International Journal of Mechanical and Thermal Engineering

E-ISSN: 2707-8051
P-ISSN: 2707-8043
IJMTE 2025; 6(1): 85-91
www.mechanicaljournals.com/ijmte
Received: 14-01-2025
Accepted: 19-02-2025

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Iron nanoparticles production for polluted water treatment for drinking and agricultural purpose: Current status and future perspective

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Abstract
With increasing population and industrialization; anthropogenic activities have led to increased water pollution, creating serious problems for accessing drinking water and water for agricultural purpose. The situation is worst for rural dwellers. This study ‘’iron NPs production for treatment of polluted water for drinking and agricultural purpose: current status and future perspective’’ is a deliberate effort towards solving the menace of water pollution. The paper has reviewed the different methods of iron NPs production. It took a critical look at the chemical method, where iron salts, reducing agents, and capping agents are used for the production of iron NPs. It then moved on to green chemistry methods, where iron salts are used with plants roots and leaves, and other organic extracts as reducing agents to produce iron NPs. This method had been adjudged to be compatible with the environment, cost effective and environmentally friendly. Ultrasound-based technologies have emerged as another powerful synthesizing technique used for iron nanoparticles production; this has also been reviewed in this work. Of interest in this review is the current research break-through where DWTS and slaughter house wastewater was used to produce iron nanoparticles for polluted and wastewater treatment. The paper has clearly posited that iron NPs can be used in the treatment of wastewater. Iron NPs remove pathogens and bacteria from polluted water through a well-articulated mechanism of coagulation, adsorption and photo-catalysis. The paper has stated the WHO standard for portable drinking water that must be met while treating water with iron NPs. The emphasis of this review is on the fact that great advancements are being made in the production of iron NPs and their use for treatment of polluted water in a world that the population is slightly above 8billion people; this is very important.

Keywords: Polluted and wastewater, iron NPS, treated wastewater, who standard; SEM image, agriculture, mechanism, adsorption

Introduction
Iron is one of the most-used engineering metals in the world today. It is the main constituent found in structural steels, which are used in the construction of buildings, ships, bridges, and railways. In the nano form, Fe behaves quite differently from its bulk form. For example, there is considerable research into using zero-valence Fe (Fe^0) or nano Fe to detoxify water contaminants and improve the quality of water for use in agriculture and drinking water supplies (Poinern, 2015) [16].
Nanoiron can be produced using many methods like green chemistry, and wet chemical methods. Nanoiron can be made from $FeCl_3$, sodium citrate and sodium borohydride ($NaBH_4$).
Ultrasound-based technologies have emerged as another powerful synthesizing technique used in nanotechnology-based research and applications. As a form of radiation, ultrasound has the capacity to break chemical bonds and create products. The ultrasound frequency range is above 20 kHz and can reach frequencies in the giga hertz level. When a liquid like water is irradiated by ultrasound, bubbles are created, which rapidly grow and on reaching a maximum size, collapse (Cavitation process). The sudden implosion of the bubbles, (about 100$um\ in\ size$) creates a local hot spot, which can reach temperatures as high as 5000k and pressures of up to hundreds of atmospheres depending on the level of ultrasound power used. At the same time the cooling rates are extremely high and can be as great as 10^{11}k/s.
The capacity of ultrasound to create these extreme temperatures and pressures within a medium makes this techniques attractive. For example, Suslick *et al.*, (1991) [20], were able to demonstrate that when $Fe(CO)_5$ was subjected to ultrasonic irradiation, NPs of Fe between 5 and 20 nm could be produced (Suslick *et al.*, 1991) [20].

A recent and novel green chemical approach to synthesize NPs involves the use of natural biological molecules as reducing and capping agents' plants extracts from leaves, stems, and roots have been used to synthesize a variety of metallic NPs, such as plates, rods, cubes, and even pyramids. In addition, both fugus and bacteria have shown the potential to synthesize NPs and appear to be low-cost and energy efficient ways to create NPs (Poinern, 2015) [16].

Nanotechnology is envisioned to constitute a significant part of the next technological revolution that is the fourth generation of industrialization to happen in this modern era; industry 4.0. Hence, the production and analysis of nanoparticles, which is the building block of nanotechnology, and their properties has become one of the most active subjects of substantial research in modern material sciences. Typically, the methods used for the formulation of metal nanoparticles can be classified into two different categories Top-down and Bottom-up (Preetha, and Rani, 2012; Essien and Otobong, 2017) [17].

In the manufacture of and fabrication of NPs and nanometer-scale structures, several synthesis parameters must be effectively controlled to deliver a satisfactory outcome (Katsnelson, 2007; Obikwelu, 2012 [15]; http:// www.nanowerk.com/) [11]. Just being below the 100nm mark is not enough, and the synthesis parameters must be controlled so that the following conditions are met: (1) identical NPs are made every time (i.e., same diameter and shape), (2) they have the same morphology, (3) the same crystal and chemical bonding occurs whether on the surface or inside the NPs and (4) the synthesis process must be stable; if these four conditions are met, then the synthetic process can be considered as reproducible and is a reliable technique.

Today, there are many techniques capable of manufacturing NPs and nanometer-scale structures from solids, liquids, and gases. The solid-base techniques used to manufacture NPs is straightforward and is usually done by attrition. Liquid-phase based techniques include hydrothermal synthesis, co-precipitation, sol-gel processing, microemulsion, reverse micelle synthesis, microwave synthesis, ultrasound synthesis, and template methods. Gas-phase based techniques are generally carried out by vaporizing a precursor material in a suitable atmosphere. This step is then followed by rapid cooling, which produces supersaturation and condensation to produce NPs and nanometer-scale structures (Kuldeep, *et al.*, 2012; Poinern, 2015; Khatoon, *et al.*, 2017) [12, 13, 16].

In nano-technology, there are two main methodologies used to design and manufacture NPs and nanometer-scale structures the first is the topdown method, and the second is the bottom up method. The second method is commonly used. For instance, NPs and nanometer-scale structures can be made by either homogeneous or heterogeneous nucleation from liquids or vapours. For example, one widely used chemical method is to use micelles or reverse micelles to contain the chemical reactions with nanometer-scale or micrometer-size volumes. Within these confined volumes nucleation and growth of NPs and nanometer-scale structure take place. The advantage of this technique are that it can be done at ambient conditions, and it can be easily scaled up to produce macroscopic quantities of nanometer material (Poinern, 2015) [16].

Dara (2007) [5] once said ''any human activity that impairs the use of water as a resource may be called water pollution. With exploding population of about 8 billion people in the world and increasing industrialization and urbanization, water pollution by agricultural, municipal, and industrial sources has become a major concern for the welfare of mankind. Water is essential for the survival of any form of life. On an average, a human being consumes about 2 litres of water every day. Water accounts for about 70% of the weight of a human body. About 80% of the earth's surface (i.e. 80% of the total 50,000 million hectares in area) is covered by water. Out of the estimated 1,011 million km3 of the total water present on earth, only 33,400m3 of water is available for drinking, agriculture, domestic and industrial consumption. The rest of the water is locked up in oceans as salt water, polar ice-caps and glaciers and underground water. Owing to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increasing tremendously. The world population is today above 8 billion people. Moreover, considerable part of this limited quantity of water is polluted by sewage, industrial wastes, and a wide array of synthetic chemicals. The menace of water-borne disease and epidemic still threatens the well-being of population, particularly in under-developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind (Dara, 2007) [5].

In this present work the authors' main objective is to review methods of producing iron nano-particles, water and the problem of pollution, application of iron-based nanoparticles to polluted water treatment, mechanisms of treating pollutants by iron nanoparticles, limitations of using iron-based nanoparticles and future perspectives.

Water for drinking and agricultural purpose: the problem of water pollution

Dara (2007) [5] once said ''any human activity that impairs the use of water as a resource may be called water pollution. With exploding population and increasing industrialization and urbanization, water pollution by agricultural, municipal, and industrial sources has become a major concern for the welfare of mankind. Water is essential for the survival of any form of life. On an average, a human being consumes about 2 litres of water every day. Water accounts for about 70% of the weight of a human body. About 80% of the earth's surface (i.e. 80% of the total 50,000 million hectares in area) is covered by water. Out of the estimated 1,011 million km3 of the total water present on earth, only 33,400m3 of water is available for drinking, agriculture, domestic and industrial consumption. The rest of the water is locked up in oceans as salt water, polar ice-caps and glaciers and underground water. Owing to increasing industrialization on one hand and exploding population of over 8 billion people on the other, the demands of water supply have been increasing tremendously. Moreover, considerable part of this limited quantity of water is polluted by sewage, industrial wastes, and a wide array of synthetic chemicals. The menace of water-borne disease and epidemic still threatens the well-being of population, particularly in under-developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind (Dara, 2007) [5].

Water pollution is a very serious problem in Nigeria. With the inability of governments at various levels to provide portable drinking water and water for agricultural purposes in Nigeria many communities are experiencing difficulties in accessing quality water for drinking and agricultural purpose. From the South-South to the North of Nigeria the story is the same. Urban dwellers are even better off than rural dwellers because they can afford boreholes. As explained above there are various sources of pollution that plague the few water sources available to the population. According to Aragaw *et al.*, (2021) [1] industrial waste water is generated with anthropogenic activities and is the most environmental threat that needs remediation to overcome the environmental damages, thereby reducing human risks. This menace is a challenge and calls for creative methods to treat the polluted sources of water for drinking and agricultural purpose. This paper is therefore looking at the possibility of using iron nanoparticles in that direction.

Characteristics of Portable Water

1. It should be colourless, odourless, and tasteless.
2. It should be free from turbidity and other suspended impurities.
3. It should be free from germs, bacteria and other pathogenic organisms.
4. It should not contain toxic dissolved impurities, such as heavy metals, pesticides, etc.
5. It should have a pH in the range 7- 8.5.
6. It should be moderately soft, having hardness preferably in the range 50-100 ppm. Its hardness should not be above 150 ppm.
7. It should not be aesthetically pleasant.
8. It should not be corrosive to the pipelines and should not cause any incrustations in the pipelines.
9. It should not stain clothes.

Table 1 gives WHO (World Health Organisation) standard for drinking (portable) water (Dara, 2007) [5].

Table 1: Standards (maximum permissible limits) for Drinking Water as Recommended by World Health Organisation (WHO)

Parameters	Level who standard
pH	6.5-9.2
BOD	6
COD	10
Arsenic	0.05 ppm
Calcium	100 ppm
Cadmium	0.01 ppm
Chromium	0.05 ppm
Ammonia	0.5 ppm
Copper	1.5 ppm
Iron	1.0 ppm
Lead	0.1 ppm
Mercury	0.001 ppm
Magnesium	150 ppm
Manganese	0.5 ppm
Chloride	250 ppm
Cyanide	0.05 ppm
Nitrate + Nitrite	45 ppm
Polyaromatic hydrocarbons (PAH)	0.2 ppm
Selenium	0.01 ppm

Source: (Dara, 2007) [5]

Synthesis method and application of iron nano-particles

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Nanotechnology is envisioned to constitute a significant part of the next technological revolution that is the fourth generation of industrialization to happen in this modern era; industry 4.0. Hence, the production and analysis of nanoparticles, which is the building block of nanotechnology, and their properties has become one of the most active subjects of substantial research in modern material sciences. Typically, the methods used for the formulation of metal nanoparticles can be classified into two different categories Top-down and Bottom-up (Preetha, and Rani, 2012; Essien and Otobong, 2017) [17].

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Green chemistry is one of the new branches of chemistry, and it involves the design of products and processes that reduce or eliminates the use or generation of hazardous substances. Green synthetic routes for manufacturing Nps and nanostructures are an emerging branch of nanotechnology as the biomolecules around us are safer generally and offer a cost-effective alternative in many cases. For example, today one would be rather reluctant to undertake Michael Faraday's 1857 method of reducing gold chloride with red phosphorus in a volatile, toxic carbon disulphide solution as a technique to create gold NPs. In many conventional methods, there is a tendency to use expensive chemicals and processes that use toxic materials that present hazards such as environmental toxicity and carcinogenic activity. There has been a push toward an alternative pathway of minimizing the use and production of hazardous materials in chemical research (Poinern, 2015; Selvam, *et al.*, 2017) [16, 18].

Sustainable or green technique pathways that creates materials utilizing relatively nontoxic chemicals to create nanomaterial are well favoured and are welcomed avenues of R & D efforts around the world. Following initial reports showing the feasibility of reducing iron ions to iron NPs and silver ions to Ag NPs, there has been a general move to explore plant extract as a means of reducing, silver to produce NPs and nanostructures of this metal. In some plants, the acidic components can easily aid the reduction of the metallic ions. Furthermore, these studies showed that Ag NPs created this way possesses good antimicrobial activity. The fact that no capping agent or templating agent is needed makes this chemical route an attractive one. For instance the biogenesis of Ag NPs by extracts such as those from the neem

(azadirachta indica), geranium leaves (pelargonium graveolens), and alfalfa (medicago sativa) has already been proven, and the list of plants capable of this reducing effect on silver ions is increasing (Shreya, *et al.*, 2015; Jannathul, and Lalitha, 2015; Biswas, and Dey, 2015;Poinern, 2015; Benakashani, *et al.*, 2016; Bansal, *et al.*, 2017; Selvam, *et al.*, 2017) [2, 3, 4, 10, 16, 18, 19].

According to Stefaniuk, *et al.*, (2016) [21] reduction of hematite (α-Fe_2O_3) or goethite (α-FeOOH) with H_2 at high temperature is another chemical method commonly used to obtain iron nanoparticles (FeH_2 NPs). These FeBH NPs have a spherical morphology with particle size ranging from 30 to 60 nm and Feo content greater than 95%. The iron nanoparticles in Figure 1 were produced using tea extract, the iron nanoparticles were spherical in shape and had a size range of 20-30 nm. The SEM image clearly shows the nanoparticles.

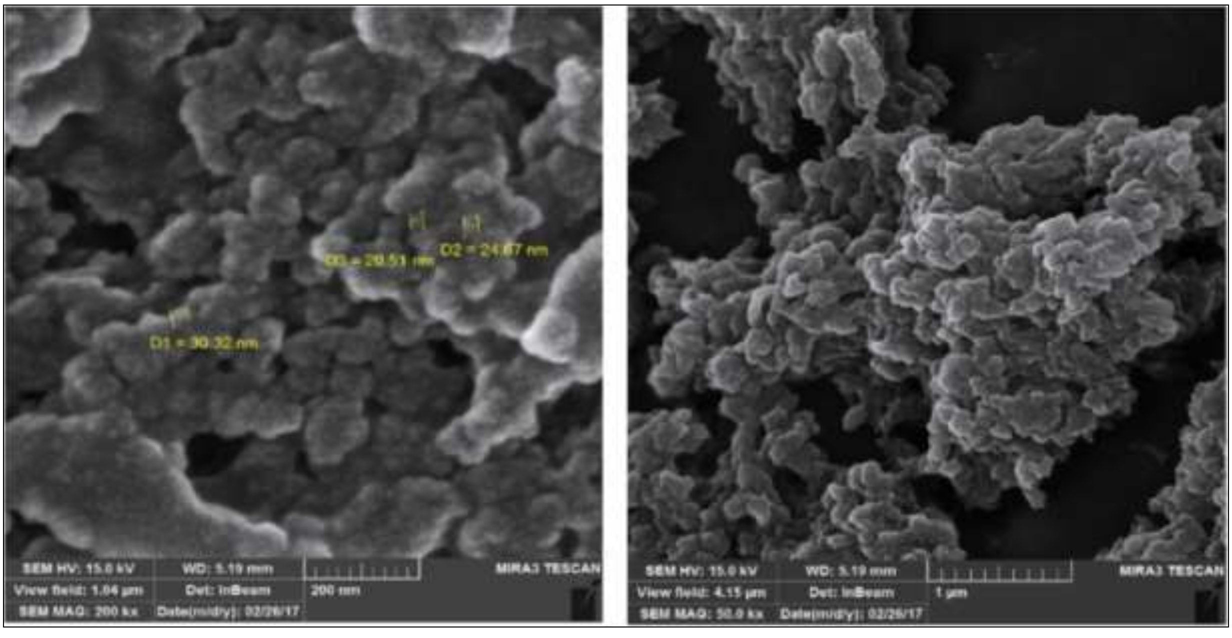

Fig 1: SEM Image of Iron Nanoparticle (Source: Yazdani *et al.*, 2018) [22]

Applications of iron nano-particles for polluted and waste water treatment

Iron oxide (Fe_2O_3, Fe_3O_4) and iron nanoparticles show high reactivity and photolytic properties against wastewater and act as a great adsorbent for water purification because they have a massive surface area and their affinity towards diverse functionalized groups. Among metal-based nanoparticles, iron-based nanoparticles received greater attention for treating contaminants from the wastewater due to cheaper cost and that iron is the second most abundant metal on earth. Since iron is an essential nutrient for all organisms, iron NPs have been considered as a potential micronutrient for methano-genesis bacteria in anaerobic digestion (AD) of organic wastes which are suitable sources for retrieving energy. It is interesting that medical application and biotechnological advances, including magnetic resonance imaging, cell separation and detection, tissue repair, magnetic hyperthermia and drug delivery, have strongly benefitted from employing iron oxide nanoparticles (IONPs) due to their remarkable properties such as superparamagnetism, size, and others. Iron nanoparticles have been used in bandages to prevent bacteria infections on wounds and injuries. In agriculture iron nanoparticles have been used to fight crop pathogens infections. The effectiveness of iron NPs in treating polluted water and wastewaters have been confirmed by several authors (Poinern, 2015; Yazdani *et al.*, 2018; Ihom, 2018; Ihom, *et al.*, 2018; Aragaw *et al.*, 2021) [1, 8, 9, 16, 22].

Mechanism of treating pollutants by iron nanoparticles

The advantage of these nanomaterials is due to their high adsorption capacity for several contaminants in water and wastewater. These characteristics are because of having properties such as high reactivity, selectivity, large surface area, a high grade of functionalization, their ability to oxidize, precipitate, reduce, and adsorb the contaminants such as nitroaromatic compounds, inorganic anions, phosphate, radio elements, nitrates, phenols, organic dyes,and chlorinated and halogenated organic compounds, make them applicable for water and wastewater purification. Several studies explained the mechanism of iron-based nanomaterials for the removal of numerous contaminants. Existing applications of various iron-based nanoparticles in the treatment of wastewater are based on adsorptive techniques that use different iron nanoparticles as a type of nano-adsorbent to enhance the efficient removal of pollutants or photocatalytic technologies that use them as semiconductor photocatalysts to converts contaminants into less toxic compounds (Poinern, 2015; Jannathul and Lalitha, 2015; Yazdani, *et al.* 2018) [10, 16, 22].

Adsorptive mechanisms

The adsorption mechanisms or principles from polluted wastewater streams include electrostatic interaction (attraction between opposite charges), ligands ion combination, and binding on surfaces. Five adsorption mechanisms are electrostatic interaction between pollutants and magnetic nanomaterial owing to the availability of different biomolecules on magnetic nanoparticles surfaces; chemical diffusion between adsorbent and adsorbate; surface precipitation; redox reactions; and ion exchange mainly because of the presence of hydroxyl/OH− functional groups. Moreover, Iron nanomaterials prepared by green methodologies are to be probed as adsorbents for the successful removal of different pollutants by evoking redox, complex formation, and ion-exchange tendencies towards the pollutants. Mostly, the removal mechanism of a certain contaminant is achieved simultaneously (A combination of physic-chemical adsorption, reduction, precipitation, and disinfection) by iron-based nanoparticles due to having various properties such as surface modifiability by various substances and functional groups.

The physicochemical adsorption is resulted due to the residual valences or imperfections in the iron oxide matrix. Redox tendencies of the ferrous and ferric ions may also contribute to the adsorption process. The nanoform of zerovalent iron when in contact with water and dissolved oxygen gets oxidized to oxyhydroxides of iron. The product of oxidation can bind impurities via complex formation, ion exchange, and physical/electrostatic interactions besides the redox potential energies. The surface binding mechanism implies contaminants either diffuse into the adsorbent or are adsorbed via electrostatic interactions for additional interactions with functional groups. It has been demonstrated that the dyes containing a hydroxyl (-OH) group have been adsorbed in higher amounts with maximum adsorption capacity as compared to the non-OH− group, as the dye-containing the OH− group can easily form hydrogen/electrostatic bonding with the surface hydroxyl group of magnetite, which leads to the enhanced adsorption of these dyes.

The mechanism of contaminant by iron nanoparticle is multiple due to the presence of several functional groups obtained from the nanoparticle surface and the surface modification practices (i.e. stabilizing agent, capping agent, and antioxidant). This analysis of how iron NPs work in treating polluted waters have been supported by several authors who have use iron NPs for treating polluted waters (Obikwelu, 2012; Poinern, 2015; Yazdani, *et al.*, 2018; Aragaw *et al.*, 2021) [1, 15, 16, 22]. Photocatalysis process is another mechanism of iron NPs removal of pollutants from wastewater in these process iron NPs are introduced into the polluted water while UV/Visible radiation is introduced. This leads to the gradual oxidation of the intermediate waste products into low molecular weight and eventually transforming them into CO_2, H_2O, and anions (NO_3^-, PO_4^{3-}, and Cl^-) (Poinern, 2015) [16].

Limitations of using iron nano-particles

The impact of nanoparticles on health and the environment has not been studied deeply. The negative impacts of some nanoparticles are due to their size or particular chemical properties, particularly those that are freely mobile and not incorporated into a material. The growing utilization of iron nanomaterials will certainly cause releasing trace amounts into the aquatic environment and consequently cause contact with living organisms that may create health problems. As discussed in the above sections, iron nanoparticles are effective nanomaterials for various contaminant removal from wastewater and other applications. However, the inherent disadvantage of using nanosized iron particles as adsorbent is that water flow in continuous columns through the bed of nanosized particles needs a pressure head. Hence, methodologies have to be developed with open columns wherein the nanoparticles are embedded in the matrix of synthetic or natural inorganic or organic polymers or beads. The host matrix may also alter the structural characteristics of the nanoparticles, and they have to be exploited for the advantage of pollutants removal from wastewater. Moreover, recent research suggested the potential cytotoxicity of iron nanomaterials along with the potential implications in medicine, chemistry, and biology (Yazdani *et al.*, 2018; Aragaw, *et al.*, 2021) [1, 22].

This present work is however, targeted at the use of iron NPs for treating polluted water for drinking and agricultural purpose, here the standard to be met is very stringent and has been clearly specified by the WHO any water treated with iron NPs must meet the WHO standard and this where the risk of any harm arising from the use of Iron NPs does not arise. For any water to meet WHO Standard it must have undergo series of laboratory analytical tests and any harmful component in the water will be detected in the process.

The use of iron NPs in wastewater streams may not have this control and so there exists fears as to what happens if the iron NPs exists in large quantities in the streams of wastewater bodies particularly if they come into contact with aquatic life or humans (Dara 2007; Obikwelu, 2012; Ihom, 2018) [5, 8, 15].

Till now, regeneration and reusing of nanomaterials synthesized from a green approach, are the major contests to researchers for developing them from pilot or laboratory scale to commercialization. The major demerits of these bio-based syntheses are that the composition (chemical) of the extracts could be altered in the biomasses, even in the same species, with different environmental weathering. For example, seasonal variation, different geography, and growth stage of each other, thereby limiting their applications and this results in hampering the growth of these phyto-green methods. But this disadvantage can be overcome by identifying and isolating the components existing in the bio extracts and then using them for water remediation purposes. Thus, investigations have to be undertaken in this direction (Bansal *et al.*, 2017; Yazdani *et al.*, 2021) [2, 22].

Current status and future perspectives

Nano-scale iron particles are recently receiving extensive attention due to their special properties. Over the last few years, various physical, chemical, and biological method (e.g. co-precipitation, hydrothermal, sonochemical, and hydrolysis) have been employed to synthesis iron-nano particles. Green synthesis however, is a clean, biocompatible, non-toxic, cost-effective and eco-friendly method for synthesis of NPs. Green synthesis of iron NPs using different plant extracts such as encalyptus leaf, mangifera indica, magnolia champaca, azadirachta indica, and murraya koenigii leaf, green and black tea leaf, microorganisms and alga extract have been reported. Studies have equally shown that commercial chemical precursors with analytical grades (e.g. $FeSO_4$, $FeNO_3$ and $FeCl_2$) had been used for biosynthesis of Iron NPs. Recently DWTS and slaughter house wastewater has been used to biosynthesis iron NPs.

Sludge produced in drinking water treatment plants known as drinking water treatment sludge (DWTS) is continuously increasing all around the world. Currently, DWTS is disposed to sanitary sewers, streams, and landfills. It contains coagulants, heavy metals, clays, and organic matters. It contains coagulants, heavy metals, clays, and organic matters. Recently, recovery of coagulants (iron, and aluminum salts) from sludge by acid or alkali treatments have been extensively considered. The obtained material can be utilized as adsorbent, carrier, and chemical precursors. For instance, recoverable Fe3+ from DWTS and synthesized iron oxide-SiO_2 Composite for reactive dye and $NaNO_2$ adsorption.

The recoverable Fe3+ solution has of recent been used in synthesizing iron nanoparticles using treated slaughter house wastewater as reducing agent. 2M HCl was used to wash out the mineral ingredients from the DWTS. 15g of DWTS was acid-washed by a liquid/solid (L/S) ratio of 20:1 at 90OC for 3 hours under constant stirring. After the acid treatment, the mixture was filtered and the obtained solution was used for the biosynthesis of iron nanoparticle using the treated slaughter house wastewater and further analysis conducted on the produced nanoparticles (Yazdani *et al.*, 2018) [22]. According to Stefaniuk, *et al.*, (2016) [21] reduction of hematite (α-Fe_2O_3) or goethite (α-FeOOH) with H_2 at high temperature is another chemical method commonly used to obtain iron nanoparticles (FeH_2 NPs). These FeBH NPs have a spherical morphology with particle size ranging from 30 to 60nm and Feo content greater than 95%.

Research in the production of iron NPs for polluted water treatment is ongoing and will continue this is because water is essential to life and agriculture. Anthropogenic activities have continued to affect the availability of quality water. Climate change is also making the availability of water and quality water scarce in some parts of the globe. These reasons will continue to push for more research in the usage of iron NPs for the treatment of polluted water to meet the needs and yearnings of the people for quality water supply (Suslick, *et al.*, 1991; Ihom, 2014; Manigandan *et al.*, 2017; http:www.nanowork.com) [8, 14, 20].

Conclusion

The topic ‘’Iron Nano-Particles Production for Polluted Water Treatment for Drinking and Agricultural Purpose: Current and Future Perspective’’ has been extensively researched and the following conclusions have been drawn from the study:

1. The study has clearly shown that iron nanoparticles can be used in the treatment of polluted water for the purpose of drinking and irrigation.
2. The study has also shown that drinking water which is called portable water must meet WHO standard
3. The study has revealed that the main mechanism of action of iron nanoparticles in removing pollutants and bacteria from wastewater is through adsorption and the large surface area of the INPs helps in uniform dispersion in the water to effectively remove the pathogens, and the other mechanism is photo-catalysis.
4. The study has revealed that iron NPs can be produced through several chemical processes involving iron salt, reducing agent and a capping agent
5. The study has revealed that in recent times several green chemistry methods have emerged of producing iron NPs from Iron salts using plant leaves, roots and other organic materials.
6. A key revelation from the study was the use of Sludge produced in drinking water treatment plants known as drinking water treatment sludge (DWTS) and slaughter house wastewater to produce iron NPs.
7. Finally, the study had shown that iron NPs produced using DWTS and plant extracts from tea were spherical in shape and had the size range of 20-30nm.

Acknowledgement
The authors of this research work wish to acknowledge the cooperation and assistance they have been receiving from the Technologist in charge of Chemical Engineering Laboratory; Engr. Peter Asangasung of the University of Uyo,Uyo. The work is surely progressing with great success because of your cooperation.

Sponsorship
This research work is a sponsored research work by TETFUND through the Internal-Based Research (IBR) of the University of Uyo, Uyo. The researchers highly appreciate the contribution of TETFUND to the successful implementation of the research work.

Conflict of interest
We the authors of this work have agreed to submit our work to your journal for publication. As far as we are concern there is no conflict of interest in the work we have submitted to you for publication.

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