Mitigating Cesium Contamination: Harnessing the Potential of Nigella Sativa for Water Remediation

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ABSTRACT

Contamination of water resources with cesium poses a significant environmental threat, necessitating effective remediation strategies. This manuscript explores the potential of Nigella Sativa, commonly known as black seed, as a novel and sustainable solution for mitigating cesium contamination in water. Through a series of controlled experiments, the adsorption and removal efficiency of Nigella Sativa for cesium ions were investigated. Our findings reveal promising results, highlighting the ability of Nigella Sativa to effectively reduce cesium concentrations in water from 0.0 to 64 % at constant pH for water and changing the concentration of nano nigella sativa (NSN) concentration. But when the pH of the water is changed from 3 to 11 and the NSN concentration value is fixed at 5 mg, the efficiency of removing cesium from polluted water will change. It was found that the best removal was at the pH value of 5. The unique chemical composition of Nigella Sativa seeds, rich in active compounds, demonstrates its potential as a natural and cost-effective material for water remediation. This research contributes to the development of eco-friendly approaches for cesium decontamination, with implications for environmental and public health. Further exploration of the mechanisms involved and the scalability of this remediation method is recommended for future applications.

Keywords: Nigella sativa, Cs-137 radionuclide, water remediation.

INTRODUCTION

The availability of water as a resource is likely to play a significant role in future planning. The utilization of electron beam processing for the treatment of drinking water, wastewater, and groundwater holds the potential to provide a cost-efficient method to ensure sufficient availability of this resource on a global scale [1]. Drinking water often contains varying quantities of naturally occurring radionuclides. Radioactive elements are introduced into the water through erosion and dissolution processes, as is the case with other cations and anions. These elements originate from rocks and minerals that make up the aquifer. Radioactivity is a statistical process that explains how, independent of their physical or chemical states, unstable atomic nuclei can spontaneously transition into more stable nuclei, a process known as nuclear fission [2,3]. The process of decay keeps going until the daughter nucleus becomes stable if the daughter product is also unstable. Consequently, the transformation's energy is released through the emission of beta or alpha particles [4]. When these particles are released into the atmosphere, gamma rays may also be released [5]. There are many works for measurement of the radionuclides in water and soil in Iraq [6-10]

Some nuclides are emitted through extracting oil [11]. They are mostly there because of nuclear weapons tests and the accident at the Chornobyl plant in 1986. The radionuclide ^{137}Cs are made by these sources and have a half-life of 30.7 years. It is a very important radionuclide. This nuclide has been spread out all over the world and has been found on land areas through rain and dry deposition. It can be taken in by plants and then used to make foods [5].

Black cumin seeds, also known as Nigella Sativa, are utilized as a form of homeopathic remedy due to their bitter taste and aroma [12,13]. It is primarily utilized in confectionary, liquors, and for medical applications. The efficacy of Nigella Sativa was examined for its adsorption capabilities in the removal of harmful ions, taking into account the problems involved and the advantages provided by the biomasses [3].

Nigella sativa is a good candidate for adsorption technology because it is cheap, widely available, and has many oxygenous groups (hydroxyl and carboxyl) on its surface [14]. Researchers have conducted adsorption experiments using Nigella Sativa material, according to certain published papers. To acquire more significant results for water contaminant removal, however, some sort of change is required [15]. There are a lot of empty spaces in nanocomposite materials that can be filled with charged contaminants by accommodating nanoparticles onto the adsorbent surface and using the material's many functional groups [16]. There are a plethora of uses for inorganic nanomaterials, and adsorption is just one of them [17, 18]. This substance has the potential to be a superior option for water treatment since it is non-toxic, easy to prepare, and inexpensive to produce. In light of these considerations, magnetite was added to the Nigella Sativa powder in order to produce magnetite. The seeds of Nigella sativa were treated with sucrose to make them more effective at removing lead (II) and chromium (VI) ions from water.

By combining the carbon framework of Nigella sativa seeds (black cumin) with iron-tin binary oxide nanoparticles (Fe_2O_3-SnO_2), we were able to create a dye remediation material that is inexpensive, chemically, thermally, and mechanically stable, and environmentally friendly. Because of its therapeutic properties, vast functional groups, low cost, nontoxicity, and global availability, Black cumin seed (BC) is an attractive option [19]. Known for their remarkable medicinal properties, nontoxic BC seeds have a spicy aroma and a strong flavor [20]. Thus, these seeds can be used effectively to treat water without causing any harm or altering the water's quality. The adsorptive removal of contaminants from water has recently made use of these seeds [21, 22].

The purpose of this research is to test the efficacy of Nigella sativa nanoparticles in treating radioactive wastewater using the filtration method and measuring the radioactivity of water after removing nanoparticles. Several previous works study different nanomaterials to reduce the effect of radioactivity such as nanonatural material [23], magnetic nanocomposite material [24], and nano turmeric [25]. Also, there are other ways to treat the long-lived radionuclides using thermal neutron interaction or gamma rays [26,27], or design materials or shielding[28].

Material and method

The materials and the companies of manufacturing that were used in this work are nigella sativa taken from the local market, HCl and NaOH, FTIR, AFM, UV-VID, FSEM devices, and gamma spectroscopy with high-purity germanium detector.

The Nigella sativa seeds were ground and milled into a fine powder using a mortar. A quantity of four grams of nigella sativa powder was combined with 100 milliliters of distilled water (D.W.) solvent. The mixture was then agitated for 60 minutes at a temperature of 45 °C. Subsequently, the mixture was subjected to distillation using filter paper, resulting in the production of a hydrous extract.

Experimental work

Fifty grams of black seeds were burned at a temperature of 300-400 C° for an hour, so the weight of the material after burning became 18 grams of nano Nigella Sativa (NSN).

CPM standard liquid (Cs-137) is 2315 Bq/L and was investigated using gamma spectroscopy with an HPGe detector. Then the sample was filtrated using nano filter papers which are produced from the CHM group. The remainder liquid was investigated again by gamma spectroscopy. After that, the experiment was done with another concentration from nigella sativa.

Results and Discussion

NSN was characterized using different methods such as UV-Vis, FTIR, AFM EDX, and FSEM.

1. **Uv-Vis analysis**

   Fig.1 shows the UV-Vis spectrum for NSN which was prepared in Nuclear Lab. College of Science, University of Baghdad. The absorption wavelength of NSN is 530nm.

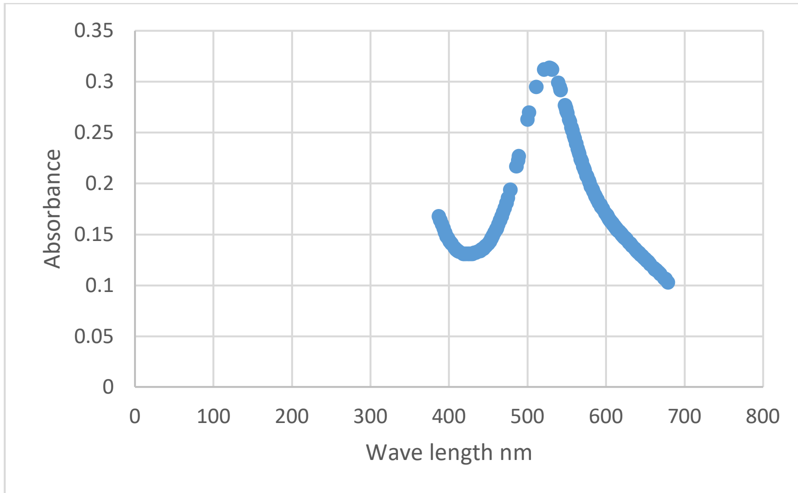


Fig 1: The UV-Vis spectrum for NSN

2. FTIR analysis

Fig.2 shows the FTIR spectra for NSN which were prepared in Nuclear Lab. College of Science, University of Baghdad.

Infrared spectroscopy, a potent analytical technique, enables chemical identification by leveraging the selective absorption of chemical substances in the infrared region. This absorption results in molecular vibration, yielding an absorption spectrum. In this study, a small quantity of powdered seeds was directly placed on the germanium piece of an infrared spectrometer, maintaining constant pressure. Data on infrared absorbance were collected across a wave number range of 4000 cm^{-1} to 650 cm^{-1} and processed using Omnic software (version 5.2). Reference spectra were obtained from a cleaned blank crystal before each sample presentation, all collected with a resolution of 4^{-1} cm.

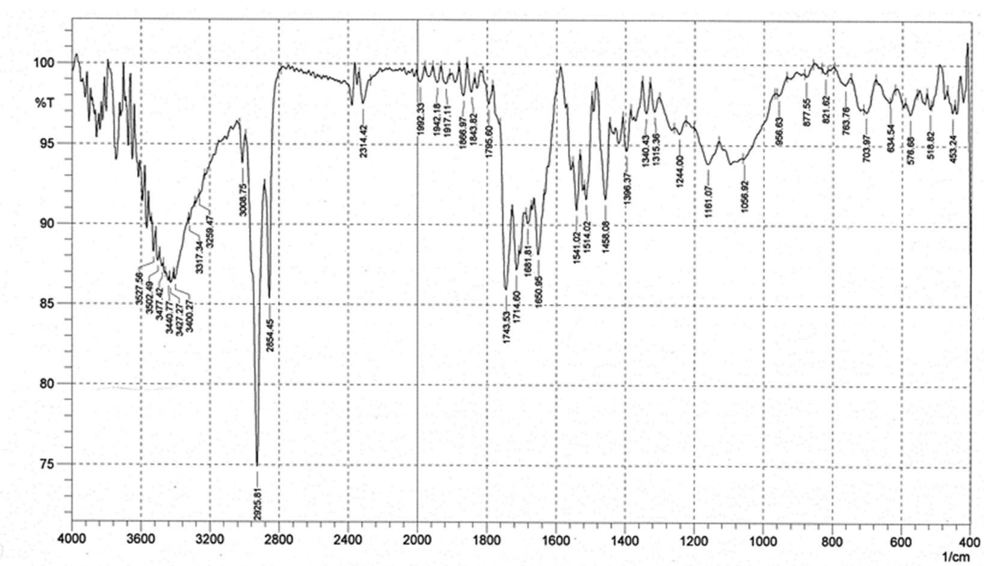


Fig.2: The FTIR spectrum for NSN

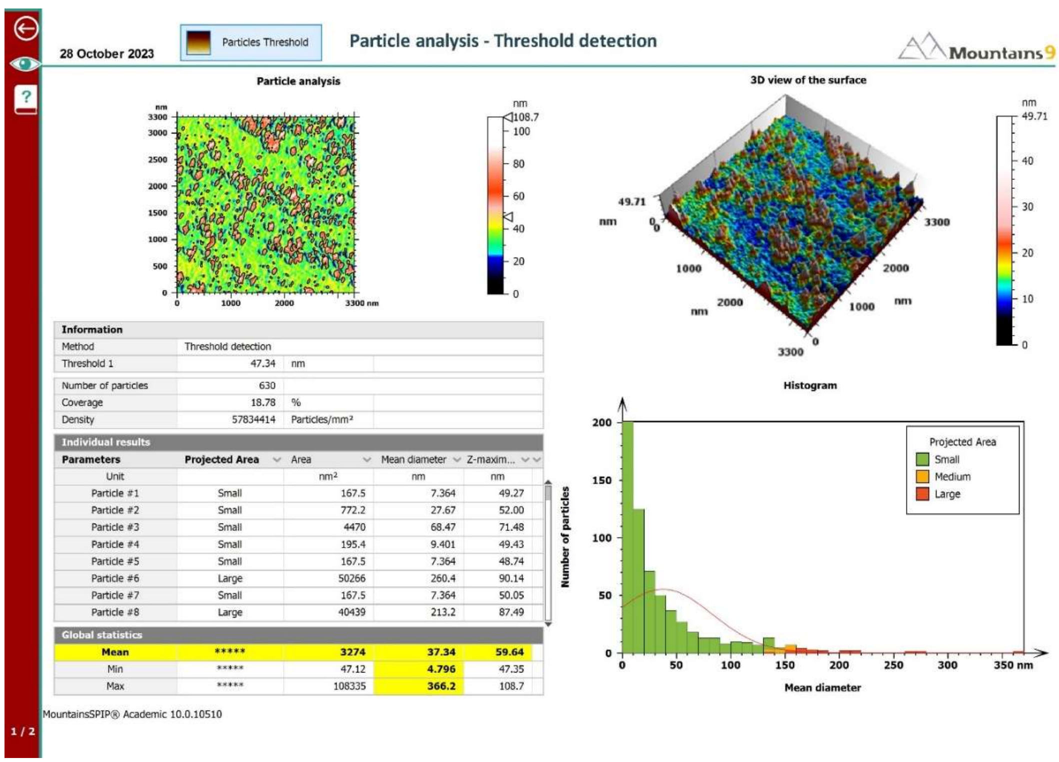
Fig.2 shows the FTIR peak values and the functional groups. The analysis revealed the presence of functional groups including amines (3378.8), alkanes (2927.80, 2854.20, and 1464.50), acids (1713.00, 1244.00), esters (1185.30), alkyl (1046.52), and alkenes (720.75-918.43). Alkanes, commonly found in plant cuticles and epicuticular waxes, play crucial roles in protecting plants against water loss, mineral leaching by rain, and microbial or insect damage. Alkenes, on the other hand, are significant in plastic manufacturing (e.g., polyethylene) and serve as fuel and illuminants. They also serve as raw materials for alcohol and aldehyde production.

3. AFM analysis

Atomic Force Microscopy (AFM) micrographs were collected utilizing "digital instruments, Inc. Nanoscope III and Dimension 3100" to evaluate the surface roughness and topography of deposited thin films. The roughness and grain size of AFM images are measured using the root mean square (RMS) method. Atomic force microscopy was utilized to determine the morphology and size of the prepared NBN. The prepared nanoparticles from Nigella sativa have an average diameter of 47.43nm, Fig.3 shows AFM images along with particle size distribution histograms. The particles are nanosized and somewhat spherical, according to the researchers.

4. FSEM Analysis

Fig.4 shows the distribution of NSN sizes and their components, which contain C, N, O, Pb, Fe, and Ce elements.



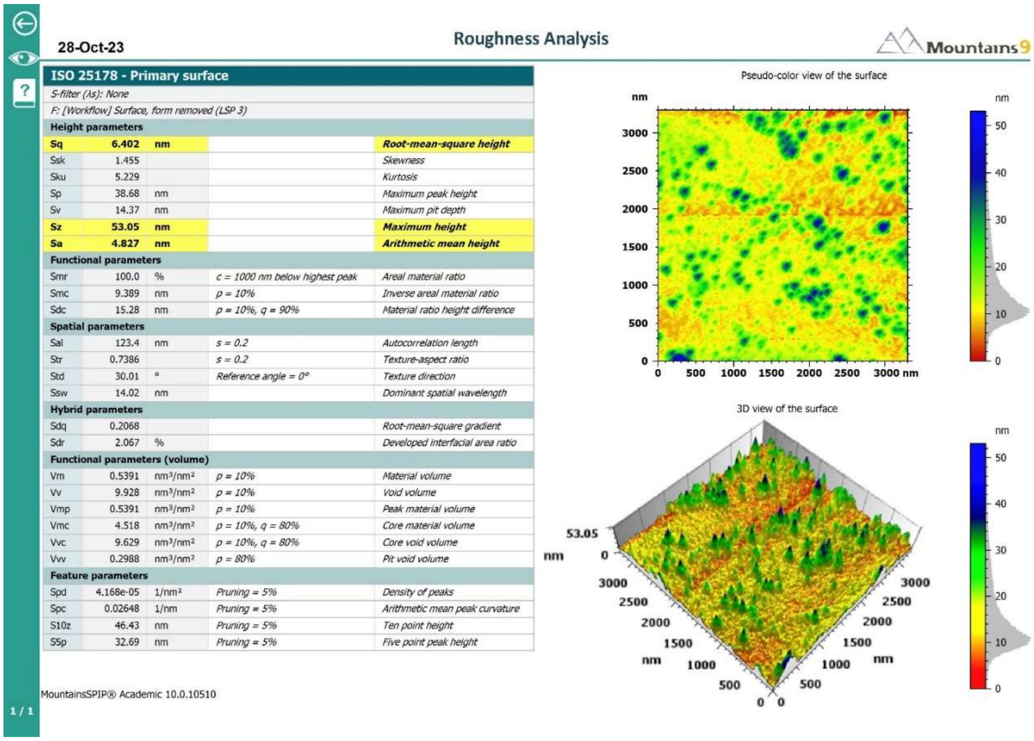


Fig.3: AFM images along with particle size distribution histograms for NBN

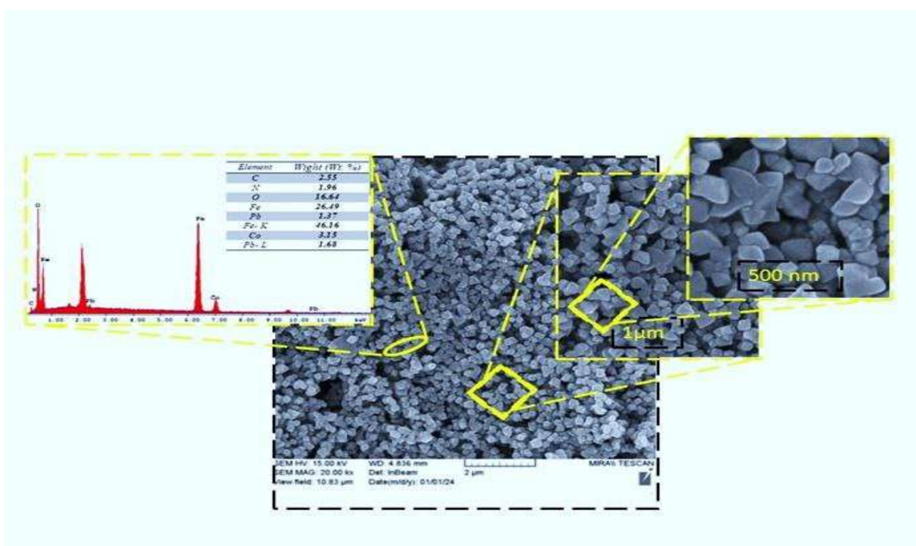


Fig.4: FSEM picture for NSN

Results and Discussion:

Table 1 presents the sample code, the concentration, the volume of Cs-137, the count per minute at the peak, and the removal percentage for Cs-137 radionuclides from water (pH is 7). The time for contact of NBN with Cs-137 radionuclides is constant and equal to 24h.

Table 1: The sample code, the concentration of NBN, the volume of Cs-137, the count per minute at the peak, and the removing percentage for Cs-137 radionuclides from water

Code	Wt. of adsorption (g)	Volume of sample ml (Cs-137)	CPM Bq/l	$R\% = \frac{Ci-Ce}{Ci} \times 100$
Ci	0.0	10ml	2315	-
A1G	0.1	10 ml	1347	0.41
A2G	0.2	10ml	1035	0.55
A3G	0.3	10ml	932	0.59
A4G	0.4	10ml	872	0.62
A5G	0.5	10ml	824	0.64

Fig.5 shows the spectrum of gamma ray emitted from Cs-137 radionuclides, the peak of 0.662 MeV was seen and the count at the peak is 2315 Bq/l.

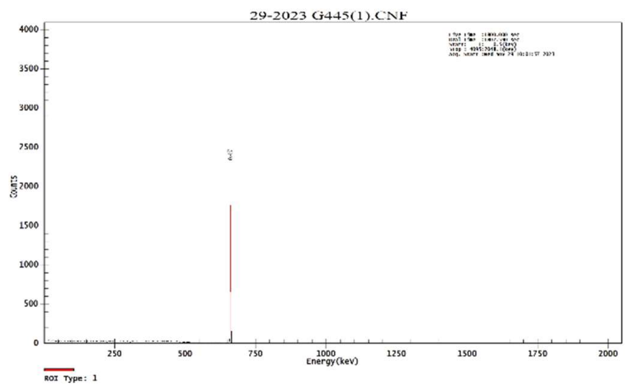


Fig.5: The spectrum of Cs-137 radionuclides in water before adding the NBN

The process efficiency of removal of Cs-137 radionuclides from contaminated water (R%) was increased from 0.0 to 64% when the concentration of NBN increased from 0.0 to 0.5g as shown in Fig.6.

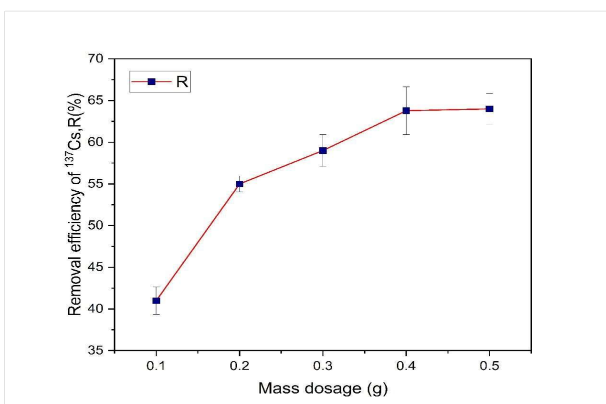


Fig.6: The relationship between the concentration of NBN and the efficiency of removal of Cs-137 from water

The results of the removal of Cs-137 from water at a constant value of NBN concentration

In the previous experiment (Fig.6), the best weight of NBN to reduce pollution from water was found to be 0.5 g. The beast amount of NBN was used in another experiment to find the optimum value of pH to reduce the radionuclides from water. Table 2 presents the code of the samples, the value of water pH, the count of gamma emission Bq/l at the peak, and the removing percentage at the constant value of NBN (0.5g) in 10 ml water.

Table 2: The code of NBN samples, the value of water pH, the count of gamma emission Bq/l at the peak, and the removal percentage at the constant value of NBN (0.5g) in 10 ml water.

Code	pH	Count (Bq/L)	R%=[1-($\frac{Cf}{Ci}$)]100%
Ci		2315	----
A-PH3	3	1110	52
A-PH5	5	847	63.41
A-PH7	7	905	60
A-PH9	9	1347	41.8
A-PH11	11	1386	40.1

The removal percentage of Cs-137 values was increased with increases in the pH value of water from 3 to 11 as shown in Fig.4, the maximum value of removing Cs-137 from contaminated water at pH equal to 5, then the removal was decreased reaching 40% at pH equal to 11as shown in Fig.7.

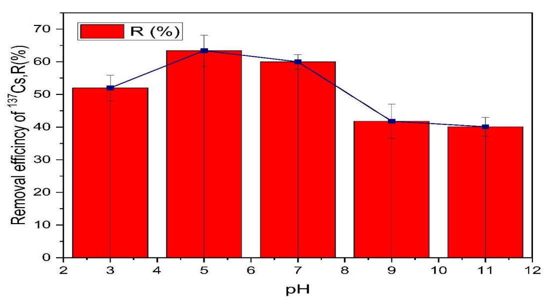


Fig.7: The removal percentage of Cs-137 values with increases in the pH value of water

Conclusions

In this study, nigella sativa nanoparticles (NSN) were synthesized via the mechanical method, which was then burned at a temperature of 300-400 C° for an hour. NSN possessed a spherical morphology, with an average particle size of 45 nm, and a surface potential of −35.23 ± 1.59 mV. The FTIR analysis indicates the implication of hydroxyl and carbonyl groups in the interactions at the interface. The obtained results of removing Cs-137 in two experiments demonstrated a high-efficiency sequestration of Cs-137. NSNs exhibited a maximum cesium adsorption capacity is 64%, with an optimal pH value (5).

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