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Removal of Nickel and Cadmium using Diatomite, Silt, Sunflower stem, and Cement (Green Concrete Components)

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ABSTRACT: Adsorption is one of the common treatment applied in heavy metal removal. Recently, studies of low-cost adsorbents, which usually are waste products from industrial, agricultural and food productions and are produced abundantly, gained intensively attention to the scientist.. Since most of the structures, ponds, and drainage pipelines are made of concrete, the use of adsorbent concrete can be an effective way to remove pollutants, especially heavy metals from wastewater. In this research, diatomite and sunflower stems were used as concrete additives to adsorb cadmium and nickel from wastewater as well as materials that could maintain and even increase the strength, durability, and stability of concrete in water and wastewater structures. Diatomite was replaced with part of the cement and sunflower replaced with part of aggregates used in concrete. The adsorption of nickel and cadmium by concrete components (cement, silt, diatomite and sunflower stem) was investigated. Cement was able to remove nickel and cadmium completely. Other components of the concrete also had a good ability to remove nickel and cadmium. The maximum adsorption capacities of Ni and Cd for diatomite, silt, and sunflower stem were 2.85, 1.88, 2.61, 2.82, 18.45, and 6.82 mgr/gr, respectively. Metal adsorption onto adsorbents was evaluated by Langmuir and Freundlich isotherms. Results indicate that both Langmuir and Freundlich isotherm models are suitable. Concrete pieces removed cadmium completely, but in nickel adsorption, the control sample had the best performance

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INTRODUCTION

Nowadays, the environmental importance of water as an essential requirement has been considered throughout the world [1]. The presence of heavy metals in the environment has become a major concern, because of their toxicity. Many industrial processes produce wastewater containing heavy metals [2]. Therefore, it is essential to remove heavy metals from industrial wastewater before discharging into the environmental cycle [3]. The adsorption method seems attractive in comparison with other methods, due to its high efficiency and ease of use in the treatment of heavy metals [4]. A large number of materials derived from natural resources, agriculture and plant waste, and by-products of industrial processes have been considered as an adsorbent for the separation of dilute metals from wastewater [3]. One of the agricultural wastes that has been proven in various studies to be efficient for removal of heavy metals is the sunflower stem. Natural compounds such as diatomite are also effective adsorbents for removal of heavy metals. Using adsorbent concrete in the construction of sewage canals is one of the ways to prevent the heavy metals' discharge into surface and underground waters. In these concretes, some materials are used as adsorbent. Due to the adsorptive properties of sunflower stem and diatomite, and also the feasibility of using these two compounds in the production of a biocompatible concrete to minimize the consumption of concrete components and reduce the production of materials such as cement that can lead to air pollution, the purpose of this study is to investigate the ability of adsorption of nickel and cadmium from aqueous solutions with compounds that are the main components of green concrete.

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METHODOLOGY

The adsorbents used in this study were diatomite, sunflower stems (which transmitted from #10 sieve and remained on #16 sieve with a specific gravity of 0.79 grams per cubic centimeter), silt, and cement, and eventually their ability to adsorb cadmium and nickel were studied by separately.

For adsorption experiments, the stock solution (1000 mg/l) was prepared from nickel and cadmium salts. For this purpose, 4.05 g of nickel (II) chloride hexahydrate and 1.79 g of cadmium chloride monohydrate were separately dissolved in an electrolyte solution of calcium chloride and, eventually, the volume was increased to 1000 ml. The required solutions

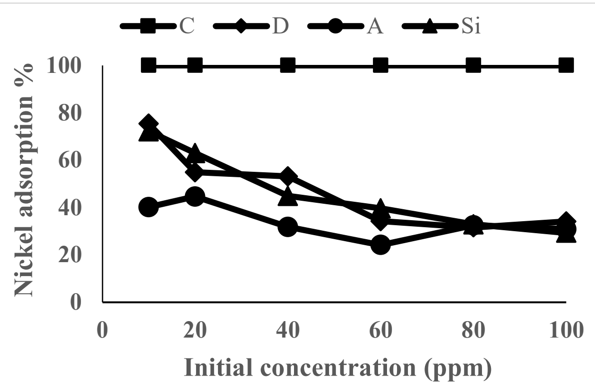

Fig 1. Effect of initial cadmium concentration on its removal efficiency by concrete particles

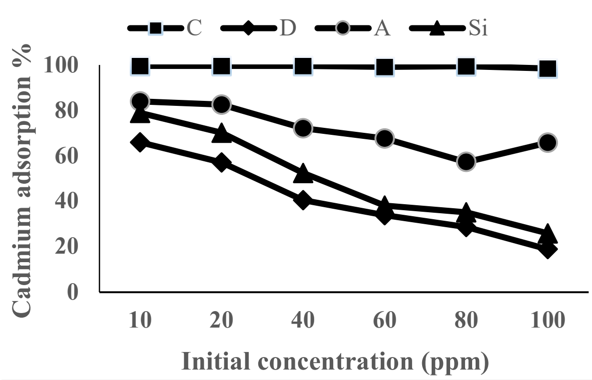

Fig 2. Effect of initial cadmium concentration on its removal efficiency by concrete particles

were then made from these solutions.

Nickel and cadmium adsorption experiments on cement, silt, diatomite, and sunflower stem adsorbents were determined using the Batch Equilibrium method. In this method, 0.1 g of adsorbents was combined with 10 ml of solutions prepared at concentrations of 10, 20, 40, 60, 80 and 100 ppm, and after transferring to centrifuge tubes (Falcon), they were shaken at 25 °C for 24 hours. The amount of nickel and cadmium adsorbed would be calculated from the difference between the initial and the final concentration of the solution. Each experiment was performed in three replicates. The percentage of removal of each heavy metal by the adsorbents was calculated by equation (1).

$$Efficiency(\%) = \frac{C_i - C_e}{C_i} \times 100 \quad (1)$$

Where Ci and Ce are the initial and final concentrations of the solution, respectively.

RESULTS AND DISCUSSION

3.1 Nickel adsorption

The effect of initial concentration on removal percentage of nickel using concrete forming particles (diatomite: D, sunflower: A, silt: Si, and cement: C) is shown in Fig. 1. With increasing initial concentration, the adsorption rate for all adsorbents decreases. For instance, with increasing initial nickel concentrations from 10 to 20 ppm, the diatomite adsorption efficiency decreased from 75.3 to 54.8%. At low concentrations, the ratio of adsorption sites to adsorbent ions is high and nickel species with functional groups of adsorbent surfaces has maximum interaction and therefore, the adsorption efficiency is the highest. At higher concentrations, due to the saturation of adsorption sites, the adsorption efficiency has also decreased [5]. As shown in Fig. 1, the adsorption efficiency of diatomite at lower concentrations is higher than silt and sunflower. With increasing initial concentrations to 100 ppm, the highest and lowest adsorption efficiency was observed in cement and silt, respectively. Therefore, in areas with high concentrations of nickel, the use of cement materials is recommended. The difference in removal percent of heavy metals by various adsorbents at similar initial concentrations, similar adsorbent dose and similar contact time, may be due to the difference in chemical efficiency and the ionic exchange capacity of different adsorbents regarding the chemical functional groups on the surface of each adsorbent[5].

3.2 Cadmium adsorption

The effect of initial concentration on the amount of cadmium adsorption by concrete particles is shown in Fig. 2. With increasing initial concentrations, the adsorption rate decreased for all adsorbents. For example, with increasing initial cadmium concentration from 10 to 20 ppm, the efficiency of silt adsorption dropped from 78.8% to 70%. At low concentrations, the ratio of adsorption sites to adsorbent ions is high and cadmium species with functional groups on adsorbent surfaces has maximum interaction and therefore, the adsorption efficiency is the highest. At higher concentrations, adsorption efficiency has also decreased due to the saturation of adsorption sites [6]. As shown in Fig. 2, the adsorption efficiency of cement and sunflower in lower concentrations is higher than silt and diatomite. With increasing initial concentrations to 100 ppm, the highest and lowest adsorption efficiency was observed in cement and diatomite, respectively. Therefore, the use of cement materials is recommended in environments with high cadmium concentrations. Differences in the removal efficiency of cadmium by different adsorbents in the same laboratory conditions can be due to the different chemical structure of the adsorbents and their interactions with different adsorbents [5].

CONCLUSIONS

Result of adsorption experiments showed that cement was able to completely remove nickel and cadmium in all studied concentrations (10, 20, 40, 60, 80 and 100 ppm). After that, sunflower had the best performance in adsorbing nickel and cadmium. Diatomite and silt were subsequently in third and fourth places, respectively. Overall, the results showed that natural compounds such as diatomite and plant wastes such as sunflower stems can be used as adsorbent materials in sewage ponds and concrete channels.

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