Extract of Water Hyacinth used in the Biosynthesis of Silver Nanoparticles for the Photocatalytic Degradation of Organophosphate and Organochlorine Pesticides

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Abstract. Water hyacinth, commonly known as *Eichhornia crassipes*, is a deadly aquatic weed known for causing environmental hazards, which include blocking river waters and canals and clogging irrigation and hydropower systems chemically. It also reduces the bio-oxygen demand (BOD) of the aquatic in the river, making the river unfriendly to the animals around it. Thus, many countries are trying their best for the removal of this weed using various methods. Green synthesis is an excellent tool utilised in the synthesis process of AgNPs. Water pollution and environmental pollution caused by organophosphate and organochlorine pesticides have threatened living organisms, animals, and humans; hence, there is a need to synthesise multifunctional materials that can be used to degrade various pollutants. This study aimed to evaluate the effectiveness of biosynthesised Silver and Iron nanoparticles for catalytic degradation of organochlorine and organophosphate pesticides. The sample was collected in Hayin Gada Mubi Road Girei Local Government area of Adamawa State with latitude $9^0\ 17^1\ 16^{11}$ N and Longitude $12^0\ 26^1\ 48^{11}$ East.

Silver and Iron Nanoparticles were synthesised using *Eichhornia crassipes* (water hyacinth extract) and characterised using XRD, SEM, TEM, SEM.EDX, UV-Spectrophotometer and FTIR. SEM/EDX, TEM, XRD, FTIR confirmed the formation of Silver and Iron Nano particles. UV-Spectrophotometer gave optical information whereby an excitation at 410 nm for silver and Iron 358 nm. Research on the photocatalytic degradation rate of Organochlorine and Organophosphate using varied concentrations of 25/75, 50/50 and 75/25 for AgNPs in the photocatalysis process was the primary goal of the present study. The influence of the main operating parameters such as photocatalyst concentration, Pesticide concentration, pH and effect of time. The result revealed that AgNPs have high and significant photocatalytic efficiency in organophosphate, and organochlorine has less degradation activity. In conclusion, the research aimed to achieve AgNPs have higher activity against organophosphate (Sniper) than Organochlorine (DDT).

Keywords: Synthesis; AgNPs silver nano particle; organochlorine; organophosphate and photocatalytic degradation.

INTRODUCTION

In recent years, society and science have become concerned about emerging contaminants (EC, also known as "contaminant of emerging concern"). These chemicals threaten the environment, human health, and water safety and are not subject to regional or international water quality regulations [1]. EC includes algal toxins, illegal drugs, industrial compounds, flame retardants, food additives, nanoparticles, pharmaceuticals (human and veterinary), personal care products, pesticides, biocides, steroids, synthetic and natural hormones, and chemical species such as surfactants [2]. In Nigeria, large amounts of pesticides are used in agriculture to control pests, and the environment continues to be polluted. Uncontrolled use of pesticides in agroecosystems and public health is increasing ecological imbalances. Many innocent animals and plants were sacrificed. The use of pesticides addresses some of the problems associated with limited arable land and rising demand for food due to a growing world population. Post-application runoff and pesticide residues can pose a variety of environmental risks. The persistence of pesticides, their inherent toxicity and their accumulation endanger human and environmental health, and carcinogenicity and neurotoxicity are among the potential adverse health effects of pesticide exposure [3].

Organochlorine pesticides (OCs) are synthetic pesticides that are widely used around the world. They belong to the group of chlorinated hydrocarbon derivatives and are commonly employed in the chemical industry and agriculture. These compounds are highly toxic, degrade slowly, and accumulate in the body. Although many of the compounds belonging to the OC family are banned in developed countries, the use of these drugs is increasing. This is particularly relevant to the abuse of these chemicals, which occurs on all continents. Although pesticides were developed with toxicity to target organisms in mind, their use often severely affects non-target species. Organophosphates, or organophosphate compounds (OPs), have been used over the past 60 years to protect crops, livestock, and human health and as agents of war. The reaction of alcohol and phosphoric acid originally produced Organophosphates (Ops). Organophosphates were initially used as insecticides [3].

However, over time, the German military developed these substances and used them as neurotoxins during World War II. They act as cholinesterase inhibitors, thereby affecting neuromuscular transmission. Organophosphates can be classified according to their structure: Phosphates and pesticides play an essential role in modern agriculture by ensuring crop yields and food security. However, the indiscriminate use of pesticides raises serious environmental concerns due to their persistence, toxicity, and potential for ecological destruction. Nanoparticles are microscopic particles less than approximately 100 nanometres (nm) in diameter. In aerosol science, this term is often used for particles less than 50 nm in diameter. "Ultrafine particles" refer to particles with a diameter of less than 100 nm [4]. Nanobiotechnology is an important emerging field that has dramatically developed for various applications. The biosynthesis of various nanoparticles has significantly increased in popularity since the beginning of the 21st century [4]. Biosynthesis (or green synthesis) is characterised by its chemical stability, good biocompatibility, easy fabrication procedure, convenient surface bioconjugation with molecular probes, excellent optical properties related to surface plasmon resonance, and low toxicity, which makes it more environmentally friendly and cost-effective [5].

The synthesis of silver nanoparticles has attracted considerable attention due to their unique properties and potential applications in various fields. Silver nanoparticles, in particular, have demonstrated excellent magnetic properties and biocompatibility. Recently, there has been increasing interest in developing environmentally friendly and cost-effective methods for synthesising magnetite nanoparticles [6]. Such approaches include using natural extracts as reducing and stabilising agents [7].

Therefore, this study investigates the effectiveness of biosynthetic iron and silver nanoparticles obtained from water hyacinth plant extract and the effectiveness of photocatalytic degradation of organophosphate and organochlorine pesticides. They are taking advantage of the unique properties of water hyacinth. This study aims to provide a sustainable and environmentally friendly approach to combating pesticide pollution in aquatic environments.

MATERIALS AND METHODS

All materials used were of analytical grade and standard, and the Solutions and reagents brand purchased were Sigma-Aldrich Chemicals and reagents.

Sampling location. Water Hyacinth (*Eichhornia crassipes*) was obtained in Hayen Gada, Mubi road, Girei local government area of Adamawa state.

Sample collection. A simple random sampling technique was employed to collect the plant samples within the Adamawa metropolis. The samples were collected manually using gloved hands, placed in polythene bags, and then transported to the laboratory for further preparation. The plant samples were identified by an application called and authenticated by a botanist from the botany section of the Department of Biological Sciences, MAU Yola.

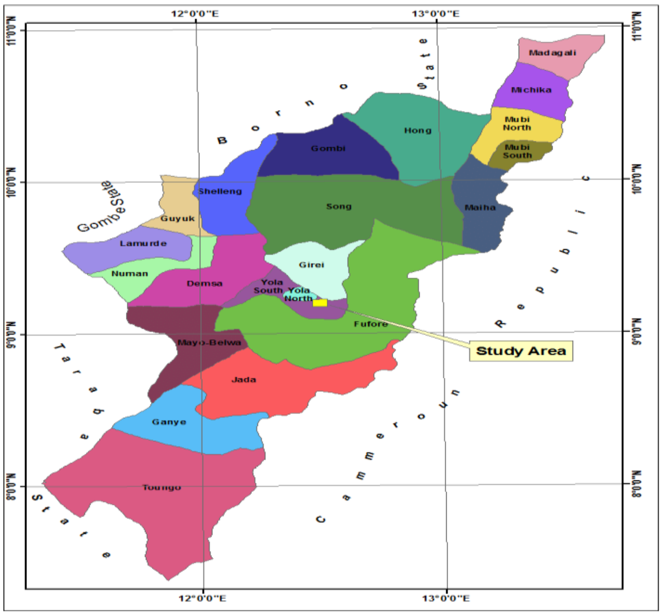
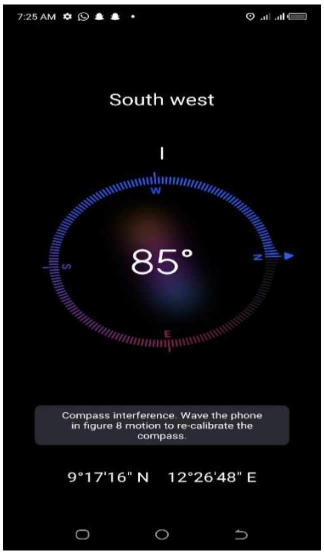


Figure 1 – Map showing the sampling location



South west

85°

Compass interference. Wave the phone in figure 8 motion to re-calibrate the compass.

9°17'16" N 12°26'48" E

Figure 2 – Showing the map of the sample location coordinate

Sample preparation. The collected samples were washed with 10% (v/v) nitric acid (HNO_3) and then rinsed with distilled water to remove airborne pollutants. The samples were then cut into pieces with a stainless-steel knife and air-dried in the laboratory for 15 Days before being oven-dried at 80 °C for 168 hours. The samples were then crushed into powder in a mortar with a pestle. After that, the samples were sieved through a 2 mm nylon sieve to obtain a powder sample, which was then transferred into a polyethene bag for analysis.

Preparation of extract. A 10 g of the powdered sample was weighed using an analytical balance and transferred into a 250 ml beaker containing 10 ml of deionised water, then boiled for 25 minutes with constant stirring with the help of a magnetic bar. The mixture was cooled and filtered through the Whatman number 1 filter paper with a suction pump. The extract obtained was stored in a hot oven at 4 °C for further synthesis and analysis.

Biosynthesis of the Eichhornia crassipes silver nanoparticles (EC-AgNPs). 25 ml of leaf extract was added to 75 ml of 1 mM silver nitrate ($AgNO_3$) solution as a silver ion-reducing agent. 25 ml of the extract was introduced into a 250 ml beaker while stirring for 60 sec, 75 ml of the prepared one mM silver nitrate ($AgNO_3$) solution was introduced with constant stirring with the help of magnetic bar at different time, concentration and temperature. The synthesised silver nano solution was centrifuged at 4000 rpm for 15 min to remove any free biomass residue or compound not the capping ligand of the nanoparticles. The centrifuge and redispersing process was repeated three times. After that, the mixture was washed.

The purified suspension was dried in a hot air oven to obtain the dried powder, the silver nanoparticle. Finally, the dried silver nanoparticles were analysed.

The effect of the reaction was analysed at different temperatures (25, 50 and 75 °C). The reduction of silver nitrate with respect to time was also evaluated at various time intervals (25, 50 and 75 min) for each temperature. The formation of silver nanoparticles was confirmed when the mixture turned yellowish-brown in colour.

Photocatalysis Experiments. The photocatalytic degradation experiments of organophosphate and organochlorine pesticides were carried out under constructive conditions of a flow rate of 4 ml per minute using ultraviolet (UV) radiation. The photoreactor was constructed with a UV-A lamp and then was employed as a UV light source with an intensity of 100 W. The radiation intensity was kept constant throughout the experiments to determine the photoreaction with a capacity of 5 ml and an inner diameter of 20 mm. The constructed UV lamp is connected to the power switch in a way that it can be controlled by switching it on and off in a manual form. The suspension was kept in the dark for 30 min to achieve the equilibrium. After this, the sample was exposed to constructed UV light; the reference samples were then analysed. A 3 cm^3 suspension was collected and analysed at a given interval using a UV–visible spectrophotometer. All experiments were performed at 30 °C, and the experiments were made in triplicates to assure the consistency and reproducibility of the results; the values shown are the average arithmetic values of the three experiments, with all experimental results obtained within ±2 % from the average value obtained [8].

The effect of catalyst dose. Effect of Catalyst The effect of catalyst dose on the degradation of organophosphate and organochlorine pesticide was varied from 1.0 to 8 mg/l with a constant time, concentration and pH UV light was introduced to determine the degradation process.

Effect of pH. The effect of pH experiments was carried out at different pH levels from 1 to 8, with a constant time, catalyst dosage, and concentration to determine the photodegradation rate.

The pH of the prepared sample solution pesticide was measured using the pH paper and meter. The pH paper reads the value from 1 to 8; the pH value is adjusted with 0.1 M HCl and 0.1 M NaOH, respectively.

Effect of Time. The impact of time on photocatalytic decomposition was performed at varying times: 10, 20, 30, 40, 50, 60, 70, and 80 min, with a constant pH, catalyst dosage, and concentration.

Effect of Concentration. Concentration's effect on photocatalytic degradation was carried out by varying concentrations of 10, 20, 30, 40, 50, 60, 70 and 80 mg/l with a constant pH, catalyst dosage and time.

RESULTS AND DISCUSSION

SEM Studies of EC-AgNPs. SEM was used to study the surface morphology of EC-AgNP samples. The presence of silver nanoparticles with different shapes and sizes was confirmed. The results shown in Fig. 4 a. EDX analysis confirmed the presence of silver (Ag) component at 76.82% by mass. EDX spectroscopy results in Fig. 4 b show that a peak around 5.5 keV indicates Ag and O are dominant elements in the sample. The strong signal energy peak for Ag atoms around 5.5 keV is typical for absorbing metallic and Ag nanocrystals onto EC [9]. A single solid energy peak indicated the purity of Ag in the sample, whereas other study reports stated the presence of C (2.20 %) and O (22.04 %) [10] with synthesised AgNPs.

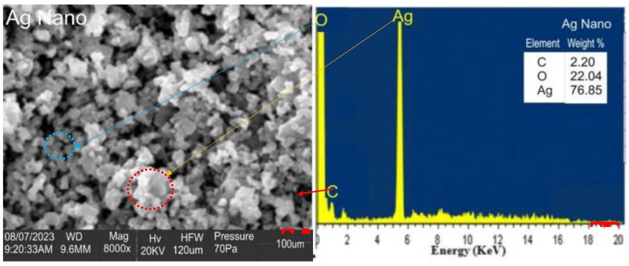


Figure 3

a) SEM image of EC-AgNPs with 100 μm scale and 8,000 x magnification; b) EDX spectrum of synthesis EC-AgNPs

Photocatalysis Experiments. The photocatalytic degradation experiments of organophosphate and organochlorine pesticide were carried out under constructive conditions of a flow rate of 4 ml/min using ultraviolet (UV) radiation, as shown in Fig above. The photoreactor was constructed with a UV-A lamp and then was employed as a UV light source with an intensity of 100 W. The radiation intensity was kept constant throughout the experiments to determine the photoreaction with a 20 ml capacity and inner diameter of 20 mm. The constructed UV lamp is connected to the power switch in a way that it can be controlled by switching it on and off in a manual form.

The synthesised silver and iron nanoparticles of the water hyacinth were immersed separately in the organophosphate and organochlorine pesticide solution as a catalyst with a concentration of 10 mg/l before each experiment.

The suspension was kept in the dark for 30 min to achieve the equilibrium. After this, the sample was exposed to constructed UV light; the reference samples were then analysed.

A 3 mL suspension was collected and analysed at a given interval using a UV–visible spectrophotometer. All experiments were performed at 30 °C.

All experiments were made in triplicates to ensure the consistency and reproducibility of the results, and the values shown are the average arithmetic values of the three experiments, with all experimental results obtained within ±2 % of the average value obtained.

Effect of Photocatalyst Concentration on the Photodegradation of Organophosphate AgNPs. In the photocatalytic process, one of the main parameters of reducing Organophosphate solution is

Photocatalyst concentration. Figure 4 showed that with increasing AgNP concentration, the degradation of organophosphate was increased.

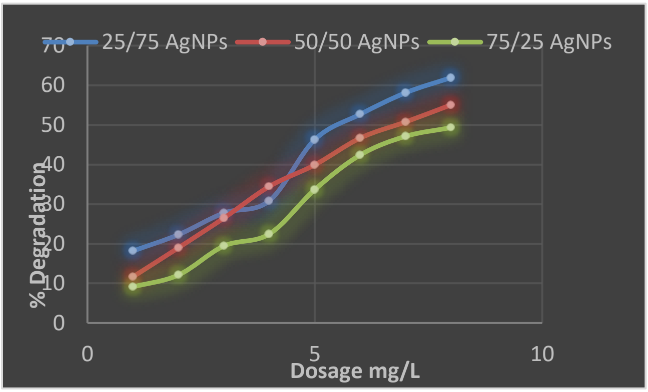


Figure 4 – Comparison diagram of photocatalytic catalyst concentration with different percent of AgNPs

The percent degradation value shows an increasing trend across different catalysts. This suggests the effectiveness of the photocatalytic degradation process as you increased the catalyst from 1 to 8 mg/l of 25/75, 50/50 and 75/25 photocatalyst concentration. Catalyst 1 to 4 mg/l of 25/75, 50/50 and 75/25 demonstrate a gradual increase in % degradation, indicating an improvement in their photocatalytic activity. Catalysts 5 to 8 mg/l of 25/75, 50/50 and 75/25 show more significant increases in this range, recommending that catalysts 5 to 8 are particularly effective in promoting photocatalytic degradation. The highest % degradation was observed at 25/75, 50/50 and 75/25 AgNPs catalyst 8 with 58.94 %, (55.07) and (49.33 %) the lowest was observed at 75/25 AgNPs catalyst 1 mg/l with % degradation of (9.20 %). These suggest that catalyst 8 is the most effective among the studied catalysts for photocatalytic degradation. For both catalysts, the percentage of photocatalytic degradation with 25/75 AgNPs was higher than 50/50 and 75/25 AgNPs. This occurs because the composition of the catalyst enhanced photocatalytic activity, and the catalyst's surface area and particle size can influence the photocatalytic process's efficiency. The result was in agreement with [11]. Who studied the photocatalysis of AgNPs on pesticides and observed a degradation efficiency of 65.3 % with a catalyst concentration of 7 mg/l. The higher degree of reducing pesticide concentration compared with different catalyst concentrations is due to the catalyst's surface area and particle size [12].

Effect of Time on the Photodegradation of Organophosphate AgNPs. Time is an essential factor to consider when testing a material's ability to degrade. The observed % degradation values demonstrate an increasing trend as time duration increases. This indicates a positive correlation between the photocatalytic process's duration and the organophosphate's degradation [13].

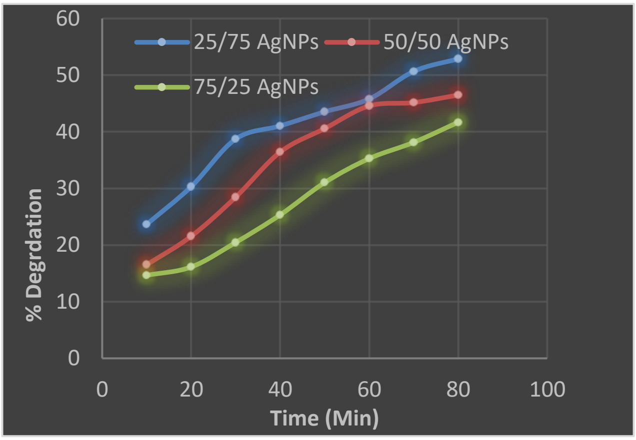


Figure 5 – Comparison of Photocatalytic Degradation of Time with Different AgNPs Concentration

The rate of degradation is relatively gradual. The highest % degradation rate was observed at 25/75 AgNPs, 52.88 % after 80 minutes and the lowest % degradation was recorded at 75/25 AgNPs, 14.66 % at 10 min [14]. This suggests that the photocatalytic process continues to be effective over an extended period. The first few time intervals of 10 to 30 minutes of 25/75, 50/50 and 75/25 AgNP show a moderate % degradation [15]. This might indicate an initial lag phase where the photocatalytic process is gaining momentum. After 50 minutes, there is a noticeable slowing down in the degradation rate. [16]. the curve appears to approach a plateau, suggesting that there might be a limit to the efficiency of the photocatalytic process under given conditions. The highest % degradation of 52.88 % is achieved at 80 minutes of 25/75 AgNPs. This suggests that extended duration is adequate. Furthermore, the results were lower than the reported [16], who observed a % degradation rate of 67.89 % at 100 minutes using AgNPs as a Photocatalyst. This is consistent with findings in studies on photocatalytic degradation of pollutants using various catalysis and light sources [17].

Kinetic Study AgNPs. The reaction rate was also investigated, as exhibited in Figure 6.

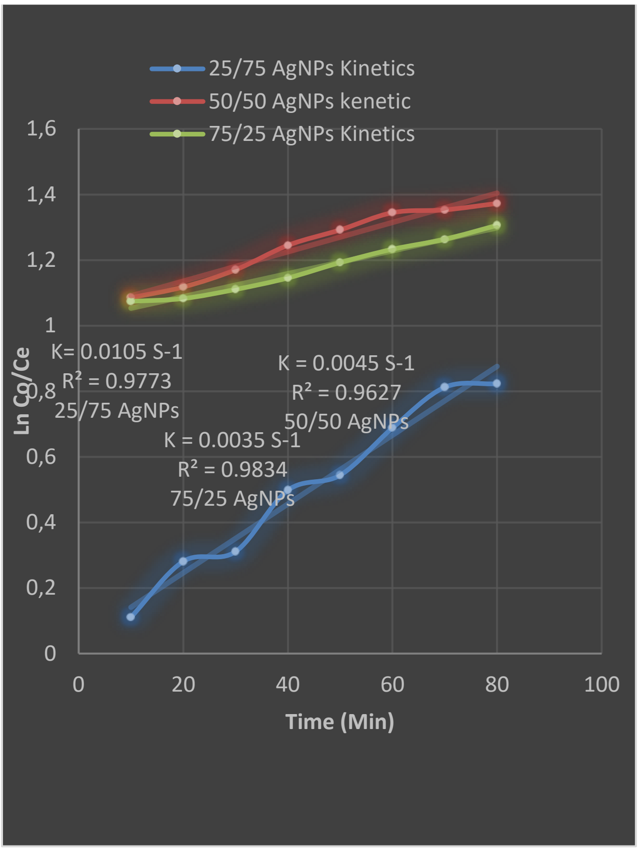


Figure 6 – Kinetic model of 25/75, 50/50 and 75/25 AgNPs

The photocatalytic results were calculated using Langmuir Hinshelwood Equation (1):

$$L_n(C_o/C_t) = kt, \qquad (1)$$

where L_n represents the reaction rate, C_o is the initial Concentration, C_t is the final concentration, *k* is the rate of reaction constant and is the response time [20].

According to the plotted results in Figure 6, the rate of a response follows the Pseudo first-order kinetics with the kinetics rate equal to *k*=0.0105 S^{-1}, k= 0.0035 S^{-1} and *k*=0.045 S^{-1} for 25/75, 50/50 and 75/25 AgNPs respectively. The high R^2-value of 0.977, 0.983 and 0.962 for 25/75, 50/50 and 75/25 AgNPs, respectively, supports the adequacy of the first-order kinetics model for describing the photocatalytic degradation process. This indicates a strong correlation between the experimental data and the theoretical model. The rate constant k of 0.0105 S^{-1} is a crucial parameter in first-order kinetics. It represents the fraction of the pollution degraded per unit time. A higher k-value indicates a faster degradation [18]. The decreasing trends in Ln Co/Ce values over time (from 1.08 to 1.37) align with expectations in first-order kinetics. As time progresses, the natural logarithms of the initial to final concentration ratio decrease. The Ln Co/Ct values represent the extent of degradation at each point. Smaller Ln Co/Ce values Indicate a more substantial degree of degradation. The progression of Ln Co/Ct values over time reflects the evolving degradation process. The R^2-values of 0.977, 0.983, and 0.962 for 25/75, 50/50, and 75/25 AgNPs indicate that the first-order kinetics model fits the experimental data. This high goodness of fit suggests that the model is reliable for predicting the degradation behaviour at untested time points within the studied range. The obtained rate constant and R^2 value is similar to those reported in the literature for similar photocatalytic degradation processes. Consistency with established values enhances the reliability of the study [15].

Effect of pH on the Photodegradation of Organophosphate AgNPs. The impact of pH on the photodegradation of organophosphate on photocatalyst degradation of dye solution in the range of 1-8 was investigated while other parameters were constant. The pH of the reaction mixture was adjusted by adding a dilute aqueous solution of 0.1 M HCl and 0.1 M NaOH. Figure 7 compares the result of photocatalyst degradation of organophosphate as a function of reaction pH.

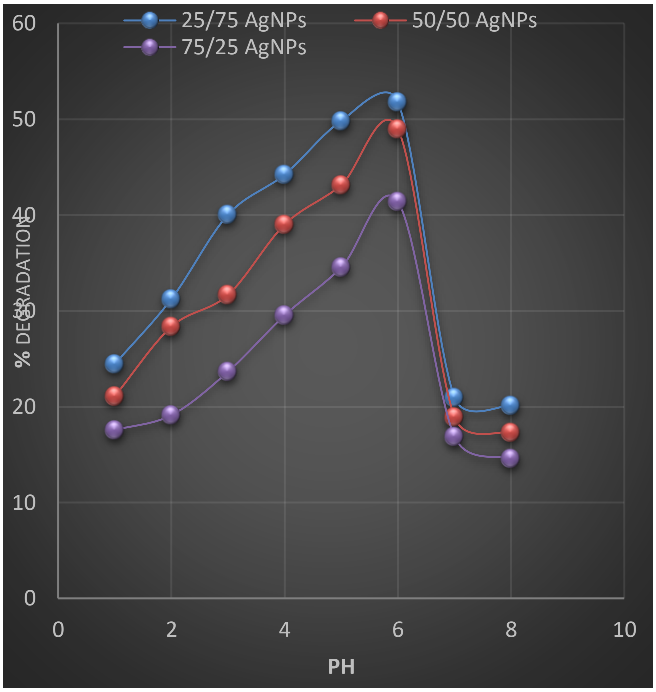


Figure 7

The observed exhibit an apparent pH-dependent trend in percentage degradation. There is a general increase in degradation efficiency up to pH 6, followed by a substantial decrease at pH 7 and pH 8 for 25/75, 50/50 and 75/25 AgNPs. The highest percentage of degradation is observed at pH 6 (51.79, 48.97, and 41.39 % for 25/75, 50/50, and 75/25 AgNPs, respectively). This suggests that the photocatalytic system is most effective under slightly acidic and neutral conditions. The surface charge and reactivity of the catalyst material likely influence the observed pH-dependent trends. The photocatalyst may have an optimal working range of pH where reactivity is maximised [19]. The pH-dependent behaviour aligns with existing literature on photocatalytic degradation. Studies often highlight the significance of pH in determining reaction rates and overall efficiency, emphasising the influence of surface charge and adsorption properties [19]. A change in pH can influence the predominant reactive species in the photocatalyst process. For instance, a shift in pH may affect the generation of hydroxyl radicals or other reactive intermediates, altering the degradation mechanism [19]. The drop in degradation efficiency at higher pH levels (pH 7 and pH 8) may be related to the buffering capacity of the system. Understanding the stability of the photocatalytic process under different pH conditions is crucial for practical applications.

Effect of Organophosphate Concentration AgNPs. The organophosphate concentration in the experiment ranged from 10 to 80 mg/l. The result illustrated in Figure 8 reveals that by increasing organophosphate concentration, photocatalyst degradation is reduced.

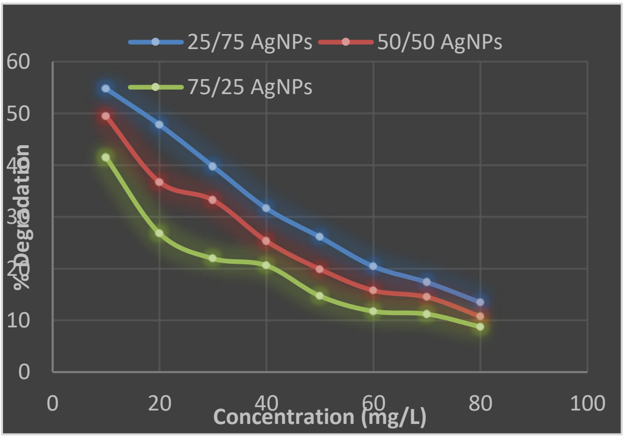


Figure 8 – Comparison diagram of photocatalytic organophosphate degradation with different organophosphate concentrations

The data reveals a clear concentration-dependent trend in percentage degradation. As the pollutant's initial concentration increases, the degradation percentage decreases. The inverse relationship between concentration and percentage degradation is consistent with photocatalytic degradation processes. Higher initial concentrations of pollutants often lead to reduced efficiency due to saturation effects and increased competition for active sites on the catalyst surface [14].

The highest degradation percentage is achieved at the lowest concentration (10 mg/l), indicating that the photocatalytic process is most effective when the initial pollutant concentration is relatively low. The decrease in percentage degradation at higher concentrations (60, 70 and 80 mg/l) suggests the possibility of saturation effects. As the catalyst becomes occupied with higher concentrations of pollutants, the degradation rate may plateau [15].

In applications such as water treatment, understanding the impact of initial pollutant concentration is crucial for optimising the photocatalytic process and designing efficient treatment systems. Studies on photocatalytic degradation often report similar concentration-dependent behaviour, emphasising the importance of understanding these relationships to create an effective photocatalytic system. The results are identical to that of previous studies [20]. When pesticide concentration increased, the quantity of intermediates increased, competing through side reactions with the parent pollutant decomposition. At higher concentrations, the UV light might be absorbed by pollutants rather than the AgNP particles, reducing the photodegradation efficiency.

Effect of Photocatalyst Concentration on the Photocatalytic Degradation of Organochlorine AgNPs. The observed data reveals a dose-response relationship between the catalyst dosage and the percentage degradation of organochlorine. As the catalyst dosage increased, there was a corresponding increase in the efficiency of the photocatalytic degradation process. The trend shows a gradual increase in % degradation with higher catalyst dosages. This aligns with the general expectation that a higher catalyst concentration provides more active sites for the photocatalytic reaction, leading to increased degradation efficiency [11].

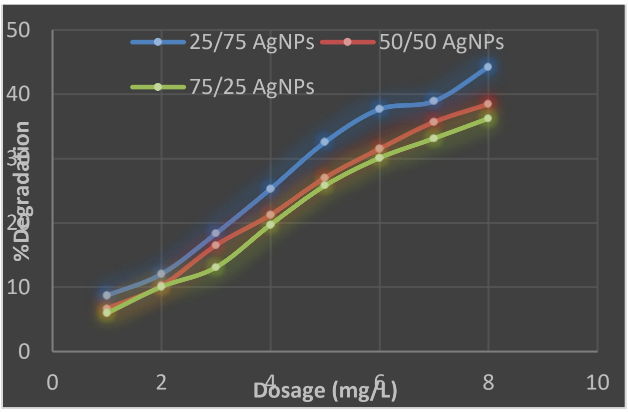


Figure 9 – Comparison diagram of photocatalytic degradation of organochlorine with different Photocatalyst Dosage concentrations

The highest % degradation is observed at the highest catalyst dosage, 44.24, 38.46 and 36.24 % for 25/75, 50/50 and 75/25 AgNPs, respectively. In contrast, the lowest % degradation was observed at a low catalyst dosage of 1 mg/l with % degradation of 8.72, 6.68 and 5.97 % for 25/75, 50/50 and 75/25 AgNPs, respectively. This suggests that increasing the catalyst dosage within the studied range enhances the photocatalytic degradation process, reaching an optimal point at the highest dosage [12]. There is a point beyond which adding more catalysts does not result in a significant increase in % degradation. This can be due to factors like the limited availability of reactive sites or other reaction kinetics considerations.

Effect of Time on the Photocatalytic Degradation of Organochlorine AgNPs. The observed % degradation values demonstrate an increasing trend as time duration increases. This indicates a positive correlation between the photocatalytic process's duration and the organophosphate's degradation [13]. The data illustrates a time-dependent trend in percentage degradation. As the duration of the photocatalytic process increases, there is a corresponding increase in the efficiency of Organochlorine pesticide degradation.

The highest % degradation was 40.51, 39.55 and 36.87 for 25/75, 50/50, and 75/25 AgNPs, respectively, achieved at 80 minutes. At the same time, the lowest degradation rate was 10.15, 8.95 and 8.01 %, completed at 10 min. This suggests that an extended duration enhances the photocatalytic degradation process. The research correlates with [14]. Studies often discuss the efficiency of reaction time conditions and their impact on the degradation process.

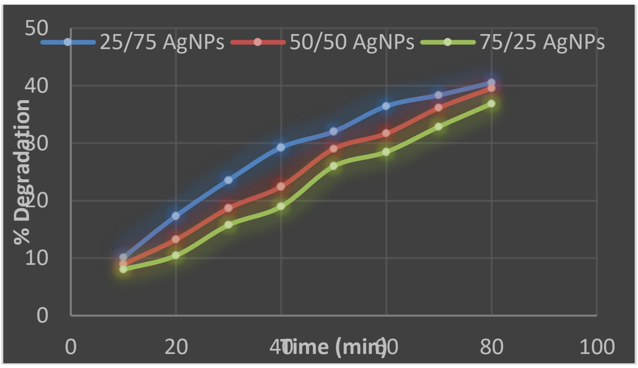


Figure 10 – Comparison diagram of photocatalytic degradation of organochlorine at different times

Kinetics Model Organochlorine AgNPs. The reaction rate was also investigated, as exhibited in Figure 11.

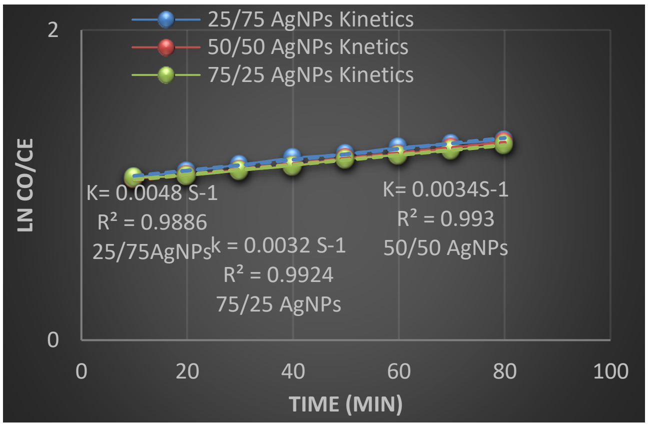


Figure 11 – Kinetic model of 25/75, 50/50 and 75/25 AgNPs

According to the plotted results in Figure 11, the rate of response follows the Pseudo first-order kinetics with the kinetics rate equal to k=0.0048 S^{-1}, k= 0.0034 S^{-1} and k=0.0032 S^{-1} for 25/75, 50/50 and 75/25 AgNPs respectively. The Ln Co/Ce values exhibit a consistent increasing trend with time. This aligns with the expectation of a first-order kinetics reaction, where the natural log of concentration decreases as the reaction progresses. The R-square value (0.924, 0.988 and 0.993) indicates the goodness of fit of the first-order kinetics to the experimental data. Higher r-square values suggest a better fit, and, in this case, they indicate a strong correlation between the model and the actual degradation data. The rate constant (k) represents the degradation reaction's speed. The observed values were 0.0048 S^{-1}, 0.0034 S^{-1} and 0.0032 S^{-1} for 25/75, 50/50 and 75/25 AgNPs, respectively, indicating the fraction of the pollutant degraded per unit time. Smaller k-values correspond to slower degradation rates. The obtained rate constant and R^2-value match those reported in the literature for similar photocatalytic degradation processes. Consistency with established values enhances the reliability of the study [13].

Effect of pH Organochlorine AgNPs. The impact of pH on photocatalyst degradation of dye solution in the range of 1-8 was investigated while other parameters were constant. The pH of the reaction mixture was adjusted by adding a dilute aqueous solution of 0.1 M HCl and 0.1 M NaOH. Figure 40 compares the result of photocatalyst degradation of organochlorine as a function of reaction pH.

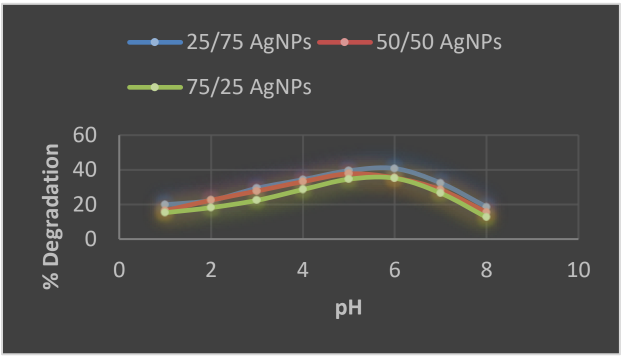


Figure 12 – Comparison diagram of photocatalytic degradation of organochlorine with different pH

The data observed exhibit an apparent pH-dependent trend in percentage degradation. There is a general increase in degradation efficiency up to pH 6, followed by a substantial decrease at pH 7 and 8 for 25/75, 50/50 and 75/25 AgNPs. The highest percentage degradation is observed at pH 6 (39.96, 35.36 and 35.14% for 25/75, 50/50 and 75/25 AgNPs respectively. This suggests that the photocatalytic system is most effective under slightly acidic and neutral conditions. The surface charge and reactivity of the catalyst material likely influence the observed pH-dependent trends. The photocatalyst may have an optimal working range of pH where reactivity is maximised [18]. The pH-dependent behaviour aligns with existing literature on photocatalytic degradation. Studies often highlight the significance of pH in determining reaction rates and overall efficiency, emphasising the influence of surface charge and adsorption properties. A change in pH can influence the predominant reactive species in the photocatalyst process. For instance, a shift in pH may affect the generation of hydroxyl radicals or other reactive intermediates, altering the degradation mechanism [19]. The drop in degradation efficiency at higher pH levels (pH 7 and 8) may be related to the buffering capacity of the system. Understanding the stability of the photocatalytic process under different pH conditions is crucial for practical applications.

Effect of Organochlorine Concentration on the Photo Degradation of Organochlorine AgNPs. The organochlorine concentration in the experiment ranged from 10 to 80 mg/l; the result illustrated in Figure 13 reveals that by increasing organochlorine concentration, photocatalyst degradation is reduced.

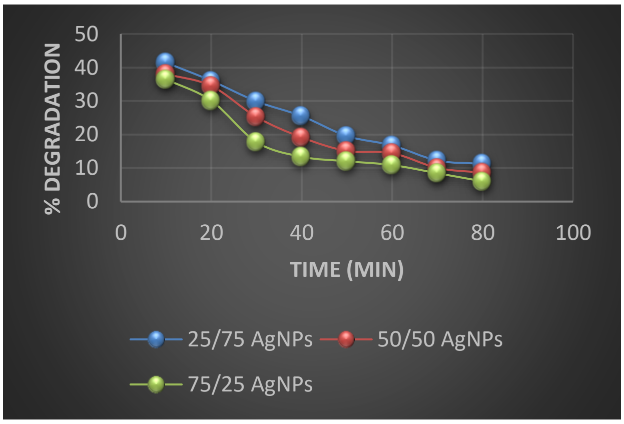


Figure 13 – Comparison diagram of photocatalytic degradation of organochlorine with different concentrations

The data reveals a clear concentration-dependent trend in percentage degradation. As the pollutant's initial concentration increases, the degradation percentage decreases. The inverse relationship between concentration and percentage degradation is consistent with photocatalytic degradation processes. Higher initial concentrations of pollutants often lead to reduced efficiency due to saturation effects and increased competition for active sites on the catalyst surface.

The highest percentage degradation is achieved at the lowest concentration (10 mg/l) with % degradation of 41.40, 38.03 and 36.47 % for 25/75, 50/50 and 75/25 AgNPs, respectively. It indicates that the photocatalytic process is most effective when the initial pollutant concentration is relatively low. The decrease in percentage degradation at higher concentrations w (60, 70 and 80 mg/l) suggests the possibility of saturation effects with %degradation of 11.25, 8.59 and 6.03 % for 25/75, 50/50 and 75/25 AgNPs. The degradation rate may plateau as the catalyst becomes occupied with higher pollutant concentrations [20].

In applications such as water treatment, understanding the impact of initial pollutant concentration is crucial for optimising the photocatalytic process and designing efficient treatment systems. Studies on photocatalytic degradation often report similar concentration-dependent behaviour, emphasising the importance of understanding these relationships to create an effective photocatalytic system. The results are identical to that of previous studies [20]. When pesticide concentration increased, the quantity of intermediates increased, competing through side reactions with the parent pollutant decomposition. At higher concentrations, the UV light might be absorbed by pollutants rather than the AgNP particles, reducing the photodegradation efficiency.

CONCLUSIONS

AgNPs were more effective in degrading the Organophosphate than Organochlorine, obtaining the highest % of 54.83 and 42.73 % degradation of the pollutant, respectively. The kinetic followed first-order kinetics for 25/75, 50/50 and 75/25 AgNPs at different intervals. The FeNPs were very low compared to AgNPs, with a % degradation of 41.11 and 26.80 of organophosphate and organochlorine, respectively. The reusability study for our materials revealed that AgNPs in organophosphate were stable compared to organochlorine.

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Conflict of Interests

The authors declare no conflicting interest.

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