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Methods for the Detection and Remediation of Ammonia from Aquaculture Effluent: A Review

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Abstract

Aquaculture practice is growing at an alarming rate in the world due to rising human population and improved agricultural activities. It is a very important sector that is contributing to the food security of various nations, generating employment and foreign exchange earnings for economic development. However, this practice produces large amount of ammonia based effluent thus threatening environmental sustainability. This review focused on the critical assessment of various physicochemical and biological treatments applied in the remediation of ammonia from aquaculture effluent. The physicochemical methods include mainly adsorption, photocatalytic and electrochemical degradation by different materials while the biological methods involve the use of plant biomass, animals and microorganisms. In addition, different detection methods of ammonia and environmental impact of climate change on aquaculture management system were discussed.

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1. Introduction

Aquaculture is a systemic rearing of fish in a confined body of water such as tanks and ponds, where its development can be monitored and controlled [1]. It is the fastest growing food processing sector across the globe [2].With the projected world population estimates of 9.3 billion by the year 2050, it constitutes a critical agricultural sub-sector that can contribute to the food security of the world [2]. It also serves as a means of employment generation and foreign exchange earnings for economic development. However, aquaculture practices have led to pollution of the environment, as some of the fish producing factories and industries in Nigeria and other developing nations do release varying degrees of untreated wastewater from ponds into different water bodies which have therefore led to water pollution problem. Treatment of aquaculture wastewater is necessary for environmental protection, water. Conservation (via recirculation), human health, etc[3]. Aquaculture effluent can also serve as an important source of natural fertilizers, irrigation, energy generation for domestic and industrial purposes [4-7]. Ammonia is one of the major constituents of aquaculture wastes, being the main product of excretion in fish. According to Lazzari and Baldisserotto [8], ammonia originates from the organic matter decomposition, excessive use of organic and inorganic fertilizers and death of phytoplankton. Ammonia presence in the aquatic environment is always in two forms; ionized

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and unionized forms. The increase in the level of un-ionized form of ammonia in water bodies leads to decrease in the rate of release of the compound in most aquatic organisms leading to prolonged accumulation in the blood tissues [9]. Furthermore, the increment in the presence of ammonia leads to defects in the aquatic organisms' physiology and thus affect the osmoregulation, growth, oxygen transportation, excretion, and disease resistance in fish [9-10]. In order to increase the quality of water in aquaculture system, different detection and treatment methods of ammonia in effluents needs to be fully understood.[11-12].

Hence, this study aims at reviewing different methods for the detection and remediation of ammonia from aquaculture effluents. It also assesses the environmental impact of climate change on aquaculture management system.

2. Environmental impacts of ammonia

Ammonia is a colourless gaseous compound with elemental composition of nitrogen (N) and hydrogen (H) in the ratio 1:3. It usually serves as a precursor to some food additives and fertilizers. Ammonia dissolution in water formed ionized species called ammonium ion [13]

i.e. $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

2.1. Effect on aquatic organisms

Toxicity of ammonia results in severe losses in fish hatcheries. This can be due to the different tolerance levels among fish species [13]. Ammonia in its unionized form is harmful to some species of fish even at concentration as low as 0.05 mg/L which can cause poor feed conversion and growth rates, infertility, susceptibility to diseases and bacterial infections [14].

In addition, exposure of fish to high concentration of ammonia may lead to hyperstability, equilibrium loss, uptake of oxygen, increased heart rate and other respiratory activity [13]. It also causes damage to tissue and gill, inactivity, convulsion, coma and finally death at concentration exceeding 2.0mg/L [15-19]. Ionic imbalance is also an effect associated with high ammonium concentration in the fish blood [20].

2.2. Eutrophication

Eutrophication usually arises when a water body becomes too enriched with minerals and Nutrients (commonly ammonia and phosphorous) and thus inducing excessive algae growth and depletion of oxygen in the waterbody [21]. The processes involved can be broken down as follows:

1. excess nutrients accompanied the discharge of waste into the soil
2. nutrients leached to the soil, which is later drained to the waterbodies
3. the nutrients lead to excessive algal formation
4. the excessive algae formed inhibits the solar light from reaching the underground of the waterbody
5. the plants under the algae died due to their inability to photosynthesise
6. the algae also died and sinks into the underground part of the water
7. bacteria decompose the remains by consuming the available oxygen through respiration
8. the decomposition leads to the depletion of oxygen in the water
9. the waterbodies can no longer support life again and thus fish and other larger organisms suffocate and die.

Globally, countries have started proposing policies and programme to prevent and mitigate the effects of eutrophication in their aquatic environment. For instance, in Europe and Asia, efforts undertaken between 2010–2020 have resulted in the formulation of baseline guidelines on the urban wastewater treatment [22].

2.3. Formation of toxins

Continuous release of aquaculture effluents containing ammonia and some other pollutants into water bodies has been found to enhance the formation of certain harmful microorganisms like algae [23].The produced toxins can stay inside algal cells for long or released into the aquatic environment. Thus, animals present in such environment may be affected by ingesting the algal cells via drinking or feeding. The toxins could also be bioaccumulated and biomagnified through the food chains till it reaches toxic levels in some organisms and later consumed by man [24].

2.4. Reduction in aesthetic value of the environment

Discharge of aquaculture effluents into soils and surrounding water lowers the aesthetic value of the environment. For instance, Akinrotimi *et al.* [25] reported the release ofn unpleasant odour caused by the presence of ammonia in the wastewater from selected catfish farms within Port Harcourt metropolis, Nigeria. It was opined that the continuous release of such untreated effluents could result in major outbreak of epidemic diseases in the future if not abated.

3. Detection of ammonia in water and wastewater

Over the years, several methods have been developed by researchers for the detection and quantitation of ammonia and ammonium ion in water and wastewater. These include nesslerization, phenate, electrochemical, fluorometric methods, etc.

3.1. Nesslerization method

This involves the reaction of alkaline solution of mercuric potassium iodide–K_2HgI_4 (Nessler's reagent) with ammonia to give a coloured complex with concentration determined by UV/Vis spectrophotometry. Researchers have continued to improve on this method with some modifications. Typical example was reported by Phansi *et al.* [26] wherein Nessler's reagent was combined with a paper-based analytical device to determine levels of ammonia in fertilizers and wastewater by capturing the colour intensities and colour image through the camera and using the Image-J program. Also, a computer camera could be used to detect the variation in colour of the wastewater upon the reaction of Nessler's reagent and ammonia concentration could be calculated from the available data [27]. The advantages of this method are low cost and relative simplicity since it involves only one reagent. However, researchers have raised concern on the toxicity of the reagents and possible interference of the process by the presence of cations [28].

3.2. Phenate method

The phenate method is based on the reaction of phenol and hypochlorite with ammonium salt in a sample to form a blue coloured compound known as indophenol via addition of a catalyst (such as nitroprusside) and further analysis by UV-Visible spectrophotometer [29]. The phenate and modified phenate methods are the commonest spectrophotometric methods deployed in the determination of ammonium level [30-32]. The major challenge of this method is that phenol is odorous and toxic in nature. In the modified phenate method, phenol is replaced with more environment friendly compounds such as salicylate, o-phenylphenol (OPP), etc [33-38]. However, the use of salicylate has not been satisfactory due to low sensitivity [39-41].

3.3. Ammonia Probe method

This method involves the transfer of ammonia across a gas permeable membrane until the partial pressure in the thin film of the solution between the probe and the glass electrode membrane equals that of the sample solution**.** According to Evans and Partidge [42], a precision of 4% was achieved from the recoveries of repeated calibrations and added ammonia in the probe. The detection limit of 0·03mg/L was reported for ammonia levels above than 0·4mg/L. This method has been employed to measure ammonia concentrations in different water samples. Its disadvantages include low detection limit, relatively high cost, etc.

3.4. Gas diffusion method

In gas diffusion method, ammonium salt is converted to ammonia in a gas diffusion unit under alkaline conditions for removal of interferences in the samples. This is followed by the diffusion of ammonia gas into an acid-base indicator solution (such as Bromothymolblue) across a membrane whose absorbance can be determined spectrophotometrically [43-46]. Other pollutants such as nitrate, nitrite and phosphate can also be measured with this method [43]. Some of the merits of the method include moderate sensitivity, short analysis time, etc.

3.5. Fluorometric method

Fluorometry is a rapid, simple and sensitive emission spectroscopic method. It is based on the absorption of radiation at one wavelength and its emission at longer wavelength by fluorophores. Fluorophores largely contain aromatic rings, conjugated double bonds, etc. Fluorometric method was first reported by Roth [47] for amino acid determination. This process involved the reaction of amino acids in the sample with o-phthaldialdehyde (OPA) usually with the aid of a catalyst such as 2-mercaptoethanol in a basic medium to produce a strongly fluorescent compound. The modified procedure involved the use of sulphite instead of 2-mercaptoethanol which formed OPA-sulfite-ammonia which is more sensitive for the determination of ammonia than amino acids [48]. Furthermore, a modified OPA-based method involving integrated system of sequential injection analysis to ascertain ammonium levels has been utilized [49]. The method was enhanced by combining with an automated micro-extraction template for pre-treatment [50]. Greater sensitivity was achieved when the system was incorporated with two independent microsyringe pumps in a gas-liquid extraction procedure which generated gaseous ammonia in the headspace of the first microsyringe while there is movement into the headspace of the second microsyringe [49]. The limit of detection (LOD) was 2.8 nM. Also, a pre-treatment method was used to trap ammonia present in sea water samples [51].

In this method, alkaline sample was introduced into purified argon to eject the ammonia from the solution into the gaseous phase and analysed with the OPA method. Recently, Cao and co-workers introduced a new approach by reacting benzylchloride with ammonium and sodiumbicarbonate, where a new fluorescent derivative was produced upon excitation and emission at 258 nm and 284 nm respectively [52]. The advantages of this method include low cost, high sensitivity, selectivity, relatively short analysis time, etc [53].

3.6. Electrochemical methods

Electrochemical methods depend on the measurement of the variations in the electrical properties (such as current, voltage, conductance, resistance, etc) as a result of chemical interaction (redox) occurring at the electrode surface in the presence of the analytes in a given matrix. Advantages of electrochemical methods are short analysis time, high efficiency, relatively low cost, etc [54-57]. Electrochemical methods that have been applied for ammonium determination include potentiometric, amperometric, voltammetric and conductivity methods [57].The most widely utilized electrodes are the ammonium ion-selective (AIS) and nanomaterial-modified electrodes. AIS electrode involves a sensitive membrane comprising polyvinylchloride (PVC) which can selectively respond to ammonium ions. A potential is developed by the membrane as the electrode is placed in an aqueous medium and thus selectively detect ammonium [58]. The last two decades have witnessed a paradigm shift towards the use of nanomaterials-modified electrodes due to their unique, tailorable electrical properties, large surface area to volume ratio, improved sensitivity, specificity and selectivity for the determination of analytes [59]. In nanomaterial-modified electrodes, modifications can be imparted through the

Figure 1. Schematic representation of methods for analyzing ammonia in water and wastewater

designation of nano-functional materials with specific chemical properties on the electrode surface. Carbon nanotubes (CNTs) are one of such nanomaterials with the capacity to completely enhance the electrode response to ammonia. CNTs possess a high surface area and their composites could serve as suitable templates for advanced sensor design. Baciu *et al* [59] utilized silver-modified CNT (Ag-CNT) for electrochemical sensing of ammonium and nitrite ions in aqueous solution. Zhang *et al* [60] carried out electrode position of platinum nanoparticles on the surface of Ag/PPy-polypyrrole-Ni foam for the sensitive and selective detection of ammonia (LOD value of 37 nM).The result showed a significant left shift by the oxidation potential. The biosensor was found to be relatively stable and displayed reliable percentage recovery compared to Nessler's method. The list of detection methods for ammonia in water and wastewater is shown in Figure 1.

4. Remediation of ammonia from aquaculture effluents

The recirculation of wastewater depends on an effective and efficient means of treatment due to the various impacts of ammonia in the ecosystem. To maintain the quality of water, methods such as biological, chemical, physical or combination of any two are applied for sustainable production of fish and other aquatic organisms [61].Important parameters usually considered during the various treatment methods include temperature, pH, dosage, etc [62].

4.1. Physical and chemical treatment

In recent years, adsorption, photocatalytic degradation and electrochemical treatments have been the main physico-chemical methods employed for ammonia remediation in aquaculture effluents. Adsorption is a surface phenomenon which involves the attachment of pollutants to the surface of the adsorbent. It is very important that the material to be used for adsorption should possess certain desirable properties such as inertness, cheap cost, eco-friendly, superficial area elevation and basic centres dispersed on the surface for adsorption of pollutants [9, 12]. Different materials that have been applied recently include clay, biochar, chitin, chitosan, composites, nanoparticles, etc (Figure 2).

4.1.1. Adsorption with clay

Several clay materials have been studied for the adsorption of toxic substances from aquaculture wastewater. Examples include clinoptilolite, bentonite, zeolite, smectite, etc. For instance, Zadinelo *et al.* [9] studied the application of smectite clay for the adsorption of $NH_4{}^+$ from aquaculture effluent. The contact time of the smectite clay in the effluent did not lead to an appreciable increment on the adsorption of $NH_4{}^+$ within 1min to 3 h range. 94% ammonia removal with little concentration of dry clay was achieved [9]. Dryden and Weatherley [63] applied clinoptilolite and natural dry clay for the adsorption of $NH_4{}^+$ from aquaculture effluent. The removal efficiency of 98% and 92% respectively were obtained. Furthermore, the presence of other cations is also a major factor influencing the removal of $NH_4{}^+$. The selectivity of clinoptilolite for different cations is in the sequence: K+>$NH_4{}^+$>Ca^{2+}>Mg^{2+} [64,65]. Thus, from literature survey, the presence of K^+ affected the exchange of $NH_4{}^+$ in clinoptilolite with remarkable reduction in the exchange capacity of zeolites in a synthetic effluent experiments of $NH_4{}^+$: K^+in1:1 [66]. Also, Sarioglu [67] observed the selectivity of zeolites for different cations according to this sequence: $K^+ > NH_4{}^+ > Na^+ > Ca^{2+} > Fe^{3+} > Al^{3+} > Mg^{2+}$. Similar pattern was reported by Dontsova *et al.*[68] using bentonite clays. The parameters influencing the removal of $NH_4{}^+$ ion with clay in the wastewater included dosage, other cations in the solution, etc.

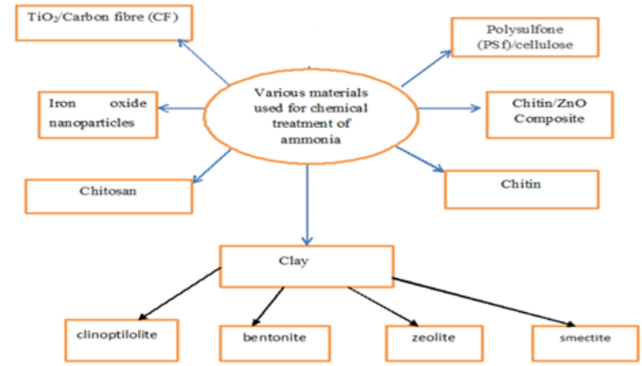

Figure 2. Schematic representation of materials used for chemical treatment of ammonia from aquaculture effluent

4.1.2. Adsorption with biochar

Biochar synthesized from rice straw was examined for its potential use for ammonium adsorption from aquaculture effluent [69]. Removal efficiency was strongly affected by pH, adsorbent concentration, modification methods of rice straw. Maximum ammonium removal efficiency was achieved at neutral pH.

4.1.3. Adsorption with chitin and chitosan

Chitin is one of the most abundant polymers in nature which is the building material for exoskeletons of insects, crustaceans and can be converted to chitosan through chemical deacetylation process [70]. Bernardi *et al.* [70] studied the adsorption efficiency of chitin and chitosan from various sources for the treatment of ammonia from natural aquaculture and synthetic effluents. Chitosan sources include freshwater and marine shrimps, three different commercial chitosan and laboratory synthesized chitosan. Commercial chitosan1and 2 gave 100% efficiency for ammonia removal from synthetic effluent whereas none of chitin sources were efficient in ammonia treatment from synthetic effluent.

4.1.4. Electrochemical treatment

Electrochemical wastewater treatment involves the application of electric field between electrodes to decontaminate toxicants found in effluents via redox processes. Monica *et al.* [71] pioneered the application of electrochemical treatment for the removal of ammonium and organic pollutants in effluents mixed with seawater. Its advantages include high efficiency, versatility, little sludge generation, etc [72-73]. Electrochemical oxidation of ammonium and organic substrates can be carried out via direct or indirect anodic oxidation methods. In the former, adsorbed hydroxyl radicals are involved in the oxidation of organic compounds [74-75]. Marinerc *et al.* [76] conducted a direct electro-oxidation of ammonium on a platinum plated anode and a titanium-plated anode. The direct electro-oxidation of nammonium was reported to be more favourable. In the case of the in direct method, anodically-generated oxidizing agents were added into the wastewater to degrade organic and inorganic pollutant [77-78]. The *in-situ* electro-generation enhanced the degradation efficiency. Mao *et al*. [79] developed a chlorine mediated reactive barrier comprising inert electrodes for ammonia contaminated groundwater remediation experiment in a batch scale.

Findings revealed that ammonia in the groundwater could be readily converted into a more desirable nitrogen. Higher ammonia removal efficiency was achieved at higher current densities and bicarbonate concentrations. In general, the overall efficiency of the electrochemical treatment is influenced by parameters such as pH, current density, electric voltage applied and the nature of electrode material used [80-83]. The nature of the anodic material and electric voltage applied are the most critical parameters determining the overall cost and optimum removal efficiency of an electrochemical treatment process. Some of the drawbacks of this method include high cost, high energy consumption, instability and poor electrocatalytic activities in the long term, etc [84].

4.1.5. Photocatalytic degradation through nanocomposites

Photocatalysis; one of the forms of advanced oxidation processes (AOPs), involves the interaction between radiation and a solid semiconductor in an aqueous medium. Nanomaterials have been reported as excellent photocatalysts for degradation of toxicants [85]. Nanocomposites exhibit excellent thermal, electrical, mechanical properties. Also, they possess large surface area, efficient charge transportation and separation, etc [86].

Nanocomposites involve the fabrication or synthesis of materials from two or more different constituent materials on a nanoscale to enhance their properties and functionality. Due to low efficiency of chitin towards the remediation of ammonia from aquaculture effluents [70], chitin/ZnO nanocomposite photocatalyst powder was fabricated by Lin *et al* [56] through sol-gel method for treatment of ammonia from aquaculture effluent under ultraviolet irradiation.

Factors affecting the degradation process include dosage, temperature of calcination, mass ratio rate, initial concentration of ammonia and conditions of illumination. 88.64% removal efficiency was achieved using 0.5g/L chitin/ZnO(2:3) photocatalyst at irradiation time of 2 h and 500 °C calcinations temperature. Yu *et al*. [87] synthesized and treated ammonia with TiO_2/carbonfibre (CF) nanocomposite, TiO_2 and carbon fibre photocatalysts from aquaculture wastewater. Parameters such as dosage, calcination temperature of the adsorbent, etc, were studied. The best conditions for ammonia treatment were 2.0g/L dosage for TiO_2/CF, calcinations temperature of 600°C, initial ammonia concentration was 30 mg/L at illumination time of 1 h and H_2O_2 concentration of 0.8g/L. The results showed that the composite (TiO_2/CF) was most effective compared with CF or TiO_2 alone for ammonia treatment.

4.2. Removal of ammonia through biological treatment

Treatment of wastewater through biological processes usually involves the conversion of ammonia and nitrate by microbes to nitrogen gas. This is a modern, cost effective method for ammonia treatment which readily converts it into nitrogen gas [62] i.e

$$NH_4^+ + NO_3^- \rightarrow N_2 + 2H_2O$$

However, biological treatment is usually time consuming as some of the process involves longer period of time spanning weeks and months before the treatment can be achieved. The schematic representation for the various biological methods is shown in Figure 3.

4.2.1. Natural biodegradation in anaerobic continuous flow system

Ching and Redzwan [88] studied the effect of concentration of salt (NaCl) in natural biodegradation of ammonia in aquaculture effluent in an aerobic continuous flow system. The ammonia removal efficiency reduced as the dilution fold of the aquaculture effluent increased.

Optimum % ammonia removal efficiency was obtained after 10 days. This procedure is suitable for small scale aquaculture wastewater treatment. The treatment method produced an odourless effluent which can be reused as an eco-friendly fertilizer because the main constituents are known organic substances which are non-toxic or carcinogenic. Further experiments should involve the impacts on the plants, soil, the different yields of the crops through irrigation with different salt content and application in a large scale fish processing industries [88].

4.2.2. Remediation with microorganisms

Studies have shown that microalgae are excellent bioremediators for effluents treatment with high nutrient concentrations [89]. Lananan and co-workers [89] reported the remediation of ammonia and phosphorous from aquaculture effluent through symbiotic process by using Effective Microorganism (EM) and

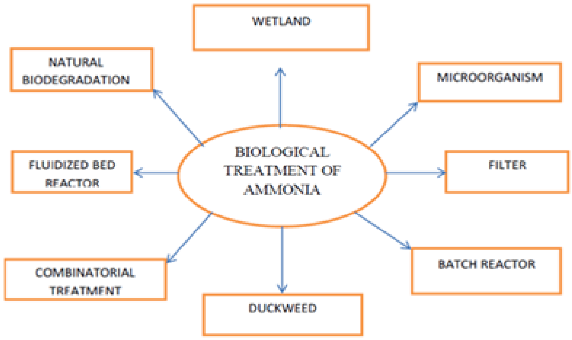

Figure 3. Schematic representation of various biological methods for the treatment of ammonia

microalgae of *Chlorella* specie. The treatment of aquaculture effluent was performed in batch scale comprising working volume of 2 L and treatment period of 14 days.Total ammonia present was almost removed from the aquaculture after the initial 7 days. Batch scale experimental data yielded varying inoculation concentrations of bioremediators and retention time which can be used in the advancement of aquaculture effluent treatment in a continuous process for real effluent application.

Omitoyin *et al.* [90] studied the application of duckweed and microorganism (*Bacillus species*) in the removal of certain pollutants in aquaculture effluent. The measured total suspended solid, biochemical oxygen demand, total ammonia nitrogen (TAN) and phosphate were above the permissible limits of wastewater discharge into surface water according to WHO standard [91]. The result of the remediation process showed that the *Bacillus sp.* has the highest removal efficiency for ammonia. The duckweed is effective for toxic organic waste removal for aquaculture effluent. The duckweed technology is simpler and more cost effective than *Bacillus specie* which required expertise for its isolation, identification, mass production, application and only effective in ammonia, nitrite and phosphate removal from wastewater.

4.2.3. Filters

Trickling filter is the main type of filter that has been employed for ammonia remediation. It consists of a fixed bed from which filtered effluents flow down over anaerobic biofilm. Important factors considered during filter selection include waterflow, surface area, etc [92]. Lekang and Kleppe [93] investigated different filter media such as Kaldnes rings, Norton rings and a rolled mat of Finturf artificial grass in the treatment of ammonia. The Leca filter gave the highest denitrification rate of 100% because it has longer retention times and larger surface area. The specific surface area indicates the surface required in homogenous water flow and biofilm growth. Disadvantages of this method include clogging and biofilm shedding, high production cost, etc [94-96].

4.2.4. Fluidized bed reactor

Fluidized bed reactor is known to be a solution to clogging problems peculiar to trickling filters. It is an efficient method to remove dissolved solids and wastes from aquaculture recirculating systems when compared to bed and trickling filters [97]. The size of the particle is an important factor influencing the treatment process [98].The performance of this system is being affected by the type of medium. Davidson *et al.* [99] studied the removal of total ammonia nitrogen (TAN) and other pollutants from effluent using two sand sizes. 88% efficiency for TAN removal was obtained from 0.11mm sand size.

Schnel *et al.* [100] investigated the use of different filters comprising polyvinylchloride strips and fixed particle sand for TAN removal. The efficiency of the whole process for total ammonia nitrogen (TAN) was 65.21%. Recently, much attention has been focused on the integration of fungal bioreactors into the wastewater treatment plants [101-102]. In particular, a microbial membrane bioreactor was designed to study the removal efficiency of ammonia and some other pollutants in marine aquaculture wastewater. 85% ammoniacal nitrogen removal efficiency was achieved after 40days [103]. Dalecka *et al.* [104] conducted a batch scale experiments and compared it with bioreactor with the use of *T. versicolor* and *A. luchuensis* for non-sterile municipal wastewater and the effect of pH on NH_4-N. The results in the fluidized bed bioreactor gave contrasting performance regarding ammonia removal relative to a batch experiment where no major change on NH_4-N reduction was observed. The fluidized bed bioreactor and batch scale experiments revealed a good starting point towards the optimization of fungal treatment application in wastewater. However, further development and optimization of fluidized bioreactor using fungi and other microorganisms should be studied [104].

4.2.5. Wetlands

Wetlands can be categorized into natural and constructed wetlands. Natural wetlands have been applied to remove microorganisms, phosphorous, nitrogen, trace elements and suspended. Solids contained in effluents [105]. Constructed wetlands which are also referred to as artificial wetlands have replaced the loss of natural wetlands in the treatment of agricultural, municipal and industrial effluents. Generally, major types of constructed waste water wetlands viz: surface flow (SF), and sub-surface flow (SSF) systems [106-108] have been applied for effluent treatment to minimise pollution. Lin *et al.*[109] reported a combination of subsurface and surface wetlands for the treatment of phosphorus and nitrate from aquaculture effluents. The removal efficiency of 82-99% was achieved for nitrate.

Currently, hybrid reed bed constructed wetlands (HRBCW) is gaining more recognition due to their higher removal efficiencies as secondary and tertiary treatment of domestic waste waters [110]. Jehawi and co-workers [111] constructed a *Scirpus grossus*-planted HRBCWsystem to treat some pollutants in a domestic waste water. The result showed that significant higher performance was observed with 84.7% ammoniacal nitrogen removal efficiency while the unplanted system recorded 74.8% efficiency. The advantages of constructed wetlands are in its cost and removal effectiveness, lesser skilled labour but required large surface area land for construction [96].

4.3. Importance of waste water remediation towards environmental sustainability

Waste water treatment, reuse, and safe disposal have gotten application for industrial, agricultural, recreational purposes, drinking water supplies, energy generation and thus becoming crucial in mitigating the effects of climate change and environmental sustainability. Climate change mitigation which is geared towards environmental sustainability involves actions to be taken to minimize the effects of global warming by reducing human emissions of greenhouse gases (GHG) [112]. The combustion of fossil fuel is responsible for most carbondioxide and GHG emissions [112]. It is therefore necessary to reduce or stop the use of constituents from petroleum and coal by replacing them with eco-friendly energy sources. One of the best ways to achieving this is proper utilization of water resources for power generation.

Furthermore, urbanization and intensive agricultural practices have led to an increase in abandoned farmland [113-114]. Desertification can be described as the major environmental challenge of our time. It has led to temporary or permanent reduction in quality of soil, vegetation, water resources, livestock and wildlife and therefore threatening food security and livelihood of man. This usually arises from inadequate potable water for grazing purpose and thus, cattle are made to move outside their ranches in search of food which usually result in the destruction of vegetation. All efforts are therefore needed to ensure generation of good water and recycling of wastewater towards environmental sustainability.

5. Future outlook and conclusion

Several chemical pollutants are found in a typical aquaculture effluent, ammonia being the major pollutant with high environmental impacts. Various detection techniques as well as remediation methods are reported for ammonia in effluents. Biological methods are highly recommended for ammonia treatment in terms of cost effectiveness and environmental concerns. However, the biological methods are relatively slower compared to the chemical treatments. Generally, technologies have been recently developed towards the use of chemical methods that are cheap and environment friendly to overcome the challenges inherent in the biological treatment methods. Among the various chemical methods, application of micro and nanomaterials for wastewater treatment is increasing due to very high global demand for freshwater. Nanotechnology has proven to be a remarkable success in the detection and remediation of ammonia due to relatively larger surface area and improved physicochemical properties. However, nanomaterials might have the potential risk of leaching into the treated water mainly during application, thereby leading to penetration of the living system through endothelial and epithelial barriers into the blood, lymph and ultimately to various tissues and organs where severe damage could be done.

Therefore, future emphasis should be placed on the investigation of the safety of nanomaterials applied for ammonia detection and remediation. Also, greener and economically sustainable synthesis routes for nanomaterials should be explored to reduce cost and improve accessibility.

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