Evaluations of pH and High Ionic Strength Solution Effect in Cadmium Removal by Zinc Oxide Nanoparticles

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ABSTRACT: For human and environmental health protection, it is necessary to remove excess cadmium in industrial wastewaters before discharging them to environment. Some laboratory experimental batch study was done to evaluate the effects of the initial cadmium concentration, adsorbent dose, pH, ionic strength, and contact time on the cadmium removal efficiency by zinc oxide nanoparticles. All tests were performed in 100 ml solution at constant temperature of 25°C and mixing rate of 150 rpm. The residual cadmium concentration in the solution was determined using flame atomic absorption spectroscopy. Statistical analyses were performed on data using SPSS16 software by applying Mann-Whitney and Kruskal-Wallis tests and the result designing graphs were provided using Excel software. Finally, experimental data were analyzed using adsorption isotherm and kinetic equations. The results show that cadmium removal efficiency increases with an increase in the adsorbent dose and contact time and decreases with the increase in initial concentration of cadmium. Furthermore, it is observed that by raising the ionic strength of solution 30 fold, the adsorption rate is increased from 90.7% to 62.3%. Due to regression coefficient ($\geq$0.99), the adsorption process follows Langmuir isotherms model and pseudo-second order equation. Attending to the outcomes, zinc oxide nanoparticles have proper efficiency in the removal of cadmium from aqueous solutions. So, they can be used in treatment of the wastewaters containing cadmium ions. However, its efficiency is deeply dependant on the ion strength and the interactions of other metals in wastewater. © JASEM

Heavy metals are considered as one of the most formidable pollutants and their presence in water environments has brought about a plethora of concern because of their aggregation in environments, toxicity even in low concentrations, biological indecomposable nature, persistence, and causing acute as well as chronic diseases (Sethi and Khandelwal, 2006 and Godt et al., 2006). These heavy metals existing normally in nature in small amounts, are also found in surface run offs and industrial wastewater discharge from industries such as textile, iron and steel, paper, petrochemical, electroplating (O`Conell et al.; 2008, Gupta et al.; 2003 and Bulmer et al.; 1938). Arrival of these pollutants through industrial, urban, and agricultural wastewater has always been a threat to human health. Consequently, their elimination is of highly significance from the viewpoint of general health and environmental pollution control (Järup et al.; 2000 and 1998).

Cadmium as a heavy metal with very high toxicity has attracted the most attention among metals and the permissible limit for Cd(II) as described by WHO is 0.001 mg/l. Cadmium is one of those contaminant metals known as carcinogenic elements by EPA (Waalkes; 2003). This pollutant, for its aggregation property, enters the food chain and assembles in the body organs of living organisms especially in liver and kidney causing disorder in their functions. Calcium metabolism disorder, skeleton damage, osteoporosis, and kidney stones are all among the other harmful effects of this metal (Morais; 2012 and WHO; 2003)

At the present time, there are various methods like chemical precipitation synthesis, ion exchange, membrane separation, evaporation, electrochemical regeneration, coagulation and flocculation process, flotation technique, biological treatment, etc., for removal and recycling of heavy metals from aqueous solution (Salmani et al.; 2013, Pan et al.; 2007 and Amuda et al.; 2006). But these treatment technologies have some major flaws among which one can mention removal of concentrated solution, high essential energy, high costs of protection, the

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produced sludge removal and its high volume, undesirable and inappropriate removal, the need of expensive equipments, etc(Chen; 2004 and Kadirveliu et al.; 2001). For instance, chemical precipitation synthesis and electrochemical regeneration are inefficient in low concentrations of metal ions in aqueous solution (ranges of 1-100 mg/l). These methods are only effective in high concentration of metals and produce plentiful amount of sludge. Ion change and membrane separation are both extremely costly techniques particularly when treating large amount of water and wastewater containing heavy metals in low concentration. Hence, none of these methods can be used in large scales (Mesfin et al.; 2011 and Olayinka et al.; 2010).

It is proved that the adsorption method is vastly productive, especially for average or low concentration of heavy metals in wastewaters. The adsorption efficiency depends on various factors such as surface area, particle size distribution, chemical polarity, and adsorbent functional groups. Low price, high efficiency, convenience, and accessibility have made the adsorption method an excellent technique for effective wastewater treatment. Although being naturally efficient, adsorption method suffers resistance to mass transfer, in a large scale for the size of the adsorbent. This problem can be solved by the utilization of nanotechnology (Setshedi et al.; 2012).

Applying nanotechnology for decreasing the adverse effects of environmental pollution can be presented as one of the environmentally favorable management solutions. Nanoparticles are very practical as filtration in water treatment. They have some key physical and chemical properties like high ratio of area/volume high area energy, a better catalytic potentiality, and nonresistance to internal diffusion (Dhermendra et al.; 2008). High area/volume ratio of nanoparticles is as a result of decreasing the adsorbent size to nano scale. This property of nanoparticles results in an increase in nano area energy that can raise reactivity area and therefore leads to a growth in the adsorption capacity of the adsorbents (Pradeep; 2009). In addition to that, nanoparticles can functionalize with different chemical groups for their stability and their reactivity (Nora and Mamadou; 2005).

Since there are more adsorbent atoms for each unit of adsorbent in adsorption area, they can actively be used in contact with these pollutants, consequently, less quantity of waste material is produced after the

treatment. These qualities can help the current technologies in wastewater treatment. Nanoparticles for having a specifically high surface area and being nonresistance to internal diffusion, are very efficient for rapid adsorption of heavy metal ions and organic molecules from aqueous solution (Hua et al.; 2011).

During the past two decades, Zinc oxide has been extensively studied as a very attractive material because its high sensitivity to light, band gap, and durability cause the destruction of different pollutant. Zinc oxide as an economical photo catalyst can be a satisfactory substitute for TiO_2 in organic compound removal from aqueous solution. Scientists have recently discovered that nano-structured zinc oxide can be effective in heavy metal removal (Aminifar and Soltaninezhad; 2011). Therefore, this paper studies the efficiency of zinc oxides nanoparticles in cadmium removal from high ionic strength solution.

MATERIAL AND METHOD

This research is an experimental-laboratory batch study. The required nanoparticle zinc oxide was purchased from Masihaye Shargh. All chemical substances were analytical grade. During the experiment, for appropriate contact and uniform mixture of cadmium and the sorbent, a shaker with a fixed shaking rate of 150 rpm was used and the environmental temperature was set to 25 °C.

At first, the 1000 ppm stock solution from cadmium was provided and the required initial concentrations were prepared in 100 ml sample solutions. A stock suspension of 1 g/l was provided by suspending zinc oxide nanoparticles of ≤80 nm particle size in demineralised water. Quickly after that, the Erlenmeyers were placed in the ultrasonic bath for 2 minutes until the sorbents spread homogeneously in the solutions. Different amounts of this suspension were added to the test Erlenmeyer, Containing a Cd(II) solution to give a set of suspension solution with different initial Cd(II) concentrations. In each batch test set, five pH values of between 3 until 7 were fixed by adding 10% nitric acid. The ionic strength in each flask was set at three levels of 0.1, 0.3, 3 mol/l using sodium sulfate. The Erlenmeyers were placed on a shaker with the shaking rate of 150 rpm. After desired time, samples were taken and filtered by a 0.2 µm filter and analyzed for residual Cd(II) by flame atomic absorption at a wavelength of 228.8nm in the standard absorption mode. The efficiency and adsorption capacity were calculated from residual concentrations of cadmium and the known initial concentration of cadmium and

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nanoparticles. Finally, Experimental data were fitted with some isotherm models and kinetic equations.

RESULT AND DISCUSSION

Five different experimental levels were designed for studying the importance of parameters on the efficiency of cadmium removal. In each of these experiments, all the parameters except the factor under study were constant.

Effect of the initial cadmium concentration, adsorbent dose, and contact time: Before survey of ionic strength and pH on the efficiency of zinc oxide nanoparticles in cadmium removal, it seems that the factors initial concentration of cadmium, adsorption dosage and contact time need to be optimized. So the affects of these factors on the removal efficacy was studied by several experiments and the obtained results were carefully calculated and placed in table(1).

Table: 1 the effect of the initial concentration of the pollutant, absorbent dose, and contact time on cadmium removal efficiency

Adsorbent mass (gr)	Tim (min)	R%			q_e		
		$C_0=5$ mg/L	$C_0=10$ mg/L	$C_0=15$ mg/L	$C_0=5$ mg/L	$C_0=10$ mg/L	$C_0=15$ mg/L
0.5	15	83.6	82.6	84.2	0.84	1.65	2.53
	30	85	83.8	84	0.85	1.68	2.52
	60	92.2	90.7	85.67	0.92	1.81	2.57
	120	88.2	85.4	82.2	0.88	1.71	2.47
	180	87.8	84.9	81.47	0.88	1.70	2.44
1	15	91	78.6	72.6	0.46	0.79	1.09
	30	90.8	80.3	74.93	0.45	0.80	1.12
	60	91.2	84.2	77.13	0.46	0.84	1.16
	120	90.6	84	76.73	0.45	0.84	1.15
	180	89	81.5	74.33	0.45	0.82	1.12

As it is observed, the removal efficiency is decreased when the cadmium concentration is increased from 5 mg/l to 15 mg/l. As reported in table (1), the maximum removal efficiency was recognized as 92.2% in the contact time of 60 minutes, initial concentration of 5 mg/l and adsorbent mass 0.5 g. In the same way, the minimum removal efficiency was spotted as 72.6% in the contact time of 15 min, initial concentration of 15 mg/l and adsorbent mass 1g.

Effect of pH: The solution pH of below 7 was selected in order to avoid metal precipitation. Figure (1) is illustrated the effect of pH on cadmium removal process by zinc oxide nanoparticles
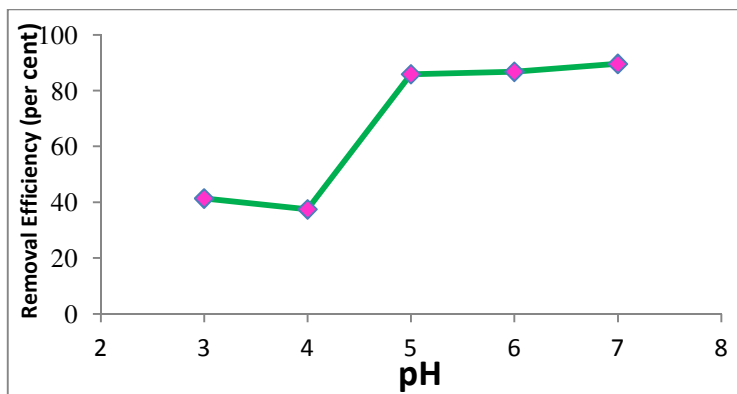
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Fig: (1) the effect of pH of the solution on the efficiency of cadmium removal
(C_0=5 mg/L, adsorbent mass =0.5 g/L, t=60min)

Generally, the efficiency of cadmium removal is increased with a raise in pH. In detail, with a change in pH from 4 to 5, the removal efficiency of cadmium is increased in a great deal, and when the pH is increased to 7, the efficiency of cadmium has had a gradual increase. Thus, the highest removal efficiency is gained in pH=7 that is 89.6%, and the lowest efficiency is measured as 38% in pH=4. Thus, in further study, the pH of 7 was selected for other tests.

Effect of ionic strength: For studying the influence of ionic strength on the efficiency of cadmium removal by zinc oxide nanoparticles, experiments were carried out in optimum condition and five distinct time durations (15, 30, 60, 120, and 180 min) with three different ionic strengths (0.1, 0.3, and 3 mol/l) solution. The results of each experiment were calculated and introduced in figure (2).
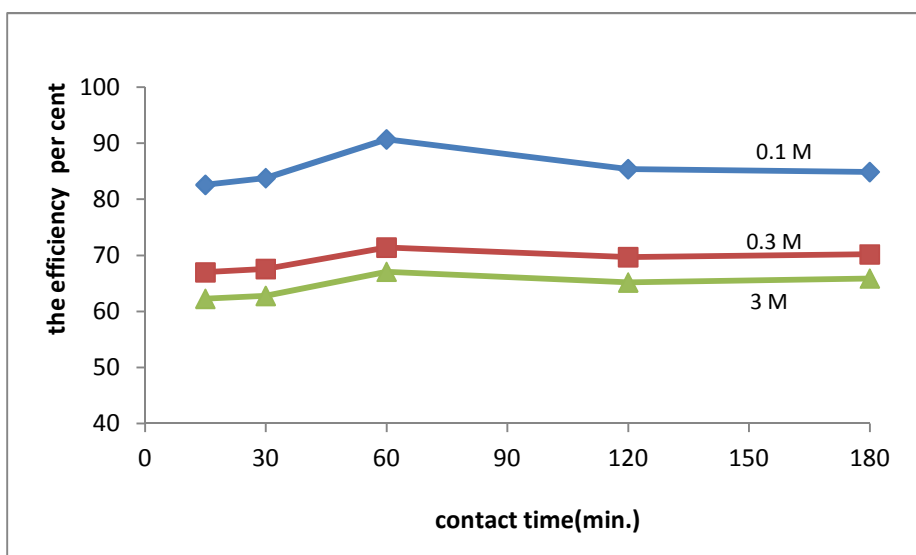

Fig: (2): the effect of the ionic strength on the removal efficiency (C_0=5 mg/L, sorbent mass =0.5 g/L and pH=7)

Following figure (2), the highest removal efficiency is 90.7%, which occurred when the contact time was 60 minutes and the ionic strength was 0.1 mol/L; in the same way, the lowest removal efficiency is

62.3%, which occurred when the ionic strength was 3 mol/L. The effects of the three different ionic strengths (0.1, 0.3, and 3 M) on adsorption capacity were calculated in the very similar conditions. The

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outcomes were fastidiously calculated to adsorption   capacity that can be seen in figure (3).
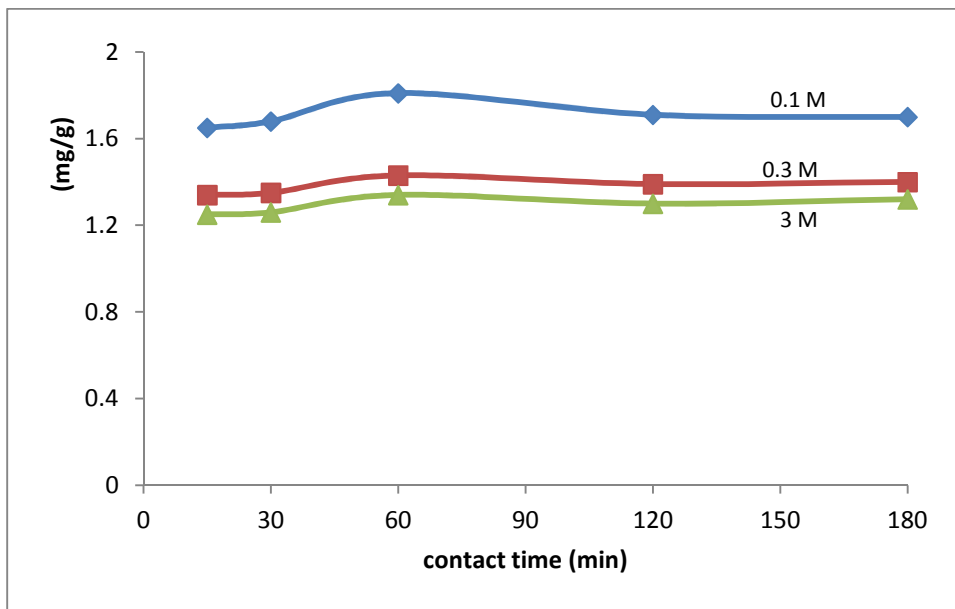

Fig: (3): the effect of the ionic strength on the adsorption capacity (C_0=5 mg/L, sorbent mass =0.5 g/L and pH=7)

The maximum q_e, as recorded in the diagram in figure (3), occurred at the contact time of 60 minutes and the ionic strength of 0.1 mol/L and it was 1.81 mg/g. likewise, the minimum q_e was reported in the ionic strength of 3 mol/L and it was 1.25 mg/g. In this study, Kraskal-Wallis test was used for analyzing and determining the effect of ionic strength as the variable on the removal efficiency. The result is in table (5).

ionic strength	N	Minimum	Maximum	Mean	Std. Deviation	P-Value
0.1	36	75.00	94.27	86.9315	4.24523	
0.3	36	67.00	91.20	78.6565	7.49500	
3	36	53.67	90.40	73.5991	10.37231	<0.001
Total	108	53.67	94.27	79.7290	9.48390	

Table 5: the statistical results of the effect of ionic strength on the removal efficiency

Focusing on table (5), with increasing the ionic strength of solution from 0.1 to 0.3, and then to 3 mol/L, cadmium removal efficiency by zinc oxide nanoparticles has decreased. The mean removal efficiency for ionic strength of 0.1, 0.3, and 3 mol/L are respectively 86.93%, 78.65%, and 73.6%.

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Isotherm study: The adsorption data are usually described by adsorption equilibrium isotherms that indicate the effect of the initial concentration of pollutant on the adsorption quantity. In this study, the equilibrium adsorption level of cadmium by zinc oxide nanopaqrticles was explored at the contact time of 3 hours, the adsorbent mass of 0.5 g, cadmium initial concentrations of 5, 10, 15, 20, 25 mol/L, and the temperature of 25°C. To determine the adsorption isotherms, Langmuir, Freundlich, and Temkin were applied. The linear equations are as follows:

$$\frac{C_e}{q_e} = \frac{C_e}{q_{max}} + \frac{1}{b.q_{max}}$$ Langmuir isotherm

$$Lnq_e = LnK_f + \frac{1}{n} LnC_e$$ Freundlich isotherm

$$q_e = B_T Ln\, K_T + B_T\, LnC_e$$ Temkin isotherm

Where q_e is the amount of the metal ion, pollutant, adsorbed at the equilibrium, q_{max} is the maximum adsorption capacity, b is the adsorption equilibrium constant, and C_e is the equilibrium concentration of metal ions (mg/l). Also, K_f is the Freundlich constant (a measure of adsorption capacity), $1/n$ is adsorption intensity, B_T is adsorption equilibrium constant, and K_T is adsorption equilibrium constant.

According to the obtained results (table 6), the experimental data fitted well to Langmuir isotherm. So this adsorption model was employed as the best for describing the characteristics of zinc oxide nanoparticles in cadmium removal from the aqueous solutions with high ionic strength.

Table (6): coefficient regression and adsorption isotherm parameters

Langmuir		Freundlich		Temkin	
R^2	0.99	R^2	0.907	R^2	0.952
b	0.61	n	2.14	K_t	0.851
q_{max}	3.69	K_f	1.29	B_t	1.398

Adsorption kinetic study: One of the most salient factors for designing an adsorption system (to determine the optimum contact time) is anticipating the speed of the adsorption process that is controlled by kinetic system. In order to ascertain cadmium adsorption kinetic on zinc oxide nanoparticles, the experiment was carried out under the optimized conditions and five different contact times as 15, 30, 60, 120, and 180 minutes were selected. To determine the reaction kinetic, pseudo-first order equation, pseudo- second order equation, and Elovich equation were considered. The linear forms of these equations are:

Ln(q_e-q_t)= Ln q_e – K_1t   Pseudo-first order

$$\frac{t}{q_t} = \frac{1}{K_2(q_e^2)} + \frac{t}{q_e}$$ Pseudo- second order

$$q_t = \frac{1}{\beta} Ln(\alpha\beta) + \frac{1}{\beta} Lnt$$ Elovich

Where q_t is the amount of the pollutant adsorbed at time t (mg/g), k_1 is the rate constant of pseudo-first-order adsorption (min^{-1}), K_2 is the rate constant of pseudo-second-order adsorption (min^{-1}). α is the initial adsorption rate (mg g^{-1} min^{-1}), and β is the desorption constant.

The correlation coefficient (R^2) for pseudo-first order equation, pseudo- second order equation, and Elovich equation were consequently 0.201, 0.999, and 0.570. As reported by the results and shown in figure (4), pseudo- second order equation was considered the most appropriate model for describing the kinetic behavior of zinc oxide nanoparticles in adsorbing cadmium from high ionic strength solution.
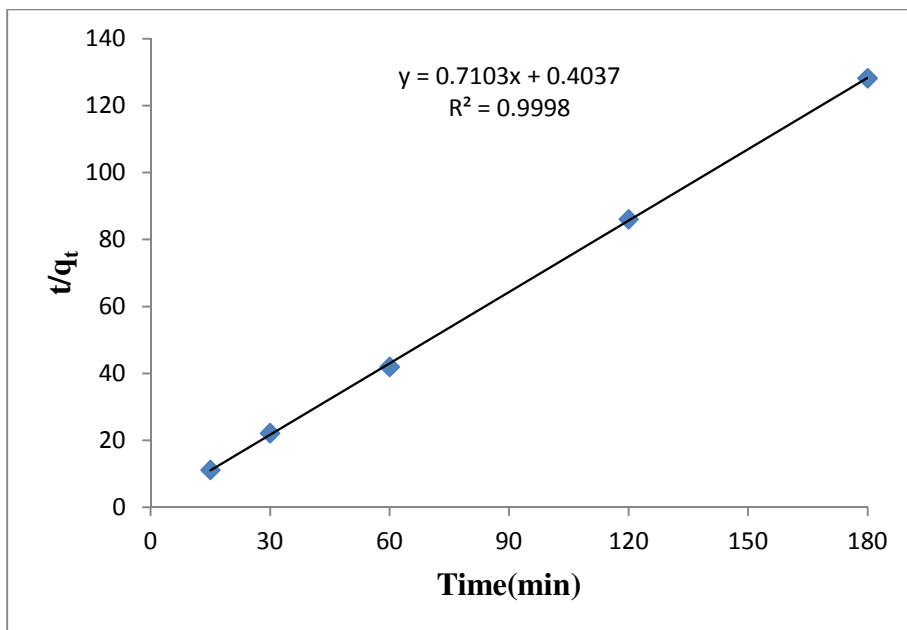
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The chart shows data points and the equation:

$$y = 0.7103x + 0.4037$$
$$R^2 = 0.9998$$

with axes labeled t/q_t (vertical) and Time(min) (horizontal).

Fig: 4: the pseudo- second order kinetic model in cadmium removal by zinc oxide nanoparticles

Analysis of the efficiency of pH: pH is one of the most important effective factors in adsorption process. It can cause a change in ionic state of the metals and ionization, and the surface charge of adsorbents. All together, these changes affect the interactions between the adsorbent and the adsorbate in various pHs. In this study, it is observed (figure 1) that the removal efficiency in acidic pH is lower. The reason is that a kind of electrostatic repulsion is created between the adsorbent surface and cadmium ions as the adsorbate is positively charged in acidic pH. In addition to that, hydrogen ion concentration in the acidic solution is increased and the ions rest on the adsorbent instead of cadmium ions. Also, with an increase in pH, the hydrogen ion concentration decreases and only the sodium ions which act less in competition with hydrogen ions enter the solution. This brings about a raise in cadmium adsorption. In this study, it is observed that cadmium removal efficiency is increased when pH goes up. When pH rises from 4 to 5, cadmium removal efficiency increases significantly and then when it changes to 7, the removal efficiency of cadmium increases gradually. As wastewaters containing cadmium has approximately this range of pH, zinc oxide nanoparticles can be used in treatment of wastewaters containing cadmium although the efficacy depends highly on ionic strength and interactions of other metals in wastewaters.

Sheela and Nayaka , in a research in 2012, used NiO nanoparticles for cadmium and lead removal. They studied the effect of pH value (pH of 3-12) on adsorption process. The results uncovered that the removal efficiency is enhanced by increasing the pH (Sheela and Nayaka 2012). In a study by Atar et al. 2012, waste material from boron enrichment process was used in cadmium removal. They investigated a pH range of 1 to 6. The results showed that cadmium removal efficiency is raised with the increase of pH. In a study by Afkhami et al. 2010, nano-alumina modified with 2, 4-dinitrophenylhydrazine were used for the removal of heavy metals such as Co(II), Mn(II), Ni(II), Pb(II), Cd(II), and Cr(III). They used the pH range of 1.5 to 5.5 to determine the effect of pH. The results showed that when the pH increases from 1.5 until 5, the removal efficiency is also increases, but after that, with an increase in pH, the removal efficiency decreases. The result of this study is not in agreement with the present research.

Analysis of the efficiency of initial concentration: The results of the study reveals (table 1), with the increase in cadmium concentration from 5 to 15 mg/L, the removal efficiency decreases but the adsorption capacity increases. The decrease in removal efficiency in high concentration is because of the saturation of the active adsorption sites on the surface of the adsorbent by the pollutant. The increase of the adsorption capacity is because of the

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access to more amount of cadmium in higher initial concentrations this may bring about a thrust for ion transfer from the solution in to the adsorbent.

Gupta and Nayak; 2012 made use of orange peel and Fe_2O_3 nanoparticles for removing cadmium from aqueous solutions. They selected the concentrations of 50 to 200 mg/L. Their studies showed that cadmium removal amount increases when the initial concentration increases.

In a research done by Salim et al. (2008), silica ceramic was chosen as cadmium adsorbent. They made use of the cadmium concentrations of 5 to 20 mg/L for studying the effect of initial concentration on the adsorption amount. The outcome says with an increase in cadmium initial concentration, the amount of cadmium adsorption increase. This confirms the result of Salim and Gupta et al.

Analysis of the efficiency of adsorbent mass: The mass of the adsorbent is one of the other factors that studies in adsorption experiments. The outcomes from this study (table 1) demonstrate that the adsorption efficiency of cadmium removal goes up when the adsorbent mass increases. As a matter of fact, the increase in the adsorbent mass causes an increase in the number of the active adsorption site in solid phase and therefore causes an increase in the efficiency of cadmium removal. With increasing adsorbent mass amount, the number of the active sites increases, so the contact area of the adsorbent and the pollutant increases and causes an increase in the adsorption capacity. According to the results of the study, the optimum adsorbent mass and the maximum removal efficiency took place when the mass of zinc oxide nanoparticles was 0.5 g. The reason is decreasing the contact between the surface of the adsorbent and the pollutant. This can be explained that adsorbents own a limited number of active sites on their surfaces; in high concentrations, these nanoparticles become agglomerated and bring about a decrease in the active sites related to mass.

Atar et al. (2012) studied adsorption of Cd (II) and Zn (II) on boron enrichment process waste in aqueous solutions using different masses of 0.1, 0.5, 1 and 4 g for studing the effect of adsorbent mass on the removal efficiency. The outcome showed that with an increase of mass to 1 g, cadmium removal efficiency increases rapidly, then with increasing the adsorbant mass from 1 to 4 g, cadmium removal efficiency increases reletively slowly. In a work done by Ding et al.(2012), it was shown that the removal

efficiency increases with an increase in adsorbent mass. It was also observed that when the adsorbent mass increases, the adsorption capasity decreases.

Analysis of the efficiency of contact time: The acquired time for the interaction between the adsorbent and adsorbate is another crucial factor that needs to be taken in to account. The results of the study suggest (table 1) that the equilibrium time for the adsorbent is approximately 60 minutes. The reason is that with an increase in the contact time, cadmium has more opportunity to interact with the adsorbent surface but the more increase of contact time can occurs the desorption process. At first, as time goes until 60 min, the adsorption capacity increases, but then, with the further increase of time longer than 60 min, the adsorption amount changes noticeably slowly. This implies an equilibrium state is reached. The increase in adsorption amount in the initial times is for the availability of more active sites and functional groups.

In a study by Kosa et al. (2012), it was shown that from the outset, with an increase in contact time of cadmium and the adsorbent, the removal efficiency increases but then does not make a significant change. Actually, the maximum adsorbed amount takes place within the first 10 minutes. Similar outcomes were observed in a study done by Saif et al. (2012). They found out with an increase in contact time, removal efficiency also increases until it reaches a state of equilibrium, which is 180 minutes for their study and after that there is no further remarkable change. Nano structured γ-Alumina were applied as a new and appropriate adsorbent for cadmium removal from aqueous solutions. For investigating the effect of time, firstly, 0.2 g of the adsorbent is mixed with 100mL of 50 mg/L cadmium solution. Then, the amount of cadmium ion adsorption by the adsorbent is recorded. It was realized, from the results, the adsorption percentage increases with an increase in the contact time. The equilibrium was reached in time of 180 minutes, and after that, the adsorption speed decreased. In other words, after 180 minutes, a state of equilibrium was attained between the solid phase and the solution (Zavar et al., 2012).

Analysis of the efficiency of ionic strength: Ionic strength parameter is very important in the adsorption process of metal ions since high ionic strength solutions are similar to wastewaters and it can bring a different condition in adsorption which is as a result of electro-statistic interaction between metal ions and

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adsorbent surface. According to the surface chemistry theory expanded by Guoy and Chapman, when solid adsorbent is contact with sorbent species in solution, they are bound to be surrounded by an electrical diffused double layer, the thickness of which is significantly expanded by the presence of electrolyte (Osipow 1972).

In this research, for investigating the effect of ionic strength on adsorption process by zinc oxide nanoparticles, the efficiency of three distinct ionic strengths (0.1, 0.3, and 3 mol/L) were selected. As figures 2 and 3 show, with an increase of ionic strength from 0.1 to 3 mol/L, cadmium removal efficiency decreases. The reason is that the concentration of Na ions increases in the solution as ionic strength of the solution increases. The Na ions are positioned adjacent to the surface of zinc oxide nanoparticles. The association of these positive ions around the adsorbent causes a decrease in the contact between cadmium and nanoparticles and at the end, cadmium adsorption potential by zinc oxide nanoparticles decreases. On the other hand, the high concentration of Na ions competes well with cadmium ions and set on the active sites present on the surface of nanoparticles. Consequently, the active sites on the surface of the zinc oxide nanoparticles saturate and bring about a decrease in cadmium removal efficiency. The ionic strength of the solution becomes 30 fold (from 0.1 to 3 mol/l) the removal efficiency decreases a little (from 90.7 to 72.1%). It illustrates that high concentration of Na ions cannot completely occupied active sites and an electrical diffused double layer occurs by Na ions that it cause a repulsion between ions in the solution.

Kosa et al. worked with multi-walled carbon nanotubes modified with 8- hydroxyquinoline for removal of heavy metals like cupper, lead, cadmium, and zinc. They made use of KNO_3 for providing solutions with ionic strength of 1, 0.1, 0.01,and 0.001 mol/L. the results indicates that as the ionic strength increases from 0.001 to 0.1 mol/L, the removal efficiency of lead, cadmium and zinc increases, but it has no effect on the efficincy of cupper removal. Also, with further increase of the ionic strength from 0.1 to 1 mol/L, the removal efficiencies of lead, cadmium, and zinc decrease (Kosa et al., 2012).

In a research done in 2012, Gupta and Nayak. studied the utilization of orange peels and Fe_2O_3 nanoparticles in removing cadmium from aqueous solutions. Sollutions with ionic strength of 0.001, 0.01, and 0.1 mol/L were applied for inspecting the effect of ionic strength. Also, $NaNO_3$ was used for ionic strength adjustment. the results said cadmium removal efficiency decreases as ionic strength increases from 0.001 to 0.1 mol/L.

Conclusion: The adsorption process by zinc oxide nanoparticles can be a good alternative in treating solution containing Cd(II). The cadmium removal efficiency is highly sensitive to the change in pH and ionic strength. In general, cadmium removal efficiency increases as the pH of the solution becomes higher from 4 to 7. The result shows that solution containing high ionic strength showed lower removal efficiency than those having low ionic strength. The adsorption capacity is high in the initial times, but it decreases with further increase in the adsorption time. The data of adsorption of cadmium ions follow Langmuir isotherm (R^2 = 0.990). Furthermore, Cadmium adsorption kinetic on zinc oxide nanoparticles is best described by the Pseudo-second order equation (R^2 = 0.999). The current study uncovered that zinc oxide nanoparticles are appropriate adsorbents for removing cadmium in wastewaters.

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