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Green synthesis of magnetic iron nanoparticles coated by olive oil and verifying its efficiency in extraction of nickel from environmental samples via UV–vis spectrophotometry

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ABSTRACT

In this research, we report the synthesis and functionalization of magnetic iron nanoparticles using green chemistry (olive oil) for application of dispersive solid–liquid phase microextraction (DSLME) as a novel method for preconcentration and determination of nickel ions in soil, potato, red tea, white tea, mushroom, lettuce, cabbage, apple, urban water, purified drinking water through household water treatment device. Nickel is a dangerous toxic metal that can cause serious damage to the environment and then its removal is necessary. Recently, iron oxide nano materials have gained much attention due to their properties, such as extremely small, non-toxic, excellent magnetic properties, high surface area, great biocompatibility and high level of reactivity with metal which makes them worthwhile in the removal of these metals. For optimizing the important parameters affecting the extraction procedure, analyte concentration, pH, type of disperser solvent, absorption time, ionic strength effect, type of desorption solvent and desorption time investigated. SEM and FT-IR spectrum used for characterization of the synthesized magnetic nanoparticles. The measurements were done under the optimized conditions. Matrices effect and accuracy were examined by the determination of the relative recovery (RR%) of the real samples. Linear range, detection limit and relative standard deviation (RSD) are 1–5000 ng/ml, 0.821 ng/ml and 0.196%, respectively.

1. Introduction

The iron nanoparticles have been used in different ways in sensors, catalysis, data storage, electronic devices, reconstruction of the environment, drug-delivery technology, biomedical research, magnetic recording devices (Palanisamy et al., 2013b). It is obvious that the magnetic nanoparticles display a limited size effect or proportion of surface to volume, out coming in a superior absorption capacity to remove metal. Also, the easy separation of metal from solution can be obtained using an external magnetic field (Kanthimathi et al., 2012). So, an scalable, efficient, economic and biocompatible Fe_3O_4 nanoparticle system for fundamental research and potential applications is strongly preferred (Wang and Hong, 2011). Pollution of heavy metals is of great concern because of its toxic effect on animals, plants and humans. Thus, an effective method for the removal of heavy metal ions is necessary. One of the toxic metals is nickel (II) that leads to serious problems, like the lung, skin diseases and nasopharynx, malignant tumors. Many of different techniques such as cloud point

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extraction, ion exchange, liquid–liquid extraction, solid phase extraction and dispersive liquid–liquid microextraction have been studied for the designate nickel ions at very low levels in different environmental samples (Karimi and Kafi, 2015; Khan et al., 2016).

In recent years, great interest was stimulated in utilization of magnetic nanoparticles (MNPs) in SPE (Asfaram et al., 2015a,b; Zare et al., 2015). Presently, SPE (solid-phase extraction) is an old technique of providing samples for analysis. The separation in this way occurs according to analyte partition ratio between the solid sorbent and the mobile phase (Wierucka and Biziuk, 2014). Using MNPs as the adsorbent SPE for their basic features, such as wide surface area, easy separation of sample via magnetic field has gained importance and after removal of metal ions, MNPs may be reusable (Yilmaz and Soylak, 2013; Yilmaz et al., 2015; Khan et al., 2016).

To overcome the traditional problems of the SPE, a quick and simple method, dispersive solid phase extraction (DSPE) was introduced in last decade.

It has two main steps: scattering phase acceptor (solid sorbent particles) inside (sample solution) and the phase separation by centrifuge. This technique enables the attractive to engage equally with all the samples, obtain greater capacity for sorbent and avoid transmitting or blocking the cartridges or disks, as happen in traditional SPE (Abdolmohammad-Zadeh and Talleb, 2012).

To increase the mobility of particles and reduce agglomeration, stabilization is mostly used (Palanisamy et al., 2013b). Surface modification by inorganic shell connection or organic molecules functions as the stabilizer for iron nanoparticles and stops them from oxidation, and also prepares a particular functional groups or sites reaction that can be selectively and specifically used for the absorption of ions and increase the capacity to adsorb heavy metals. The small size of iron oxide nanoparticles is suitable for release of metal ions from the solution onto the surface active sites of adsorbent ($-NH_2$, $-COOH$, $-SH$, $-OH$, etc.). The mechanism of the reaction on the surface modification of nanomaterials iron oxide for absorption of heavy metals is the chemical interaction (chemisorptions) to form of surface chemical binding sites and modified, improved ligand combination or complex formation and physical interactions (physisorption) with the surface to form of Vander wall and electrostatic interaction. Separation of analytes by using external magnetic field and easy restoration process of magnetite nanoparticles for further usage makes it affordable and effectual procedure in the removal of heavy metals from water (Neyaz et al., 2014). Surface modification of magnetic nanoparticles is an important factor in the preconcentration and separation of analytes because extraction of metal ions with nanomagnetites is not selective, especially in complex matrices (Sadeghi et al., 2012).

Polarography, X-ray fluorescence, atomic fluorescence spectrometry, atomic absorption spectrometry, chromatography, etc. have been utilized for determination of ions in various samples. Among the analytical methods UV–vis spectrophotometry techniques widely used because of resulting experimental rapidity and simplicity (Ghasemi et al., 2003).

In this paper magnetic iron nanoparticles modified and stabilized by olive oil (Fig. 1). It is a natural stabilizer that acquired without any chemical reaction. Olive oil is a fatty acid (Table 1) used to control the trend of precipitation and agglomeration of iron oxide nanoparticles morphology (Palanisamy et al., 2013a,b,c).

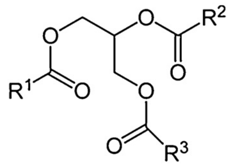

Fig. 1 – General chemical structure of olive oil (triglyceride). R^1, R^2 and R^3 are alkylgroups (approx. 20%) or alkenyl groups (approx. 80%).

Linoleic acid and oleic acid in olive oil are the elementary fatty acids. Linoleic acid is polyunsaturated and forms 15% of olive oil. Oleic acid is monosaturated and Constitutes 85% of olive oil $CH_3-(CH_2)_7-CH=CH-(CH_2)_7-COOH$ or ($C_{17}H_{35}COOH$). Oleic acid is a familiar surfactant in stabilizing colloid and other long chain carboxylic acids, like linoleic acid and erucic acid also have been utilized. Oleic acid because of easily available and inexpensive natural sources is normally preferred (e.g., olive oil). The olive oil-mediated synthesis of particles showed that nanoparticles for several months without any decomposition stable and in favor of homogeneous particles (Palanisamy et al., 2013a,b,c). In addition, oleic acid is widely used in the synthesis of ferrite nanoparticles, because formed the single dense protective layers. Oleic acid is a coating agent because it forms a protective monolayer and for making monodisperse and highly uniform nanoparticles is necessary (Patil et al., 2014).

This paper reports the spectrophotometric determination of nickel in complex with the mixture of ligands, DMG and GLY. One of the most usually used ligands coordinating of nickel ions is the dimethylglyoxime that forms nickel dimethylglyoxime complexes because of its stability and sensitivity.

Dimethylglyoxime (DMG) is a suitable ligand, and especially well-suited for nickel. DMG makes strong complexes with Ni and complex of Ni–DMG transmits and reflects red light (600–450 nm). DMG commonly used in ethanol-containing solutions and water, ethanol was found to increase the influence of the tissue by DMG (Gramlich et al., 2011). Glycine (GLY) operated as a uninegatively monodentate ligand and coordinated through its carboxylic groups to the metal ions (Zayed et al., 2006).

In this research, we have fabricated olive oil coated superparamagnetic iron oxide nanoparticles based on $FeCl_2$ and $FeCl_3$ using coprecipitation method to extract and measure nickel in soil, potato, red tea, white tea, mushroom, lettuce, cabbage, apple, urban water, purified water from household water treatment device. Also, the effect of analyte concentration, pH, disperser solvent, absorption time, ionic strength, desorption solvent and desorption time investigated via UV–vis spectrophotometry. SEM and FT-IR used for characterization of the synthesized magnetic nanoparticles.

Table 1 – Fatty acids content in olive oil.

Fatty acids (%)	Olive oil
Oleic acid	63–8
Linoleic acid	5–15
Palmitic acid	7–14
Stearic acid	3–5
α-Linolenic acid	–