SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

Project Report of 2022: SVP-2213

"Nanosponges: Environmentally Sustainable Solution for Water Treatment"

IQAC
Sri Venkateswara College
University of Delhi
Dhaula Kuan
New Delhi -110021

SRIVIPRA PROJECT 2022

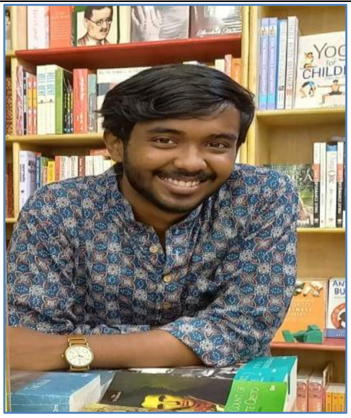
Title : Nanosponges: Environmentally Sustainable Solution for Water Treatment

	Photo
Name of Mentor: Dr. Shikha Gulati **Name of Department: Chemistry** **Designation: Assistant Professor**	
Name of Mentor: Dr. Manoj Trivedi **Name of Department: Chemistry** **Designation: Assistant Professor**	

List of students under the SRIVIPRA Project

S.No	Name of the student	Course	Photo
1	Sheetal Olihan	B.Sc. (Hons.) Chemistry Semester 6 2022	

2	Mansi	B.Sc. (Hons.) Chemistry, Semester 5	
3	Rachit Wadhwa	B.Sc. (Hons.) Chemistry, Semester 5	
4	Sneha Vijayan	B.Sc. (Hons.) Chemistry, Semester 5	
5	Harish Neela Lingam B	B.Sc. (Hons.) Chemistry, Semester 5	

			
6	Bharath Harikumar P	B.Sc. (Hons.) Chemistry, Semester 5	
7	Arikta Baul	B.Sc. (Hons.) Chemistry, Semester 5	

8	Anshdha Nandra	B.Sc. Life Sciences Semester 5	

Sri Venkateswara College University of Delhi

SRIVIPRA-2022

(Sri Venkateswara College Internship Program in Research and Academics)

This is to certify that this project on "Nanosponges: Environmentally Sustainable Solution for Water Treatment" was registered under SRIVIPRA and completed under the mentorship of Dr. Shikha Gulati & Dr. Manoj Trivedi during the period from 21st June to 7th October 2022.

Sharda Pasricha and S. Krishnakumar

Coordinators

Prof. C Sheela Reddy

Principal

Dr. Shikha Gulati and Dr. Manoj Trivedi

Mentors

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Objectives

- The main objective of this project is to give students practice at developing their research skills, scientific aptitude, and knowledge about Nanosponges and their applications in water treatment.
- To impart computational skills on the use of various scientific softwares that are essential for students in doing research work and writing the paper.

Abstract:
This discusses the development and use of several nanosponges for water purification while highlighting factors to be taken into account in future studies. The synthesis of nanosponges can be carried out using a number of different techniques, such as the melt method, solvent method, solvent-diffusion approach, microwave-assisted synthesis, and ultrasound-assisted synthesis. It has been reported that cyclodextrin-based nanostructured materials have undergone a number of chemical changes to increase their affinity for the pollutants. The different characterization methods, including FT-IR, TGA, P-XRD, porosity, Zeta potential, SEM and TEM, and Raman Spectroscopy, are also discussed in order to confirm the synthesis of nanosponges.

Introduction

An essential human need is water. In the modern world, urbanisation, industrialisation, improper sewage disposal, chemical waste disposal, and radioactive waste disposal all worsen water quality. Water treatment is thus currently a significant global issue.
Distillation, chemical techniques, coagulation and flocculation, biological treatment, UV, RO, ultrafiltration, nanofiltration, and microfiltration are a few of the classic ways used to purify water. Water quality is impacted by the impurities that traditional water treatments are unable to eliminate (Jedla et al., 2022). These pollutants, which can get past aqua filters, can be surface or bulk ions.
The current task is to bring attention to alternate water clean up strategies.
Nanomaterials might be a practical and efficient way to overcome major impediments in the creation of effective remedial technologies for environmental protection. Nanoparticles offer a lot of advantages, but one major disadvantage is that they can agglomerate, which will impair their capacity to bind substances. Therefore, polymer-based nanoparticles are presented as a substitute. Nanosponges are one of the most anticipated nanostructured materials (ENMs), which are now widely used for wastewater treatment.

Methods of Synthesis of Nanosponges

There are several techniques mainly used to prepare cyclodextrin nano-sponges which are as follows

1. Melt method
2. Solvent method
3. Solvent diffusion - methods
4. Ultrasound-assisted synthesis

Characterization techniques

There are several techniques that can be deployed to characterize the Nanosponges:

1. ***Porosity*** - Porosity analysis is done to determine how many nanochannels and nanocavities have actually formed. A helium pycnometer is used to measure the porosity of micro sponges because helium gas may pass through both inter- and intra-specific channels in materials. The helium displacement method is used to calculate the material's actual volume. Due to their porous makeup, nano sponges have greater porosity than the parent polymer that was utilised to create the system. Equation provides the percentage of porosity.

   % Porosity (E) = $\frac{Bulk\ volume - true\ volume}{bulk\ volume} \times 100$ (Tejashri et al., 2013)

2. ***Average diameter and polydispersity indices of nanosponges***.– Typically, a particle size analyzer will be used to determine this utilising the dynamic light scattering (DLS) method, also referred to as photon correlation spectroscopy (PCS) PCS connects the intensity variation of scattered light to particle size with the aid of the auto correlation function. PCS/DLS calculates the hydrodynamic diameter by assuming that all the particles are spherical. DLS/PCS calculates the particle size while taking the dispersion medium's effective viscosity, temperature, and refractive index into account. Consequently, the parameter produced after taking into account all the variables would be the measured particle size (Tejashri et al., 2013)

3. ***Zeta potential***.– Any system under investigation's zeta potential is a gauge for its surface charge. The factor affecting body distribution and interactions with the biological environment is surface charge. The electric potential, or diffusion coefficient and electrophoretic mobility, are taken into account while measuring zeta potential. Calculated from the Smolu-chowski equation or Stokes equation, these values are then converted to zeta potential. When determining the zeta potential, the pH and electrolyte concentration must be taken into account. Zeta potential measurements can be used to gauge the stability of newly generated nanoparticles.

4. ***SEM and TEM***.– These instruments are used to assess the particle size and form. In SEM, a concentrated electron beam is utilised to add conductivity to the produced particles while they are in a vacuum. The morphology of particles suspended in liquids is investigated using TEM.

5. ***Fourier transform-infrared spectroscopy (FT-IR)***– It is a crucial tool for figuring out whether functional groups are present. The presence of functional group peaks in the FT-IR spectra during polymer synthesis is a sign that bonds between the polymer's two monomer units have formed. The hydrophobic and hydrophilic components of the proposed system can also be identified using FT-IR. The formation of nano-sponges from -CD is justified by two main characteristics peaks of plain nano-sponge around 1720cm-11750cm-1and 1590cm-1attributed carboxyl group (C=O). In addition, there were other characteristics peaks of NS at 1030 cm-1 and 1451 cm-1that are respectively attributed to C-O stretching vibration of primary alcohol and C-H bending vibration of alkane (Rafati et al., 2019).
6. ***Powder X-ray diffraction (P-XRD).*** – It is an essential tool for determining the presence or absence of functional groupings. When bonds between the polymer's two monomer units have formed, functional group peaks in the FT-IR spectra during polymer formation indicate this. (73). FT-IR can also be used to distinguish between the proposed system's hydrophobic and hydrophilic elements. The two main features peaks of plain nano-sponges about 1720cm-11750cm-1 and 1590cm-1attributed carboxyl group (C=O) provide support for the production of nano-sponges from -CD. Additionally, there were additional NS characteristics peaks at 1030 cm-1 and 1451 cm-1 that are, respectively, attributable to the primary alcohol's C-O stretching vibration and the alkane's C-H bending vibration (Rafati et al., 2019).

7. ***Raman spectroscopy***. – Because the width, intensity, and wavenumber of the Raman peaks are sensitive to the environmental and conformational changes of the molecules as well as to intermolecular interactions, Raman spectroscopy is an effective technique for examining molecular structures. This study looks into the possibilities of defining CD-behavior NS's when it transitions from a dry to a swollen condition (Tejashri et al., 2013).

8. ***TGA studies*** - These investigations are done to comprehend the particles' melting point, thermostability, and crystalline behaviour. According to Trotta et alresearch, .'s under a nitrogen atmosphere, -CD decomposes in a single step and leaves a thermally stable carbonaceous residue that decomposes slowly at higher temperatures. The char is oxidised to volatile compounds when heated in air below 600 °C, leaving a ceramic-like residue that is stable at 800 °C. The cyclodextrin rings are opened during the charring process, and then the cyclodextrin undergoes chemical evolution akin to that of cellulose, losing its glycoside structure and hydroxyl groups while gaining unsaturation, carbonyl groups, and aromatic structures. Similarly, nano-sponges breakdown in a single step with a maximum rate of weight loss at 320 °C and generate a char stable at 800 °C in both atmospheres. Weight loss percentage starts on the

nanosponge TGA curve at a lower temperature than it does on the pure -CD. This event showed that the nano-sponge structure has weaker linkages than pure -CD, which might be linked to the conditions that led to the development of the nano-sponge.

Application of Nanosponges in water treatment

Cyclodextrin-based nano-sponges' success is unquestionably attributable to their ability to evolve while keeping their original properties, such as low cost, environmental friendliness, non-toxicity, and the capacity to host a variety of molecules

Various Types of Nano-sponges	**Purpose**
○ Graphene oxide–modified CD	adsorption of Rhodamine (R6G) dye
	Absorbent for perfluorinated compounds
○ Cyclodextrin based imprinted polymers	for the removal of toxic metals and organic pollutants such as Pb (II), Cd (II), bisphenol-S,ciprofloxacin, procaine, and imipramine from wastewater
	adsorbent for the removal of organic pollutants, including fertilizers, pesticides, and dyes
○ chitosan-EDTA-β-cyclodextrin (CS-ED-CD) tri-functionalized adsorbent	the adsorption of different cationic and anionic dyes
○ Nano-sponge cyclodextrin polyurethanes	eliminate heavy metal ions from water
○ Inorganic halloysite clay and organic cyclodextrin (HNT-CDs)–based	removal of methylene blue (MB) and methyl orange (MO) dyes
	water disinfection
○ TiO2/β-CD nanocomposites	Removal of bacteria in water samples
	selective removal of Pb^{+2}, $Cd^{+2}Ni^{+2}$ ions
○ glycine-β-cyclodextrin-modified TiO2(gly-CD-TiO2)	for the removal of pesticides
	capturing $Pb^{2+}$from wastewater

○ Nano-sponge β-CD polyurethanes with TiO2 and silver nanoparticles ○ co-polymerized β-CD with Ag impregnated CNTs ○ carboxy methyl-β-cyclodextrin (CM-β-CD) polymer-modified with Fe_3O_4 nanoparticles ○ β -CD nanosponge polymer with Fe_3O_4 nanoparticles ○ β-cyclodextrin covalently cross-linked with tannic acid nanosponges ○ phosphorylated multi-walled carbon nanotube-cyclodextrin/Ag-doped TiO_2 nanosponges ○ Glycopolymer Nanosponges ○ B-Cyclodextrin based nanosponges immobilized with magnetic nanoparticles ○ β-cyclodextrin in the company of poly(vinyl alcohol) via cross linking of 1,2,3,4-butanetetracarboxylic acid	for removing $Pb^{2+}$and Co^{2+}metal ions from wastewater for eliminating boron from water capturing organic micropollutants. elimination of cationic contaminants from water for the elimination of dinotefuran from water to eliminate Pb2+ions from aqueous solutions. Adsorb heavy metals in the attendance of meddlesome salts from sea water For removing paraquat from water. for the photocatalytic degradation of rhodamine B and Congo red dye

○ Superparamagnetic Fe_3O_4nanoparticles are decorated on the surface of β-cyclodextrin-derived carbonate nanosponge	

Conclusions and future outlooks:

For the sake of both the environment and public health, contaminated water must be cleaned up. Advanced technologies, such as nanotechnology, can be employed for this purpose, as well as the treatment of harmful and hitherto untreatable contaminants. For increasing the cost-effectiveness of industrial wastewater treatment, nano-based methods have immense promise. The use of CD-based materials offers out considerable opportunity for a long-term solution to the issue of water pollution. Nanosponges are appealing options for absorbing and eliminating organic/inorganic pollutants/contaminants (such as dyes, medicines, and heavy metals) from water and wastewater due to their high porosity, ease of functionalization, simplicity, and cost-effectiveness. When using CDs for various purposes, safety precautions must be taken because they can penetrate the human body, particularly in industries like wastewater treatment and air purification. So long as the toxicological considerations are taken into account, they can be employed in a variety of applications without risk.

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