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Artificial Neural Network Modeling for Removal of Cd (II) and Pb (II) from Wastewater by Using Three Ferrite Nanomaterials (Cu0.9Zn0.1Fe_2O_4, Cu0.8Zn0.2Fe_2O_4, and Cu0.7Zn0.3Fe_2O_4) and Study the Antimicrobial Effectiveness of these Ferrite Substances

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Abstract: *Adsorption of Pb(II) and Cd(II) from wastewater utilizing three nano-magnetic materials (Cu0.9Zn0.1Fe_2O_4, Cu0.8Zn0.2 Fe_2O_4, and Cu0.7Zn0.3 Fe_2O_4) were studied. The nano-magnetic materials were prepared from the Cu Frites powder and then the Cu ions were replaced by Zn ions in three concentrations, these materials were characterized by X-ray diffraction (XRD) which has conformed good crystallinity with spinel structure and particle size in the range (26.5–23.9 nm). Artificial neural networks were applying to model the removal of Pb(II) and Cd(II) on three adsorbents from wastewater. The operating conditions that affect on adsorption process are adsorbent dose (0.1, 0.25, and 0.5) g, pH (3, 7, and 9), and contact time (15, 30, and 45) min. Three Multilayered feed-forward neural networks (3:9:2) were successfully used for modeling of removing heavy metals on three adsorbents. The antimicrobial effectiveness of ferrite substances was studied against two types of bacteria. The three adsorbents showed an excellent removal for Cd (II) ions 100% complete removal on Cu0.9Zn0.1 Fe_2O_4, Cu0.8Zn0.2 Fe_2O_4, and it was 95% on Cu0.7Zn0.3 Fe_2O_4, and less removal for Pb (II) ions on Cu0.9Zn0.1Fe_2O_4, Cu0.8Zn0.2 Fe_2O_4 were 78.4% and 78.8%, and 83.4% on Cu0.7Zn0.3 Fe_2O_4. ANN models show efficient simulation with a high correlation coefficient (R2 = 0.99) for all three adsorbents, Sensitivity Analysis demonstrated that pH, time, and a dose of the adsorbent have a strong impact on the process of removal.The results for antimicrobial effectiveness showed that Cu0.9Zn0.1 Fe_2O_4 had the most antibacterial properties against two types of bacteria and the S. aureus killing rate was less than the E. coli killing rate of all ferrite composite nanoparticles.*

Keywords: *Cu-ferrites, wastewater, artificial neural network, antimicrobial effectiveness*

1. Introduction

The attendance of weighty metals in water resulting from various productions like metal plating, battery manufacturing, and mining processes lead to severe environmental pollution and health effects on humans because these minerals are not degradable, toxic and accumulate in waters. Cleaning up wastewater of these heavy metals has become an important and essential need [1]. Adsorption technique is broadly utilized to remove heavy metals from wastewater because it is a cost-effective, flexible, and simple design [2].

Recently, numerous scholars have interested in studies on the possibility of applying magnetic nanoparticles to solve environmental problems like water treatment processes, especially their use as an adsorbing material to remove heavy metals from wastewater [3, 4]. One of these materials is a ferrite, which is a ceramic material that consists of iron oxide as seen in the form of M Fe_2O_4 where M is metallic ions such as (Ni, Cu, Zn, Mn) [5]. Ferrite has great attention to removing heavy metal ions from the watery solutions because of its unique physical and chemical properties, ease of preparation, and a large surface area [6, 7]. Vazquez-Olmos et al. Examined the effectiveness of M Fe_2O_4 (M = Co, Ni, and Zn) ferrite for adsorbing lead ions from a weary solution [8].

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Tran et al. have prepared Cu0.5Mg0.5Fe_2O_4 for Pb (II) adsorption by a batch method at *p*H 7 [9]. Ebrahim et al. studied competitive adsorption in Binary, ternary, and quaternary systems for adsorption of Cu (II), Ni (II), Zn (II), and Cd (II) on Fe_3O_4 nanomaterial [10].

Magnetic nano-particles, for example, iron oxide nanoparticles, were existed to become stronger in the resistances of transferrable disease [11-14]. Copper, zinc, chromium, and nickel Metals are replaced into cobalt ferrite nanoparticles and revealed amazing antimicrobial properties [15]. Besides, silver nanoparticles stacked into copper ferrite ($CuFe_2O_4$) magnetic empty strands indicated magnificent antimicrobial adequacy against four microscopic organisms: *V. parahaemolyticus, S. Typhi, E. coli,* and *S. aureus* [16]. Some types of ferrites, for example, Cu-ferrites, are remarkable as delicate magnets, since they could be magnetized or de-magnetized and by encapsulating it enabled to control on their magnetic properties. A few scientists recommended that the replacement of spinel iron oxide with metals may support in enhancing the biomedical characteristics of the ferrite nanoparticles [15, 17].

The adsorption process requires a powerful modeling technique such as the application of an artificial neural network (ANN) due to many effective variables that make the process complicated, and it is difficult to use the traditional mathematical model. ANN is a tool able to processing information and establishing a relationship between inputs-outputs that may guess the behavior of a procedure under diverse circumstances. ANN represents a powerful predictive model that employs experimental data for learning and does not require knowledge of system rules [18, 19].

In this study, we examined the effectiveness of using three nano-magnetic materials (Cu0.9Zn0.1 Fe_2O_4, Cu0.8Zn0.2 Fe_2O_4, and Cu0.7Zn0.3 Fe_2O_4) prepared by the sol-gel method to removal Cd (II) and Pb (II) from wastewater by batch adsorption process and focus on applying the ANN model to expect a relationship between the experimental variables (adsorbent dose, *p*H, and interaction period) and the response variables (elimination efficiency of heavy weight metals), and studied the antimicrobial effectiveness of this ferrite substances in concentrations against two types of bacteria.

2. Materials and methods

2.1. Preparation of Ferrites Powder

Cu-ferrites powder and substituting of Cu ions by Zn ions as in the form Cu1-xZn xFe_3O_4 where x is (0.1, 0.2, 0.3) as seen in the table (1), ferrites were synthesized by the sol-gel process; chemicals were analytical grade with purity ≥99% and utilized in a distinctive process, cupric nitrate hydrate Cu $(NO_3)_2$ • $6H_2O$, ferric nitrate non-hydrate Fe $(NO_3)_3$•$9H_2O$ and zinc nitrate Zn $(NO_3)_2$ were used as initial materials. Mixed solutions of these materials were made in deionized water with stirring at room temperature. A specific volume of ammonia NH_3OH was put to the above-mixed solution. After, the solution of NH_3OH was added until the *p*H value reached 7. The obtained final powder samples were calcined for 2 h at 500°C.

Table 1. Present chemicals formulas of samples

Sample	Zn content	Chemical formula
A	**0.1**	$Cu_{0.9}Zn_{0.1}Fe_2O_4$
B	**0.2**	$Cu_{0.8}Zn_{0.2}Fe_2O_4$
C	**0.3**	$Cu_{0.7}Zn_{0.3}Fe_2O_4$

2.2. XRD Analysis and Particle Size

Figure 1 represents the X-ray powder diffraction pattern of synthesized Cu1-xZnxFe_2O_4 ferrite samples annealed at 500°C (where, x= 0.1, 0.2 0.3). The packs show the creation of a single-phase cubic spinel structure with diverse echo planes indexed as (111), (220), (311), (222), (400), (511), and (440). As a result, the mean particle size was found in the range 0f (26.5–23.9nm) calculated from the peak (311) of the XRD diffraction gram employing by Scherer's formula [20]:

$$D_x = \frac{0.9\ \lambda}{(\beta \cos \theta)} \quad (1)$$

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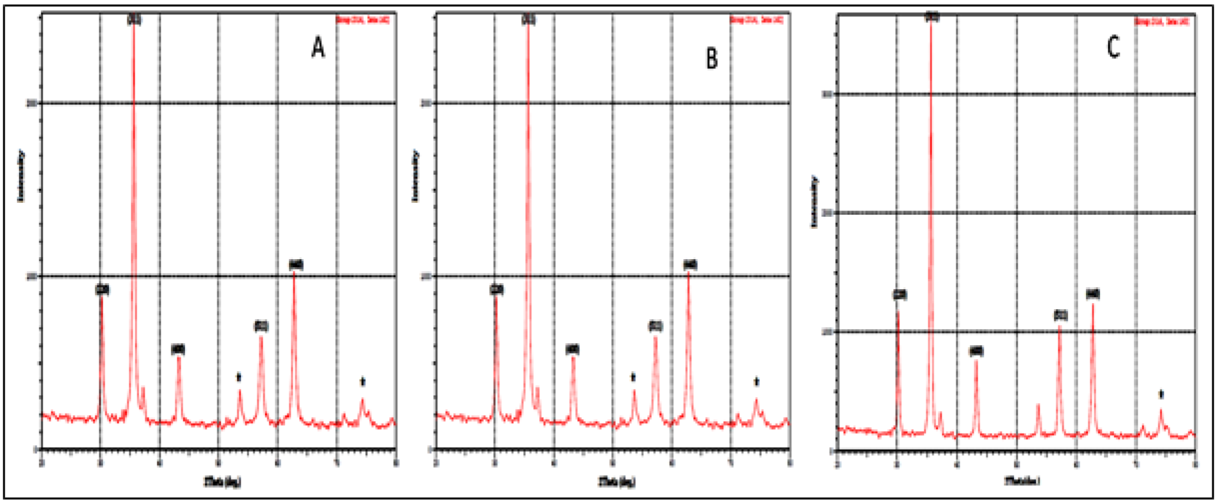

Figure 1. Pattern of X-ray powder diffraction of synthesized Cu1-xZnxFe$_2$O$_4$ ferrite samples casing at 500°C with deferent content of Zn where find extra peak denote by (*), the samples: A) x=0.1, B) x=0.2, C) x=0.3

3. Wastewater Treatment Procedure

The batch adsorption process was studied by adding (0.1, 0.25, and 0.5) g of adsorbents into 100 mL solution in a binary system with concentrations of heavy metals (10 mg/L of Pb (II) and 10 mg/L of Cd (II)) in flasks at selected *p*H, then mixed and placed in the stirrer At ambient temperature (25-30°C). After specific time periods (15, 30, 45) min, samples was collected for filtered through Whatman filter paper to remove adsorbents, then estimated metal ions by using atomic absorption (Shimadzu Model AA-6300). The competence of Cd (II) ions and Pb (II) ions removed were determined by means of equation (2).

$$R\,\% = \frac{C_0 - C_t}{C_0} * 100\% \quad (2)$$

where (R %) is the metal ions exclusion effectiveness, Co and Ct are the early and last concentrations (mg/L) of the metal ions before and after adsorption.

4. Antimicrobial Activity Procedure

The antimicrobial action of ferrite nanoparticles was tried versus staphylococcus aureus (*S. aureus*) (gram-positive bacteria) and Escherichia coli (*E. coli*) (gram-negative bacteria) that found on it from biomedical nanotechnology department in nanotechnology and the center of unconventional constituents research at the university of technology, Iraq. After transplantation, overnight at 37°C on a nutrient agar plate to obtain on bacterial samples with concentration ~107-108 CFU/mL by 0.5 McFarland standards.

All tests (Cu0.9Zn0.1Fe$_2$O$_4$, Cu0.8Zn0.2 Fe$_2$O$_4$, and Cu0.7Zn0.3 Fe$_2$O$_4$) were performed using different concentrations of ferrite nanoparticles and incubated aerobically with *E. coli* and *S. aureus* at 37°C for 24 h shaked (200 rpm) in normal saline. The culture and ferrite nanoparticles were diluted for three-time and L shaped spreader was using to spread 100 µL of these combinations on an agar plate. Colonies quantity on inlaid plates was calculated after raised for 24 h at 37°C. The colony's constituent units (CFUs) have been figured by doubling colonies amount by the dilution factor [21]. The microbial rates compute by equation (4) [22].

$$\text{Bacteriostatic rate } 100\% = (1 - \text{colonies of test groups/colonies of control group}) * 100 \quad (3)$$

5. Artificial Neural Network (Ann) Model

Non-natural nervous networks are effective computational instruments that can learn process behavior and the relationship between variables with no apparent system model. It was developed on a precept work similar to that of the biological nervous system. Neural networks are composed of units named neurons or nodes utilizing for processing. A neural network is interconnected parallel buildings consist of three kinds of layers: input, hidden, and output [23, 24]. The data presented to the network layers are calculated by taking a weighted sum of the result from the previous layer, and this process is performed with weights which is the force of communication between two neurons, altered by the transfer function [25].

3. Results and discussions

3.1. ANN Modeling for removal Pb (II) and Cd (II) from wastewater

In the present work, using the neural network tool Matlab 2015 b software, we built three neural networks for three adsorbents with three input and two output as a topology: a multilayered feed-forward neural network (3:9:2) was used for modeling of removing heavy metals (Figure 2) with the functions of tangent sigmoid transfer (tansig) and linear transfer (purelin) for veiled and production layers and utilized Levenberg–Marquardt backpropagation (LMA) training algorithm. Mean square error (MSE) and correlation coefficient have been employed for choosing the ideal quantity of veiled nodes and to determine the activity of the net network.

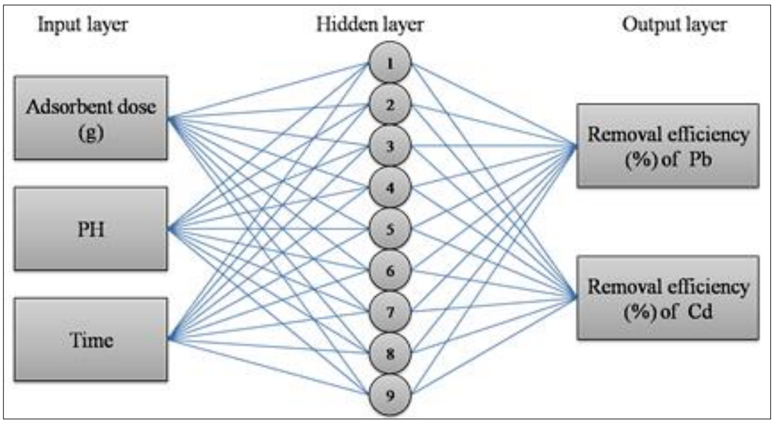

Figure 2. Neural Network structure

The three neural networks modeling appear optimum result when compare between experimental and predicted data for Pb (II) and Cd (II) for all three adsorbents depended on A regression analysis for networks as shown in Table 2 and Figure 3 .

Table 2 Comparison of ANN model output for three adsorbent with experimental data

Run	Adsorbent dosage (g)	PH	Time (min)	A ($Cu_{0.9}Zn_{0.1}Fe_2O_4$)				B ($Cu_{0.8}Zn_{0.2}Fe_2O_4$)				C ($Cu_{0.7}Zn_{0.3}Fe_2O_4$)			
				Experimental		ANN predicted		Experimental		ANN predicted		Experimental		ANN predicted	
				Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb
1	0.1	3	15	12.5	20.5	12.515	20.5354	26.7	24.3	26.70	24.300	14	13.8	13.993	13.84
2	0.1	3	30	32	45	39.901	45.0425	36.3	44	36.30	44	26	38.5	26.608	35.22
2	0.1	3	45	61.6	51.7	60.386	56.0721	64	52.3	67.9581	56.565	62	52	61.996	51.99
4	0.25	3	15	16	25.7	22.90	27.0046	35	29	31.9431	28.828	18	16	17.879	16.16
5	0.25	3	30	45	50	45.0768	50.041	44.6	45.3	44.5999	45.2999	35	43	35.4148	42.85
6	0.25	3	45	66.3	58	66.192	57.9637	73	55.3	73	55.2999	65	56	64.98	56.00
7	0.5	3	15	31.8	33	31.103	33.0352	44.5	26	44.500	26.00	27.9	17	27.933	17.0
8	0.5	3	30	62	54.6	62.4181	54.7687	64	48.5	63.999	48.4999	49.5	50	50.489	49.974

9	0.5	3	45	77.3	61.6	77.736	61.6529	81.74	60	81.7399	59.9999	79	61.75	75	62.059
10	0.1	7	15	56.5	36	56.4781	35.9891	62.5	31.3	60.9636	30.8750	58.6	43	57.57	41.82
11	0.1	7	30	83.3	67	81.913	60.453	89	64.2	88.999	64.1991	81.7	63	81.63	63.1
12	0.1	7	45	100	78.4	99.977	78.80	100	78.8	100	78.800	95	83.4	98.45	83.74
13	0.1	9	15	51.7	33	51.561	32.95490	51.7	30	55.7999	30.00	51	40	52.14	40.99
14	0.1	9	30	70	54.3	70.0298	53.255	70	56	78.500	56.00	68.2	55.2	69	54.367
15	0.1	9	45	84	70.8	84.153	70.4029	84	74	86.1259	75.0906	81.1	77.3	81.04	78.299

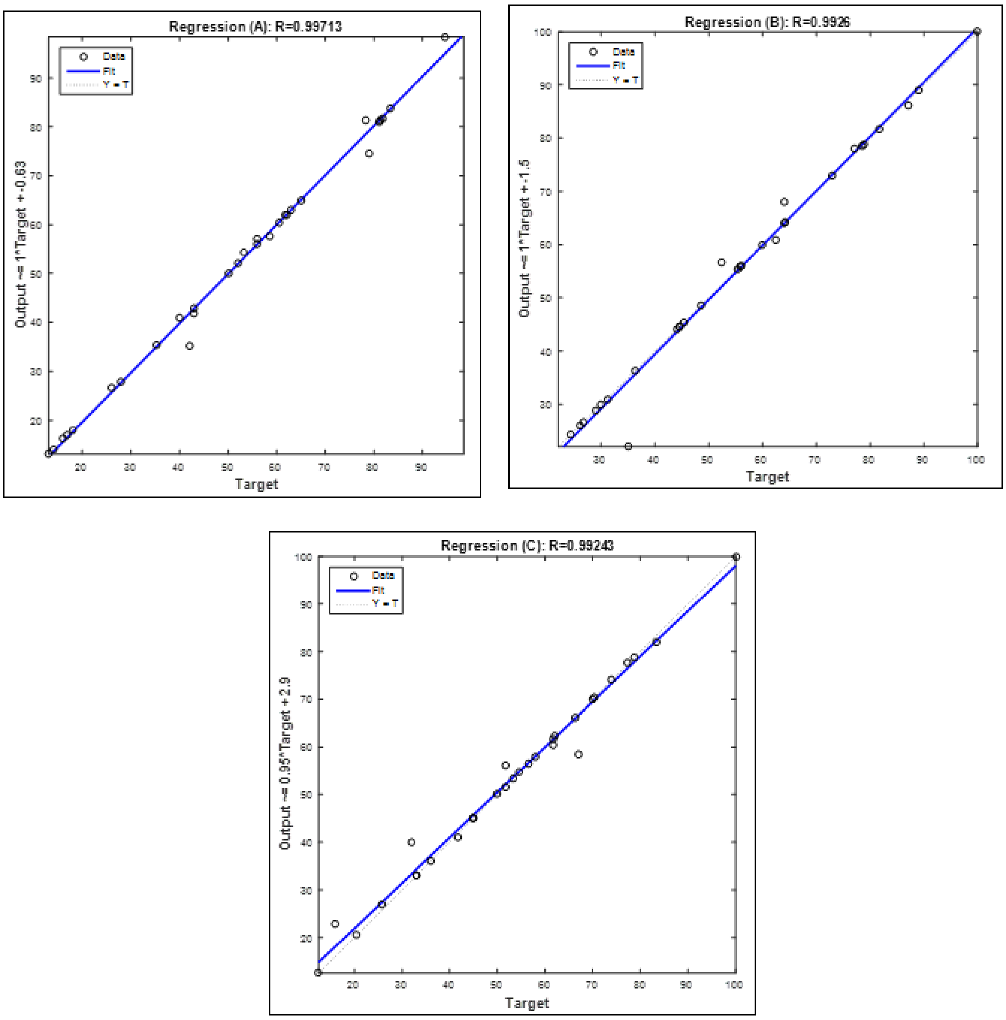

Figure 3. Regression for three neural networks

3.2. Elimination of Pb (II) and Cd (II)

3.2.1 Effect of Adsorbent Dose

Different adsorbent dosage (0.1 g, 0.25 and 0.5 g) was used for all three adsorbents (Cu0.9Zn0. 1Fe_2O_4 (A), Cu0.8Zn0.2Fe_2O_4 (B), and Cu0.7Zn0.3 Fe_2O_4 (C)) at *p*H 3 and 45 min of contact time. Figures 4 and 5 show that increasing adsorbent dosage increase the metal ions percentage removal, this remark could be clarified concerning the availability of active sites on adsorbent [26]. At a dose of 0.5g of adsorbent, the removal efficiency on sample A has obtained 77.4% Cd (II) and 61.6% Pb (II), for sample B were 81.74% Cd (II) and 60% Pb (II), and for a sample C were 79% Cd (II) and 61.75% Pb (II). From Figures 4 and 5, they can be observed an excellent match between the expected values of the ANN model and the investigation data.

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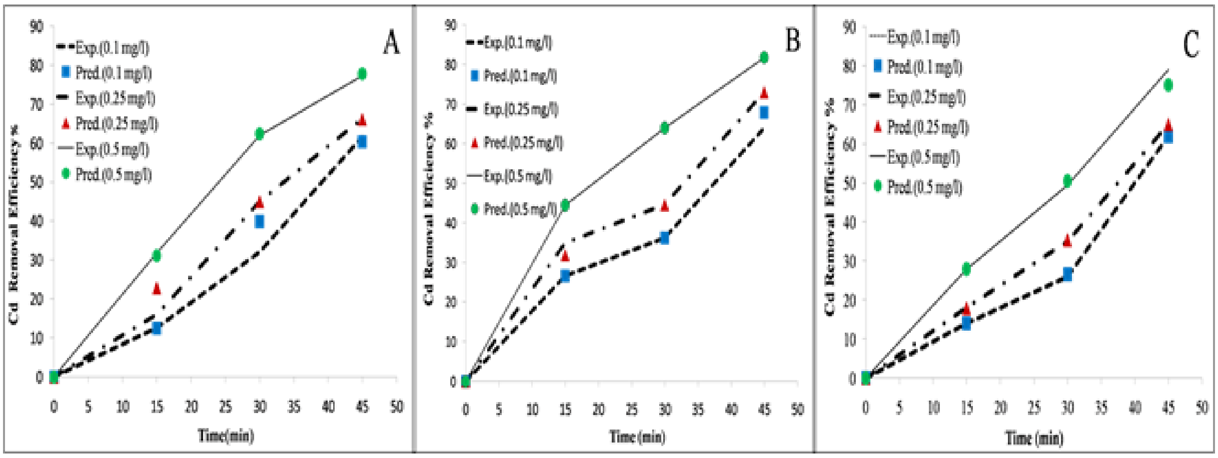

Figure 4. Impact of dose on the adsorption of cadmium by synthesized Cu1-xZnx Fe_2O_4 ferrite samples (Time=45 min and *p*H=3)

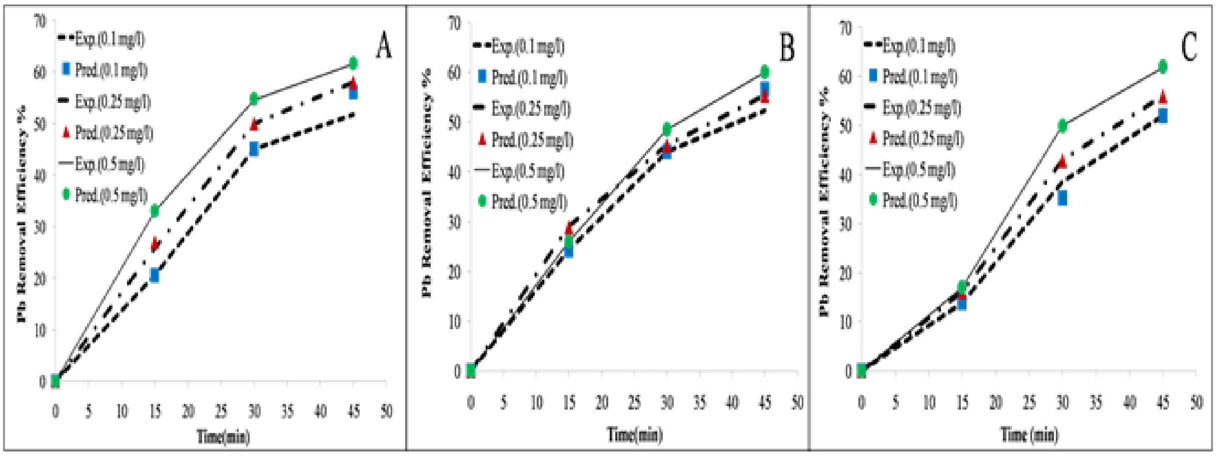

Figure 5. Impact of dose on the adsorption of lead by synthesized Cu1-xZnx Fe_2O_4 ferrite samples (Time=45 min and *p*H=3)

3.2.2. Effect of *p*H

The *p*H of the solution plays an important character in affecting the adsorption properties of Cd (II) and Pb (II) removal by utilizing three nano-magnetic materials (Cu0.9Zn0.1 Fe_2O_4 (A), Cu0.8Zn0.2 Fe_2O_4 (B), and Cu0.7Zn0.3 Fe_2O_4 (C)). The effects of *p*H on the removal of ions were studied from a range of 3, 7, and 9 under the conditions: The time used 45 min, the adsorbent dosage 0.1 g. Figures 6 and7 demonstrate that the greatest elimination of Cd (II) ions and Pb (II) ions on all three adsorbents occurred at *p*H 7, When *p*H values decrease, they increase the concentration of hydrogen ions that contest with the metal ions on the vigorous positions of nano-magnetic materials and reduces the elimination of Cd (II) and Pb (II), and at *p*H 9 became more basic and the adsorption declines as metal hydroxides precipitate, At *p*H 7, removal efficiency for cadmium ions was 100% complete removal on adsorbents A and B, and it was 95% on sample C [27,28].This decrease in the adsorption of Cd (II) on Cu0.7Zn0.3 Fe_2O_4 was due to a decrease in the percentage of Cu concentration and an increase in the proportion of Zn concentration in nano-magnetic materials and the maximum removal of Pb (II) was obtained respectively: on the samples A and B were 78.4% and 78.8%, and 83.4% on sample C was the highest removal of lead ions due to an increased concentration of Zn, this because of the oxidation and reduction reaction that happens between the metal ions and the adsorption surface [8]. It can be seen that ANN outputs were well compatible with the experimental data.

In general, the removal of Cd (II) ions is higher than the Pb (II) ions on all three nano-magnetic materials in the wastewater. It can be explained by the competitive influence of Cd (II) ions and Pb (II)

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ions with each other on the adsorbent and as a consequence of the difference of the ionic radius of metal ions, highly ionic radius of Pb (II) (1.20 A) compared to the smaller ionic radius of Cd (II) (0.97 A) [29].

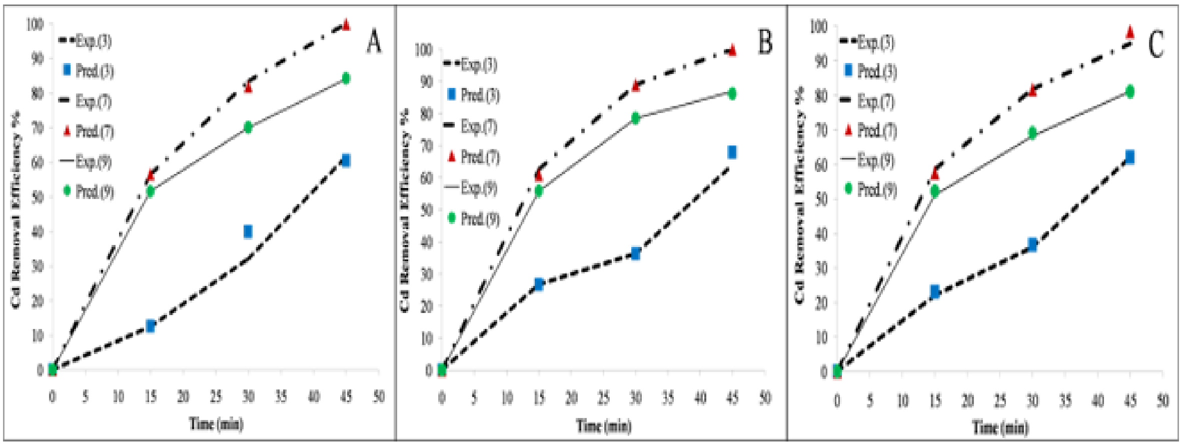

Figure 6. Impact of *p*H effect on the adsorption of cadmium by synthesized Cu1-xZnx Fe_2O_4 ferrite samples (Time = 45 min, dosage =0.1g)

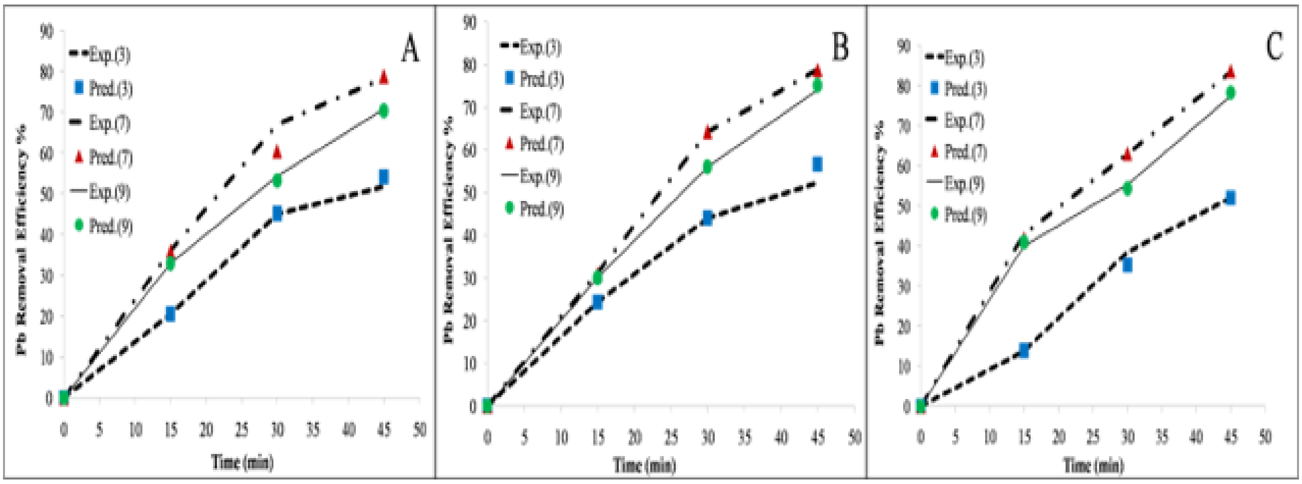

Figure 7. Impact of *p*H on the adsorption of lead by synthesized Cu1-xZnx Fe_2O_4 ferrite samples (Time = 45 min, dosage =0.1g)

3.2.3. Effect of Contact Time on Adsorption of Heavy Metals

The association between contact time of metal ions on the adsorbent and the removal efficiency of Cd (II) and Pb (II) from wastewater by adsorption processes on three nano-magnetic materials are shown in Figures 4-7. The contact time of the process studied within the range (0-45 min). It can notice that when taking the optimal *p*H, the adsorption of Cd (II) and Pb (II) increased rapidly with the contact time on all three adsorbents. For cadmium ions at optimum *p*H and 0.1 g adsorbent dose for 45 min gave an excellent removal of 100% on both adsorbents (A and B), and for adsorbent (C) was 95%, and for lead (II) removal when in optimum conditions when increasing contact time leads to increases the removal efficiency [30].

3.3. Sensitivity Analysis

Sensitivity analysis based on the Garson equation is employed to accurately calculate the beneficial effect of each input variable on the desired outcome of the process using the ANN model. Garson (1991) proposed an equation based totally on the partitioning of connection weights as shown in equation (4) [24, 31].

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$$RI = \frac{\sum_{D=1}^{D=HNn}\left(\left(\frac{\left|Cw_{iD}^{ilnl}\right|}{\sum_{P=1}^{IN}\left|Cw_{PD}^{ilhl}\right|}\right)\times\left|Cw_{Dn}^{hlol}\right|\right)}{\sum_{P=1}^{P=INn}\left\{\sum_{D=1}^{D=HN}\left(\frac{\left|Cw_{kD}^{lihl}\right|}{\sum_{P=1}^{IN}\left|w_{PD}^{ilhl}\right|}\right)\times\left|Cw_{Dn}^{hlol}\right|\right\}} \quad (4)$$

where RI on the output variable is relatively important to the input variable Jth; INn and HNn are the numbers of input and unseen neurons; CW represents the joining weights; the symbols il, hl, and ol denoted as input, unseen, and output layers, respectively; and symbols P, D, and n represent input, hidden, and output neurons. Table 2 shows the weights (W1) between input and veiled layers and weights (W2) between unseen and output layers for lead ions and cadmium ions. The relative importance demonstrated that all studied variables (*p*H, time, and adsorbent dose) as shown in Table 3 have a strong impact on the remove heavy metals.

Table 3. Weight matrixes, weights W1 between input, and hidden layers and weights W2 between hidden and output layers

A ($Cu0.9Zn0.1Fe_2O_4$)					
Neuron	W1			W2	
	Input			Output removal efficiency	
	dose	pH	Time	Cd	Pb
1	1.531891	2.094614	6.097508	-1.10087	2.37478
2	-0.76538	-1.42463	1.664859	7.398854	-4.3291
3	-3.2598	-0.82989	0.706704	0.907597	-2.02006
4	-5.04751	-2.15788	1.014614	7.793538	-3.90885
5	3.278002	10.08707	2.551699	3.758591	-3.76668
6	0.134582	-0.28952	-0.41463	4.339166	-1.5973
7	-3.30044	4.539701	0.490454	4.473481	0.35688
8	-4.54978	3.789718	-0.29774	-3.45536	0.663132
9	-0.28385	1.083311	-2.14344	3.34984	-2.8733
B ($Cu0.8Zn0.2\ Fe_2O_4$)					
Neuron	W1			W2	
	Input			Output removal efficiency	
	dose	pH	Time	Cd	Pb
1	-0.060776	2.314776	2.161732	-1.20504	0.534787
2	-1.916812	0.122129	1.797533	0.233048	1.869616
3	-2.242517	-1.817352	-0.421554	0.567053	-0.94997
4	1.733876	1.529245	-2.651626	0.978464	0.435186
5	-2.226246	1.303428	-1.097956	-0.79671	0.162232
6	-0.914441	1.423113	-3.102355	1.504676	-1.85424
7	0.52269	1.680648	0.931753	-3.35591	-1.49776
8	0.907181	-2.987748	0.197963	-0.85625	-0.61553
9	-0.399798	0.858952	2.301635	0.479228	0.336931
C (Cu0.7Zn0.3fe2O4)					
Neuron	W1			W2	
	Input			Output removal efficiency	
	dose	pH	Time	Cd	Pb
1	1.670775	1.257421	2.079593	-0.74413	0.675243
2	0.567013	-2.740658	-1.969579	0.445656	-0.52328
3	-1.188781	-2.811859	0.196921	1.002562	1.699028
4	2.220343	2.479469	-0.820134	0.488149	1.820264
5	0.43516	0.71296	-2.802105	-1.05258	0.943679
6	-1.622989	0.971016	-2.161367	-0.12119	1.293762
7	0.336759	2.643255	0.973647	2.045672	0.061981
8	-2.396424	1.36111	-0.986938	-0.75586	-0.18308
9	-2.218439	1.018479	1.092751	0.90391	-0.82423

Table 4. Relative importance of input variables

Relative importance Cd adsorption			
Input variables	Importance % A (Cu0.9Zn0.1fe2O4)	Importance % B (Cu0.8Zn0.2fe2O4)	Importance % C (Cu0.7Zn0.3fe2O4)
pH	29.2	41.13	23.13
dose	24.1	27.24	29.13
Time	46.7	31.63	47.74
Relative importance Pb adsorption			
Input variables	Importance % A (Cu0.9Zn0.1fe2O4)	Importance % B (Cu0.8Zn0.2fe2O4)	Importance % C (Cu0.7Zn0.3fe2O4)
pH	34	37.7	28.7
dose	25	26.2	27.7
Time	41	36.1	43.6

3.4. Results and Discussion of Antibacterial Activities

In this research, we used three ferrite substances A (Cu0.9Zn0.1Fe_2O_4), B (Cu0.8Zn0.2 Fe_2O_4), and C (Cu0.7Zn0.3Fe_2O_4) against two kinds of bacteria; the results demonstrate the capability of nano-magnetic materials to the effect of Staph. Aureus (gram-positive) and *E. coli* (gram-negative) in diverse percentages of inhibition bacteria.

The results demonstrated the ability of sample A to influence *Staph. aureus* more than used samples B and C, because the percentage of copper in sample A was higher than the other samples and zinc percentage was lower than others in sample A, and also the effect increased when the concentration of nano-magnetic materials increased too. The percentage of inhibition bacteria in samples A, B and C: were (77, 65, and 60) % when the concentration was (1 mg/mL) and (85, 72, and 65) % when the concentration was (2.5 mg/mL) while were (90, 86, and 72) % in concentration (5 mg/mL), the results appeared in Figures 8 and 9.

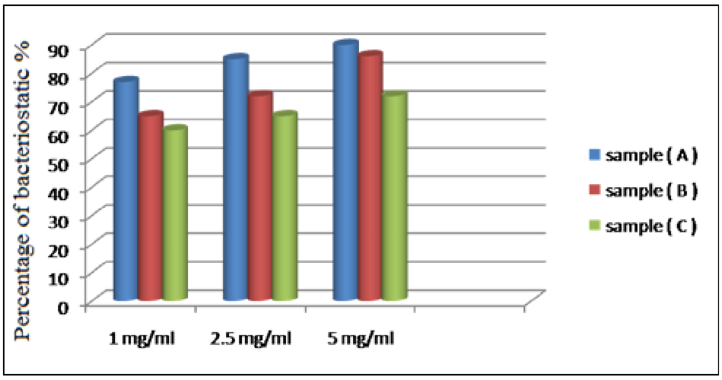

Figure 8. Bacteriostatic rate of A, B and C in different percentage against *Staph. aureus* bacteri

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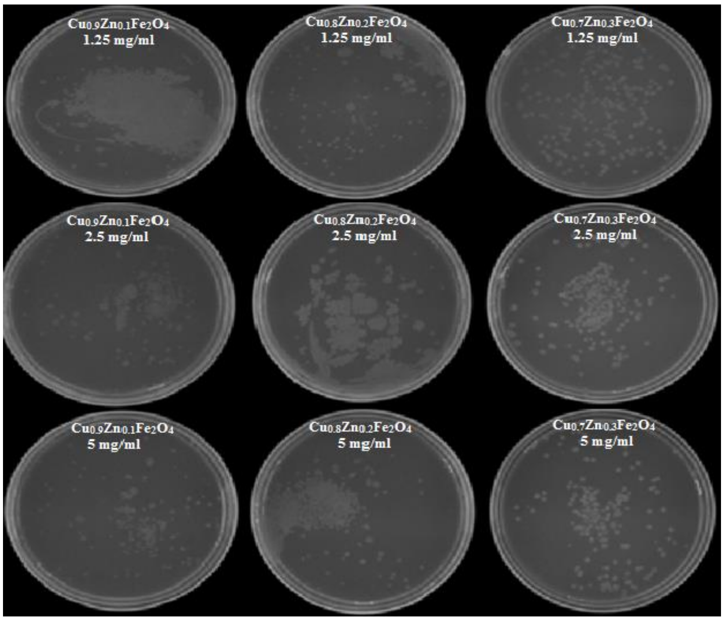

Figure. 9. Images of antibacterial activity of A(Cu0.9Zn0.1 Fe_2O_4), B(Cu0.8Zn0.2 Fe_2O_4) and C (Cu0.7Zn0.3 Fe_2O_4) in different percentage against *Staph. aureus* bacteria

While the results of samples A, B, and C against *E. coli* appeared the ability of these materials to have an effect on these bacteria in relative ratios appeared in Figure 10. The percentages of antibacterial were (96, 95, 93) % when the concentration was (1 mg/mL) and (97, 97, 94) % when the concentration was (2.5 mg/mL) while were (100, 99, 95) % for concentration (5 mg/mL), (Figure 11).

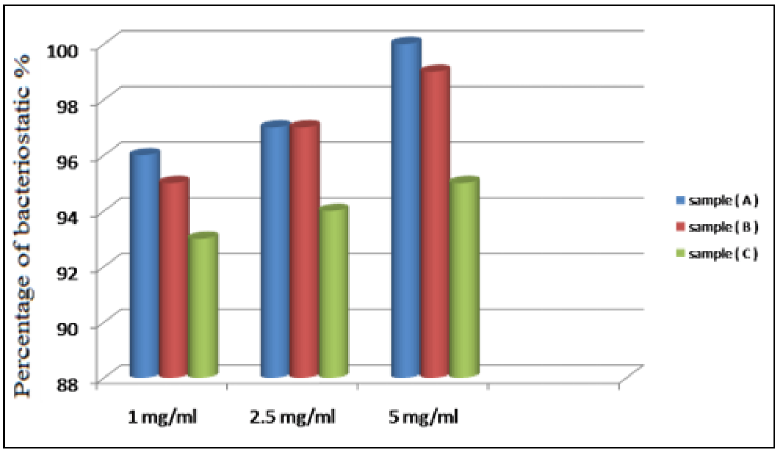

Figure 10. Bacteriostatic rate of A, B and C in different percentage against *E. Coli* bacteria

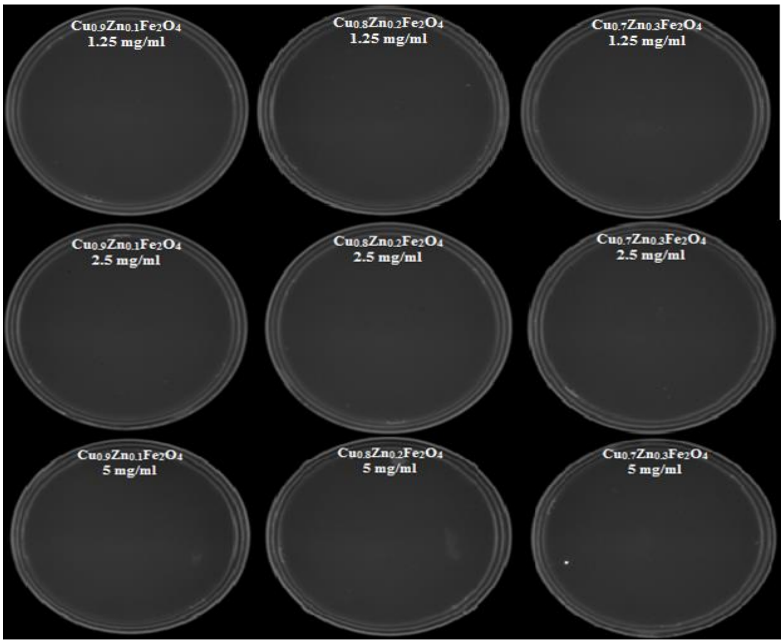

Figure 11. Images of antibacterial activity of A (Cu0.9Zn0.1 Fe_2O_4), B (Cu0.8Zn0.2 Fe_2O_4) and C (Cu0.7Zn0.3 Fe_2O_4) in different percentage against *E. coli* bacteria

These results indicated A (Cu0.9Zn0.1Fe_2O_4) has the most antibacterial properties against two types of bacteria compared with another nano ferrite that used in this research and the proportion killing of *S. aureus* was smaller than that of killing of *E. coli* of all ferrite composite nanoparticles.

Some studies believed that when *E. coli* reacted with copper nanoparticles, and the morphology of the cell membrane becomes different. Adhesion between these nanoparticles and the bacteriological cell barrier happened and penetrated over the cell membrane [32]. Destruction of the bacterial cell wall by copper ions caused the cytoplasm degradation and lysis that prompting cell demise. Rising foci of copper nanoparticles show whole cytoharmfulness versus *E. coli* [33]. Nanoparticles possess a huge outward territory, along these lines their bactericidal viability was improved contrasted with huge measured particles. Hereafter, nanoparticles are alleged to convey cytoharmfulness to microorganisms. Their bioaction promotes and forms them, active agents for bactericides because copper nanoparticles display a large surface-to-volume proportion [34]. Regarding the zinc nanoparticles framework, results indicated that zinc ties to the microorganism coats, for example mammalian cells, dragging out the slack duration of the progress round and growing age time of the living creatures so it necessitates every life formed greater investment to end the division of cells [35].

4. Conclusions

The Cu-ferrites powder was prepared and substituting of Cu ions by Zn ions as seen in the formal Cu1-xZn x Fe_2O_4 where x is (0.1, 0.2, 0.3) As of Cu0.9Zn0.1 Fe_2O_4 (A), Cu0.8Zn0.2 Fe_2O_4 (B) and Cu0.7Zn0.3 Fe_2O_4 (C) created by the sol-gel technique then investigated the effectiveness of these adsorbents for removing Cd (II) ions and Pb (II) ions by batch adsorption process. Compared between the two metals Cd (II) ions have the largest removal efficiency on all three nano-magnetic materials in aqueous solution. The highest removal for cadmium ions was 100% on adsorbents A and B and the highest removal for Pb (II) ions on adsorbent C was 83.4% when increased concentration of Zn in adsorbent material, at optimum condition (*p*H 7, dosage 0.1 g for 45 min). Three neural networks for three adsorbents were built with 9 neurons and successfully applied to simulations and gave the best fit for the experimental batch process showed an excellent correlation coefficient for A, B, and C are 0.99713, 0.9926 and 0.99243. We find all the variables used in the adsorption process have a robust impact on removing metals ion from wastewater based on the sensitivity analysis. For antimicrobial effectiveness results that A (Cu0.9Zn0.1 Fe_2O_4) have the most antibacterial properties against two types of bacteria compared with another Nano ferrite that used in this research and the proportion of killing of the *S. aureus* killing was smaller than that of killing of *E. coli* all ferrite composite nanoparticles

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