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Enhancing the Remediation Capacity of Mercury Ions from Fluorescent Lamp Using Roasted Date Pits and Its Modified Forms

Mohammad A. Al-Ghouti[1], Dana Al-Dana[1], Haya Alduroobi[1], Maymoona Ayesh[1], Sana Khan[1], Fatemeh Fahraei[1], Mariem Safi[1], Mohammed Abu-Dieyeh[1], Basem Shomar[2]

[1]Department of Biological and Environmental Sciences, College of Arts and Sciences, Qatar University, State of Qatar, Doha P.O. Box: 2713
[2]Environmental and Chemical Sciences, Qatar Environment and Energy Research Institute (QEERI), Hamad Bin Khalifa University, Qatar Foundation, Doha, Qatar

Email: mohammad.alghouti@qu.edu.qa

Abstract

One of the most toxic heavy metals in the environment is mercury (Hg). However, it still has major uses in various industrial and agricultural applications; leading to localized mercury pollution. There has been an increase in the number of used fluorescent lamps compared to incandescent bulbs. Mercury is being used in fluorescent lamps in the elemental form where it can be vaporized under high pressure. The elemental form of mercury is also lipid soluble and can pass through both brain barrier and the placenta which can cause neurological disorder. Due to its harmful effect, the spent fluorescent lamps (SFLs) are being classified as hazardous wastes where mercury may leach and contaminate soil and groundwater. For these reasons the fluorescent lamps should be treated to reduce potential Hg toxicity or to use other components after recycling; e.g. glass and aluminum cap.

Various extraction methods are available in the literature. However, in this project, two methods of extracting mercury from SFL were performed to assess their efficiency: acid extraction and microwave digestion. It was shown that the acid extraction only, using different acids ratios, were not able to remove all mercury from phosphor powder. However, the combination of acid extraction with a microwave digestion enhanced the efficiency of mercury extraction by more than 90%.

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Physicochemical treatment such as adsorption is also viewed as one of the easiest, safest, adaptable, and cost-effective physical chemical treatment methodologies in remediating toxic metals from aqueous medium. Though, the growing costs and environmental concerns linked with the commercial adsorbents has steered a new research orientation, which intended at developing low cost adsorbents that are produced from waste materials which are natural and renewable resources. Date pits as agricultural waste materials have been effectively employed as an adsorbent for remediating various heavy metals from aqueous media and normally with the benefits of being low cost, naturally available, and environmentally friendly. Chemical modifications processes were also be employed to improve their remediation capacity and selectivity.

The current study, therefore, investigated the effect of different modification treatments on the roasted date pits (RODPs) surface chemistry and therefore; enhancing the mercury remediation capacity. The RODPs was grafted with organosilane to remediate Hg^{2+} from the extracted fluorescent lamp solution. The remediation of Hg^{2+} from the extracted fluorescent lamp solution was investigated in a batch isotherm remediation system pertaining to pH, concentration, particle sizes, and contact time.

The SFLs of different brands were collected from throughout Qatar. Two main types of SFLs were collected and tested; the T8 and T12. The SFL were scratched and the powder inside was carefully collected by brushing the inside of the lamps (approximately 100 g have been collected). Various reagents and materials were used for the mercury extraction experiments such as HCl, HNO_3, and H_2O_2. The instruments and methods mainly adapted in these experiments were Cold Vapor Atomic Absorption Spectrophotometer (CVAAS) for the mercury analysis, incubator shaker to maintain constant shaking with temperature, microwave for the extraction enhancement, and oven. In the experiments, the ratios of HCl, HNO_3, and H_2O_2 as extracting agents were carefully chosen to achieve the maximum exactable mercury.

The collected date pits were roasted at 150°C for 5 h and the sulfur-modified roasted date pits was carried out to investigate the adsorption enhancement after modification. In order to study the impacts of different pH values on the adsorption, the FTIR spectra of the RODP and RODP at different pH values were recorded. The FTIR measurements were performed over 4000–400/cm. Scanning electron microscope (SEM) was also used to evaluate the surface morphology of the adsorbents using the JEOL model JSM-6390LV.

After determining Hg^{2+} concentration in the extracted SFL solutions, various initial Hg^{2+} concentrations were prepared. The residual Hg^{2+} in solution was analyzed after adsorption onto RODP. Different key parameters will also be performed such as the effect of pH, mass, and the solution temperature.

From the initial results, we can conclude that the highest Hg adsorption occurred at pH 6 with almost 80% adsorption value. Moreover, at pH 8 and pH 10, the adsorption decreased with an average Hg concentration of 3.5 and 8.01 ppm, respectively. This decreasing in the adsorption capacity is due to the formation of mercury (II) hydroxide $Hg(OH_2)$ which forms a precipitation; resulting in decreasing the adsorption. However, pH 2 and pH 4, have average concentration of mercury equal to 18.8 and 18.3 ppm, respectively, which is very high concentration and it is over range.

From the FTIR results we can determine the functional groups of the RODP which can determine the reactivity of the RODP towards mercury. According to the results obtained from CVAAS that pH 6 is the best pH for the adsorption process, functional groups found in the RODP having pH 6 are mainly hydroxyl and carboxyl acid which means that these functional groups have the highest ability to adsorb mercury more than other groups.

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