THE NEXT STEP IN WATER PURIFICATION: NIGELLA SATIVA AND MANGANESE FERRITE

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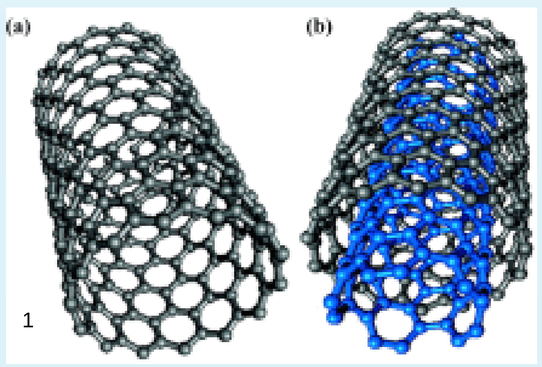
Abstract

- Over 2 million reported deaths reported globally every year caused by bacteria in drinking water.
- Many more cause by other pollutants like heavy metal ions such as lead or harmful dyes.
- A large problem in the United States as well, up to 63 million Americans are exposed to unsafe drinking water.
- This number is also continuously increasing as due to oil spills, increasing amounts of harmful organic dyes and bacteria from soil runoff and leakage of organic waste, along with heavy metal ions from industrial waste in where we get our water.
- Crises in recent memory include the Flint, Michigan crisis that led to a dozen deaths.
- No current large scale water purification method can filter all of those contaminants and as the concentration of them increases it will show.
- A solution to this is water purification with carbon nanomaterials but with how expensive they are to produce tis is a far fetched goal unless produced naturally.
- This is why we decided to focus our research on $MnFe_2O_4$/BC(Manganese Ferrite on Black Cumin).
- Although $MnFe_2O_4$/BC has been around for centuries, its recently discovered ability to filter out such a wide range of contaminants from heavy metal ions to bacteria.
- Our research goes into studies of using nanomaterials as water and how to get this high potential purification system implemented in the U. S. as soon as possible in a cost effective way.

Nanomaterials and Nigella Sativa

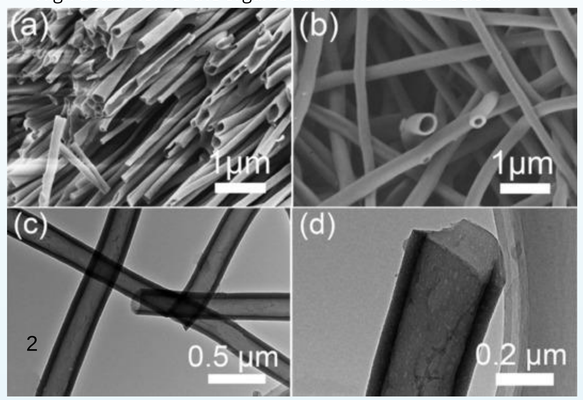
Nanoadsorbents:

- Nanoadsorbents are the key to the whole nanomaterial filtration process.
- They are nanoparticles that have high adsorbing potential due to their porosity, active surface and ability to adsorb without releasing a toxic payload.
- Can be natural or manufactured.
- The most ideal nonoadsorbent structures are single(a) and multi(b) walled carbon nanotubes (Structure below).



Nigella Sativa:

- An inexpensive biochar that is healthy for the human body.
- When coated and used it is called **Black Cumin.**
- A seed that is primarily grown in the Middle-East but can be grown anywhere.
- Surface composed of naturally occurring carbon nanotubes.
- Has strong water filtration properties by itself but must be coated with a metal oxide to achieve applicable potential.
- High detail view of the organic carbon nanotubes below.



Nanomaterials:

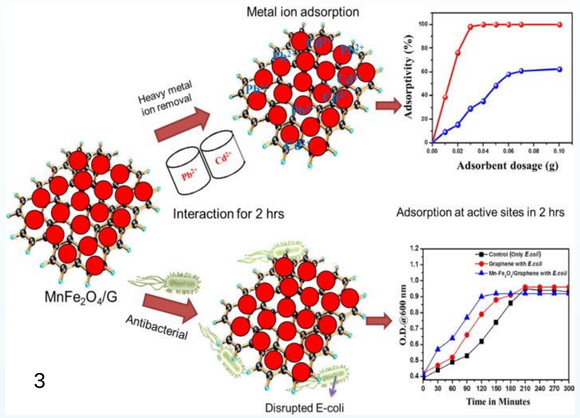
- Magnetic nanomaterials are crucial for this filtration process because of they are required to help pull contaminants to the pores of the nanotubes.
- **Transition Metal Oxides** are ideal for this role because of their selectivity and attraction of heavy metals like lead (Pb).
- Manganese Ferrite($MnFe_2O_4$) was the metal oxide used because of its low cost, non-toxicity, and great magnetic properties.

Production

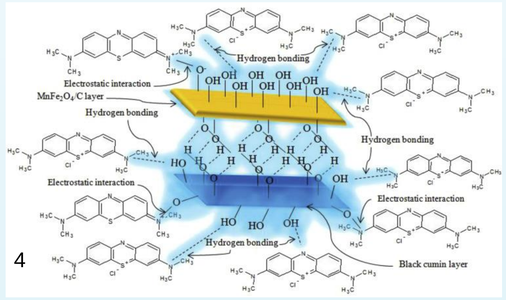
- Black cumin seeds are first added to a solution of $FeSO_4 \cdot 7H_2O$.
- Under continuous stirring, a second solution of $KMnO_4$ is added and allowed to react for three hours.
- When mixed with the Black Cumin the formed $MnFe_2O_4$ bonds to its surface via hydrogen bonds(shown below) and after being washed with deionized water are left to dry over night .
- $MnFe_2O_4$/BC is formed. Figure 4 shows the hydrogen bonding at its center.

How it Works

- $MnFe_2O_4$/BC has many different purification tactics for the wide range of contaminants it filters.
- Metal ions are adsorbed magnetically mostly into the pores of the Black Cumin carbon nanotubes as shown in the upper part of figure 3.
- Living organic bacteria are adsorbed then disrupted and take a bit longer to suppress, as demonstrated in the bottom part of figure 3.

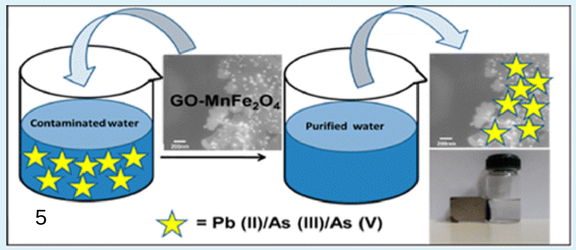


- Polar molecules are adsorbed chemically via hydrogen bonds in many cases as shown below.
- Nonpolar molecules tend to be adsorbed physically by the nanotubes on the Black Cumin.
- Varies from molecule to molecule.



Application

- After larger particles like dust are filtered out through coagulation and sedimentation(like any other process) Black Cumin is added to the unfiltered water.
- After being left for a couple hours, seeds are filtered out with the contaminants adsorbed to the seeds. The current method is via magnet as shown in the figure below.
- No plans large scale processes yet, but will follow this general format.



Key Facts and Experimental Results

Production Efficiency:

- Save costs in purification. No heating or cooling required as max adsorption capacity and magnetic field occur at room temperature.
- Are done with over 99% of adsorption within 3 hours so leaving over night is not necessary. Most adsorption done within 15 minutes.
- Having them in for a shorter amount of exposure time maximizes reusability potential.
- No need to purchase NaOH to make the BC production process a basic solution. Normal deionized water with a pH of 7 Is fine.

Materials and Purification:

- Black Cumin and Manganese Ferrite both aren't the highest performing nanomaterials in their classes respectively but a combination environmental safety and lower costs makes them much more ideal and applicable for a large scale filtration process.
- Also being researched for wastewater treatment but this research is further behind.
- Filtered out metal ions in the top tear of all nanomaterials that were tested.
- Was chosen over materials like gold oxide because of its cost and nontoxicity.
- Was as able to suppress all bacteria growth.
- Nigella Sativa filtered a wider range of contaminants as a base compared to bases like graphene.
- Strong antibacterial activity against gram-negative and gram-positive bacteria due to its high stability.

Reusability

- Depending on which contaminants are being filtered and what thresholds must be filtered, Black Cumin is quite reusable.
- The process of restoring them is quite simple as once they are placed in an acidic solution and washed with deionized water they can be restored to over 90% of their original adsorption capacity in some cases.
- The only drawback is that this process would be hard to integrate to a large scale facility.
- Certain heavy metal ions can be adsorbed at a high rate for over five filter-restore cycles!

Next Steps

- With continued research and funding from the government this technology can be implemented on a large scale in the next decade.
- A first step to cross country implementation would be to open a facility where one is needed anyway.
- Although more expensive currently process like this is necessary for our continuously more threatening water supply.
- Black Cumin's filtration effectiveness, economic efficiency and reusability make it the perfect candidate for nanoparticle water purification to reduce our ecological footprint and bring guaranteed safe drinking water to millions.