mesopores in enabling rapid initial uptake and subsequent molecular diffusion toward internal active sites within the adsorbent matrix [23 24]. These results demonstrate that the synthesized coconut shell–derived charcoal nanoparticles are highly effective for ammonia adsorption, confirming their potential application for controlling nitrogen based odor pollution in domestic wastewater.

Effect of Coconut Shell–Derived Charcoal Nanoparticles on pH Parameters

The pH value of liquid waste before treatment was at an alkaline condition with a pH value of 8. The addition of coconut shell activated charcoal nanoparticles with a mass of 0.03 g showed no significant pH change. However, at the addition of the absorbent mass of 0.05 g and 0.07 g, the pH value decreases to 7 which indicates a neutral condition.

Table 3. Changes in the pH of Liquid Waste after CSCNPs Treatment

Treatment	**pH**
Liquid Waste (control)	8.0
LW + 0,03 g CSCNPs	8.0
LW + 0,05 g CSCNPs	7.0
LW + 0,07 g CSCNPs	7.0

The decrease in liquid waste pH from 8.0 to 7.0 following the addition of CSCNPs at doses ≥ 0.05 g indicates the role of activated carbon in stabilizing the chemical conditions of the solution. Interactions between oxygen containing functional groups on the activated carbon surface and dissolved basic species through ion exchange mechanisms contribute to the shift of pH toward a more stable state [25]. Similar pH adjustments toward near neutral conditions have been reported in studies employing coconut shell based activated carbon for wastewater purification, reflecting a common characteristic of biomass derived activated carbons in regulating acid base properties [17] [26]. The observed increase in wastewater clarity further confirms the effectiveness of coconut shell activated carbon in adsorbing suspended particles and organic compounds responsible for turbidity. The presence of micro and mesoporous structures in the activated carbon facilitates efficient turbidity removal [27], thereby supporting its application as an environmentally friendly material for domestic wastewater treatment.

Reduction of Physical Quality of Waste and Improvement of Clarity

Treatment using CSCNPs also causes visual changes in the physical characteristics of liquid waste. Samples without treatment appeared cloudy and dark in color, while at the addition of CSCNPs especially at the masses of 0.05 g and 0.07 g, the wastewater appeared clearer.

This increased clarity indicates the absorption of suspended particles and dispersed organic compounds on the surface of activated carbon. Activated carbon is known to be effective in reducing turbidity-causing particles through absorption and microfiltration mechanisms, thereby contributing to the improvement of the physical quality of water [6].

Overall, the coconut shell–derived charcoal nanoparticles synthesized in this study demonstrated strong adsorption performance toward hydrogen sulfide and ammonia, which are the primary contributors to odor in liquid waste. The simultaneous reduction of H_2S and NH_3 concentrations, stabilization of pH toward neutral conditions, and improvement in wastewater clarity collectively confirm that the CSCNPs produced via the hydrothermal synthesis method are effective odor reducing materials derived from biomass waste. These findings directly support the objectives and title of this study.

CONCLUSION

This study successfully synthesized coconut shell derived charcoal nanoparticles using a hydrothermal method and demonstrated their effectiveness in reducing hydrogen sulfide and ammonia concentrations in odorous liquid waste. Based on the research that has been conducted, coconut shell activated charcoal nanoparticles (CSCNPs) can be made using hydrothermal methods at high temperatures and pressures. The effectiveness of CSCNPs in reducing the odor of liquid waste containing H_2S and NH_3 shows the effect of the absorbance value of the UV-Vis spectrophotometry test. The addition of 0.07 g of CSCNPs, the concentration of H_2S decreased from 1.173 mg/L to 0.145 mg/L. Therefore, the addition of CSCNPs to reduce H_2S is recommended to use a higher level than 0.07 g for more optimal results. In the addition of 0.03 g of CSCNPs, the concentration of NH_3 decreased from 1.963 mg/L to 0.000 mg/L. This indicates that the overall content of NH_3 is perfectly absorbed without residue. Liquid waste that has a pH that is too acidic or alkaline can also be neutralized (pH=7) through the addition of CSCNPs of 0.05 g so that the waste becomes more environmentally safe. In this study, CSCNPs successfully reduced the unpleasant odor of wastewater from the UNESA Food Court with H_2S and NH_3 as parameters. CSCNPs has the potential to provide a solution to environmental problems, particularly in reducing unpleasant odors in wastewater. However, in future research, if reducing H2S content using this method is intended, it is recommended to use other types of domestic wastewater samples to better demonstrate that CSCNPs is stronger and more effective in eliminating odors. For absorbing ammonia (NH_3), it is suggested that future studies use other methods or synthetic materials for the production of activated carbon nanoparticles. Future research is expected to examine CSCNPs ability to reduce contaminants with parameters other than H_2S and ammonia as indicators of pollutant sources.

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CONFLICT OF INTEREST

The authors declare no conflict of interests related to the publication of this paper.

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