Mesopo. Environ. J., Vol.4, No.2,pp(79-88), 2018

Mesopotamia Environmental Journal
ISSN 2410-2598
Journal homepage http//:www.bumej.com

Removal of Nickel from simulated wastewater using granular dead anaerobic sludge

Zaman Ageel Hammood

Faculty of Engineering.

Corresponding author: aube_z@yahoo.com

To cite this article:

Hammod Zaman Ageel   Removal of Nickel from simulated wastewater using granular dead anaerobic sludge. *Mesop. environ. j., 2018, Vol. 4, No.2, pp. 86-95.*

Received date: 7/4/2017   accepted date: 31/5/2017   published date:15/3/2018

Abstract

The possibility of using sewage sludge for treatment of water contaminated with nickel ions was investigated. Batch tests were conducted to evaluate the equilibrium sorption properties of the granular dead anaerobic sludge in nickel-containing aqueous solutions. Contact time, initial pH, initial concentration, sorbent dosage and agitation speed were found to be the most factors influenced on the treatment process. The best values of these parameters that will achieved removal efficiency of nickel (=99.5%) were 1h, 5, 50 mg/L, 0.2 g/100 ml and 300 rpm respectively. The results signified that the Langmuir isotherm model is a suitable for the sorption data of nickel by sewage sludge under the studied conditions.

Keywords: Nickel; Granular dead an aerobic sludge; Sorption; Wastewater

Introduction

The presence of toxic heavy metals in wastewater brings about significant changes in the properties of water resources and must be avoided to preserve the environmental quality. These metals, such as cadmium, nickel and lead, can be related to many anthropogenic sources, and their compounds are extremely toxic [1]. Water pollution with heavy metals is closely associated with several human activities such as mining, the metal processing industry, petroleum industry, power industry and on a smaller scale by electroplating wastes, metal-based pigments and numerous other industrial wastes, besides the high exhaust emissions in urban regions from car engines, burning of hospital wastes and domestic solid waste, as well as wasteland-landfills [2]. There are several methods to treat the metal contaminated effluent, but the selection of the adequate method is based on the concentration of pollutant and the cost of treatment [3]. These methods include chemical precipitation, electroplating, ion exchange, and reverses osmosis which are expensive and inefficient especially for low metal concentration as cited by many studies [4, 5].

Sorption technique is considered a promising method and this can be attributed to its simplicity in design and operation, low cost, and insensitivity to toxic materials. Investigation the usage of low cost sorbents for treating large quantities of wastewater has become a substantial issue. In this concern, sewage sludge has been used by many researchers to remove heavy metals and organic pollutants from industrial wastewater. In the present study, granular dead anaerobic sludge or dead biomass from drying beds, which is richer with different micro-organisms than aerobic activated sludge [6], was used as a biosorbent to remove nickel from synthetic contaminated wastewater.

The regular biological activities of municipal wastewater treatment plants produce large quantities of byproduct biomass wastes. Thus, reuse of this waste as a reactive medium is attractive in terms of sustainable development and reduced disposal costs. Accordingly, the present study aims to investigate the potential application of sewage sludge biosorbent as an inexpensive material for the treatment of wastewater contaminated with nickel ions.

Materials and methods

Nickel was selected as a representative of heavy metal contaminants. To simulate the water's nickel contamination, a solution of $Ni(NO_3)_2$ (manufactured by BDH, England) was prepared and added to the specimen to obtain representative concentration. The sewage sludge was collected as slurry from about 50 cm depth of drying bed in Al-Rostomia municipal treatment plant, Baghdad/Iraq. It was dried at atmospheric temperature for 5d and sieved using 1/0.6 mm diameter mesh. The sieved portion was washed five times with distilled water and dried at 70°C for 6 h prior to use [7].

Batch experiments

Batch equilibrium tests are carried out to identify the best conditions of, initial concentration, contact time, initial pH, shaking velocity, and resin dosage. This means that these tests are suited to identify the activity of the granular dead an aerobic sludge and the sorption isotherm. Series of 250ml flasks are prepared and each flask was filled with 100 ml of nickel solution which has an initial concentration of 50 mg/l. About 0.2 g of biosorbent was added into each flask and the solution was kept stirred in high-speed orbital shaker at 300 rpm for 2 h. A fixed volume (20 ml) of the solution was pipetted out from each flask and this solution was filtered to separate the sorbent and a fixed volume (10 ml) of the pure solution was taken for determination the concentration of nickel ions still present in the solution. The measurements were carried out using atomic absorption Spectrophotometer (Norwalk, Connecticut (USA)). These measurements were repeated twice and the average value has been taken. The concentration of nickel ions sorbed on the biosorbent was found by a mass balance. From the best experimental results, the amount of metal ion retained in the granular dead biomass phase, C_s, was determined by using [8]:

$$C_s = (C_o - C_e)\frac{v}{m} \quad (1)$$

where C_s is the amount of metal separated from the aqueous solution (mg/g), C_o is the initial concentration of metal in the aqueous solution before mixing with biomass (mg/l), C_e is the concentration of metal remaining in the aqueous solution at the experiment (mg/l), v is the volume of solution in the flask (l), and m is the mass of biomass in the flask (g). The sorption isotherms models were used to find the relationships between the C_s and C_e at the constant temperature. There are two major equations of sorption isotherm specifically the Langmuir and Freundlich models [9]. These models are usually used for the description of sorption data. The Langmuir model is:

$$C_s = \frac{qbCe}{1+bCe} \quad (2)$$

Where q is the maximum sorption capacity (mg/g) and b is the saturation coefficient (l/mg). The Freundlich isotherm is calculated by:

$$C_s = K_f\, Ce^{1/n} \quad (3)$$

Where n is an empirical coefficient and K_F is the Freundlich sorption coefficient.

Results and discussion

Contact Time and Initial pH

The time in the batch experiments must be specified at certain value which is achieved the equilibrium state for partitioning. The influence of elapsed time on the nickel removal efficiency at different values of initial pH ranged from 3 to 8 with added 0.2 g of sewage sludge to 100 ml of contaminated water in the room temperature (25ºC) is plotted in Figure 1. It is clear that there is a significant increase in the removal efficiency as a result of increasing of contact time where a rapid increase was recognized in the sorption rate for the initial stages. Then, the rate was gradually stabilized and this may be attributed to occupy all active sites of sorbent.

The pH of the aqueous solution is one of the important factors governing the sorption of metal ions. It seems that removal efficiency of Ni (II) ions from the aqueous solution is very low (20%) at pH value of 3 and it is raised with increasing the initial pH of the aqueous solution where the maximum value was achieved at pH of 5.

The influence of pH can be related with the fact that the protons will compete the metals ions in the acidic environment and this resulted in reduction of metal removal efficiency. By increasing pH, electrostatic repulsion decreases due to reduction the density of positive charge on the sorption sites and this will enhance the sorption of the metals [10, 11, 12].

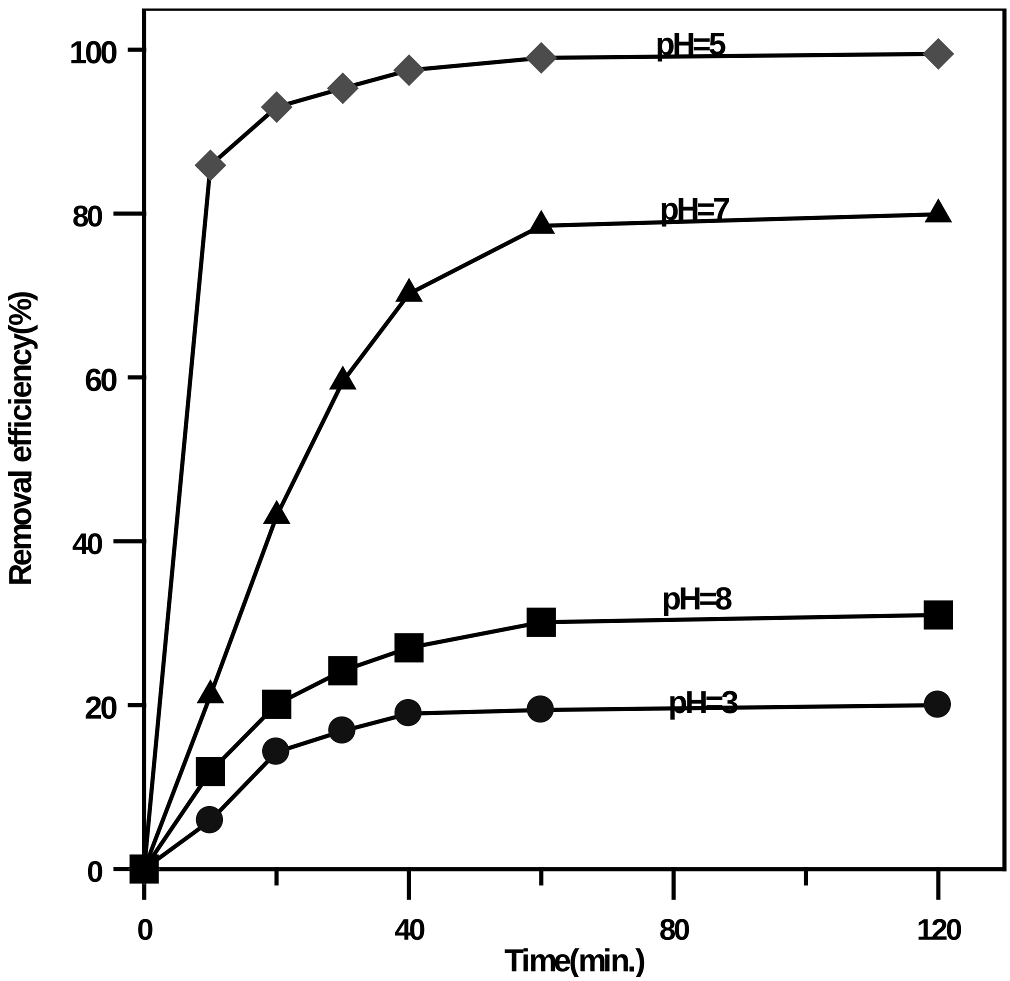

Fig. 1. Effect of pH on removal efficiency of nickel (speed = 300 rpm; C_o = 50 mg/l; sorbent dose=0.2 g/100 ml; T = 25°C).

Initial Concentration

The metal uptake is depended on the initial concentration of heavy metals where these metals are adsorbed by limited active sites at low concentrations, while lower sorption yield is due to the saturation of sorption sites at higher concentrations. Figure 2 signified that an increase in metal concentration can be caused the decrease in percentage of sorption. This may be attributed to absence of sufficient surface area to accommodate much more metal available in the solution [13]. It is clear that the removal efficiency has the value of 99.5% at C_o equal to 50 mg/l and this value decreased to 54.6 % when C_0 equal to 200 mg/l.

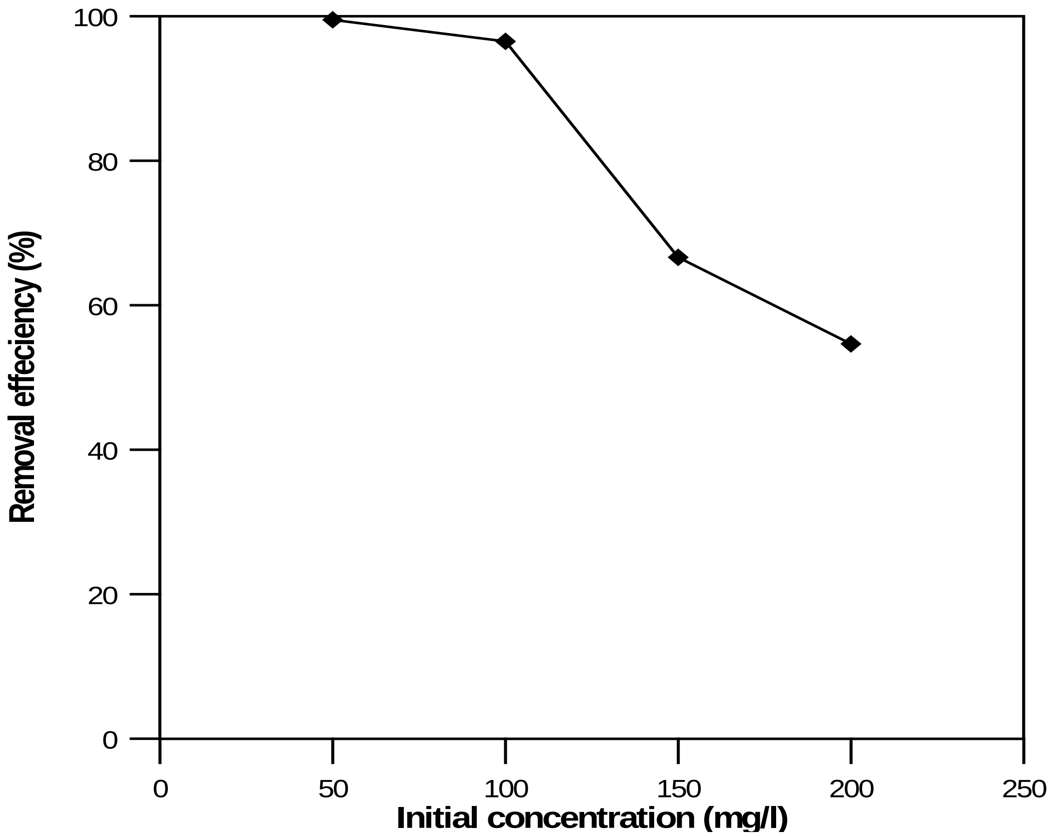

Fig. 2. Effect of sorbent concentration on removal efficiency of nickel (contact time = 1 h; speed = 300 rpm; sorbent dose =0.2 g/ 100ml; pH = 5; T = 25°C).

Sorbent Dosage

The amount of dead anaerobic sludge was changed from 0.1 to 2 g using 100 ml of contaminated water for investigation the effect of sorbent dosage on the sorption of nickel ions at 25ºC as shown in Figure 3. The batch experiments were conducted with elapsed time of 1hr, initial pH of contaminated water equal to 5 and agitation speed of 300 rpm. It is clear that

the removal efficiency is increased due to increase of sorbent dosage and this acceptable due to the fact that the higher dose of sorbents in the solution, the greater availability of exchangeable sites. In addition, this figure certifies the maximum sorption sets in after 0.2 g and hence the amount of nickel bound to the sorbent and the amount of nickel in solution remains constant even with further addition of the dose of sorbent [14].

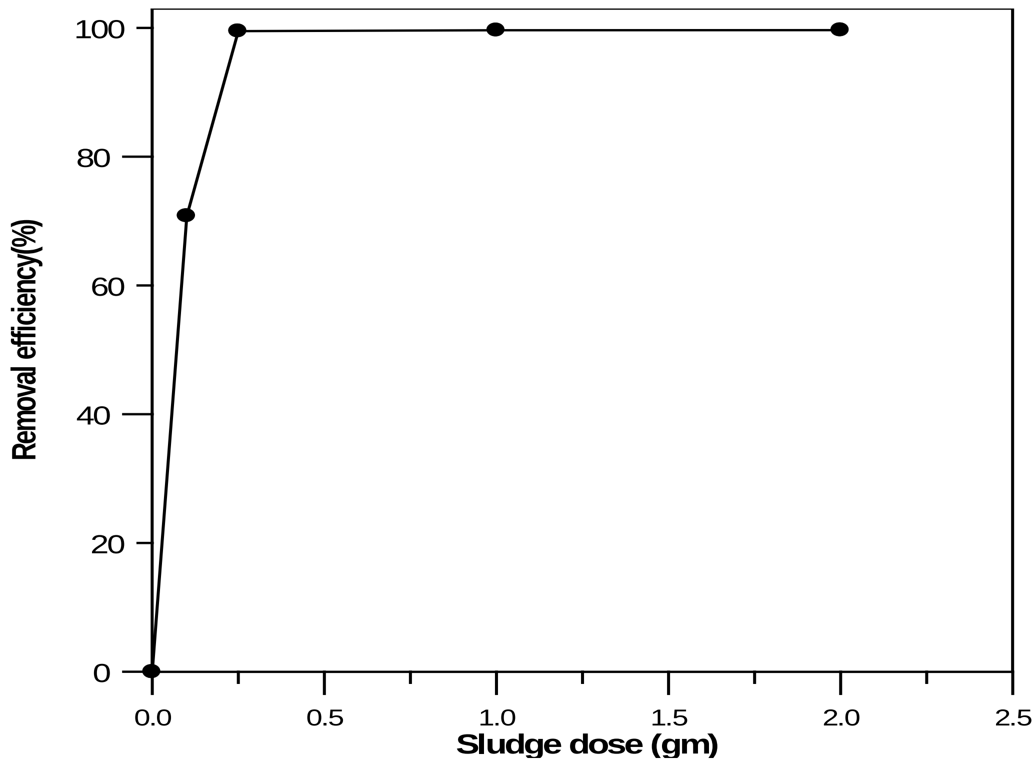

Fig. 3. Effect of sorbent dose on removal efficiency of nickel (C_o = 50 mg/l; speed = 300 rpm; contact time = 1 h; pH = 5; T = 25).

Agitation Speed

Figure 4 illustrates that about 61% of the nickel ions were separated at a shaking speed equal to 150 rpm when the contact time at equilibrium and that Ni removal increases with the increase of shaking speed. There was a significant increase in removal efficiency when agitation speed was raised from 150 to 300 rpm at which about 99.5% of Ni ions have been removed at equilibrium time. These results can be related to the fact that the increase of the agitation speed improves the diffusion of metal ions near the surface of the sorbent. Thus, suitable contact is grew between metal ions in solution and the binding sites, which encourage effective transfer of sorbate ions to the sorbent sites. This figure also shows that best equilibrium was achieved at the agitation speed of 300 rpm.

.

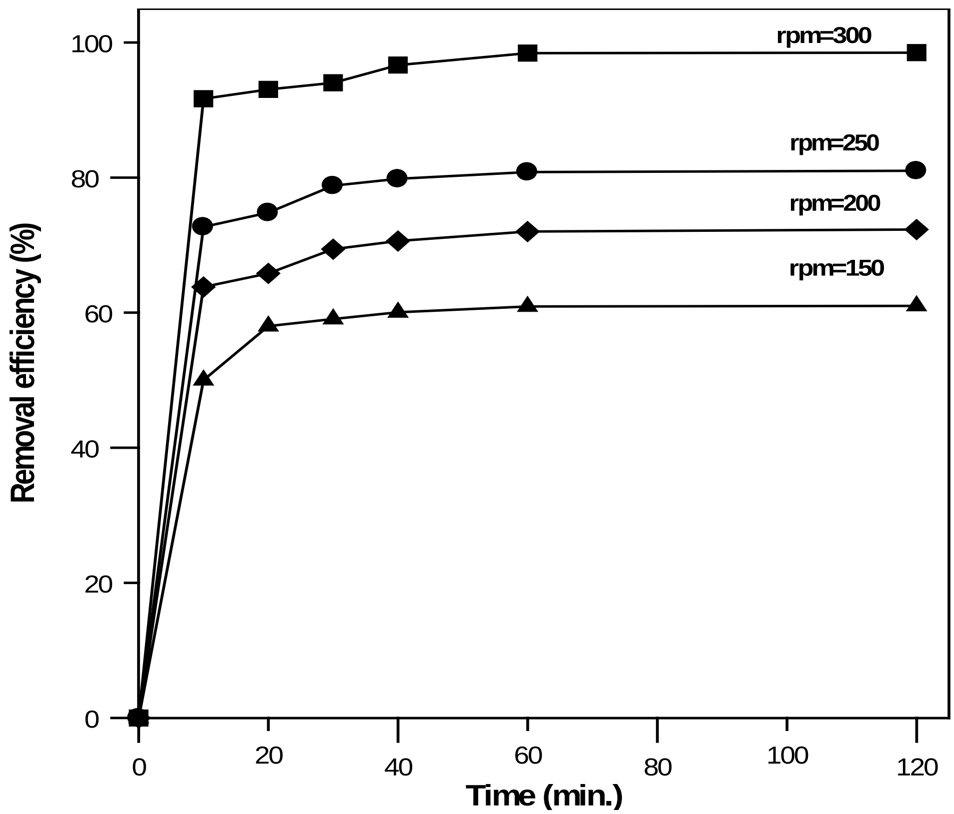

Fig. 4. Effect of agitation speed on removal efficiency of nickel as a function of contact time (C_o = 50 mg/l; T = 25°C; sorbent dose = 0.2 g/100 ml; pH = 5).

Sorption Isotherms

Mathematical models describe the partitioning process of contaminant between the water and solid phases at certain temperature are called "sorption isotherms". These isotherms are depended on a set of assumptions related to the homogeneity/heterogeneity of reactive material, interaction between the contaminants and the type of coverage. These isotherms relate metal uptake per unit mass of sorbent (C_e/C_s) to the equilibrium sorbate
concentration in the bulk phase (C_e) [15, 16]. The constants for isotherm models (Table 1) were estimated by linearization using the GRAPHER Version 1.09 – 1993 (Figures 5 and 6). This table showed that the best correlation was represented by the Langmuir isotherm model in comparison with Freundlich isotherm model for sorption of nickel on the sewage sludge.

Table 1: Sorption isotherm constants with coefficients of determination for Ni^{+2} on the sewage sludge.

Model	Parameters	Ni^{2+}
Langmuir	q_m (mg/mg)	1.348
	b (l/mg)	0.92

Mesopotamia Environmental Journal
ISSN 2410-2598
Mesop. environ. j. 2018, Vol.4, No.2 :86-95.

	R^2	0.997
Freundlich	K_F (mg/g)	26.4962
	1/n	0.120
	R^2	0.821

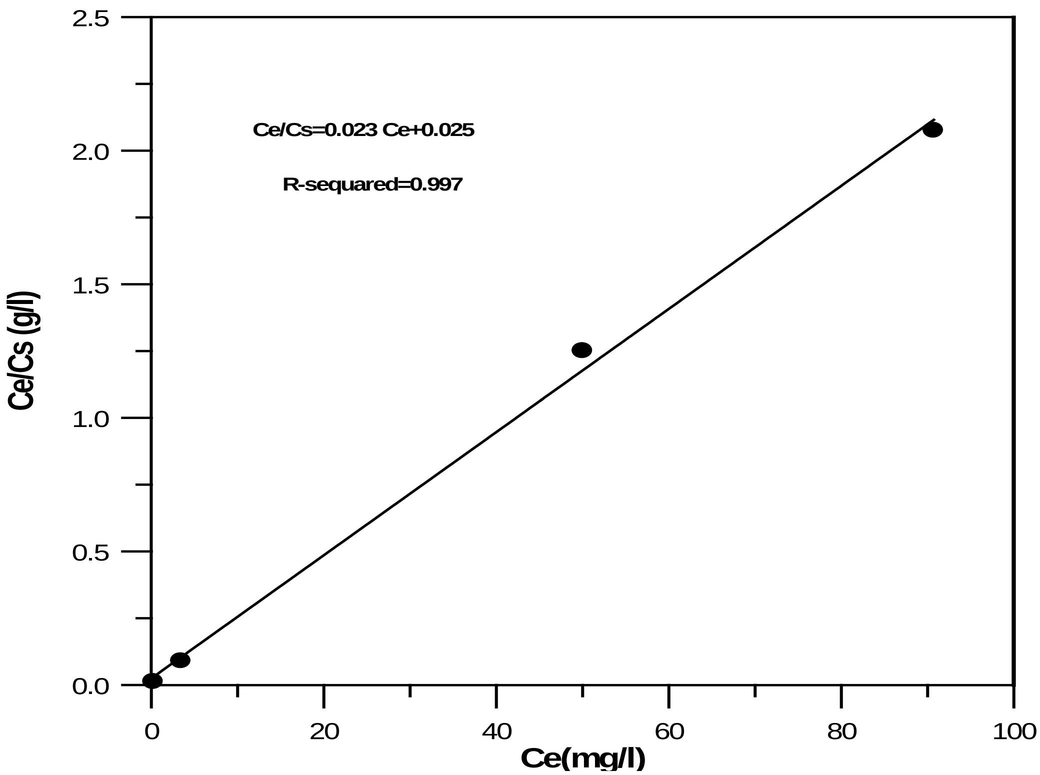

Figure 5: Langmuir Isotherm model

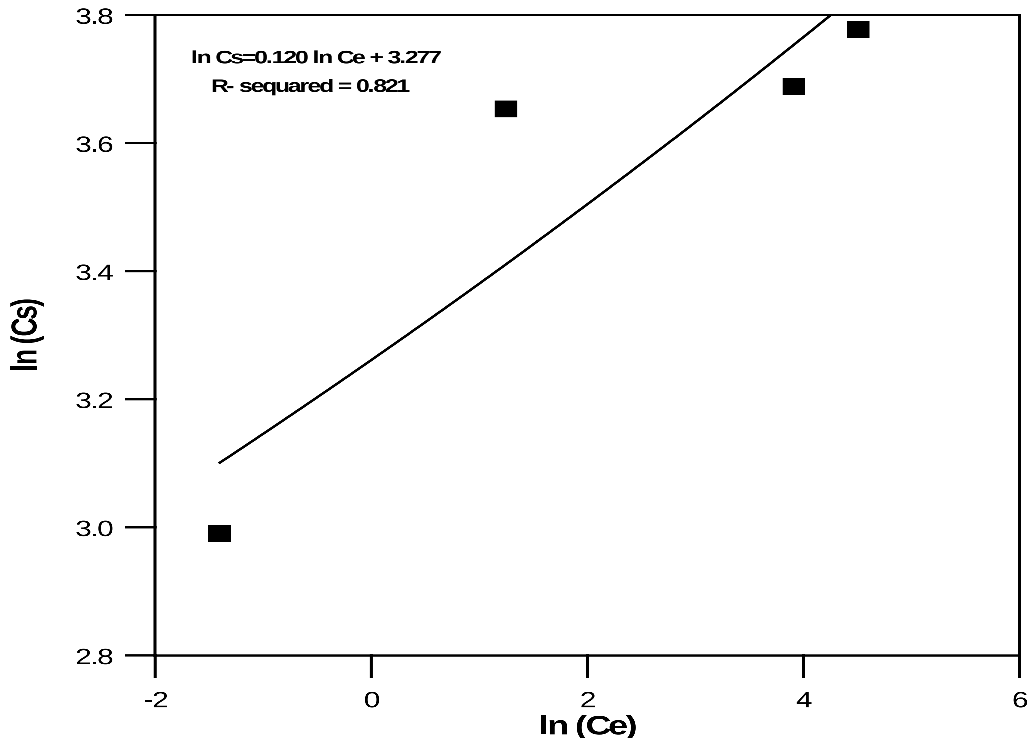

Figure 6: Freundlich Isotherm model

Conclusions

1. Granular dead anaerobic sludge can be used as effective sorbent for treatment the wastewater contaminated with nickel.
2. Contact time, initial pH of the solution, initial metal concentration, sorbent dosage, and agitation speed were the parameters affecting the sorption process between nickel and sewage sludge. The best values of these parameters to achieve the maximum removal efficiency of nickel (99.5%) were 1 h, 5, 50 mg/l, 0.2 g/100 ml, and 300 rpm respectively.

3. Nickel sorption data on sewage sludge were correlated reasonably well by the Langmuir sorption isotherm with coefficient of determination values (R^2) of 0.997

References

[1] **F. Di Natale, M. Di Natale, R. Greco, A. Lancia, C.Laudante, D.Musmarra**, "Groundwater protection from cadmium contamination by permeable reactive barriers",J. Hazard. Mater. 160 428–434, 2008.

[2] **Hashim, M.A., Mukhopadhyay, S., Sahu, J.N., Sengupta, B.,** "Remediation technologies for heavy metal contaminated groundwater". J. of Environmental Management, 92, 2355-2388, 2011.

[3] **Hilal, N.M., Ahmed, I.A., El-Sayed, R.E,** "Activated and Nonactivated Date Pits Adsorbents for the Removal of Copper (II) and Cadmium (II) from Aqueous Solutions". International Scholarly Research Network ISRN Physical Chemistry, doi:10.5402/2012/985853 985853, 2012.

[4] **Dabrowski, A., Hubicki, Z., Podkoscielny, P., Robens, E.,** "Selective removal of the heavy metal ions from waters and industrial wastewaters by ion-exchange method". Chemosphere, 56, 91-106, 2004.

[5] **El-Ashtoukhy, E.S.Z., Amin, N.K., Abdelwahab, O**.,"Removal of lead (II) and copper (II) from aqueous solution using pomegranate peel as a new adsorbent". Desalination, 223, 162-173, 2008.

[6] **Metcalf & Eddy,** Wastewater Treatment, Disposal and Reuse, McGraw-Hill, New York, NY, 1991.

[7] **A. Mathews, I. Zayas,**"Particle size and shape effects on adsorption rate parameters", J. Environ. Eng. 11541–55, 1989.

[8] **R.J. Watts,** Hazardous Wastes: Sources, Pathways, Receptors, John Wiley, New York, NY, 1998.
[9] **Choi J, Lee J Y, Yang J S,** "Biosorption of heavy metals and uranium by starfish and Pseudomonas putida". Journal of Hazardous Materials, 161: 157–162, 2009.

[10] **Li X, Tang Y, Cao X, Lu D, Luo F, Shao W,** "Preparation and evaluation of orange peel cellulose adsorbents for effective removal of cadmium, zinc, cobalt and nickel". Colloids and Surfaces A: Physicochemical Engineering Aspects, 317: 512–521, 2008.

[11] **Bhattacharya A K, Mandal S N, Das S K,** "Adsorption of Zn (II) from aqueous solution by using different adsorbents". Chemical Engineering Journal, 123: 43–51, 2009.

[12] **Bojic A, Purenovic M, Bojic D,** "Removal of chromium (VI) from water by microalloyed aluminium based composite in flow conditions". Water SA, 30: 353–359, 2004.

[13] **Faisal, A. A.; and Hmood, Z. A.,** "Groundwater protection from cadmium contamination by zeolite permeable reactive barrier". Desalination and Water Treatment, doi: 10.1080/19443994.2013.855668, 2015.

[14] **El-Sayed , G O .; Dessouki H A.; Ibrahim , S S,** "Biosorption of Ni (II) and Cd (II) Ions from Aqueous Solutions Onto Rice Straw". Chemical Sciences Journal, Volume 2010.

[15] **Hamdaouia, O., Naffrechoux, E.,** "Modeling of adsorption isotherms of phenol and chlorophenols onto granular activated carbon Part I. Two-parameter models and equations allowing determination of thermodynamic parameters". Journal of Hazardous Materials, 147, 381–394, 2007.

[16] **Kumar, P., Kirthika, K.,** "Equilibrium and kinetic study of adsorption of nickel from aqueous solution on to bael tree leaf powder". Journal of Engineering Science and Technology, 4(4) 351 – 363, 2009.