CHAPTER-4

Efficient Green Removal and Quantification of Toxic Heavy Metals from Losartan Using Silica Nanoparticles Derived from Rice Husk Ash

4.1: INTRODUCTION

Contamination of the natural environment is one of the most significant challenges that the current iteration of human civilization must contend with. Degradation of the surrounding environment and pollution with toxic heavy metals pose a significant risk to the ecosystem [1-3]. It is well knowledge that even at low quantities; toxic heavy metals can be toxic to living beings. Toxic Heavy Metals are particularly dangerous as a category because of the cancer-causing and poisonous qualities they possess, as well as the fact that they are not biodegradable and have a tendency to build up in the environment over time. The fact that heavy metals and other toxins are still present in water, medicine, food, and the environment is a major cause for concern [4].

The removal of contaminants of this nature is widely recognised as one of the most difficult components of environmental clean-up and restoration work. Several diverse processes, such as chemisorption, complexation, adsorption on surface, diffusion via pores, and ion exchange, can all contribute to the sorption of biomass. The economic benefits and high removal efficiency ascribed to various functional groups of agricultural waste for the aim of removing heavy metals from wastewater, pharmaceuticals, and food items have sparked a great deal of attention [5,6]. When discussing environmental issues, only a subset of the chemicals labelled as heavy metals are given much attention. Some of the most harmful heavy metals and metalloids to the environment are V, Co, Ni, Cd, Hg, Pb, and As. [7-11].

There have been a number of successful works done in connection with bio sorbents. There are numerous kinds of bio-waste, each of which has the potential to be used as an adsorbent in the process of cleansing polluted water and the environment. There are a few distinct kinds of bio-waste that can be utilised as bio sorbents in order to remove dangerous and harmful metals from food products, pharmaceuticals, and the environment [12, 13]. These bio sorbents have several potential applications. Furthermore, there is published research on the utilisation of algae and seaweeds for the elimination of toxic heavy metals [14]. This means that bio waste doesn't have to be thrown without first being processed to remove potentially harmful toxic heavy metals. Microorganisms (both living and non-living) have been used as adsorbents for the removal and recovery of materials from aqueous solutions for only the last three decades, despite research into this capability dating back to the 18th and 19th centuries. These might be either live or non-living microbes. Bio sorption methods were first put to use in the treatment of sewage and garbage. The first patent application for a bio-sorption device was filed in 1973 [15] by Ames Crosta Mills & Company Ltd. The gadget was designed to be used in the biological wastewater treatment process.

The term "bio-sorption" is used to describe a type of sorption in which the sorbent is a substance derived from a living organism. Bio sorption has become a popular method for cleaning the air because it is easy to implement, inexpensive, and environmentally friendly. Bio sorption, for the sake of this article, covers any method by which contaminants are eliminated via adsorption onto a substance of biological origin (biomass). Microbial biomass has recently been considered as a viable option for developing environmentally and economically sound wastewater treatment methods [16-18]. Due to this, biotechnology's role in metal pollution prevention and clean-up has come under the microscope, and it is quickly becoming a topic of discussion among experts in the field of pollution management. Bio sorption is one such alternate method, and it employs a wide range of natural materials with a biological origin. Natural substances encompass a wide range of organisms, from bacteria and fungi to yeast and algae. Bio sorption has been studied extensively over the past decade, and recent developments in the field have only served to increase people's excitement about employing it to combat environmental degradation. Numerous articles have been written about bio sorption, either to test whether or not specific compounds function as bio sorbents, or to develop complex hybrid substances that are more effective [19, 20].

The goal of this work is to purify losartan by removing heavy metal contaminants, and two types of silica nanoparticles are the primary focus. If any pollutants are present, the silica nanoparticles can take them in. We are using a modified bio-sorbent created from a pharmaceutical drug called losartan in an attempt to remove heavy metals from the waste water at this facility that have proven difficult to remove despite everyone's best efforts. Silica nanoparticles have many potential uses, especially in the medical field, and this study presents a method for their effective green synthesis. Silica nanoparticles' unique structural qualities give them a leg up on other materials when it comes to adsorption applications. The silanol groups on the surface make it easy to modify the structure, and other benefits include structural stability, high specific surface area, tuneable pore structure, reduced environmental impact, straightforward synthesis, low cost, etc.

4.2: RESULT AND DISCUSSION

4.2.1: TGA

At temperatures ranging from 1000 to 1200 ^{0}C, the thermo gravimetric plot for the SNPs-4-900 and SNPs-8-900 experiments predicted a minimum weight loss of 14% and 5%, respectively. It's possible that the sample has lost some of its moisture. Aside from that, the thermal stability of both SNPs is excellent, reaching up to 600 ^{0}C. It should be brought to everyone's attention that the DTG analysis of the SNPs reveals no appreciable weight loss over a temperature range of 24-600 ^{0}C (Fig. 2).[21].

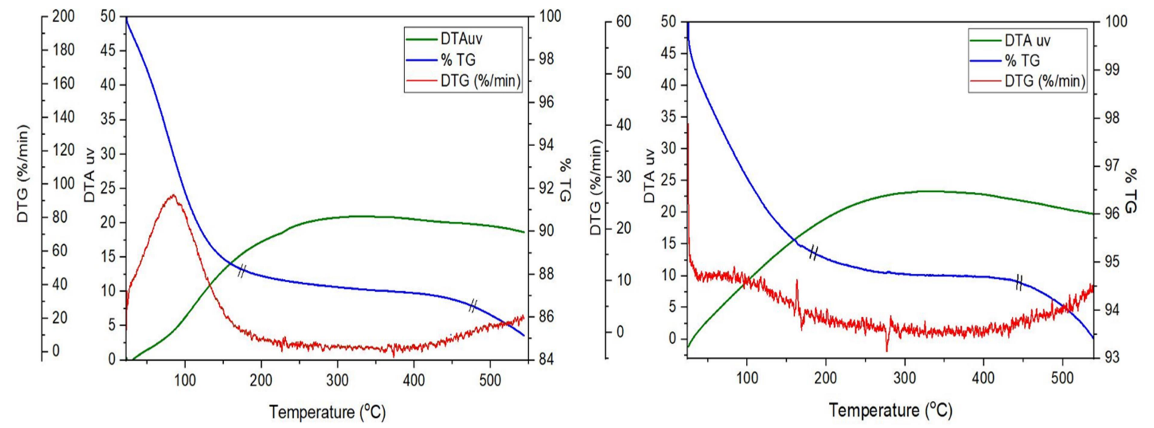

(a) SNPs-4-900 (b) SNPs-8-900

Fig.1: TGA analysis of samples: (a) SNPs-4-900 (b) SNPs-8-900

4.2.2: FT IR

The FT IR profile of SNPs revealed distinct peaks for SNPs-4-900 at 1092.5 cm^{-1}, 792.8 cm^{-1}, and 621.5 cm^{-1}, as well as SNPs-8-900 at 1097.5 cm^{-1}, 620.9 cm^{-1}, and 476.8 cm^{-1}. These peaks, which might be attributable to siloxane stretching (Si-O-Si), were found in the SNPs. In addition to this, the 1725.2 cm^{-1} signal is thought to be caused by H-O-H bond bending vibrations, which are caused by water molecules that are trapped inside SNPs. The peak that can be seen at 3750.1 cm^{-1} in Table 1 was caused by the stretching vibrations of water molecules that were trapped in SNPs.

Table 1: FT IR of Silica nanoparticles

Peak Assignment	Wavenumber (cm-1)	Attributed Function
Si-O-Si Stretching (SNPs-4-900)	1092.5	Si-O-Si Stretching
Si-O-Si Stretching (SNPs-4-900)	792.8	Si-O-Si Stretching
Si-O-Si Stretching (SNPs-4-900)	621.5	Si-O-Si Stretching
Si-O-Si Stretching (SNPs-8-900)	1097.5	Si-O-Si Stretching
Si-O-Si Stretching (SNPs-8-900)	620.9	Si-O-Si Stretching
Si-O-Si Stretching (SNPs-8-900)	476.8	Si-O-Si Stretching
Trapped Water (H-O-H Bending)	1725.2	Trapped water molecules (H-O-H)
Trapped Water Stretching	3750.1	Stretching vibrations of trapped water

As a direct result of this, the FT IR spectra did not display any peaks that could be interpreted as indicating the presence of either organic or inorganic components; thus demonstrated the extremely high purity of the SNPs that were produced (Fig. 3) [22-24].

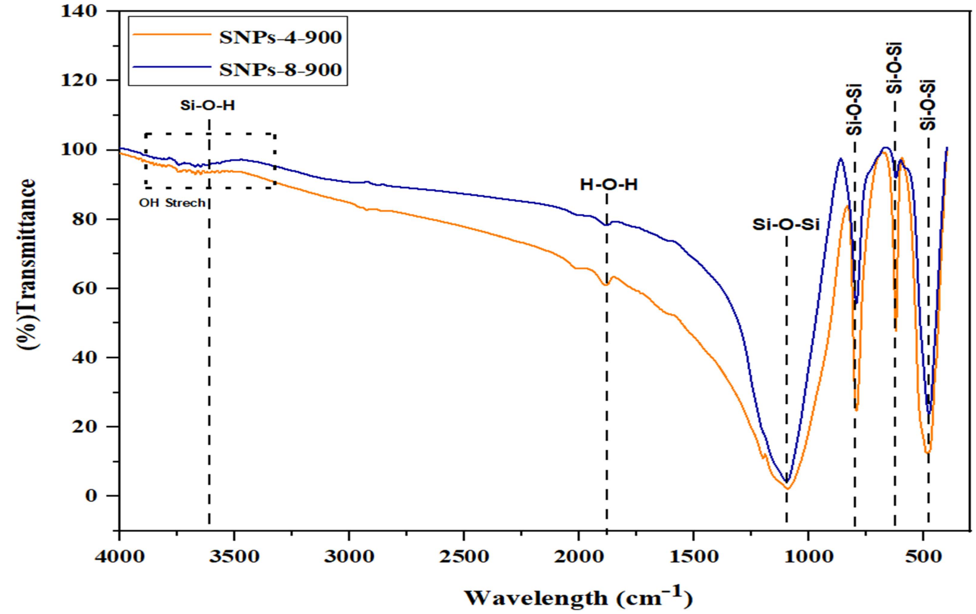
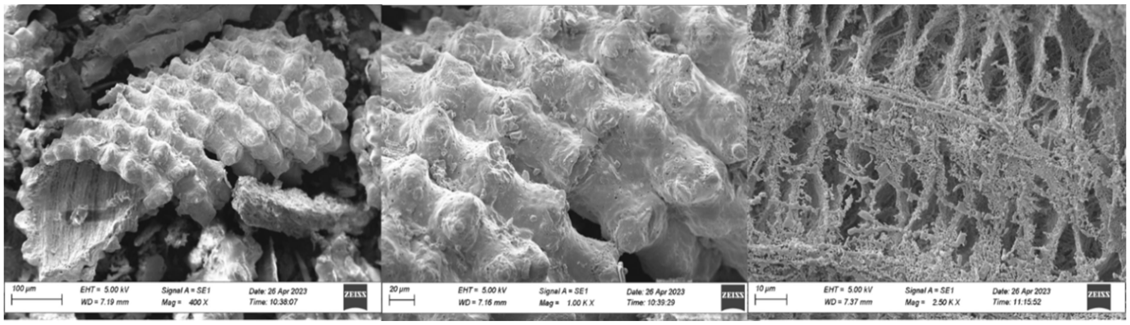


Fig.2: FT IR of SNPs: SNPs-4-900 and SNPs-8-900

4.2.3: SEM

SEM of silica produced from RHA by the calcination process at various temperatures are shown in Figure 4. It was discovered that SNPs diameters reduced due to increasing aggregation when calcination temperatures increased. That was true even if the temperature never changed. The surface shape of SNPs that were produced from SNPs biomass can be seen in these photographs. The topological differences that are present in SNPs obtained from different treatments can be defined in a clear and concise manner by SEM analysis. The results of the scanning electron microscopy showed that all of the nanoparticles displayed a significant amount of aggregation, with the SNPs-4-900 and SNPs-8-900 exhibiting the most aggregation [25].

(a) SNPs-4-900



(b) SNPs-8-900

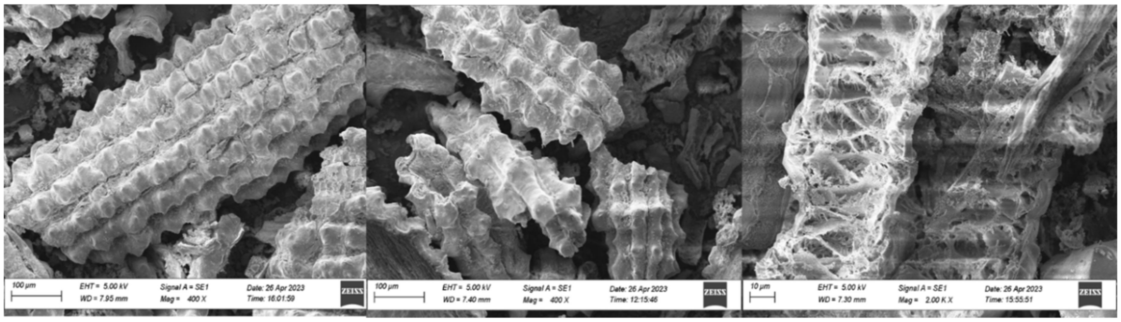
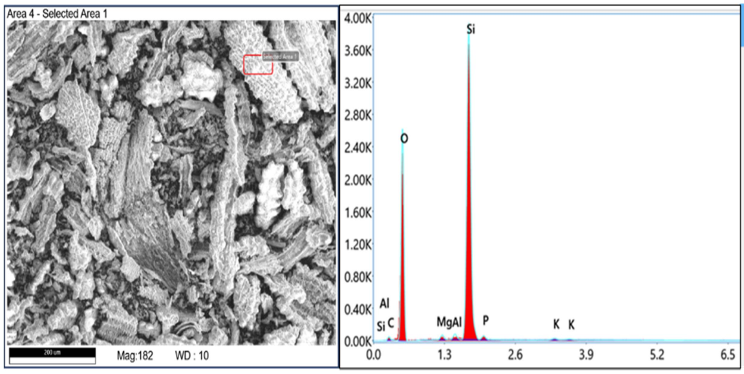


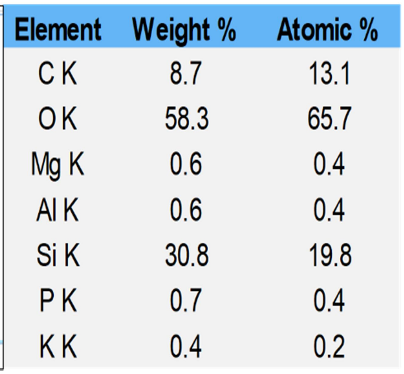
Fig.3: SEM photographs of the following samples: (a) SNPs-4-900 (b) SNPs-800 to -1000

4.2.4: Analysis by use of energy-dispersed X-rays (EDX)

High-quality silica was isolated from the recovered rice husk ash, as shown by EDX analysis. Energy dispersive x-ray spectroscopy was used to acquire silica spectra, and these spectra are shown for both SNPs-4-900 and SNPs-8-900 (Fig. 5). Spectra only displayed the expected signal peaks for Si (30.8%), O (58.3%), and C (8.7%) for SNPs-4-900 (Fig. 5 (a)), and for SNPs-8-900 (Fig. 5 (b)), the signal peaks were Si (41.1%), O (52.7%), and Mg (0.8%). According to the findings, SNPs-8-900 has a higher concentration of silica than SNPs-4-900 does. The presence of peaks in the EDX spectrum that correspond to silica and oxygen provides further evidence that silica was utilised in the production of the nanoparticles [26, 27].

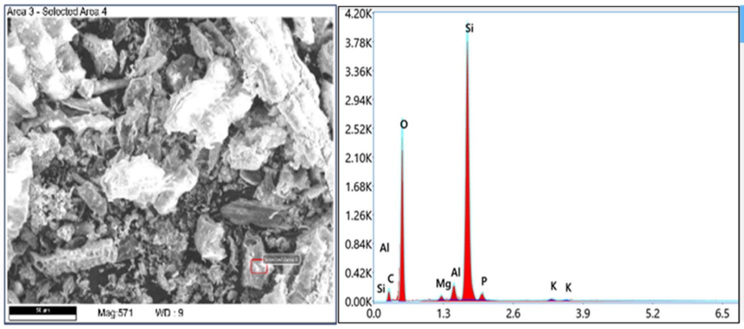
(a) SNPs-4-900





Element	Weight %	Atomic %
C K	8.7	13.1
O K	58.3	65.7
Mg K	0.6	0.4
Al K	0.6	0.4
Si K	30.8	19.8
P K	0.7	0.4
K K	0.4	0.2

(b) SNPs-8-900



Element	Weight %	Atomic %
C K	22.1	30.4
O K	53.1	54.9
Mg K	0.5	0.3
Al K	1.4	0.9
Si K	21.8	12.9
P K	0.9	0.5
K K	0.3	0.1

Fig.4: EDX analysis of samples: (a) SNPs-4-900 (b) SNPs-8-900

4.2.5: Particle size distribution (PSD)

DLS measured a particle size range of 20 to 50 nm, which was significantly bigger than the size estimated by TEM (which ranged from 15 to 30 nm). This is due to the fact that the DLS method is frequently utilised to estimate the dynamic diameter particle sizes of SiO2 NPs that are scattered in water (Fig. 6) [28].

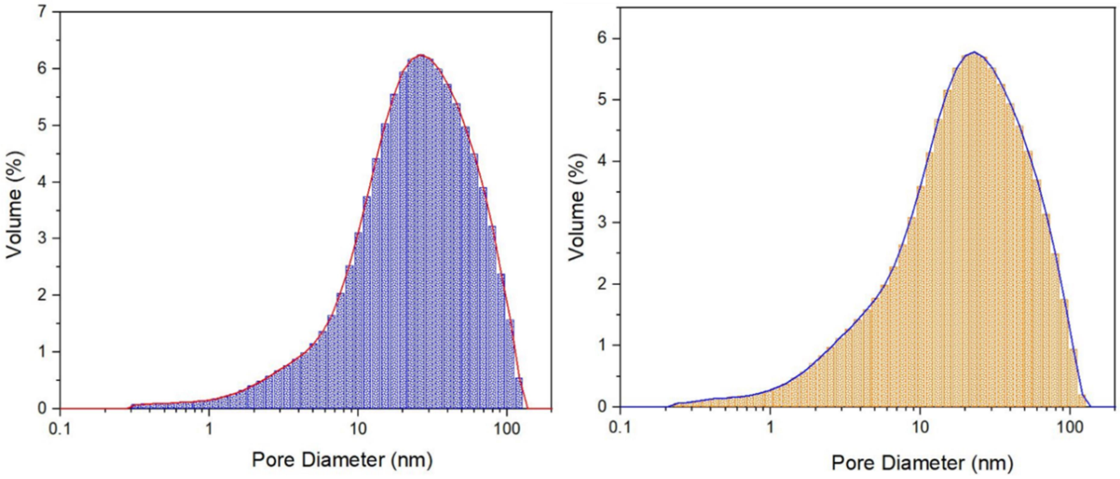

(a) SNPs-4-900 (b) SNPs-8-900

Fig.5: Particle size of samples: (a) SNPs-4-900 (b) SNPs-8-900

4.2.6: Surface area and pore structure analysis (BET)

The specific surface area, or BET, of SNPs was determined by generating N_2 adsorption-desorption isotherms using a device called a Micrometrics ASAP 2010. The samples were preheated at 100 ^{0}C for 24 h before being analysed. The N_2 adsorption isotherm data was used with the BET method to determine the particle's specific surface area. SNPs-4-900 has pores that are 38.002 microns in size, whereas SNPs-8-900 pores are 79.388 microns in size. Because of this, pores with a bigger size have a greater capacity for adsorption (Figure 7) [29, 30].

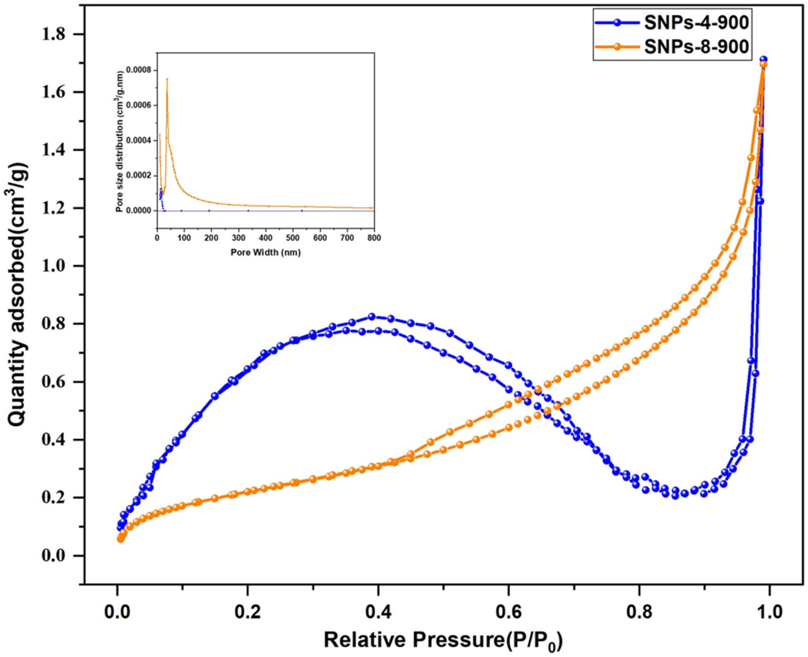
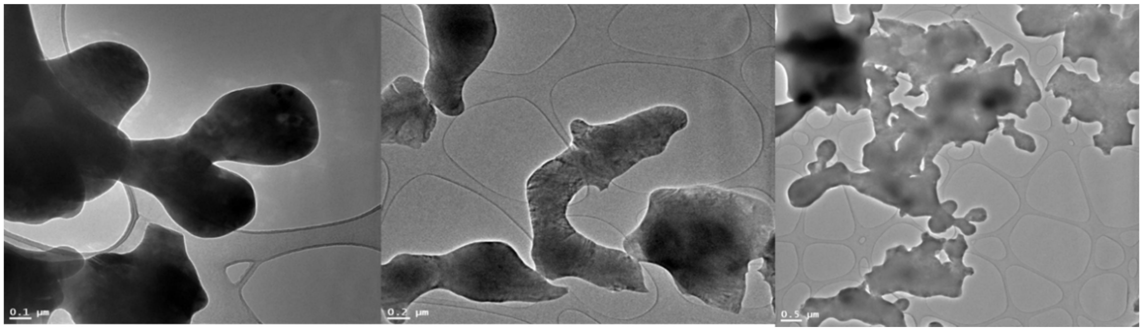


Fig.6: BET analysis of samples: SNPs-4-900 and SNPs-8-900

4.2.7: Microscopy using transmission electron microscopy (TEM)

Clusters of original particles with irregular geometries and spherical morphologies were seen in the TEM of the SNPs, together with a very broad size distribution. The electron micrograph (Fig. 8) shows that the particle size of SNPs produced by SNPs-4-900 is 20 nm, while the particle size produced by SNPs-8-900 is 17 nm. Every major particle was connected to and affixed to another main particle. [31-33].

(a) SNPs-4-900



(b) SNPs-8-900

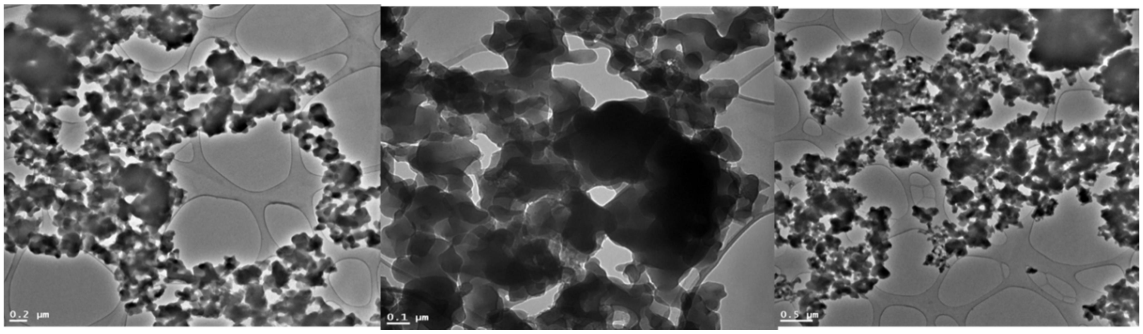


Fig.7: TEM images of samples: (a) SNPs-4-900 (b) SNPs-8-900

4.2.8: AFM

An image of the surface of a material that is quantitative and rendered in three dimensions can be produced by a type of microscope known as an AFM. Examining the surfaces of samples is the primary purpose of this kind of microscope. In order to scan the surface of the object, a very sharp tip is coupled to a flexible cantilever, and this combination is used. When the atoms on the tip of the cantilever come into touch with the atoms on the surface of the sample, the cantilever bends in the opposite direction. This deflection is measured, and then it is used to create the picture. [34, 35].

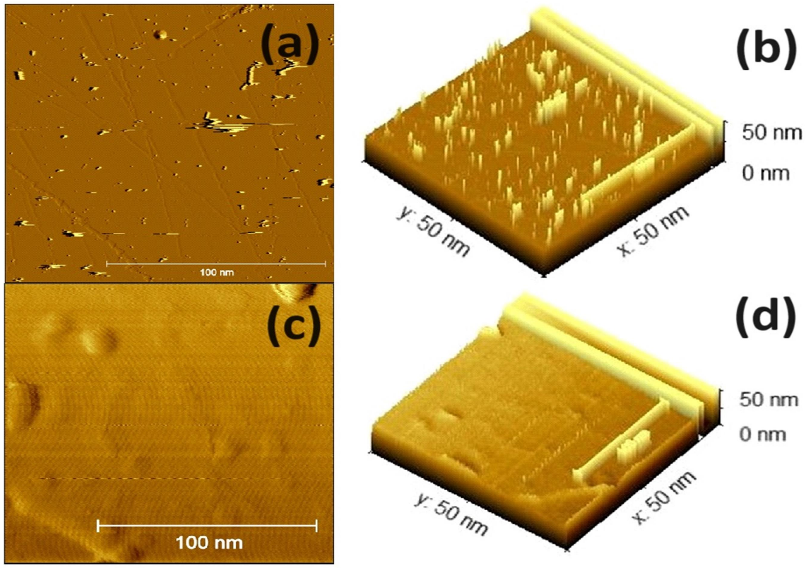


Fig.8: AFM images of the following samples: (a) a 2D image of SNPs-4-900 (b) an image of SNPs-8-900 (c) an image of SNPs-900 picture of SNPs-8-900 in two dimensions (D) photos in three dimensions of SNPs-8-900

4.2.9: XRD

During the XRD analysis, strong distinctive peaks were captured, which gives one reason to suspect that SNPs have a crystalline structure in their natural state. The crystalline structure of the materials can be determined using a process called XRD, which is of special significance in this regard. XRD diffractogram of SNP-8h-900 and SNP-4h-900 taken with an angle range of 0 to 800^0, CuK1 radiation at a wavelength of 1.5406 nm, and an accelerating voltage of 40 kV. The values of the two products that are produced are 22.38 and 22.71, 26.48 and 28.94, 30.04 and 31.97, and 37.21 and 37.77 respectively. The peak that stood out the most was found at 2θ = 22.38^0 (Table 2).

Table 2: XRD of SNPs

Sample	2θ (Degrees)	Identified Peak	Miller Indices (hkl)
SNP-8h-900	22.38	Prominent Peak	(111)
SNP-8h-900	26.48		(220)
SNP-8h-900	28.94		(311)
SNP-8h-900	30.04		(400)
SNP-4h-900	22.71	Prominent Peak	(111)
SNP-4h-900	31.97		(220)
SNP-4h-900	37.21		(311)
SNP-4h-900	37.77		(400)

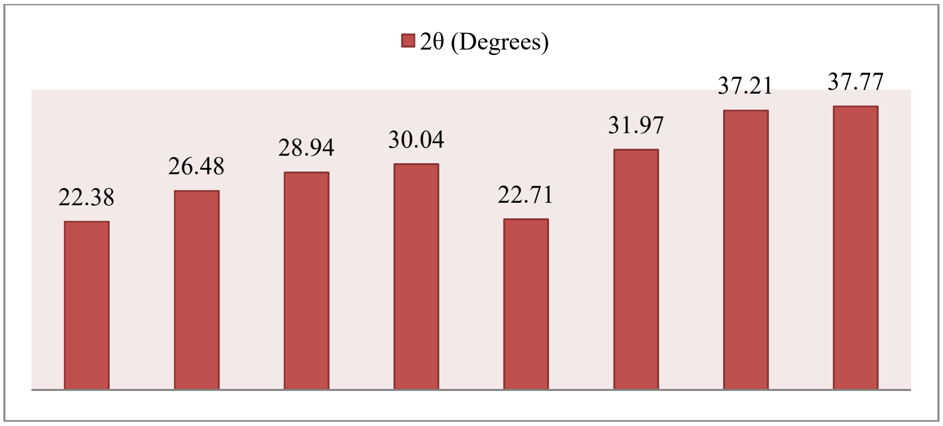


Figure 10: XRD of Silica nanoparticles

The miller indices hkl (111), (220), (311), and (400) planes are mirrored in the XRD diffractogram of cubic silicon (Fig. 10) [36-38].

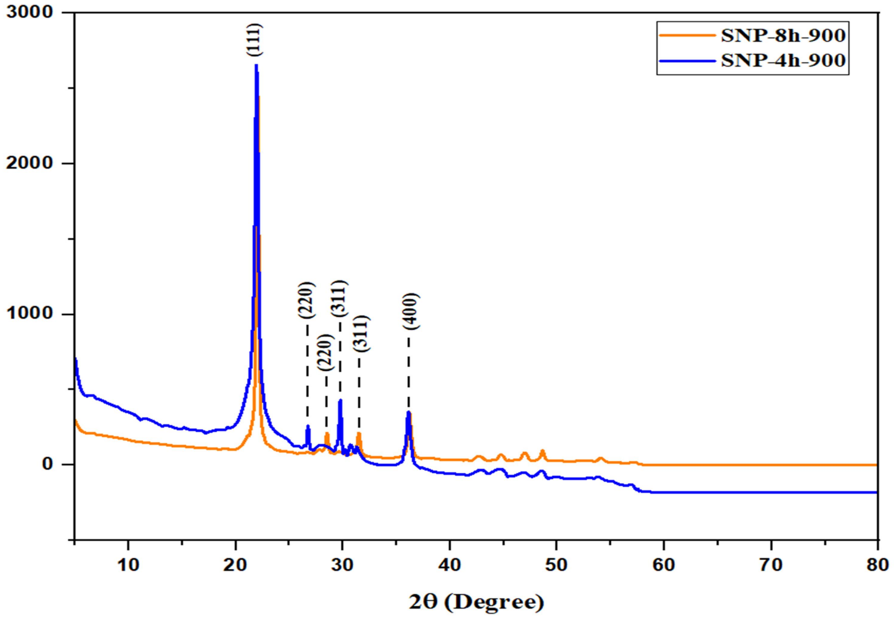


Fig.11: XRD analysis of samples: SNPs-4-900 and SNPs-8-900

4.3: HEAVY METAL CONTAMINATION

Both high blood pressure (also known as hypertension) and diabetes-related damage to the kidneys can be treated with the medication losartan, which is also used to protect the kidneys against damage. Stroke, heart attack, and kidney disease are all averted when blood pressure is reduced. Losartan potassium, however, has been found to have a variety of heavy metals and hazardous metals in it, including V, Co, Ni, Cd, Pb, As, and Zn (Table 3).

Table 3: The amount of heavy metals that were found in the Losartan sample that was submitted

Elements	Initial Concentration (µg/L)
V	0.328
Co	1.532
Ni	15.228
Cd	0.790
Hg	Not present
Pb	0.273
As	0.015
Zn	31.851

V, Co, Ni, Cd, Hg, Pb, As, and Zn are just some of the heavy metals found in a Losartan sample, as shown in Table 3. The data shows that some heavy metals were present in the sample, while others were not detected. Vanadium was found at a low concentration of 0.328 µg/L, suggesting a relatively low presence. Cobalt had a higher initial concentration of 1.532 µg/L, suggesting a somewhat higher presence. Nickel was notably higher at 15.228 µg/L, indicating a significant concentration. Cadmium was detected at 0.790 µg/L, while mercury was not present. Lead was found at 0.273 µg/L, indicating a relatively low presence. Arsenic was detected at a very low concentration of 0.015 µg/L, indicating minimal presence. Zinc had the highest initial concentration at 31.851 µg/L, suggesting a substantial amount of zinc present. The results can guide further investigation or measures to ensure the Losartan product meets safety and regulatory standards, protecting consumers from potential harm associated with heavy metal contamination. Pollution from heavy metals is a worldwide issue that endangers all kinds of life [39]. This is because heavy metals are harmful to living things. Even at minute concentrations, these metals can induce significant reactions. Traditional physical and chemical cleanup approaches fail to eliminate the problem and instead generate enormous amounts of dangerous waste. The bioremediation of metal pollutants has received a lot of interest in recent years. Because of their low environmental impact and efficiency in resource and cost management, biosorbents are a practical solution for cleaning up heavy metal polluted areas. Taking medication for a protracted period of time increases the risk of developing cancer [40]. As a consequence of this, it is very necessary to do away with or significantly lessen the amount of heavy metals in the medicine losartan.

4.4: EFFECT OF BIOMASS CONCENTRATION ON METAL REMOVAL

In this particular investigation, a conical flask containing a solution containing 1000 ppm of the target metal in losartan potassium medication and various weights of biomass (g) of SNPs-4-900 and SNPs-8-900 adsorbents was agitated in a rotary shaker at 250 rpm at room temperature for a period of six hours. A rotary shaker was used for the shaking. We conducted a number of experiments throughout the course of our study, and the biomass weight varied between 0.25 g and 2.0 g in each trial. Experiments were run with varying amounts of biomass, and the results are summarised in Table 4.

Table 4: Effect of weight of adsorbents on removal of heavy toxic metals

Sample	Weight of Adsorbent (g)	Heavy Toxic Elements Concentration (µg/l)						
		V	Co	Ni	Cd	Pb	As	Zn
SNP-4-900	0.25	0.285	1.499	10.906	0.695	0.233	0.013	19.512
SNP-8-900		0.255	1.446	10.503	0.656	0.228	0.012	19.372
SNP-4-900	0.50	0.229	1.325	7.388	0.555	0.164	0.009	15.764
SNP-8-900		0.223	1.322	7.369	0.542	0.163	0.008	14.764
SNP-4-900	1.0	0.180	1.261	4.952	0.538	0.115	0.007	14.243
SNP-8-900		0.166	1.217	4.925	0.520	0.111	0.007	13.105
SNP-4-900	1.5	0.126	1.167	4.356	0.529	0.107	0.006	10.616
SNP-8-900		0.103	1.136	4.322	0.513	0.103	0.006	10.130
SNP-4-900	2.0	0.088	1.150	3.107	0.515	0.102	0.005	10.232
SNP-8-900		0.087	1.134	3.103	0.509	0.102	0.005	10.101

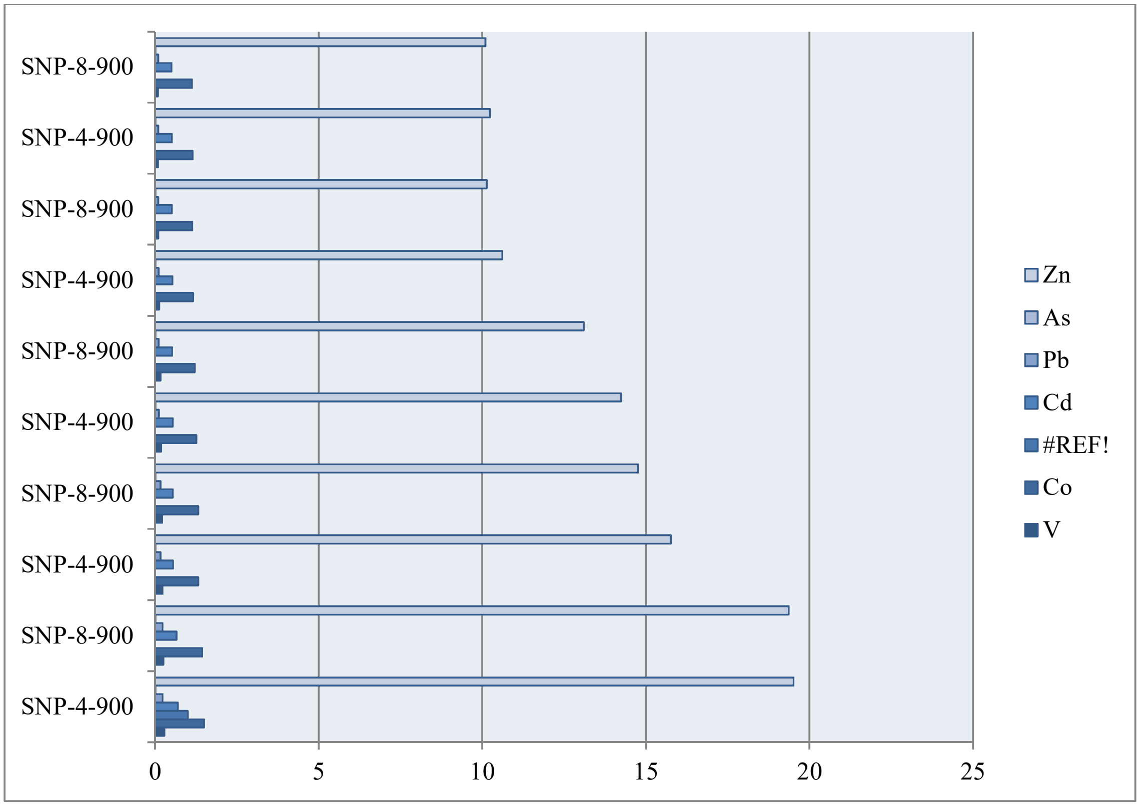


Figure 12: Impact of Adsorbent Weight on the Removal of Hazardous Heavy Metals

Table 4 displays information on the effect of adsorbent weight on the recovery of potentially dangerous heavy metals from different samples. Experiments with varying amounts of heavy hazardous elements and a variety of adsorbent weights are shown. An important pattern relating the weight of adsorbents and its effect on the removal of heavy metal concentrations emerges from the investigation. As the weight of adsorbents increases, the concentrations of heavy toxic elements decrease, indicating that a higher weight results in more effective removal. For example, as the weight of adsorbent increases from 0.25g to 2.0g, the concentrations of heavy metals like vanadium, cobalt, nickel, cadmium, lead, arsenic, and zinc consistently decrease. This information is crucial for understanding the efficiency of adsorbents in eliminating heavy metals from samples and can guide future research or practical applications in water purification or environmental remediation. It suggests that heavier doses of adsorbents may be more effective in reducing heavy metal concentrations, potentially leading to improved water quality and reduced health risks associated with heavy metal exposure.

We used different amounts of biomass, ranging from 0.25 g to 2.0 g, and found that this effectively reduced the heavy metal pollutants found in losartan potassium. After shaking the sample with SNPs-4-900 for six hours, the percentages of metal removal are as follows: V = 73.18%, Co = 24.94%, Ni = 79.6%, Cd = 34.82%, Pb = 62.64%, and As = 66. In addition, the percentages of metals removed by using SNPs 8-900 are as follows: V = 73.48%, Co = 25.98%, Ni = 79.63%, Cd = 35.57%, Pb = 62.64%, and As = 66.67%. (See Table 5).

Table 5: The influence that the weight of the adsorbents has on the removal

Sample	Heavy Toxic Metals Concentration (%)					
	V	Co	Ni	Cd	Pb	As
SNP-4-900	73.18	24.94	79.6	34.82	62.64	66.67
SNP-8-900	73.48	25.98	79.63	35.57	62.64	66.67

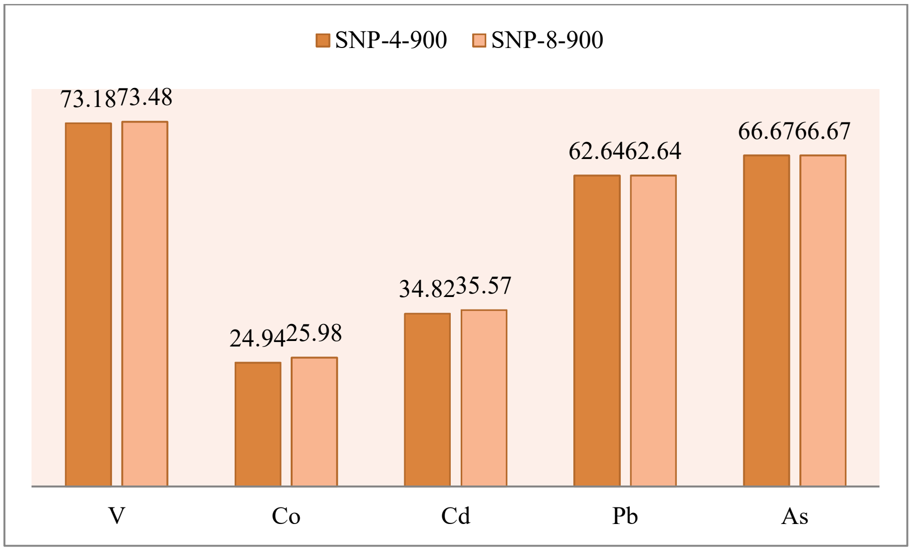


Figure 13: Influence that the weight of the adsorbents has on the removal

The removal of vanadium, cobalt, nickel, cadmium, lead, and arsenic, among other heavy hazardous metals, from samples is shown in Table 5 below as a function of adsorbent weight. The data displays two samples, SNP-4-900 and SNP-8-900, and their removal percentages. Weight of the adsorbents appears to have little effect on the efficacy of removing these heavy hazardous metals, as shown by the table's minor variance in removal percentages between the two samples. This indicates that increasing the adsorbents' mass does not considerably enhance the removal of certain heavy metals under certain conditions or with certain materials. Other factors, such as the type of adsorbents, contact time, or initial metal concentration, may have a more significant influence on removal efficiency. Further investigation or optimization of the removal process may be necessary to enhance the effectiveness of the adsorbents in eliminating these heavy toxic metals from the samples.

After the slurry had been allowed to equilibrate, it was filtered through Whatman 41 filter paper. When compared to SNPs-4-900, this indicates that SNPs-8-900 have absorbed a significantly higher percentage of heavy metals than SNPs-4-900. If there is a higher concentration of biomass, there will be a greater number of potential binding sites, which will result in a higher percentage of removal.

4.5: EFFECT OF SHAKE TIME IN METAL REMOVAL

Biomass of a known mass (2.0 g) was added to a solution containing 1000 ppm of the target metal ion in the losartan. Then, for 6 h at RT, the solution was agitated thoroughly at 250 rpm in a rotary shaker (Electroquip, dbk - Metabolic shaker). The slurry was then filtered using Whatman 41 filter paper after it had had time to acclimatise. Our studies involved recording the duration of time spent shaking from 1 to 6 hours. After 6 h of shaking, we were able to successfully eliminate heavy metal pollutants from losartan potassium using biomass. Table 6 displays the results of a previous experiment designed to maximise metal removal by biomass while simultaneously decreasing the required incubation period.

Table 6: The effect of shaking duration combined with adsorbents on the removal of hazardous heavy metals

Sample	Shaking time (h)	Heavy Toxic Elements Concentration (µg/l)						
		V	Co	Ni	Cd	Pb	As	Zn
SNP-4-900	1	0.259	0.052	11.886	0.359	0.193	0.010	26.164
SNP-8-900		0.236	0.051	11.248	0.348	0.189	0.009	25.944
SNP-4-900	2	0.148	0.515	9.912	0.291	0.160	0.008	18.745
SNP-8-900		0.135	0.495	9.862	0.286	0.155	0.008	18.695
SNP-4-900	3	0.133	0.412	8.255	0.212	0.083	0.004	12.691
SNP-8-900		0.127	0.401	8.196	0.210	0.082	0.003	12.121
SNP-4-900	4	0.103	0.299	7.592	0.188	0.035	0.002	11.178
SNP-8-900		0.099	0.237	7.468	0.148	0.032	0.002	11.088
SNP-4-900	5	0.095	0.251	7.522	0.175	0.032	0.002	10.778
SNP-8-900		0.094	0.219	7.456	0.126	0.026	0.001	10.551
SNP-4-900	6	0.072	0.234	4.624	0.151	0.020	0.001	9.462
SNP-8-900		0.071	0.117	4.335	0.125	0.019	0.001	9.262

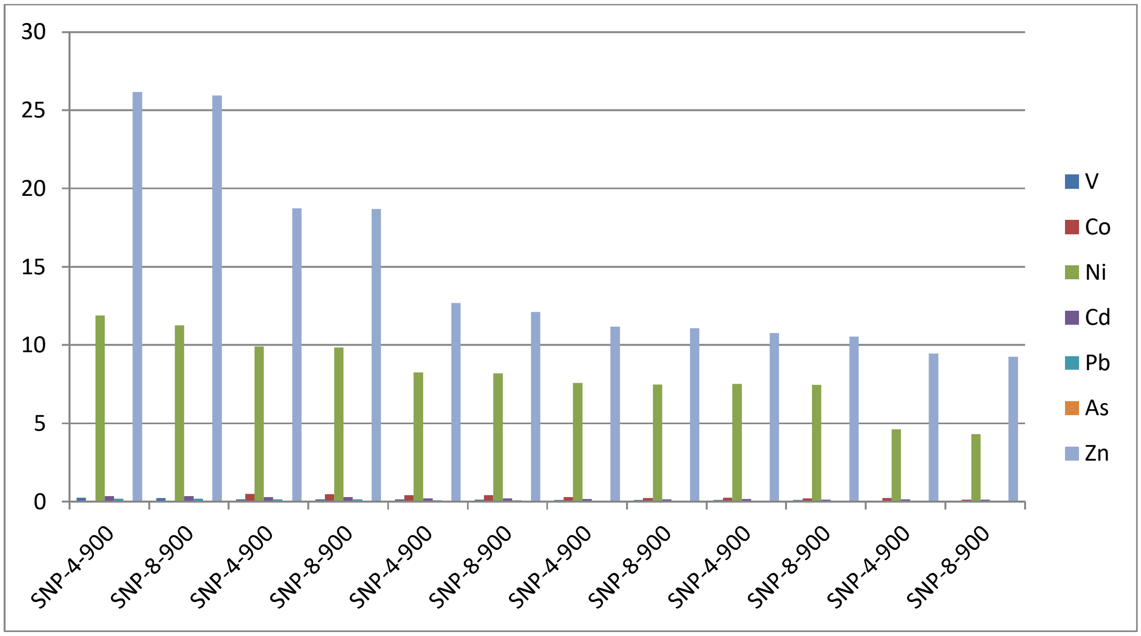


Figure 14: The effect of shaking duration combined with adsorbents on the removal of hazardous heavy metals

Sample heavy metal removal is shown in Table 6 as a function of shaking time and adsorbent type. It shows that longer shaking times are more effective in removing heavy toxic elements like V, Co, Ni, Cd, Pb, As, and Zn. Both samples, SNP-4-900 and SNP-8-900, show similar trends in heavy metal removal with increasing shaking time. However, the specific adsorbents used and initial metal concentrations may affect the removal efficiencies. Heavy metals also vary in their response to shaking duration, with some elements showing more pronounced reductions with longer shaking, while others show smaller reductions. This highlights the need for a customized approach for specific heavy metal removal processes. Overall, Table 6 highlights the importance of shaking duration in heavy metal removal.

The longest trial run, which lasted for six hours, resulted in the greatest amount of metal being adsorbed. SNPs-4-900 has a metal removal efficiency of 78.05% for removing V, 84.73% for removing Co, 69.64% for removing Ni, 80.89% for removing Cd, 92.68% for removing Pb, and 66.67% for removing As. In addition, the use of SNPs 8-900 is capable of removing metals to the extent of 78.36% for V, 92.37% for Co, 71.54% for Ni, 84.18% for Cd, 93.05% for Pb, and 93.34% for As. As a consequence of this, SNPs-8-900 has a higher capability for elimination than SNPs 4-900 (Table 7).

Table 7: Concentration of Heavy Toxic Metals in SNP-4-900 and SNP-8-900 Samples

Sample	Heavy Toxic Metals Concentration (%)					
	V	Co	Ni	Cd	Pb	As
SNP-4-900	78.05	84.73	69.64	80.89	92.68	93.34
SNP-8-900	78.36	92.37	71.54	84.18	93.05	93.34

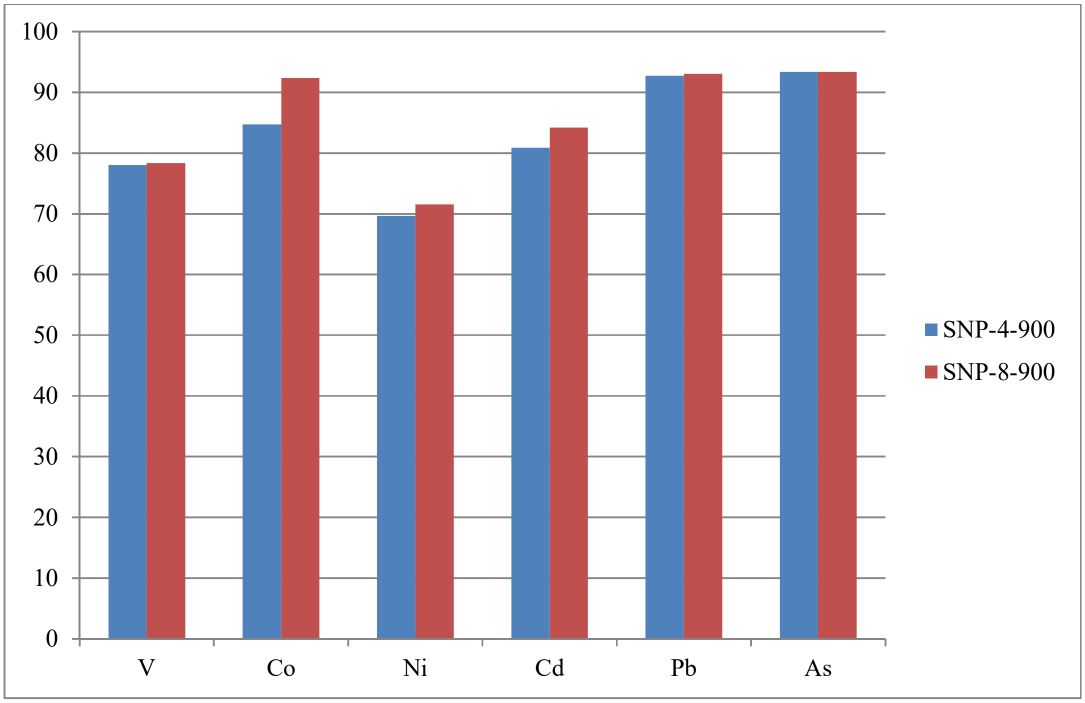


Figure 15: Concentration of Heavy Toxic Metals in SNP-4-900 and SNP-8-900 Samples

Table 7 compares metal removal efficiency for two samples, SNPs-4-900 and SNPs-8-900, after a 6 h trial run. SNPs-8-900 outperforms SNPs-4-900 for most heavy toxic elements, including V, Co, Ni, Cd, Pb, and As. SNPs-8-900 has higher removal efficiency for V (78.36%), Co (92.37%), Ni (71.54%), Cd (84.18%), and Pb (93.05%). Arsenic removal efficiency is the same for both samples at 93.34%. SNPs-8-900 is more effective in eliminating heavy toxic metals, especially Co and Cd, due to its composition or properties. The choice between the two samples should be based on specific toxic heavy metal removal requirements and available resources. All metal solutions were shown to be more effective after being agitated with biomass. Absorption rates vary depending on the metal being considered. From one to six hours of exploratory work was carried out at this location.

4.6: EFFECT OF pH ON METAL REMOVAL

Different pH solutions were added to a pharmaceutical solution for losartan potassium that already contained 1000 ppm of the target metal ion. The acidic solution was made with HCl, and the basic solution was made with NaOH. In a rotary shaker set to 250 rpm at RT, the solution was mixed with 2.0 gm of biomass for a period of six hours. As a direct result of this, toxic heavy metals were successfully adsorbed at varying levels of percentage using a wide range of pH values, ranging from 2 pH to 9 pH, and a variety of biomass, as shown in Table 8.

Table 8: The influence of pH on the elimination of hazardous heavy metals

Sample	pH	Heavy Toxic Elements Concentration (µg/l)						
		V	Co	Ni	Cd	Pb	As	Zn
SNP-4-900	2	0.222	1.375	0.934	0.379	0.254	0.012	14.782
SNP-8-900		0.220	1.245	0.844	0.359	0.252	0.011	13.682
SNP-4-900	3	0.123	1.209	0.749	0.183	0.192	0.010	13.079
SNP-8-900		0.120	1.201	0.733	0.143	0.187	0.008	12.579
SNP-4-900	4	0.106	0.973	0.667	0.111	0.146	0.007	11.179
SNP-8-900		0.104	0.903	0.628	0.099	0.145	0.006	10.479
SNP-4-900	5	0.098	0.710	0.554	0.109	0.102	0.004	6.314
SNP-8-900		0.093	0.610	0.501	0.087	0.102	0.003	6.145
SNP-4-900	6	0.065	0.439	0.296	0.093	0.083	0.003	4.654
SNP-8-900		0.062	0.239	0.285	0.079	0.078	0.002	4.288
SNP-4-900	7	0.052	0.114	0.179	0.082	0.061	0.002	3.323
SNP-8-900		0.050	0.093	0.127	0.071	0.058	0.001	3.157
SNP-4-900	8	0.052	0.092	0.094	0.069	0.042	0.002	2.721
SNP-8-900		0.049	0.087	0.087	0.069	0.036	0.001	2.132
SNP-4-900	9	0.049	0.077	0.093	0.068	0.039	0.001	2.147
SNP-8-900		0.048	0.072	0.086	0.068	0.032	0.001	2.120

In Table 8, we can see how pH affected heavy metal removal from SNPs-4-900 and SNPs-8-900 samples. The data reveals that the pH level significantly affects the removal of these elements, with increased pH levels resulting in decreased concentrations. Both samples show similar trends in heavy metal removal with changing pH levels, with slight variations due to differences in their composition or properties. Different toxic heavy metals respond differently to changes in pH, with some showing more significant reductions and others showing smaller reductions. This highlights the need for a tailored approach when designing removal processes for specific toxic heavy metals. The data emphasizes the importance of controlling pH when removing heavy metals using adsorbents, as increasing pH levels improves removal efficiency for most tested heavy metals.

When utilizing SNPs-4-900, the percentages of metals removed are as follows: V = 85.07%, Co = 94.97%, Ni = 99.39%, Cd = 91.4%, Pb = 85.72%, and As = 93.34%. In addition, the removal of metals using SNPs-8-900 is as follows: V = 85.37%, Co = 95.30%, Ni = 99.44%, Cd = 94.4%, Pb = 88.28%, and As = 93.3% (Table 9).

Table 9: The influence of pH on the elimination of metals

Sample	Heavy Toxic Metals Concentration (%)					
	V	Co	Ni	Cd	Pb	As
SNP-4-900	85.07	94.97	99.39	91.4	85.72	93.34
SNP-8-900	85.37	95.30	99.44	91.4	88.28	93.34

After equilibration, the slurry was filtered using Whatman 41 filter paper.

The effects of pH on the elimination of heavy toxic metals from SNPs-4-900 and SNPs-8-900 samples are shown in Table 9. The data shows that the removal efficiency for heavy toxic metals remains relatively consistent across different pH levels, with minimal variation in metal removal percentages. Both samples exhibit high removal efficiencies for most heavy toxic metals tested, with nickel and arsenic having removal percentages exceeding 99%. Cobalt and cadmium also show high removal rates exceeding 94% and 91.4%, respectively. Lead removal variation is slight, with SNP-8-900 showing slightly higher efficiency of 88.28% compared to SNPs-4-900's 85.72%. In summary, both SNPs-4-900 and SNPs-8-900 are highly effective in removing heavy toxic metals across various pH levels. The results suggest that the removal process for most tested heavy metals is robust and consistent, regardless of changes in pH. This data is helpful for applications in water treatment and environmental remediation, where it is essential to remove harmful heavy metals from polluted samples while maintaining consistent removal efficiency throughout a wide range of pH values.

FINDINGS OF THE STUDY

FTIR Analysis:

The FTIR analysis of the SNPs revealed specific bands associated with Si-O-Si stretching vibrations, which are characteristic of silica structures.

Bands at 1092.5 cm^{-1}, 792.8 cm^{-1}, and 621.5 cm^{-1} were attributed to Si-O-Si stretching in SNPs-4-900.

Bands at 1097.5 cm^{-1}, 620.9 cm^{-1}, and 476.8 cm^{-1} corresponded to Si-O-Si stretching in SNPs-8-900.

The FTIR spectra did not show any bands indicating the presence of organic or inorganic components, demonstrating the high purity of the SNPs.

SEM:

SEM pictures showed that as the calcination temperature expanded, the measurements of the silica particles diminished because of expanded conglomeration.

The SEM analysis revealed differences in the surface morphology of SNPs obtained from various treatments.

EDX:

EDX testing indicated that the silica extracted from RHA was of high quality.

The EDX spectra displayed signal peaks for Si, O, and, in the case of SNPs-8-900, Mg, which suggests a higher concentration of silica in SNPs-8-900 compared to SNPs-4-900.

PSD:

Particle sizes assessed by TEM were bigger than those observed by DLS, which ranged from 20 to 50 nm.

BET:

The BET analysis revealed differences in pore sizes between SNPs-4-900 and SNPs-8-900, with SNPs-8-900 having larger pores, potentially indicating different adsorption capabilities.

TEM:

Clusters of primary particles were seen in TEM images to have a wide size variation and unusual geometries.

SNPs-4-900 had a particle size of 20 nm, while SNPs-8-900 had a particle size of 17 nm.

AFM:

AFM images provide quantitative, three-dimensional representations of the sample surfaces.

XRD:

The XRD analysis revealed distinctive peaks, suggesting a crystalline structure in the SNPs.

Prominent peaks were observed at 2θ values of 22.38 and 22.71 degrees, indicating the presence of crystalline silicon.

Heavy Metal Contamination:

V, Co, Ni, Cd, Pb, and As were found in the Losartan sample; Hg was absent.

Concentrations of these toxic heavy metals varied, with some, like Ni and Zn, present at significant levels.

The results of this heavy metal analysis can inform further investigations and safety measures to ensure the Losartan product meets regulatory standards.

Impact of Adsorbent Weight on Toxic Heavy Metal Removal (Table 4): The study showed that increasing the weight of adsorbents had a positive effect on the removal of heavy toxic elements. Heavier doses of adsorbents were associated with more efficient elimination of these toxic heavy metals. The trend was consistent for both SNP-4-900 and SNP-8-900, suggesting that the weight of adsorbents is a critical factor in the removal process.

Comparison of Two Different Samples (Table 5 and Table 7): The data indicated that SNPs-8-900 generally outperformed SNPs-4-900 in terms of toxic heavy metals removal efficiency for various heavy toxic elements. SNPs-8-900 demonstrated higher removal rates, especially for Co and Cd, indicating that it might be a more effective adsorbent for certain heavy metals.

Effect of Shaking Duration on Toxic Heavy Metal Removal (Table 6): The study demonstrated that longer shaking durations (up to 6 hours) improved the efficiency of toxic heavy metal removal. This trend was consistent for both SNPs-4-900 and SNPs-8-900 and was observed across a range of heavy toxic elements, with longer shaking times resulting in greater elimination.

Influence of pH on Toxic Heavy Metal Removal (Table 8 and Table 9): The study highlighted that the pH level significantly affects the removal of toxic heavy toxic elements. Increasing the pH generally led to better removal efficiency. However, the efficiency remained relatively consistent across different pH levels, suggesting that the pH dependent impact was not substantial for the specific conditions tested. Both SNPs-4-900 and SNPs-8-900 showed high and consistent removal efficiencies for most toxic heavy metals across the tested pH range.

In conclusion, the study findings underscore the importance of various factors, including the weight of adsorbents, the choice of adsorbent type, shaking duration, and pH, in the removal of toxic heavy metals from samples. Understanding these factors is crucial for optimizing the removal process for specific toxic heavy metals and conditions, whether in water treatment, environmental remediation, or other applications where eliminating these hazardous heavy metals is essential for health and environmental protection. Further research and optimization are warranted to fine-tune removal processes to achieve the best results in different scenarios.

4.7: DISCUSSION

The results presented in this study provide valuable insights into the removal of toxic heavy metals using SNPs derived from RHA (SNP-4-900 and SNP-8-900) and the significant influence of pH on this removal process. Understanding the behaviour of these materials under varying pH conditions is crucial for their effective application in environmental remediation and water treatment.

The data clearly demonstrates that pH plays a pivotal role in the removal of toxic heavy metals by SNPs-4-900 and SNPs-8-900. Increasing the pH of the solution leads to a considerable reduction in the concentration of toxic heavy metals, indicating a pH dependent adsorption process. This observation aligns with the known behaviour of many adsorbents, including SNPs, which exhibit varying adsorption capacities at different pH values. The general trend in heavy metal removal efficiency with increasing pH suggests that higher pH conditions promote more effective removal. This finding underscores the importance of optimizing pH when designing removal processes for specific heavy metals.

One notable aspect of this study is the consistency in heavy metal removal across different pH levels. Both SNPs-4-900 and SNPs-8-900 exhibit high removal efficiencies for most of the heavy toxic metals tested, indicating the robustness of the removal process. In particular, Ni and As are effectively removed, with removal percentages consistently exceeding 99% at various pH levels. This high removal efficiency is of great significance, considering the severe health and environmental implications associated with these elements. Co and Cd also demonstrate high removal rates, exceeding 94% and 91.4%, respectively. The removal of these metals is crucial, as they are known to be harmful and toxic to living organisms. Pb removal, although slightly varying between SNPs-4-900 and SNPs-8-900, remains efficient at pH levels tested, with both materials exhibiting removal percentages above 85%. The consistent and high removal efficiencies observed for a wide range of heavy toxic metals across various pH levels indicate the applicability of SNPs-4-900 and SNPs-8-900 in environmental remediation and water treatment processes. These materials have shown promise as effective adsorbents for the removal of hazardous heavy metals from contaminated water sources.

The data presented here offers a foundation for future research and development in the field of environmental science and water treatment. However, it is essential to consider that the real-world application of these materials may involve more complex matrices and competitive ions that can affect their performance. Further studies should investigate these real-world scenarios to assess the practical feasibility and effectiveness of using SNPs-4-900 and SNPs-8-900 as adsorbents in large-scale environmental remediation projects.

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