Latest trends on Ammonia Extraction: A detailed review of ten current literatures

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Abstract

Purpose: This study was done to present a detailed review and analysis of the extraction of ammonia from a range of waste sources.

Methodology: Ten excellent quality kinds of literature were selected for this study. In each literature, the authors have analysed, reviewed and described the adopted methodology, main findings and shortcomings of original research papers.

Main Findings: Extraction of ammonia is a challenge as well as an opportunity, due to its potential application in fertilizer and hydrogen production.

Novelty: Unlike other reviews, it is detailed in nature. The authors have reviewed the methodology, important tables, and images from the original literature.

INTRODUCTION

The environmental problems of the accumulation of waste go beyond unpleasant odours and bad views to the leakage of toxins and the formation of fertile environments for the spread of many diseases and epidemics. In addition to this, an increase in carbon dioxide emissions through burning fossil fuels during waste disposal processes, or through the emissions of methane, ammonia, and sulfur dioxide directly from the waste, contributes the global warming.

In farms and disposal plants, massive volumes of biomass wastes, such as animal manure and sewage sludge, are continually produced. One of the most popular techniques for disposing of these wastes is to utilize landfill and/or incineration, which require a lot of energy and generate pollution in the air and soil. Since biomass wastes contain nitrogen compounds and a variety of hydrocarbons, a novel alternative procedure for converting the wastes into valuable chemicals is required.

One such chemical of concern is ammonia, which has long been employed as a fertilizer and is now gaining popularity as a hydrogen transporter. At room temperature, ammonia is a liquid with a pressure of 0.8 MPa and a large capacity for hydrogen storage (17.7 wt per cent hydrogen in ammonia). The breakdown of ammonia using catalysts such as ruthenium and nickel has created hydrogen. As a result, ammonia recovery from biomass wastes is required. After ammonia recovery, the leftover liquid wastes with lower ammonia concentrations might be utilized as liquid fertilizer, but raw biomass wastes with high ammonia concentrations cause soil eutrophication.

Benefits and Risks of Ammonia: Ammonia (NH_3) is a prevalent toxin found in the garbage, fertilizers, and natural processes. Both the ionized (ammonium, NH_4^+) and the unionized forms of ammonia nitrogen are used (ammonia, NH_3). A higher pH encourages the development of the more poisonous unionized form (NH_3), whereas a lower pH encourages the formation of the ionized (NH_4^+) type. Bacterial breakdown of organic waste that has accumulated in sediment produces ammonia in sediments.

By dissimilatory nitrate reduction, sediment microorganisms generate ammonia or mineralize organic nitrogen. Because nitrification (the conversion of ammonia to nitrite [NO_2^-] and nitrate [NO_3^-]) is impeded in anoxic sediments, ammonia is particularly common. Benthic and surface water biota may be harmful to ammonia produced in sediment. (Milne I, et al., 2000).

Techniques to Reuse/Recollect/Capture Ammonia: The scientific and technical development in dealing with waste has led to reconsidering the tons of waste produced daily and looking at it as an alternative source of energy. The concept of generating energy from waste is based on treating it chemically by extracting ammonia gas and then converting it into a liquid through pressure and store in special containers to produce biogas, green hydrogen and green ammonia.

Magnesium ammonium phosphate ($MgNH_4PO_4.6H_2O$) also known as MAP precipitation is an effective method for extracting ammonium ions from liquids. At a pH over 7, MAP can be precipitated by adding magnesium and phosphate to an ammonium solution. The recovery of ammonium ions from an aqueous solution was reported to be possible using an adsorbent made from the MAP. Thermal treatment over 353 K extracted ammonia from MAP, generating a solid that serves as an adsorbent for the recovery of aqueous ammonium ions. The use of MAP-derived adsorbents for both gaseous and aqueous ammonium ion adsorption might be a potential way to recover ammonia from biomass wastes. (Fumoto, et al., 2011)

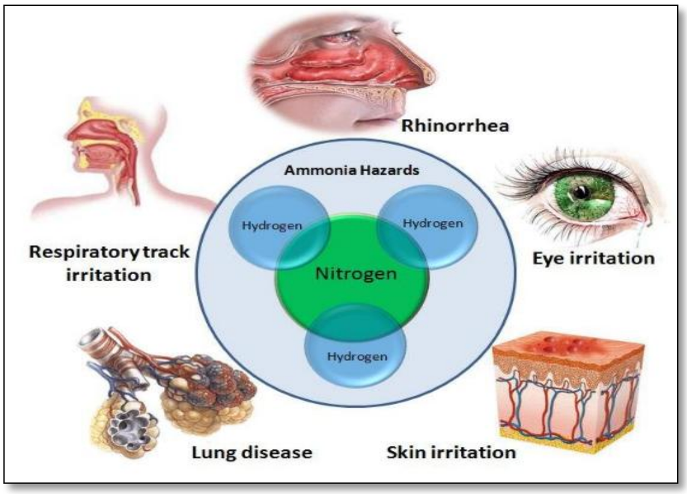

Figure 1: Effects of ammonia exposure (Thirunavakkarasu, 2017)

LITERATURE REVIEW

One: Removal of ammonia by biofilters with straight and wavy lamellar plates.

Baltrėnas (2021) evaluated the performance of two newly developed plate-type biofilters in treating air contaminated with ammonia vapour at different inlet air temperatures (24, 28, and 32 °C).

Methodology: The biofilter received ammonia-contaminated air through the intake duct. The airflow rate was regulated by a valve fitted in the input duct. A sample site was created in the input duct to measure the investigated parameters. The polluted air flowed into the biofiltration system-equipped casing. The airflow was routed throughout the packing material via a perforated plate. The polluted air proceeded towards the exit between the plates of packing material soaked in a solution. The modified airflow was released through the output duct. An aperture in the output duct was created to measure the researched parameters. The humidity of the packing material, the temperature of the liquid medium, and the airflow were all monitored on a regular basis. The liquid temperature medium was controlled by an electric heater, while the temperature of the air was controlled by a channel heater mounted under the supplied air blower. (Figure 2)

Ammonia was evaporated on an electric stove, and the produced ammonia vapour was fed into the biofilter. The same temperatures (24, 28, and 32 °C) were kept in the reservoir at the bottom of the biofilter bio medium. The packing material's porous plates were submerged in a nutrient-rich liquid media (bio medium). A TESTO 400 instrument was used to test the temperature and humidity of the air in the biofilter. Air temperature and humidity were recorded and monitored at airflow inlets and outlets 500 mm from the opening of the airflow inlet. The biofilter's packing material was used to provide the ammonia-contaminated air. The airflow rate was measured and monitored daily. The experiment was separated into three parts (at temperatures of 24, 28, and 32 degrees Celsius).

The microorganisms were acclimated for 15 days before testing the performance of the biofilter to cleanse the air from the pollution. Every day of the experiment, ammonia-contaminated air was fed into the biofilters. Following the acclimation phase, a further ten days were spent investigating biofiltration effectiveness and quantifying microorganisms in the packing material using ammonia vapour-polluted air.

Table 1: Biofilter technical features

No.	Parameter	Parameter value
1	Biofilter dimensions (l × b × h)	0.85 × 0.70 × 2.00 m
2	Biofilter cartridge dimensions (l × b × h)	0.80 × 0.65 × 1.30 m
3	The packing material of bio filters	Lamellar plates
4	Biofilter output	100 m^3/h

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No.	Parameter	Parameter value
5	Temperature of bio medium	24–32 °C
6	Humidity of packing material	70–80%
7	pH of bio medium	7.0
8	Contaminant	Ammonia
9	Initial concentration	300 mg/m^3

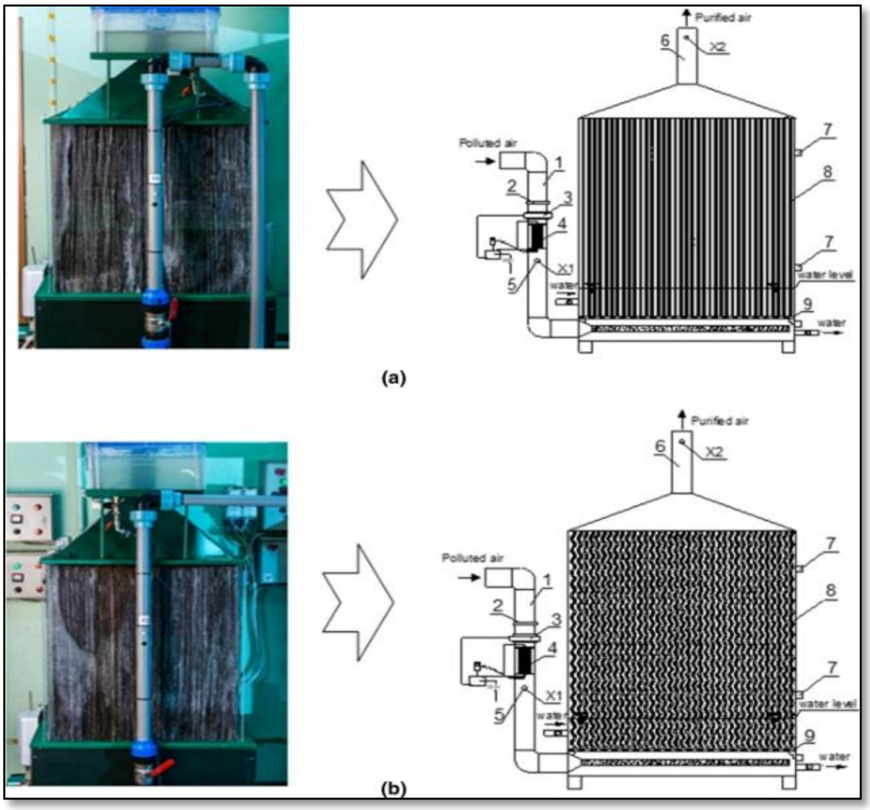

Figure 2: Wavy lamellar plates are used to create a biofiltration system.

The intake and output ammonia concentrations were used to calculate the efficiency of ammonia removal. A MiniRAE 2000 photoionization detector was used to estimate the pollutant concentration.

Discussion and Results: The air temperature in the biofilters was 24± 1, 28± 1, and 32 ±1 °C throughout the trial. The influence of air temperature on the degree of ammonia vapour removal was measured by altering the incoming air temperature. The treated air has a minor temperature difference from the biofilter air. Because the intake air stream traveled through the 25-cm layer of water and grew colder, the temperature of the inlet air was sometimes higher to maintain a steady air temperature in the biofilters. Unless thermophilic bacteria are cultivated in the biofilter, a provided air temperature more than 40 °C may cause the microorganisms to die.

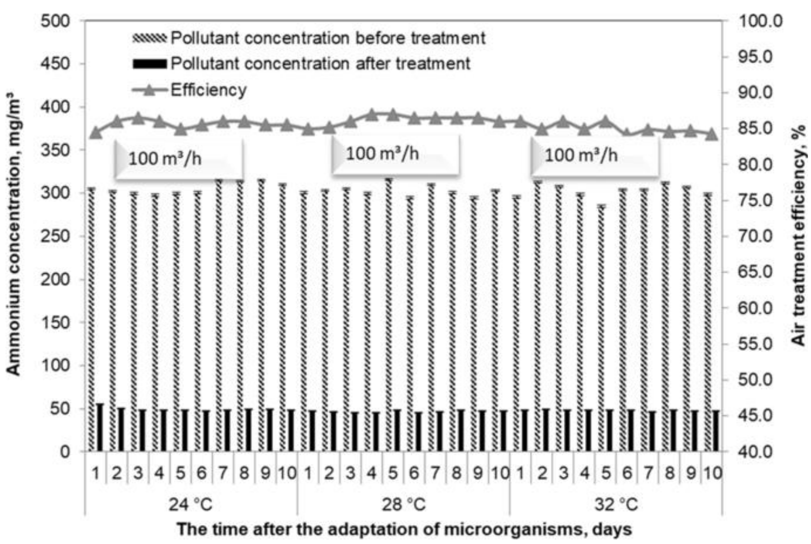

Figure 3: Time and air temperature of the biofilter with wavy lamellar plates affect the air treatment efficiency

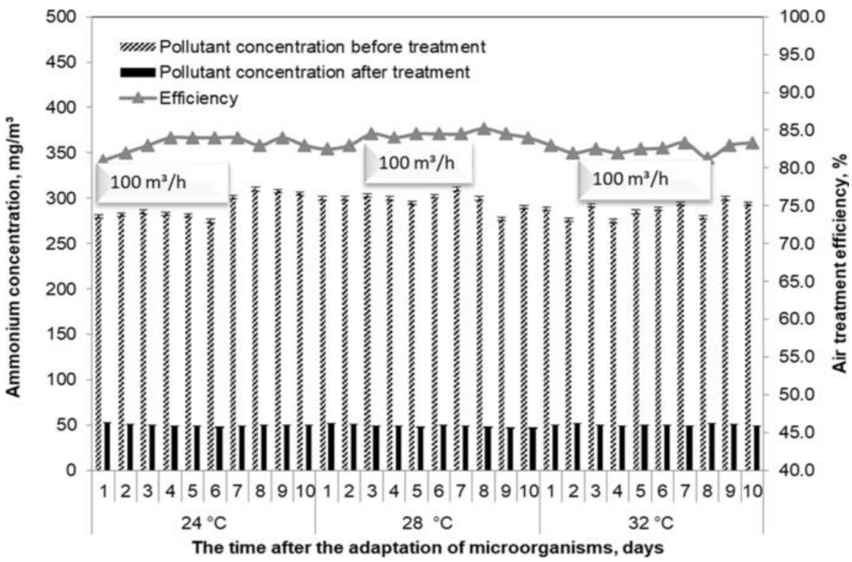

Figure 4: The effect of time and air temperature on the air treatment effectiveness of a biofilter with straight lamellar plates

The findings revealed that increasing the NWCM's operating duration had no effect on its structure, which remained steady. However, as the length of time spent operating rose, the number of new brown-coloured formations on the NWCM's side increased. Both SLP and WLP were used to examine these forms on the biofilter's NWCM.

Recommendations to author: Maintain the optimal mode of operation of the biofilter as follows: pH 8.6, airflow humidity more than 90%, aqueous medium temperature between 28 and 32 °C, and airflow rate between the plates no more than 0.16 m/s to achieve the air treatment efficiencies in this study.

When it came to the growth of microorganisms in the packing materials of the experimental biofilters utilized in this study, 28 °C was the best temperature for their development.

Conclusion: The findings of this investigation revealed that a biofilter cartridge made up of wavy NWCM plates outperformed a biofilter made up of straight plates. The ammonia vapour removal efficiency in the biofilter with SLP achieved 81.0–85.2 per cent at a flow rate of 0.16 m/s, according to the findings. The effectiveness of ammonia vapour removal was 84.2–87.0 per cent when the biofilter with WLP was utilized. The contact duration between the packing material and the ammonia-contaminated air was 1.5 times longer in the biofilter using WLP, resulting in improved air treatment efficiency. The wavy lamellar plate-type biofilter was 2–3% more efficient, and the construction was more solid and sturdy, allowing the plates to be spaced more evenly. Because the production costs of straight and wavy NWCM plates are equivalent, and the WF coating process utilized is the same, a biofilter with WLP is advantageous in terms of reducing ambient air pollution.

Two: Consideration of Potential Technologies for Ammonia Removal and Recovery from Produced Water.

Chang et al (2022) have done a comparison of various technologies for ammonia removal and recovery from technical, economic, environmental, maturity, and scale-up perspectives.

Methodology: Adsorption, ammonia stripping, chemical precipitation, ion exchange, oxidation, membrane filtration, biological treatment, and electrokinetic processes are among the several ammonia removal/recovery procedures that have been researched. Ammonia extracting is a standard method for removing ammonia from aqueous streams.

Ammonia is recovered in the permeate stream using a hydrophobic membrane to generate high-quality fertilizers in membrane distillation (MD) and membrane contactor (MC). With significant ammonia recoveries, both MD and MC were employed to extract ammonia from N-rich solutions. As a result, while both MD and MC may be successful in recovering ammonia from tight oil or shale gas PW, the risk of membrane fouling and wetting owing to the presence of other pollutants may limit their broad adoption. Both electrochemical systems and bioelectrochemical systems (BES) have been extensively studied in terms of electrokinetic separation processes. By transferring ammonia over a cation exchange membrane, electrodialysis, electrodeionization, and capacitive deionization (CDI) might successfully recover ammonia. The cation exchange membrane in the BES recovers NH4+ as it migrates to the cathode chamber.

Table 2: Total dissolved solids (TDS)

No.	Parameter	Parameter value
1	Concentrations of NH_4^+	127 mg/L
2	The annual volume of PW	3.9 billion m^3
3	Concentrations of TDS	--------------

No.	Parameter	Parameter value
4	Global annual PW volume increased	18.9 billion m3
5	The global ammonia nitrogen (NH4+-N) contained in PW	1.87 million tons
6	Total nitrogen fertilizer consumption	more than 1.5%

Discussion and results: Anaerobic ammonium oxidation (anammox) uses less energy than traditional activated sludge processes (produces energy). The anammox process has a long starting time and is sensitive to changing environmental conditions, making it best suited for N-rich wastewater.

To attain carbon neutrality, however, N_2O (a very strong greenhouse gas) emissions must be closely managed. Due to the development of antifouling and anti-wetting membranes, MD and hollow fibre MC demonstrated excellent results for ammonia recovery. Recent studies using FCDI and hollow fibre MC or stripping, (16) solar-driven BES and anaerobic MBR, (17) membrane CDI and ion exchange (18) have shown that combined electrokinetic and stripping technologies for ammonia removal/recovery often provide greater recoveries while consuming less energy.
Recommendations to the author: To recover ammonia from aqueous solutions, many membrane filtering systems have been suggested. Although reverse osmosis (RO) can often concentrate NH4+ ions in input solutions, it is energy expensive and has a higher selectivity for salts other than NH4+, thus further recovery methods may be necessary.

FO drawn fertilizer is likely to be a promising technology because it requires minimal post-treatment. Despite the weak electrical conductivity of the carbon electrodes, flow-electrode CDI (FCDI) has been proposed for cost-effective salt removal and ammonia recovery from wastewater. In this journal, the writer must mention the parameters used and the method used in specific. It will be more understandable so that we can get all the details.

Three: Recent Development in Ammonia Stripping Process for Industrial Wastewater Treatment.

Lennevey et al (2018) highlighted the recent development of the ammonia stripping process for industrial wastewater treatment. In addition, this study reviews ammonia stripping applications for varied types of industrial wastewater and several significant operating parameters.

Methodology: The mass transfer concept is used in the ammonia stripping process. Figure 5 shows a schematic diagram of the lime precipitation and ammonia removal processes. Prior to stripping, lime is added to raise the pH of the influent, which is then neutralized via a re-carbonation process. Calcium oxide (lime) forms calcium carbonate in the wastewater and acts as a coagulant for hard and particle materials, in addition to increasing the pH.

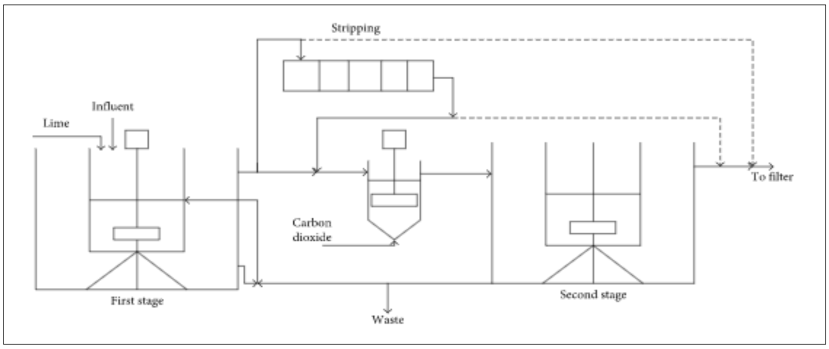

Figure 5: Ammonia removal diagram for leachate-polluted groundwater

(Figure 6), for the coagulation-flocculation and sedimentation processes at pH greater than 11, polyelectrolyte, sodium hydroxide, and iron (iii) chloride were introduced. A heater heated the effluent to 38°C, and ammonia was recovered via sulphuric acid absorption. Finally, using sulfuric acid, the effluent was neutralized. Therefore, they discovered that at an initial ammonia concentration of 199.0 mg/L, the ammonia stripping system for leachate-polluted groundwater had a removal effectiveness of 95.4 per cent.

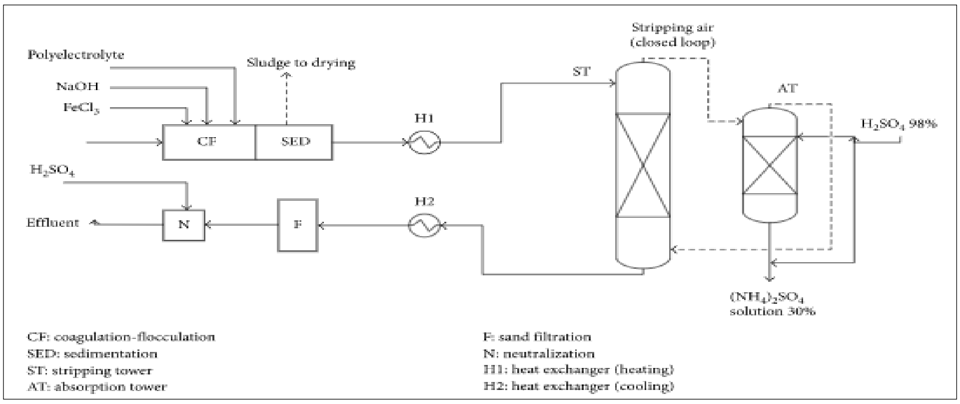

Figure 6: Ammonia removal diagram for leachate-polluted groundwater

Table 3: Parameters of process for industrial wastewater treatment

No.	Parameter	Parameter value
1	pH	higher than 11
2	Temperature of wastewater	38°C
3	Efficiency	95.4%
4	Initial ammonia concentration	199.0 mg/L.
5	removal of ammonia from landfill leachate	60°C

Discussion and results: Higher air-stripping efficiency at a reduced running cost is one of the most essential components of ammonia stripping reactor development. As a result, structural optimization can serve as a thorough design guide for gas-liquid contractors that are optimized. Vortex is used to induce gas-liquid mass transfer in two of the advanced gas-liquid contactors (rotating packed bed and water-sparged aerocyclone). As a result, these water vortexes might potentially be used to gather energy. The microwave-assisted ammonia stripping method has a 94.2 per cent process efficiency.

Recommendations: Before using the ammonia stripping process at full scale, pilot-scale research and economic evaluation are necessary. Furthermore, the future study can concentrate on the three points below. Initially, more study into structural optimization for each of the ammonia stripping process reactors is needed. Because the majority of the new sophisticated ammonia stripping reactors were originally intended for a variety of uses, it's critical that they're customized for ammonia stripping procedures. Secondly, greater research into the capital and operating expenses of improved liquid-gas contactors in ammonia stripping is required. Finally, they have been suggested that improved gas-liquid contactors be combined with a water vortex generator. This might be a viable technique for promoting an energy-independent ammonia extraction process.

Conclusion: The ammonia stripping method is ideal for treating wastewater containing high levels of ammonia and hazardous chemicals because of its ease of use, high efficiency, and great treatment stability, making it an excellent choice for treating wastewater. This review article discusses the many types of ammonia stripping reactors available for ammonia stripping. The typically packed tower for the ammonia stripping method is distinguished by its superior mass transfer performance and better total suspended solids tolerance. Further study is suggested in the following directions. For improved air-stripping efficiency at a reduced operational cost, each of the ammonia stripping processes should first undergo structural improvement. Furthermore, a comprehensive cost study of innovative ammonia stripper techniques is required to determine their economic feasibility in certain wastewater treatment scenarios. Finally, an energy self-sufficient wastewater treatment is presented by combining sophisticated gas-liquid contactors with a vortex power generator.

Four: Reaction Rate of Hydrothermal Ammonia Production from Chicken Manure.

Yukihiko et al (2021) have treated chicken manure in an autoclave under hydrothermal reaction conditions, and the ammonia release rate was determined in the temperature range of 250–400 °C for holding times ranging from 2 to 120 min.

Methodology: For the hydrothermal treatment of chicken manure, an autoclave reactor with an inner capacity of 300 cm^3 was utilized. The reactor and its contents were heated using rod heaters put into the reactor wall. The lid was then snugly closed, and the rod heaters were turned on. A K-type thermocouple was used to monitor the temperature within the reactor, which was kept at 300 or 350 °C. The product gas was collected first, followed by filtration of the product slurry in the reactor to separate the solid and liquid products. A smaller autoclave (96 mL) was utilized as a first experiment to evaluate nitrogen behaviour throughout a larger temperature range of 250–400 °C for holding durations of 10 and 60 minutes.

An electric balance was used to weigh the solid product after it had been dried. A high-pressure pump LC-20AD, a column oven CTO-20A, and an electric conductivity detector CDD-10Avp made up the ion chromatography system. Other nitrogen-containing molecules were found in the liquid phase. The Kjeldahl technique was used to quantify the recovered ammonia instead of titration to measure the quantity of nitrogen in the liquid product. The ratio of the molar amount of nitrogen in these compounds to the molar amount of nitrogen in feedstock chicken manure, which was the total of nitrogen in the solid phase and nitrogen in ammonia, was used to calculate the nitrogen yield of ammonia and liquid-phase nitrogen other than ammonia.

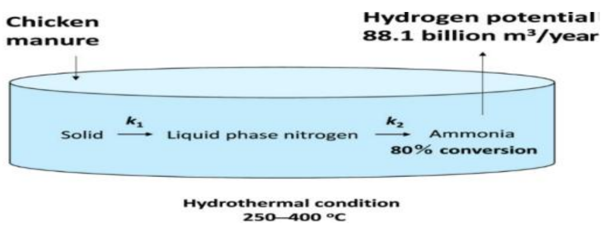

Figure 7: Treatment of chicken manure in an autoclave under hydrothermal reaction conditions

Results and Discussion: Using a 96 cm^3 autoclave, the effects of temperature and holding duration were explored as preliminary research. To ensure repeatability, the experiments were performed at least twice under the same conditions. Figure 8 depicts all data points and depicts the data dispersion pattern. Although this exploratory investigation yielded a considerable dispersion of data, a greater temperature leads to a larger nitrogen production of ammonia. The rise in yield with increasing temperature was somewhat repetitive, and there was no discernible stepwise shift.

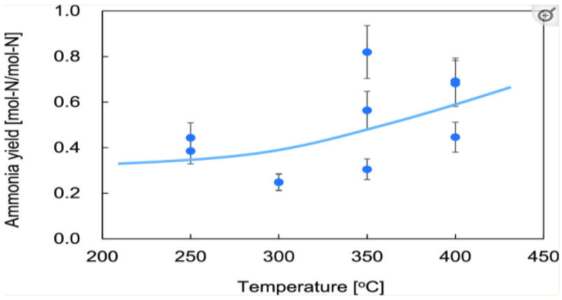

Figure 8: Effect of temperature on ammonia recovery yield (holding time 10 min)

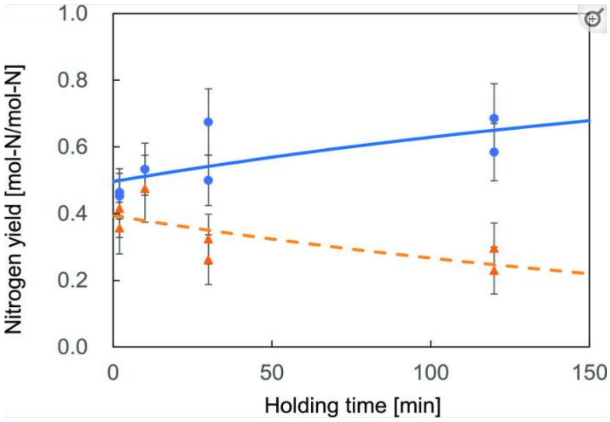

Figure 9: Change in nitrogen yield with a holding time (300 °C) (circle: ammonia, triangle: other liquid-phase nitrogen)

Using a 300 cm^3 autoclave, a comprehensive analysis of the rise in ammonia output with a holding time was undertaken. The yield of liquid-phase nitrogen was also determined. Figure 9 shows the findings obtained at 300°C. At a holding duration of 0 minutes, the ammonia production is approximately 0.5 mol-N/mol-N. Before treatment, the chicken dung contained 0.270 mol-N/mol-N ammonia.

A solid line represents the fitted curve. The reaction rate constants k1 = 0.000540 min^{-1} and k2 = 0.00408 min^{-1} produced a fair agreement between the experimental and model results.

Ammonia Generation Characteristics of Chicken Manure at 350 °C. Figure 10 illustrates the change in nitrogen yields for ammonia and liquid-phase nitrogen. At 300°C, a similar pattern was seen, with larger ammonia yields and decreased liquid-phase nitrogen yields.

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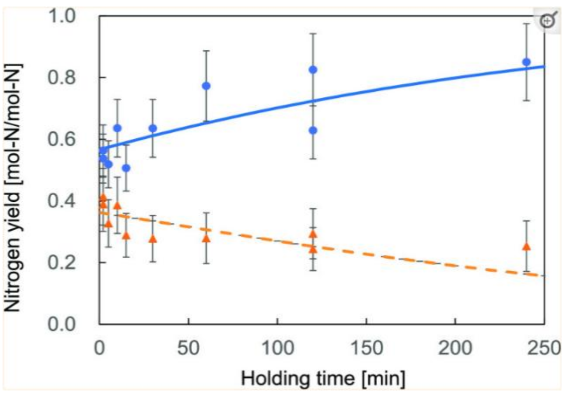

Figure 10: Change in nitrogen yield with a holding time (350 °C) (circle: ammonia, triangle: other liquid-phase nitrogen)

The initial ammonia output is at 0.55 mol N/mol N, which is slightly higher than the 0.5 mol N/mol N for 300 °C. It takes longer to heat the reactor to 350°C, thus greater conversion during this time is feasible. The data and model calculation outputs were in good agreement after fitting with the model again. k1 = 0.00918 min^{-1} and k2 = 0.00426

min^{-1} were the reaction rate constants. These values are greater than those at 300°C, which is logical given the Arrhenius equation; yet, k2 did not change considerably.

Recommendations to the author: The strength of the details offered by the researchers in the process of recovering ammonia from chicken manure, in addition to the indicated recovery duration, was extremely excellent and sufficient, and was one of the scientific papers strongest points. In addition, multiple temperature ranges were used to achieve the optimum results.

One of the paper's weaknesses is that the researchers only utilize one kind of manure. In addition, images of the phases of doing the experiments step-by-step, beginning with the collecting of chicken manure and finishing with the final result, should be included in the scientific article. Finally, methods for developing the study were not mentioned, and other alternatives to the materials used were not mentioned if they were not available.

Five: An environmentally friendly animal waste disposal process with ammonia recovery and energy production: Experimental study and economic analysis.

Ye et al (2017) have proposed an environmentally friendly animal waste disposal process with combined ammonia recovery and energy production and investigated both experimentally and economically.

Methodology: The feedstocks employed in this research were horse manure, wood bedding, and straw. The weight percentages of 3 major components (dry basis) varied from batch to batch, but the overall weight percentages of each component were (20–40% horse manure), (30–50% wood bedding), and (20–40% straw). The study was carried out using a Shimadzu DTG-60AH thermal analyzer at 900 C with a heating rate of 20 C/min under nitrogen and air as carrier gas.

The feedstock's high heating values (HHV) were computed. The ASTM D3174 and D3175 methods were used to estimate ash and volatiles, while the difference technique was used to calculate fixed carbon. For 6 hours, horse manure waste was dissolved in water at a ratio of 6 g HM/100 mL water. The ammonia solution remained in the liquid phase after the filter separation operation. The influence of pH on Mg: N:P ratios ranging from 8 to 11 was first examined. Mg/N and P/N ratios were changed from 0.8 to 1.2 at pH 9.5 for 1 hour after the optimal pH was determined. The magnesium and phosphate sources were magnesium sulfate ($MgSO_4$) and potassium phosphate dibasic ($K_2HPO_4{:}2H_2O$), respectively.

Ammonia concentration before and after precipitation experiments was measured by the salicylate method using HACH High Range Ammonia Kit. In this method, ammonia firstly combines with chlorine to form mono-chloramine, which will be oxidized in the presence of a sodium nitroprusside catalyst to form a blue-coloured compound.

Results and Discussion: Horse manure had a greater heating value of 17.7, 18.7, and 17.1 MJ/kg, respectively, which may be recovered as energy during the gasification process. Under the dry basis, which is comparable to that of straw and wooding, horse manure was found to have a greater ash content than wooding and straw. As shown in Fig. 11 (a & b), magnesium and phosphate concentrations were also regarded as critical factors in the precipitation process. The stoichiometric ratio for magnesium, ammonia, and phosphate supply, according to the precipitation process, was 1:1:1. The effectiveness of ammonia elimination was observed to improve as the Mg supply was increased.

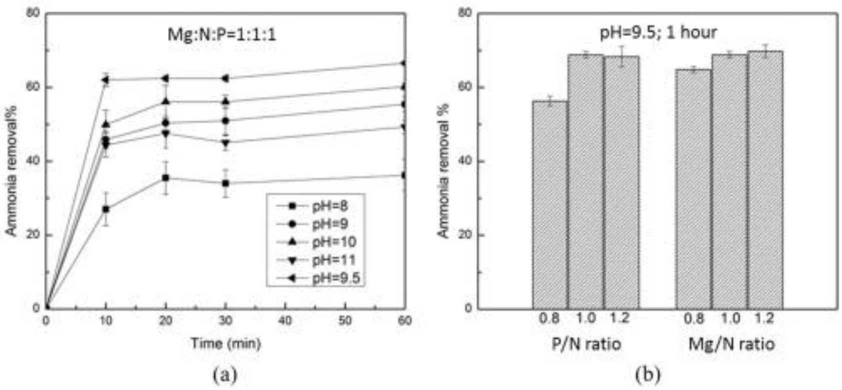

Figure 11: Lab-scale studies on optimal struvite precipitation process. (a) Effects of pH on ammonia removal efficiency. The Mg: N:P ratios remained at 1:1:1 for all cases. (b)

Recommendations to the author: The strength of the details offered by the researchers in the procedure of ammonia recovery is one of the scientific paper's strengths. In addition to a thorough analysis of the results acquired using graphs and an examination of all data obtained. In addition, different chemical equations are used to provide more precise findings. One of the paper's flaws is that the researchers did not describe how they developed the study, and additional resources that may have been used were not indicated if they were not available.

Six: Ammonia recovery from food waste digestate using solar heat-assisted stripping-absorption.

Lucas et al (2020) have used a simplified system that uses no chemicals, and a renewable source of energy for heating was tested to recover nitrogen as ammonium sulfate from food waste digestate.

Methodology: The pH of ground waste combined with tap water was 7.5, alkalinity was 7697, COD was 6548, and ammonia–nitrogen concentration (NH4-N) was 1381, 137 mg/L. Ground waste was piped to a fully stirred tank reactor (CSTR) and digested further in a UASB (Up-flow Anaerobic Sludge Blanket) reactor. Biogas was monitored, collected, processed, and stored under pressure in both reactors. A solid-liquid separator was used to separate the UASB reactor's effluent digestate.

Two 0.15-inch PVC columns and an air-stripping column made up the experimental arrangement (1.80 diameters). With various operational settings, both columns were run in an open-loop, semi-batch manner. All batch runs were completed in duplicate and lasted seven days. Figure 12 depicts a schematic flow diagram of the ammonia recovery process using solar heat and absorption.

The system was run in an open-loop, semi-batch mode with varied operational settings (25°C and 45°C; 1700 and 2600 gas/liquid ratios). The LD percolated through the packed bed within the stripping column and was collected for recirculating in a reservoir at the bottom. All batch runs lasted seven days and were done in pairs. The pH was determined using a digital pH meter (DIGIMED model DM-44) and the ammonia-nitrogen content was determined using the colourimetric phenol technique specified in Standard Methods for Water and Wastewater Examination. A portable thermocouple digital thermometer was used to take the temperature every day at 12 pm.

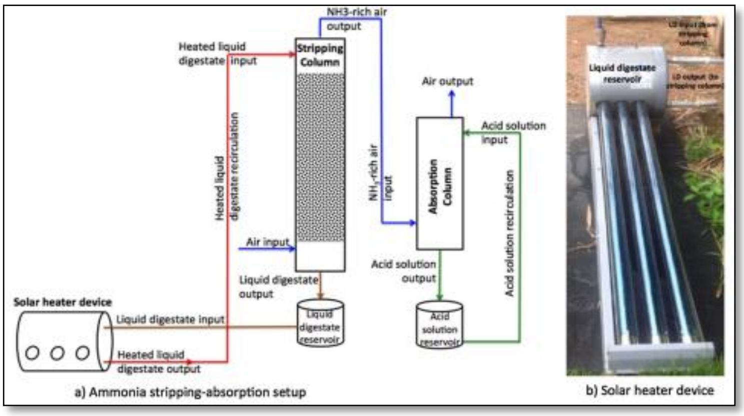

Figure 12: Schematic diagram of the ammonia recovery experimental setup

Results and Discussion: The results indicate that the studied process performed well, with high removal efficiencies reached for a variety of beginning ammonia concentrations, digestate types, treatment sizes, and experimental settings. The effects of various temperatures (25°C and 45°C) and gas to liquid ratios (1700 and 2600) on ammonia removal and recovery were investigated. For all of the tested experimental circumstances, ammonia removal efficiencies of more than 91% were attained. The solar heater could raise the temperature of the liquid digested by 21°C and maintain it at 30°C throughout the trial. Lower intake airflow rates and packing material in the absorption column might have theoretically resulted in higher absorption efficiency.

Recommendations to the author: The quality of the information offered by the researchers in the approach, as well as the described process conditions, was great and sufficient and was one of the scientific paper's strongest points. Additionally, reaction equations were used to determine the constant rate and yield of ammonia removal from food waste digestate. One of the paper's weaknesses is that the researchers used very expensive materials. Furthermore, images of the phases of doing the experiments step-by-step, beginning with the collecting of food waste and finishing with the final result achieved, should be included in the scientific article. Finally, no techniques for conducting the research were specified if alternatives to the materials utilized were unavailable.

Seven: Landfill Leachate Treatment Methods and Its Potential for Ammonia Removal and Recovery.

Hashlina et al (2021) have highlighted the recent development of landfill leachate treatment methods and their potential for ammonia removal and recovery.

Methodology: The absorption process is carried out when the air stripping process is completed. High concentrations of ammonia are produced during this process which can be used in the production of fertilizer. Air pollution reduction is also suggested by this process. The process involves the conversion of pollutants into a liquid phase. It is commonly done using acidic solutions. However, details about the absorption process following air stripping have only been studied in a few studies.

Table 4: Study on ammonia recovery through absorption

Type	Site	Absorption Media	Recovery Efficiency	Application

Municipal Solid Waste	Italy	H_2SO_4	N/A	Fertilizer
Municipal sanitary landfill	Sao Carlos, Brazil	H_2SO_4 solution	80%	Fertilizer
Plant waste	India	Phosphoric acid	N/A	N/A
Wastewater	China	N/A	99.9%	N/A

Discussion and results: The efficiency of the ammonia absorption process is high, with a figure of around 90%. H_2SO_4 is commonly used as an absorbent.

Recommendations to the author: Use some figures to explain the method. Write the procedures in general. Bring some more details to clarify. Only a few research has documented in detail the use of air stripping followed by ammonia recovery (absorption). In several cases, no information on the effectiveness of ammonia recovery or the absorbent utilized was provided.

Eight: Coupling electrochemical ammonia extraction and cultivation of methane-oxidizing bacteria for the production of microbial protein.

Khoshnevisan (2020) has done a study on the coupling electrochemical ammonia extraction and cultivation of methane-oxidizing bacteria to produce microbial protein. To limit pollution, nutrient removal is the main method of treating residual resources. However, recovering nutrients from various sources is not always an ideal solution. This is because the quality of the recovered resources can be very different from that of the original. Anaerobic digestion (AD) wastes and streams could potentially provide a platform to produce high-quality microbes. In this study, we explored the possibility of combining the recovery of nitrogen from these streams with the cultivation of Methanotrophs.

Methodology: A two-chamber electrochemical cell was used for the extraction of ammonium nitrate from aqueous solution. The cell was equipped with an anodic and a cathodic electrode. The reactor was also equipped with a cation exchange membrane. The cell was able to produce a volume of 200 cm3 in two chambered units. The reactor was equipped with an anodic, a cathodic, and a cation exchange membrane. The latter has a total exchange capacity of approximately 1.6 to 0.1 meq/g.

The compartments for the anode and cathode were made from Perspex frame components. A 10 current sensor was also added to the circuit to determine the current state. The anodic electrodes were made from titanium alloy and had a projected surface area of around 16 cm2. The anodic electrodes were made from titanium alloy and had a projected surface area of around 16 cm2. A titanium wire mesh was also used in the cathodic chamber.

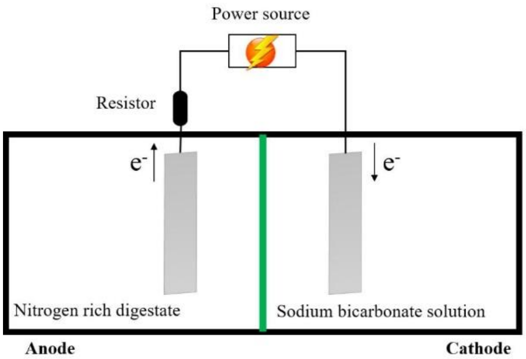

Figure 13: Electrochemical cell used for ammonium extraction: left anodic chamber filled with nitrogen rich waste streams and right cathodic chamber filled with bicarbonate media

The reactor was operated in batch mode at the ambient temperature of 22 degrees Celsius. The anodic chamber was filled with the ammonia-rich substrate while the cathodic chamber was filled with a 50 mmol sodium bicarbonate solution.

Table 5: Summary of alternated parameters for each experiment

Exp	Objective	Source of nitrogen	Total nitrogen	Voltage
1	Effect of nitrogen concentration and voltage on extraction efficiency	Synthetic urine	5 and 12 g N/L	3 V
2	Transfer of micro-pollutants during electrochemical extraction	Real male urine	10.33 g N/L	3.5 V
3	Effect of nitrogen sources from different residual streams on extraction efficiency	Manure-AD effluent	Varying based on the feed	3.8 V

Table 6: Characterization of aqueous residual streams tested in the present study for nitrogen recovery

Parameter	Unit	OFMSW digestate	Manure digestate	Urine
TS	g/kg	3.93	6.52	-

VS	g/kg	3.14	5.26	-
pH	-	7.3	8.1	6.1
TAN	g NH4-N/L	2.5	2.32	0.68
TKN	g N/L	3.5	3.06	10.33

TS = Total Solid; VS = Volatile Solid; TAN = Total Ammonium Nitrogen; TKN = Total Kjeldahl Nitrogen.

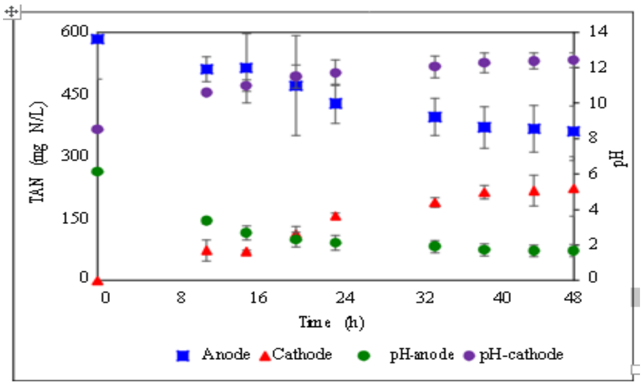

Figure 14: pH drift and transfer of ammonia nitrogen between anodic and cathodic chambers using male urine as nitrogen source in the anodic chamber

Discussion and results: The high and low ammonia concentrations were analyzed while the reactor was operating at 3.3 and 3.5V. The total nitrogen from ammonia and pH were measured in the anodic and the cathode compartments. The results of the experiments were then terminated after no significant TAN extraction was observed in the two consecutive measurements. In order to extract nitrogen from human urine, the reactor used a residual stream composed of human urine. After 48 hours, the TKN in the anode chamber decreased by 38%, reaching a value of 7.02 g N/L. The results indicated that a significant portion of the initial nitrogen was transferred to the anodic compartment. The transfer of nitrogen between the two chambers caused a significant drop in the pH of the anode chamber.

Nine: Ammonia recovery from wastewater using a bioelectrochemical membrane-absorbed ammonia system with authigenic acid and base.

Zhiqiang et al (2021) have done a study on ammonia recovery from wastewater using a bioelectrochemical membrane-absorbed ammonia system with authigenic acid and base.

Methodology: Na_2SO_4 and N-containing solutions were prepared for the salt and electrolyte solution. The anolyte was then synthesized with acetate solution, which included 0.13 g/L KCl, 3.32 g/L $NaH_2PO_4H_2O$, and trace minerals and vitamins. The solution was then fed to the anode chamber and exhibited various characteristics. These included a pH of 7.0, a conductivity of 7.0, and a COD of 0.65. The BEMAA system consists of five chambers and four membrane pieces. All of the chambers are made of plastic, and each has a hollow-core design. The anode chamber has a volume of 120 and 60 cm3 respectively, while the CaC has a volume of 60 cm3.

The other three chambers have the same net volume of 30 cm3. The anode chamber, DeC, and AbC are referred to as desalination chambers. The two main components of the system were separated by a piece of BPM, which was then arranged in an anion exchange membrane. The CaC and DeC were then subjected to a cation exchange membrane. A GPM was then set between the AbC and the CaC using a PP-supporting membrane. The anode was made of a 60 mm long graphite fiber brush, while the cathode was a piece of stainless-steel mesh. The two components were inoculated through a single-chamber membrane called the MEC. The anode chamber has a pore size of 22 mm, while the cathode has a 150e190 mm thickness. The anode was inoculated with an anaerobic sludge solution from a wastewater treatment facility. The CaC was then filled with a synthetic N-containing solution to maintain its purity. The DeC was then fed with a salt solution to maintain its purity.

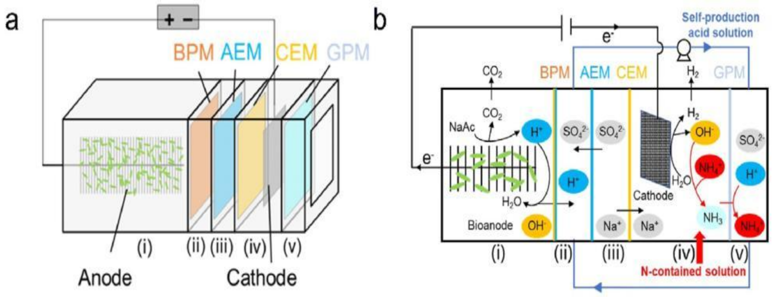

Figure 15: BEMAA system schematic diagram of (a) structure and (b) working principle: (i) AnC, (ii) AcC, (iii) DeC, (iv) CaC and (v) AbC

The 6 mM Na2SO4 solution was then added to the AbC and the AcC to maintain its purity. The two components were then connected to an emulsion tube, and the electrolyte was pumped through a peristaltic pump. The anolyte and catholyte were then recirculated through the pump's chambers, which each have a rate of 50 mL/min. The power supply was then used to apply voltage to the system. All of the experiments were performed in a 24-h duration, and the initial concentration of ammonium was set at 80 mM. The voltage was set at 1.0 V, and the initial ammonia recovery was set at 2.0 V. The various operation conditions of the system were shown in Table S1.

Analyzing the samples collected from the AnC was performed using a needle filter and a spectrophotometer. The objective of the study was to determine the variation in the chemical oxygen demand. The samples from the other two chambers were then analyzed using a spectrophotometer. They were then compared with the standard method to determine the ammonium concentration. The efficiency of an ammonium removal process is calculated by taking into account the initial and terminal concentration of the compound.

The concentration of the ammonium in the two chambers is Ca, e, and Vb. The distribution of ammonium is calculated as the following: Di 14 ci, e Vi, and P (ci, e Vi). In the case of the ammonium concentration in the chamber, the concentration of the compound is 14 mg/L, and the volume of the chamber is Vi. Since the 6 mM of ammonia used as the electrolyte in the AbC and the ACC, the efficiency of the process is higher in the CaC.

Table 7: Energy consumption comparison among various processes

Process	Energy consumption (kWh/kg-N)
Ammonia recovery (air-stripping and acid absorption)	5.04-57.7
Conventional ammonia removal	12.4
N-based fertilizer production	11.7
Haber-Bosch	10.3
BES ammonia recovery	4.5
BEMAA system	2.91

Discussion and results: A bioelectrochemical system was developed that enables the recovery of ammonia from wastewater by converting it into free ammonia using a combination of base and acid. This system was achieved using a desalination process that produces base and ammonium nitrate. In the solution, the recovery of ammonia was achieved with a high initial ammonium concentration and a low applied voltage. The efficiency of the recovery was 97.3 0.5% and 68.1 3.4%, respectively, with a low initial ammonium concentration of 20 mM. The high salt concentration in the chamber could also affect the recovery. The energy consumption of the system was relatively low at 2.91 kilowatt-hours per kilogram-hour. This is lower than the reported processes. The results of the study demonstrate that the system can potentially save energy by recovering ammonia from wastewater.

Recommendations to the author: Authors should mention kind of different values that were covered, and they should mention the limitations of the study as well.

Ten: Removal of Ammonia from the Municipal Waste Treatment Effluent using Natural Minerals.

Seruga, et al (2019) have done a study on the removal of ammonium ions using ion-exchange on various commercial minerals, in 3 h long batch ion-exchange experiments. Furthermore, research on the sodium chloride activation of the selected mineral was also conducted. Due to the various environmental problems that exist in wastewater, it is necessary to remove nitrogen from it. This study focused on the removal of ammonium ions from industrial wastewater.

Methodology: The wastewater was collected in a tank that was 650 m^3. To test the effects of various factors on the composition of the wastewater, such as its pH value, a batch ion-exchange experiment was performed. An electrochemical device was introduced to measure the ammonium ions. The screening of the minerals was performed to determine their removal efficiency. The results of the study were compared with those of the other minerals. The activation process was performed by mixing natural sorbent, which is bentonite I, with an aqueous solution containing sodium chloride. To study the effects of varying NaCl concentrations, 25 g samples of bentonite were suspended in the solution. Equilibrium concentrations of the NH_4^+ were considered to arrive at the total amount of ions that were adsorbed at a given time. The ammonium content of the wastewater was measured using an ion-selective electrode and a silver-chloride reference electrode. The values obtained by this method were then used to control the final concentration and the chemical oxygen demand was also measured using a cuvette device.

Discussion and results: The mineral with the highest potential for removal was identified based on the changes in the NH_4^+ cations. The maximum removal efficiency was achieved for ammonium ions with a capacity of 4.92 mg/g. For bentonite, the efficiency was 52.3%. The Langmuir and Freundlich models were also used to analyze the data. The Langmuir model exhibits a well-defined equilibrium, while the Freundlich model exhibits a mismatched result. The results of the study revealed that natural sorbents could be used in the treatment of wastewater. As the size of the sorbent particles decreases, the adsorption capacity increases, and the efficiency improves. However, the treatment with NaCl did not improve the efficiency.

Recommendations to the author: The author could mention storing the ammonia and different ways to collect it after the process.

CONCLUSION

The objective of this study was to review various processes to extract ammonia from a variety of sources. All pieces of literature were reviewed thoroughly for methodology and main findings. At the end of each literature, strengths and weaknesses have been notified. This study helped the team to develop a better understanding of the latest trends in ammonia extraction.

In the next stage, researchers are designing a system to extract ammonia from municipal waste in the Muscat municipality area.

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REFERENCES

1. Baltrėnas, P., Januševičius, T., Zagorskis, A. et al. (2021). Removal of ammonia by biofilters with straight and wavy lamellar plates. *Int. J. Environ. Sci. Technol. 18*, 1181–1190. https://doi.org/10.1007/s13762-020-02916-5
2. Chang, H. et al., (2022). Consideration of Potential Technologies for Ammonia Removal and Recovery from Produced Water. *Environmental Science & Technology*, *56*(6), 3305–3308. https://doi.org/10.1021/acs.est.1c08517
3. Fumoto, E., Tago, T. & Masuda, T., (2011). Recovery of Ammonia and Ketones from Biomass Wastes. *Progress in Biomass and Bioenergy Production*, 458. https://doi.org/10.5772/19914
4. Haslina, H., Ruwaida, J., Dewika. M, Rashid. M., Ali. A., Khairunnisa. M., and Daniel A. (2021). Landfill Leachate Treatment Methods and Its Potential for Ammonia Removal and Recovery - A Review. *IOP Conf. Series: Materials Science and Engineering*, 11. https://doi.org/10.1088/1757-899X/1051/1/012064
5. Khoshnevisan, B (2020). Coupling electrochemical ammonia extraction and cultivation of methane-oxidizing bacteria for the production of microbial protein. *Journal of environmental management*, *265*, 13. https://doi.org/10.1016/j.jenvman.2020.110560
6. Kinidi, L., Tan, I.A.W., Wahab, N.B.A., Tamrin, K.F.B., Hipolito, C.N., Salleh, S.F. (2018). Recent Development in Ammonia Stripping Process for Industrial Wastewater Treatment. *International Journal of Chemical Engineering*. https://doi.org/10.1155/2018/3181087
7. Lucas, M., Erik, M., César, M. (2020). Ammonia recovery from food waste digestate using solar heat-assisted stripping-absorption. *Waste Management*, *113*, 244-250. https://doi.org/10.1016/j.wasman.20 20.05.047.
8. Milne, I., Seager, J., Mallett, M. and Sims, I. (2000), Effects of short-term pulsed ammonia exposure on fish. *Environmental Toxicology and Chemistry*, *19*, 2929-2936. https://doi.org/10.1002/etc.5620191213
9. Ye, S., Michelle, T., Clive, C., Wende, X., Chi-Hwa, W. (2017). An environmental friendly animal waste disposal process with ammonia recovery and energy production: Experimental study and economic analysis. *Waste Management*, *68*, 636-645. https://doi.org/10.1016/j.wasman.2017.07.027.
10. Seruga, P., Krzywonos, M., Pyżanowska, J., Urbanowska, A., Pawlak-Kruczek, H., Niedźwiecki, Ł. (2019). Removal of Ammonia from the Municipal Waste Treatment Effluents using Natural Minerals. *Molecules*, *24*(20), 3633. https://doi.org/10.3390/molecules24203633
11. Thirunavakkarasu, P. (2017). *Optical fibre-based ammonia gas sensor with carbon nanotubes sensing enhancement*. https://doi.org/10.1109/TENCONSpring.2017.8069983
12. Yukihiko. M., Yuito, S., Takayuki. I., Wookyung. K., Yutaka. N., and Keiya. N. (2021). Reaction Rate of Hydrothermal Ammonia Production from Chicken Manure. *ACS Omega*, *6*(36), 23442-23446. https://doi.org/10.1021/acsomega.1c03418
13. Zhiqiang. Z., Zuobin. W., Jiao. Z., Ruifeng. D., Huaxia. P., Yaqi, G., Pengyu. X., Siqing. X. (2021). Ammonia recovery from wastewater using a bioelectrochemical membrane-absorbed ammonia system with authigenic acid and base. *Journal of Cleaner Production*, *296*, 126554. https://doi.org/10.1016/j.jclepro.2021.126554