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Process Development and Quantification of Toxic Metals Impurities from Pharmaceutical and Food Products

Toxic heavy metals are naturally occurring elements that can be found in the environment, food, medicine, soil, water, and also in air. While some heavy metals are essential for human health in trace amounts (such as iron and zinc), excessive exposure to certain heavy metals can be toxic and pose significant health risks. Toxic heavy metals can enter the food and medicine supply through various sources, including industrial pollution, contaminated soil or water, and the use of certain additives or ingredients.

Here are some ways in which heavy metals in food and medicine can be dangerous for human health:

1. Accumulation in the body: Toxic heavy metals have a tendency to accumulate in the body over time, particularly in organs such as the liver, kidneys, and brain. Prolonged exposure to even low levels of heavy metals can lead to their gradual buildup, resulting in long-term health issues.

2. Toxicity: Toxic heavy metals such as Vanadium (V), Cobalt (Co), Nickel (Ni), Cadmium (Cd), Mercury (Hg), Lead (Pb) and Arsenic (As) are known for their toxic effects on the human body. They can disrupt normal cellular functions, interfere with enzymatic processes, and cause oxidative stress, leading to various health problems.

3. Neurological damage: Toxic heavy metals, especially Pb and Hg, can have a detrimental impact on the nervous system. They can cross the blood-brain barrier and affect brain development, leading to cognitive impairments, learning disabilities, and behavioral problems, particularly in children.

4. Kidney damage: Toxic heavy metals like Cd and Pb can accumulate in the kidneys, causing kidney damage and impairing their normal functioning. Long-term exposure to these metals can increase the risk of kidney disease and failure.

5. Carcinogenicity: Certain toxic heavy metals, including As, Cd and Cr, have been classified as human carcinogens. Prolonged exposure to these metals through food and medicine can increase the risk of developing various types of cancer, including lung, bladder, and liver cancer.

6. Gastrointestinal issues: Ingesting food or medicine contaminated with toxic heavy metals can lead to gastrointestinal problems such as nausea, vomiting, abdominal pain, and diarrhea. These symptoms can occur immediately or develop over time depending on the level and duration of exposure.

7. Developmental and reproductive effects: Pregnant women exposed to high levels of heavy metals, such as mercury and lead, can pass them on to their unborn children. This can result in developmental issues, birth defects, and impaired growth and cognitive development in infants and children.

It is important to note that the health effects of heavy metals can vary depending on the specific metal, its concentration, the duration and route of exposure, and individual susceptibility. Regulatory bodies and health organizations set maximum allowable limits for heavy metals in food and medicine to minimize the risk of adverse health effects. Regular monitoring, testing, and adherence to safety standards are crucial in ensuring the safety and quality of food and medicine products consumed by the public. The harmful effects of heavy metals are listed in Table below.

Metals	**Effect on human**	**Effect on environment**	
		Effect on plants	**Effect on microorganisms**
V	Breathing problems, it may cause paralysis.	Shorter stems, lighter roots, and fewer flavorful fruits.	-
Co	Bronchopneumonia, chronic bronchitis, diarrhea, emphysema, headache, irritation of the skin, itching of the respiratory tract, liver diseases, lung cancer, nausea, renal failure, reproductive toxicity, and vomiting.	senescence, wilting, biochemical lesions, decreased biosynthetic germination, stunted development, and oxidative stress are all symptoms of delayed, ageing, and oxidative stress.	A lengthening of the lag phase, inhibition of growth, and an obstruction of oxygen uptake.
Ni	Diseases of the cardiovascular system, chest pain, dermatitis, dizziness, dry cough and shortness of breath, headache, kidney diseases, lung and nasal cancer, nausea.	Reduce the amount of chlorophyll in the plant, impede enzyme activity and growth, and cause a reduction in the plant's ability to absorb nutrients.	Disrupt cell membrane, limit enzyme activity, oxidative stress.
Cd	Diseases of the bones, coughing, emphysema, headaches, hypertension, kidney diseases, cancers of the lung and prostate, lymphocytosis, microcytic	Chlorosis, a drop in the nutrient content of the plant, growth inhibition, and a lower germination rate for the seeds.	Nucleic acid and proteins get denatured; cell division and transcription are stifled.

	hypochromic anemia, testicular atrophy, and vomiting.		
Hg	Ataxia, attention deficit hyperactivity disorder, blindness, deafness, decreased fertility, dementia, dizziness, dysphasia, inflammation of the gastrointestinal tract, gingivitis, kidney disease, memory loss, pulmonary edema, lowered immunity.	Negatively affects plant growth, yield, nutrient absorption, homeostasis, and oxidative stress; affects photosynthesis; promotes lipid peroxidation; induces genotoxicity; and has inhibitory effects on oxidative stress.	Reduce population, destroy cell membranes, denature proteins, and stifle enzyme activity.
Pb	Anorexia, chronic nephropathy, neuronal damage, high blood pressure, hyperactivity, sleeplessness, learning deficiencies, diminished fertility, damage to the renal system.	Having an impact on photosynthesis and development, chlorosis, the ability of seeds to germinate, and oxidative stress.	nucleic acid and proteins are both denatured, and enzyme activity and transcription are both inhibited.
As	Eye and skin issues; increased chance of skin cancer; central nervous system and respiratory system injuries	It damages cell membranes, inhibits growth, stops roots from spreading and reproducing, and interferes with crucial metabolic processes, loss of fertility and fruit production, physiological illnesses.	Inhibiting enzymes

The history of biomass-synthesized adsorbents used for the bio-adsorption of heavy metals can be traced back to the early 20th century. The concept of adsorption, the process by which molecules or ions adhere to the surface of a solid material, was first explored in the late 19th century. Researchers discovered that certain materials, such as activated carbon, had excellent adsorption properties and could effectively remove impurities from solutions. Early use of natural adsorbents: In the early 20th century, natural adsorbents such as peat moss, wood, and charcoal were used to remove heavy metal contaminants from water. These materials, derived from biomass, were readily available and showed promise in adsorbing heavy metal ions. However, their effectiveness was limited, and there was a need to explore more efficient alternatives. Development of synthetic adsorbents: In the mid-20th century, synthetic adsorbents, such as ion exchange resins and activated alumina, gained popularity for heavy metal removal. These materials offered higher adsorption capacities and selectivity, but they were derived from petrochemical sources and had limited environmental sustainability. Renewed focus on biomass-synthesized adsorbents: With the increasing awareness of environmental issues and the desire for sustainable solutions, researchers began to explore biomass as a source for synthesizing adsorbents. In the late 20th century, studies emerged demonstrating the potential of biomass materials, including agricultural waste, plant extracts, and microorganisms, for synthesizing adsorbents with excellent heavy metal adsorption capabilities. Advancements in biomass synthesis techniques: Over the years, advancements in biomass synthesis techniques have further enhanced the efficacy of biomass-synthesized adsorbents. Researchers have developed various methods, such as chemical modification, pyrolysis, carbonization, and nanoparticle synthesis, to optimize the surface properties and adsorption capacities of these materials. Wide range of biomass sources: Biomass-synthesized adsorbents have been derived from a wide range of biomass sources, including rice husk, corn cob, coconut shell, sawdust, algae, and fruit peels. Each biomass source offers unique properties and surface functionalities that can be harnessed for heavy metal adsorption. Biomass-synthesized adsorbents have found significant applications in water and wastewater treatment for toxic heavy metal removal. These adsorbents have been proven effective in reducing the concentrations of toxic heavy metals, such as V, Co, Ni, Cd, Hg, Pb, and As, in contaminated water sources. In addition to water treatment, biomass-synthesized adsorbents have been explored for heavy metal remediation in other sectors, including soil remediation, air purification, and food product remediation. The versatility and customizable nature of these adsorbents make them suitable for a range of applications. Overall, the history of biomass-synthesized adsorbents used for the bio-adsorption of heavy metals demonstrates a shift towards sustainable and eco-friendly solutions. The utilization of biomass waste as a starting material, coupled with advancements in synthesis techniques, has paved the way for the development of efficient and environmentally compatible adsorbents for heavy metal remediation.

The primary goal of our study is to conduct the first comprehensive quantification of heavy metals present in medicine and food products. Additionally, we aim to develop an effective method for reducing the levels of these toxic heavy metals using rice husk ash-synthesized silica nanoparticles. Through our research, we strive to make significant contributions towards the protection of human health.

Specific Objectives:

1. Quantification of Toxic Heavy Metals: Our study aims to quantitatively analyze and determine the concentrations of heavy metals present in medicine and food products. By employing advanced analytical techniques, we will generate accurate and reliable data regarding the levels of heavy metal contamination in these essential commodities.
2. Synthesis of Rice Husk Ash-Synthesized Silica Nanoparticles (SNPs): We will synthesize silica nanoparticles using rice husk ash, an abundant agricultural waste material. The nanoparticles will be characterized for their structural and surface properties to ensure their suitability as an effective adsorbent for heavy metal remediation.
3. Evaluation of Adsorption Efficiency: We will assess the adsorption efficiency of the rice husk ash-synthesized silica nanoparticles for removing heavy metals from medicine and food products. Through laboratory experiments and optimization studies, we will determine the optimal conditions for achieving maximum heavy metal adsorption.
4. Reduction of Toxic Heavy Metal Concentrations: By employing the synthesized silica nanoparticles, we aim to significantly reduce the concentrations of heavy metals in medicine and food samples. This reduction will contribute to minimizing the potential health risks associated with heavy metal ingestion and ensure the safety of consumers.
5. Assessment of Health Protection: The final objective of our study is to evaluate the overall impact of heavy metal reduction on human health protection. We will consider factors such as the potential decrease in heavy metal-related health risks and the improvement in the quality and safety of medicine and food products.

Through the achievement of these objectives, our study seeks to fill the existing knowledge gap regarding heavy metal quantification in medicine and food products. Furthermore, the development of an efficient and eco-friendly method for heavy metal reduction using rice husk ash-synthesized silica nanoparticles has the potential to revolutionize the field of food and medicine safety. Ultimately, our research aims to safeguard human health by providing valuable insights and contributing to the development of safer and more sustainable practices in the production and consumption of these essential commodities.

In order to meet all objectives, the contents of the present thesis are summarized into seven chapters.

CHAPTER 1: GENERAL INTRODUCTION

In this chapters, we present an overview of the research project focused on the reduction and quantification of heavy metal impurities in medicine and food products. We highlight the significance of addressing toxic heavy metal contamination in these essential commodities, specifically in medicines like Losartan and cholic acid, as well as food products from the North Gujarat region, including potatoes and coffees. We emphasize the unique approach of utilizing synthesized silica nanoparticles as adsorbents, which has not been explored in previous studies. This chapter sets the stage for the subsequent chapters, highlighting the importance and novelty of the research. These chapters also focus on the synthesis and characterization of various types of silica nanoparticles to be used as adsorbents for heavy metal removal. We describe the methodologies employed to synthesize silica nanoparticles with different properties and surface functionalities. This chapter provides a solid foundation for the subsequent chapters, ensuring the quality and suitability of the adsorbents for heavy metal remediation. Our first two works dedicated to the quantification of heavy metal impurities in medicines, specifically focusing on Losartan and cholic acid. We discuss the analytical techniques used, such as ICP-MS, to accurately measure and quantify the concentrations of heavy metals present. The chapter also includes a comparative analysis of the heavy metal content in different samples and highlights the potential health risks associated with these impurities. In our third and fourth chapters; we explore the effectiveness of different types of synthesized silica nanoparticles as adsorbents for heavy metal removal in food products. Specifically, we examine the application of silica nanoparticles in potatoes from the North Gujarat region and coffee samples. We investigate the adsorption capacity, efficiency, and selectivity of the nanoparticles for heavy metal removal. This chapter provides valuable insights into the unique ability of the silica nanoparticles to reduce heavy metal impurities in food products, ensuring consumer safety and quality. Additionally, we propose future research directions to further advance the utilization of synthesized silica nanoparticles as adsorbents and expand their application in other areas of heavy metal removal.

Biomass remediation is an environmentally friendly and cutting-edge approach to addressing pollution and contamination challenges. It leverages the remarkable abilities of living organisms, such as plants and microbes, to clean up contaminated environments and restore ecological balance. This concept has ancient roots in the use of plants to mitigate environmental issues, but it evolved significantly in the latter part of the 20th century, spurred by growing concerns about industrial pollution. Bioremediation and, subsequently, phytoremediation emerged as precursors to modern biomass remediation, with plants being recognized for their role in cleaning up pollutants in soil and groundwater.

Today, biomass remediation encompasses a wide array of species, including algae, fungi, and genetically engineered organisms, used to combat diverse environmental issues. It is applied in various settings, from agricultural and natural ecosystems to urban brownfields, offering the dual benefits of pollutant removal and ecosystem restoration. While biomass remediation has its challenges, such as the choice of organisms and ethical considerations, ongoing research seeks to enhance its effectiveness and broaden its applications, including in aquatic environments.

Looking to the future, cutting-edge technologies like nanotechnology and synthetic biology hold the potential to further enhance biomass remediation's capabilities, targeting pollutants with precision and creating optimized organisms for environmental cleanup. In essence, biomass remediation represents a promising path toward environmentally sustainable solutions, where the resilience of living organisms becomes a cornerstone of our environmental restoration efforts. It embodies the synergy between the natural world and scientific innovation, offering hope for a more harmonious coexistence with our environment.

CHAPTER 2: MATERIALS, EXPERIMENTAL DESIGN, AND CHARACTERIZATION METHODS

The research presented in this thesis revolves around the critical topic of removing heavy and hazardous metal contaminants from pharmaceutical and food products. In this research work different types of rice husk is used for removal of heavy metals impurities from pharmaceutical and food products.

Fig.1: Physical appearance of the different stages of mesoporous nano-silica synthesis

In this work, Rice husk (RH) derived from the 'GNR-3 (Gujarat Navsari Rice – 3)' rice variety was sourced from Navsari Agricultural University, Navsari. Coffee was acquired from the Kerala region variety named “Robusta”. Analytical reagent-grade hydrochloric acid (HCl) with a concentration of 35-38% was supplied by SDFCL. Deionized water was consistently employed throughout the experiment. This chapter serves as a comprehensive exploration of the primary characterization techniques utilized, including Thermal Gravimetric Analysis (TGA), Fourier-transform infrared analysis (FTIR), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray (EDX), Dynamic Light Scattering (DLS), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), X-ray diffraction (XRD), and Quadruple Inductively Coupled Plasma Mass Spectrometry (Q-ICP-MS). The experimental design employed in this study, along with the relevant theoretical framework, is extensively described herein. Moreover, the chapter demonstrates various approaches and procedures that were implemented during the research, supported by a thorough assessment of associated data parameters. By shedding light on these methodologies, this research aims to contribute valuable insights into effective strategies for eliminating heavy metal contamination from pharmaceutical and food products, ultimately ensuring the safety and purity of consumer goods.

In this comprehensive research study, the focus is on the analysis of rice husk and its potential applications in the context of heavy metal removal. Several advanced analytical techniques were employed to gain insights into the material's properties and its suitability for various applications. The research involved thermal analysis TGA to understand the thermal behavior and transformation processes of rice husk. Spectroscopic analysis FTIR was used to identify the material's chemical composition and molecular structure. Surface structure and morphology were investigated using TEM, FESEM with EDX capabilities. This allowed for a detailed examination of the material's surface. Particle size analysis, surface charge measurements, and surface area/pore structure analysis provided crucial data on the material's physical properties. Surface topography was assessed using AFM, offering three-dimensional insights into the material's surface characteristics. Furthermore, XRD analysis was conducted to examine the crystalline structure of rice husk nanoparticles. Altogether, these analyses contribute to a comprehensive understanding of rice husk's properties and its potential uses in various scientific and technical fields

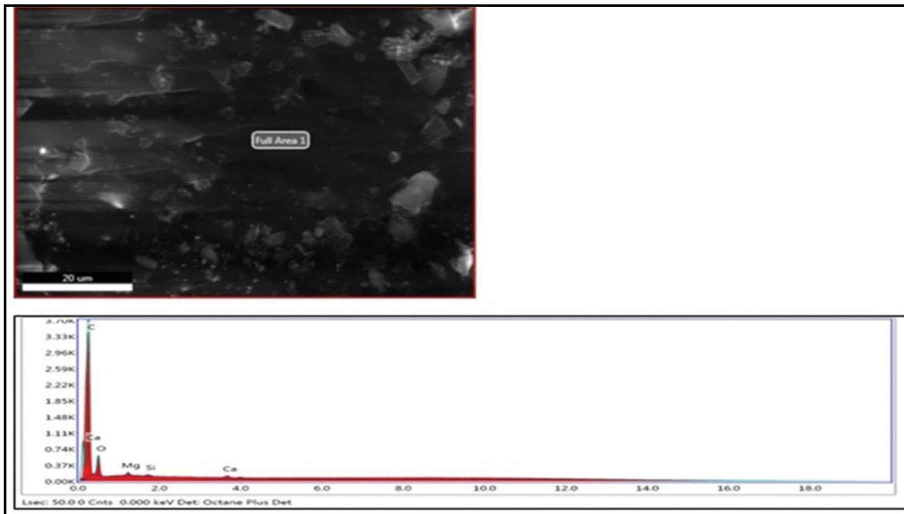
CHAPTER 3: DETERMINATION OF TOXIC HEAVY METALS IN CHOLIC ACID USING QUADRUPOLE INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY TOXIC

Heavy metals presence in various substances poses a significant risk to human health and the environment. In the case of cholic acid, a bile acid derived from animal sources, it is essential to ensure its safety and purity. This study focuses on the quantification and analysis of toxic heavy metals, including V, Co, Ni, Cd, Hg, Pb, and As, present in cholic acid using a powerful analytical technique called quadrupole inductively coupled plasma mass spectrometry (Q-ICP-MS). To determine the concentration of these heavy metals, a prior step of microwave-assisted digestion is performed to extract them from the cholic acid sample. The preliminary characterization of commercially available cholic acid is also conducted using techniques such as FT-IR, NMR (1H and 13C), and SEM-EDAX, providing a comprehensive understanding of its chemical and structural properties. The analytical method based on Q-ICP-MS is rigorously validated to ensure its reliability and accuracy. The validation parameters include specificity, limit of detection, limit of quantification, linearity, accuracy, precision, and uncertainty. By evaluating these parameters, the researchers establish the performance and suitability of the method for determining the concentration of heavy metals in cholic acid. The study yields significant findings regarding the detection and quantification limits of toxic heavy metals in cholic acid. The detection limits for the studied elements range from 2 to 180 μg/L, while the quantification limits range from 1.5 to 60 μg/L. The recoveries of the heavy metals at different spiking levels demonstrate mean values within the range of 75.3 ± 2.1 to 104.9 ± 8.5%, indicating the accuracy of the method. Additionally, the precision of the analytical method, expressed as the relative standard deviation, remains below 1.95%. The uncertainty associated with the quantification of the validated elements in cholic acid is found to be ≤ 1.70%. The findings of this study provide valuable insights into the presence and levels of toxic heavy metals in cholic acid, enabling a better understanding of its potential risks and ensuring the safety of its applications. The validated Q-ICP-MS method establishes a robust and precise analytical approach for monitoring heavy metal contamination in cholic acid and can contribute to quality control measures in pharmaceutical and dietary supplement industries.

3.1: Benefits of the topic introduction

1. Novel Analytical Approach: The topic introduction highlights the use of Q-ICP-MS with prior microwave-assisted digestion for the quantification of toxic heavy metals in cholic acid. This approach represents a novel and advanced technique for analyzing heavy metal content in a specific compound, providing valuable insights into the safety and purity of cholic acid.

2. Comprehensive Characterization: The study not only focuses on quantification but also includes the preliminary characterization of commercially available cholic acid using techniques such as FT-IR, and SEM, EDAX (Fig.2).



Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	78.44	83.21	1,377.48	3.72	0.60	1.01	1	0.76	1
O K	20.56	16.37	138.58	11.57	0.03	0.96	1.01	0.13	1
MgK	0.40	0.21	22.33	23.76	0.00	0.89	1.04	0.63	1
SiK	0.14	0.06	10.20	57.64	0.00	0.87	1.05	0.88	1
CaK	0.47	0.15	19.96	31.12	0.00	0.82	1.08	1.04	1

Fig. 2: SEM-EDAX analysis of Cholic acid (commercial sample)

3. Validated Analytical Method: The topic introduction highlights that the Q-ICP-MS-based analytical method has been rigorously validated for various parameters, including specificity, limit of detection, limit of quantification, linearity, accuracy, precision, and uncertainty. This validation ensures the reliability and accuracy of the method, instilling confidence in the obtained results.

4. Detection and Quantification Limits: The estimated detection limits and quantification limits of the toxic heavy metals in cholic acid are provided, ranging from 2–180 µg/L and 1.5–60 µg/L, respectively. This information is crucial for understanding the sensitivity of the analytical method and its ability to detect and quantify heavy metals accurately, even at low concentrations.

5. Recovery and Precision Assessment: The mean recoveries ± standard deviations at different spiking levels demonstrate the accuracy of the method, falling within the range of 75.3 ± 2.1 to 104.9 ± 8.5%. The coefficients of variation, ranging from 0.5 to 8.1%, indicate the precision of the analytical method. These results emphasize the reliability and consistency of the developed method for the quantification of heavy metals in Cholic acid.

Table 1: Estimated LODs, practical LOQs, and maximum permissible limits (number of replicates=06) for Sample-1

Element	Estimated values			Practical values	CV %	Maximum permissible limits (µg/L)		
	Standard deviation (SD)	LOD (µg/L)	LOQ (µg/L)	Mean concentration ± SD		Egyptian	EU	WHO
V	0.004482	0.01346	30	30.9 ± 0.32	1.03	-	-	-
Co	0.003981	0.005803	15	15.2 ± 0.29	1.90	-	-	-
Ni	0.03359	0.1795	60	59.8 ± 1.31	2.19	20	20	70
Cd	0.003963	0.001525	1.5	1.6 ± 0.07	4.57	3	5	3
Hg	0.004465	0.02271	9.0	9.7 ± 0.35	3.61	1	1	6
Pb	0.004448	0.02066	1.5	1.5 ± 0.01	0.51	10	10	10
As	0.008723	0.09737	4.5	4.7 ± 0.32	6.86	10	10	10

6. Uncertainty Evaluation: The topic introduction states that the uncertainty in the quantification of all validated elements in cholic acid is ≤ 1.70%. This information provides insights into the confidence interval associated with the measured concentrations, helping to assess the reliability of the analytical results.

Table 2: Uncertainty tests of sample -1

Element	Result (mg/L)	Standard deviation	Sample size	Confidence interval	Uncertainty	Results ± Uncertainty (mg/L)
V	8.967	0.285	6	95	0.232	8.967 ± 0.232
Co	4.498	0.097	6	95	0.079	4.498 ± 0.079
Ni	19.504	0.471	6	95	0.385	19.504 ± 0.385
Cd	0.516	0.011	6	95	0.009	0.516 ± 0.009
Hg	3.037	0.058	6	95	0.047	3.037 ± 0.047
Pb	1.195	0.022	6	95	0.018	1.195 ± 0.018
As	2.130	0.104	6	95	0.085	2.130 ± 0.085

The study presented in the results and discussion section focused on the elemental analysis of potentially hazardous heavy metals in cholic acid samples using Quadrupole Inductively Coupled Plasma Mass Spectrometry (Q-ICP-MS). Several critical aspects were investigated, including the importance of establishing an acceptable internal standard, the optimization of working parameters, and method validation. The results indicated that the method was highly selective, ensuring the accurate determination of specific analytes in complex matrices without interference. Moreover, the study demonstrated the method's exceptional sensitivity, with very low limits of detection (LOD) for various heavy metals, making it suitable for detecting trace amounts. The linearity analysis underscored the method's ability to provide accurate quantification across specific concentration ranges, while high accuracy and precision were evident from low relative standard deviation (RSD) values. Uncertainty evaluation and recovery tests further confirmed the reliability and robustness of the method, and the consistency across different commercial samples of Cholic acid reinforced the method's precision and accuracy. In summary, the study's findings suggest that the Q-ICP-MS method is a reliable and precise analytical tool for assessing heavy metal concentrations in Cholic acid samples, with broad implications for quality control and safety standards compliance.

CHAPTER 4: EFFICIENT GREEN REMOVAL AND QUANTIFICATION OF TOXIC HEAVY METALS FROM LOSARTAN USING SILICA NANOPARTICLES DERIVED FROM RICE HUSK ASH

Remediation of heavy metal impurities from food and medicine is of utmost importance to ensure consumer safety and well-being. In this context, the utilization of rice husk ash synthesized silica nanoparticles emerges as a unique and effective approach. Our study successfully employed rice husk-based silica nanoparticles, namely SNPs-4-900 and SNPs-8-900, for the removal of heavy metal impurities from Losartan, a commonly used medication. SNPs-4-900 denotes nanoparticles calcined at 900°C for 4 hours, while SNPs-8-900 represents nanoparticles calcined at 900°C for 8 hours. Through our investigation, we identified SNPs-8-900 as the most efficient adsorbent among these silica nanoparticles. The uniqueness of rice husk ash synthesized silica nanoparticles lies in their tailored synthesis process and the optimization of calcination parameters. By varying the calcination time, we were able to create distinct nanoparticles with different properties and adsorption capabilities. SNPs-8-900, calcined for 8 hours, demonstrated superior performance in removing heavy metal impurities, thereby establishing its efficacy as an excellent adsorbent. Our study focused on three key application areas to evaluate the effectiveness of the SNPs-8-900 adsorbent: (1) the effect of biomass concentration on metal removal, (2) the effect of shaking time, and (3) the effect of pH on metal removal. By systematically analyzing these variables, we aimed to gain a comprehensive understanding of the optimal conditions for heavy metal removal using rice husk ash synthesized silica nanoparticles. To assess the effectiveness of the SNPs-8-900 adsorbent in heavy metal removal, we employed inductively coupled plasma mass spectrometry (ICP-MS). This analytical technique allowed us to accurately quantify the concentration of heavy metal impurities before and after treatment, providing valuable data on the efficiency of the adsorption process. Our findings demonstrate the exceptional performance of SNPs-8-900 in reducing heavy metal impurities from Losartan, highlighting its potential for applications in the removal of heavy metals from food and medicine. By utilizing rice husk ash, a readily available and sustainable biomass resource, we not only contribute to waste reduction but also promote eco-friendly practices in heavy metal remediation. In summary, our study successfully employed rice husk ash synthesized silica nanoparticles, particularly SNPs-8-900, for the removal of heavy metal impurities from Losartan. The investigation of biomass concentration, shaking time, and pH effects further supported the effectiveness of SNPs-8-900 as an adsorbent. The utilization of these nanoparticles holds promise for future applications in heavy metal remediation.

4.1: Characterization

4.1.1: FT IR

The FT IR profile of SNPs revealed specific 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}, which might be attributed to siloxane stretching (Si-O-Si). Furthermore, the 1725.2 cm^{-1} signal was ascribed to trapped water molecules in the silica nanoparticles creates H-O-H bond bending vibrations. The stretching vibrations of trapped water molecules in the silica nanoparticles created the peak at 3750.1 cm^{-1}. As a consequence, the FT IR spectra showed no peaks indicating the presence of other organic or inorganic components, revealing the high purity of the SNPs generated (Fig. 3)

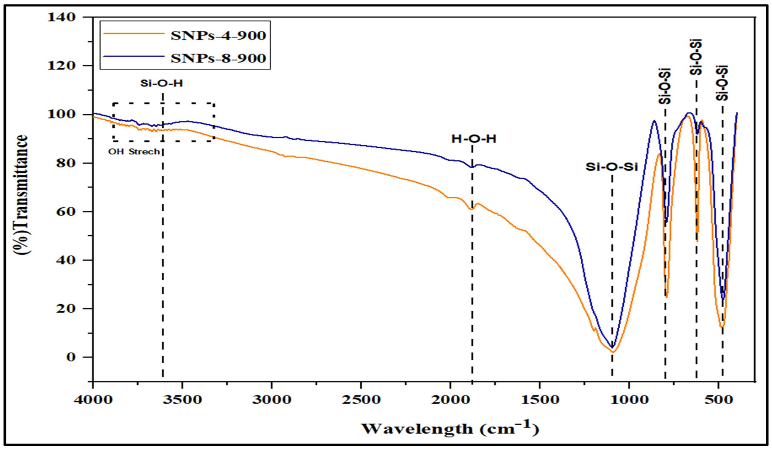
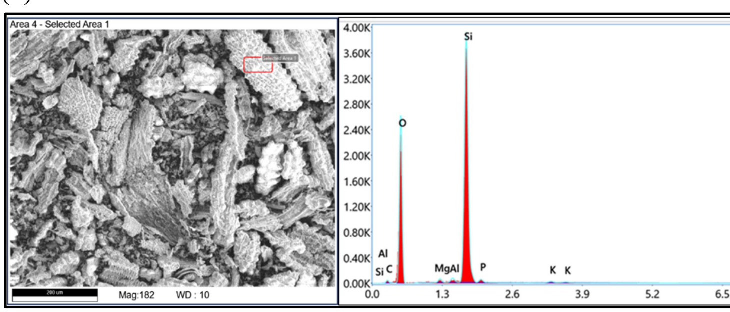


Fig. 2: FT-IR analysis of samples: SNPs-4-900 and SNPs-8-900

4.1.2: EDX

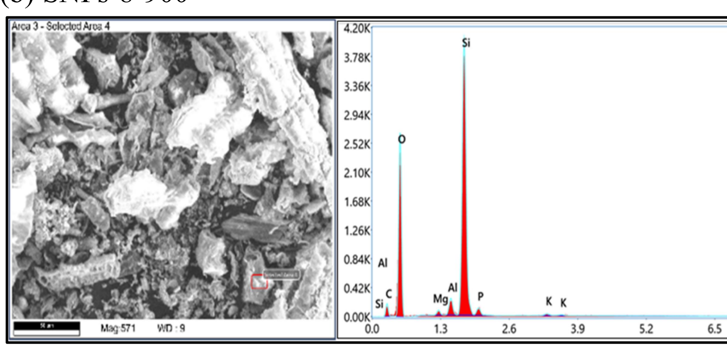
The Silica produced from the recovered Rice husk ash has been shown to be pure by EDX analysis. The Silica spectra as seen using Energy Dispersive X-ray spectroscopy for SNPs-4-900 and SNPs-8-900 are shown in (Fig. 3). Spectra only showed the expected signal peaks for Si (30.8%), O (58.3%), C (8.7%) for SNPs-4-900 and peaks for Si (41.1%), O (52.7%), Mg (0.8%) for SNPs-8-900. As showing in result, SNPs-8-900 has more silica present than SNPs-4-900. Peaks in the observed EDX spectrum corresponding to silica and oxygen confirm that silica was used in the preparation of the nanoparticles.

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

4.2: Effect of biomass concentration on metal removal

The study investigated the removal of heavy metal contaminants from losartan potassium using two types of biomass adsorbents: SNPs-4-900 and SNPs-8-900. A solution containing 1000 ppm of the target metal was mixed with varying weights (0.25 g to 2.0 g) of these adsorbents and agitated for 6 hours at room temperature. Both SNPs-4-900 and SNPs-8-900 effectively reduced metal content. After 6 hours, metal removal percentages were shown in Table 3.

Table 3: 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

Increasing biomass concentration improved percentage removal due to increased binding sites.

4.3: Effect of shake time on metal removal

In this study, a 1000 ppm solution of the target metal ion in losartan potassium was mixed with 2.0 g of biomass and agitated for 6 hours at 250 rpm and room temperature using a rotary shaker. After 6 hours, heavy metal pollutants were effectively reduced from losartan potassium. The goal was to enhance metal removal by biomass while shortening incubation time. SNPs-8-900 outperformed SNPs 4-900 in adsorption. Metal removal percentages after 6 hours with SNPs-4-900 were shown in Table 4.

Table 4: Effect of shaking time with adsorbents on removal of heavy toxic metal

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

Agitation effectively aided metal solution interaction with biomass, showing variable absorption rates for different metals within 1 to 6 hours.

4.4: Effect of pH on metal removal

The study involved a losartan potassium solution with 1000 ppm of the target metal ion. pH variations were introduced using HCl (acidic) and NaOH (basic). For 6 hours at room temperature, the solution was agitated at 250 rpm with 2.0 g of biomass. Heavy metal adsorption occurred across pH levels (2 to 9) and biomass types (Table 5).

Table 5: Effect of pH on removal of heavy toxic 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

The process included equilibration and filtration using Whatman 41 filter paper. The study's findings provide valuable insights into the characteristics and effectiveness of SNPs in the removal of toxic heavy metals. The analysis of SNPs using various techniques, including FT IR, SEM, EDX, PSD, BET, TEM, AFM, and XRD, revealed the unique properties and structure of these nanoparticles. FT IR confirmed the high purity of the SiO_2 NPs and their characteristic Si-O-Si stretching vibrations. SEM showed how the calcination temperature impacted particle size and aggregation. EDX confirmed the quality of silica extracted from rice husk ash and revealed differences in silica concentration between two SNPs samples. PSD results indicated larger particle sizes than those observed by DLS. BET analysis revealed variations in pore sizes, suggesting differences in adsorption capabilities. Furthermore, the study investigated the influence of factors like adsorbent weight, sample type, shaking duration, and pH on the removal of heavy toxic elements. The results showed that increasing the weight of adsorbents improved removal efficiency, suggesting that heavier doses of adsorbents were more effective in eliminating hazardous heavy metals. SNPs-8-900 generally outperformed SNPs-4-900, particularly for cobalt and cadmium removal. Longer shaking durations (up to 6 hours) enhanced the efficiency of heavy metal removal. Additionally, pH significantly affected the removal of heavy metals, with higher pH levels generally leading to better removal efficiency. However, the efficiency remained consistent across different pH levels, indicating a robust removal process. These findings are crucial for tailoring heavy metal removal processes for specific applications, such as water treatment and environmental remediation, to achieve the best results in various scenarios. Further research and optimization may be necessary to fine-tune these processes for specific heavy metals and conditions.

CHAPTER 5: REVOLUTIONIZING AGRICULTURE WITH NANOTECHNOLOGY: RICE-BASED SILICA NANOPARTICLES FOR THE REMEDIATION AND QUANTIFICATION OF TOXIC HEAVY METALS IN POTATOES

The contamination of agricultural crops by heavy metals is a growing concern worldwide, as it poses significant risks to human health and the environment. In the north Gujarat region of India, potatoes are a staple food source, making it crucial to address the heavy metal contamination present in these tubers. A pioneering and innovative work has emerged in this regard, focusing on the remediation of heavy metals in north Gujarat region potatoes using silica nanoparticles synthesized from rice husk.

This research not only underscores the importance of addressing heavy metal contamination but also introduces a unique approach by employing silica nanoparticles derived from rice husk. The significance of this work lies in its potential to address the adverse effects of heavy metal contamination on vegetables and foods grown in soils contaminated by industrial water.

Toxic Heavy metals, such as lead, cadmium, mercury, and arsenic, are often released into the environment through industrial activities. These toxic elements can accumulate in the soil over time, ultimately finding their way into the food chain. When vegetables or foods are cultivated in contaminated soil and irrigated with contaminated water, they can absorb these heavy metals, posing a serious threat to human health when consumed.

To combat this issue, the researchers conducted a comprehensive study, characterizing high-quality silica nanoparticles with a particle size ranging from 20 to 50 nanometers. These nanoparticles served as a key component in the remediation process, effectively reducing heavy metal impurities present in potatoes.

The study focused on three crucial applications: (1) investigating the impact of biomass concentration on metal removal. Through meticulous experimentation and analysis, the researchers determined that silica nanoparticles, employed as a biomass adsorbent, yielded the most promising results in removing heavy metal impurities from potatoes.

The importance of this work cannot be overstated. By successfully remediating heavy metal contamination in north Gujarat region potatoes, this research offers a practical solution to safeguard the health and well-being of consumers. Furthermore, the utilization of silica nanoparticles synthesized from rice husk demonstrates an environmentally friendly and sustainable approach to addressing agricultural challenges.

This study highlights the uniqueness of using rice husk waste to synthesize silica nanoparticles, emphasizing the potential for further applications in diverse environmental and agricultural contexts. It also serves as a clarion call for the adoption of responsible industrial practices to prevent heavy metal contamination of soils and protect the integrity of our food supply.

5.1: Characterization

5.1.1: FTIR

Figure 4 defines, FT-IR spectrum of the RHA-Silica samples reveals several important bands that correspond to specific functional groups and vibrations. The band at 3457.05 cm^{-1} is attributed to the stretching vibration of the O-H group. This indicates the presence of hydroxyl groups (O-H) in the samples. The band observed at 1649.57 cm^{-1} is common to both silica samples and is attributed to the bending vibration of H_2O molecules in the Si-OH group. This suggests the presence of water molecules associated with the silanol (Si-OH) groups. The bands appearing at 1083.29 cm^{-1} is assigned to the asymmetric stretching vibration of Si-O-Si bonds. This indicates the presence of silicon-oxygen-silicon linkages in the samples. The strong peak observed at 795.48 cm^{-1} is due to the symmetric stretching vibration of Si-O bonds. This suggests the presence of silicon-oxygen (Si-O) bonds in the silica network. The bands at 463.46 cm^{-1} correspond to Si-O bending vibrations of the siloxane groups present in the RHA-Silica samples. This indicates the presence of silicon atoms bonded to oxygen in a bent configuration. The data also indicates that sodium silicate solubilization with hydrochloric acid results in the formation of silanol groups (Si-OH), while siloxane groups are formed through condensation reactions. This information gives insight into the structural changes and functional group transformations that occur during the treatment process (Table. 6).

Table 6: FTIR spectral data of silica nanoparticles synthesized from GNR-3 rice

Wavenumber (cm^{-1})	Functional Group/ Vibration	Assignment
3457.05	O-H Stretching	Stretching vibration O-H group
1649.57		Bending vibration of H_2O molecule in the Si-OH group
1083.29	Si-O-Si Asymmetric Stretching	Asymmetric stretching vibration of Si-O-Si
795.48	Si-O Symmetric Stretching	Symmetric stretching vibration of Si-O bond
463.46	Si-O Bending (siloxane group)	Si-O bending of siloxane group

Overall, the FT-IR analysis provides valuable information about the composition and bonding characteristics of the RHA-Silica samples, aiding in the understanding of their chemical structure and properties.

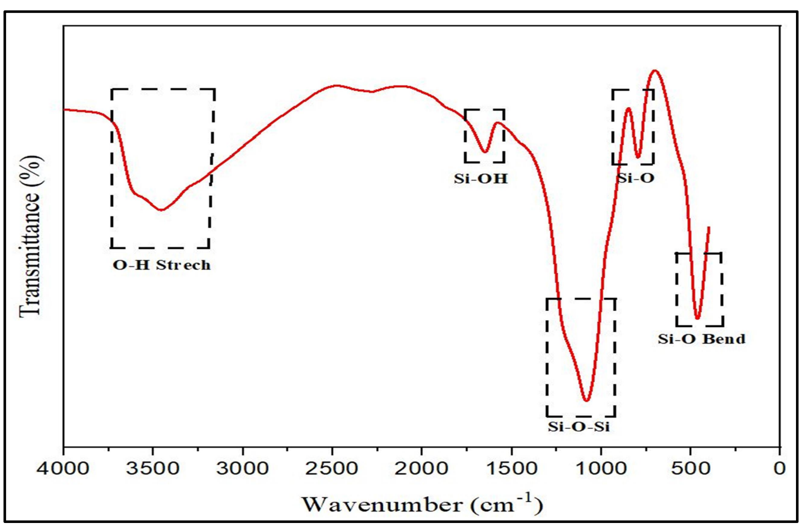


Fig. 4: FT-IR analysis of silica nanoparticles synthesized from GNR-3 rice husk

In conclusion, the remediation of heavy metal contamination in north Gujarat region potatoes using silica nanoparticles synthesized from rice husk represents a groundbreaking contribution to the field. By addressing the adverse effects of heavy metal contamination on vegetables and foods, this work has far-reaching implications for human health, sustainable agriculture, and environmental conservation. The findings of this study inspire further exploration and innovation in the development of effective strategies to combat heavy metal contamination and ensure the safety of our food resources.

5.2.3. EDX

Through EDAX analysis, the purity of the SNPs isolated from rice husk (RH) was confirmed. The SNPs' EDX spectra are shown in Fig. 5. The SEM image of figure (a) shows SEM image selected area for EDX analysis. As shown in Figure (b), the spectra showed distinct signal peaks for the elements Si (45.36%), O (37.65%), Na (9.84%), and Au (7.14%). The created nanoparticles were certainly silica, as shown by the EDX spectra, which showed that the observed peaks matched those of oxygen and silica. This result demonstrates the accuracy of the SNP sample. Additionally, the examination discovered a gold coating, proving that there was (Au) present in the results.

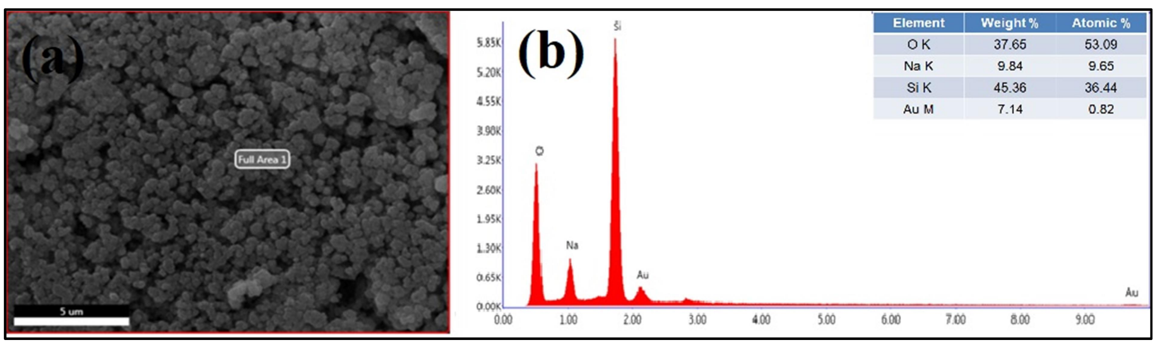


Fig. 5: (a) SEM image of SNPs (b) EDAX spectrum of SNPs

The results and discussion of this study primarily focused on the analysis of silica nanoparticles (SNPs) synthesized from rice husk ash and their potential application in removing heavy metals from potatoes. Firstly, the characterization of SNPs through various techniques, such as Fourier Transform Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDX), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), and X-ray Diffraction (XRD), was conducted. FT-IR analysis revealed the presence of functional groups like Si-O, Si-OH, and Si-O-Si, indicating the structural modifications during synthesis. SEM and TEM images demonstrated the size, shape, and uniformity of SNPs, showing spherical morphology with sizes ranging from 20 to 50 nanometers. AFM images suggested some agglomeration of nanoparticles, while XRD data indicated the presence of both crystalline and amorphous SiO_2 structures in the SNPs. The study then delved into the critical issue of heavy metal contamination in potatoes, emphasizing the significance of food safety, especially in staple foods like rice and potatoes. It highlighted that rice has a higher tendency to accumulate heavy metals compared to wheat. The health risks associated with heavy metals, even at concentrations below maximum allowable limits, were discussed, and the importance of considering variables like body weight, age, and dietary habits in health risk assessments was emphasized.

The study presented valuable insights into the effectiveness of SNPs in removing heavy metals from potatoes, with specific focus on the adsorbent dose. The data revealed that increasing the adsorbent dose generally improved removal efficiency for all heavy metals, including Co, Ni, Pb, and Cr. However, specific removal patterns were observed for each heavy metal, and some variations between replications were attributed to experimental conditions and the diverse behavior of heavy metals in different environments.

Chapter 6: Revolutionizing Coffee toxicity: Sustainable Heavy Metal Remediation Using Rice Husk Synthesized Silica Nanoparticles and Metal Quantification

Coffee has been enjoyed as a beverage for centuries, with a rich history of cultivation and consumption in various regions around the world. The North Gujarat region, known for its coffee production, has contributed significantly to this global coffee culture. However, alongside its popularity, coffee cultivation faces a growing concern due to the presence of heavy and toxic metals in the soil, which poses significant threats to both crop quality and human health.

The accumulation of heavy metals in coffee is a consequence of environmental pollution and human activities. These metals find their way into the coffee plants through contaminated soil, water, and air, as a result of industrial processes, agricultural practices, and improper waste disposal. Such pollution can lead to the incorporation of heavy metal impurities into the coffee beans, thus affecting the quality of the final product and posing health risks to consumers.

The detrimental effects of heavy metals on human health have been well-documented in scientific literature. Chronic exposure to heavy metals, such as lead, cadmium, arsenic, and mercury, through contaminated food and beverages like coffee, can lead to various health problems. Accumulation of these metals in the human body over time may result in organ damage, neurological disorders, and even cancer. Therefore, it becomes essential to implement effective remediation strategies to address heavy metal contamination in coffee and safeguard consumer health.

This study presents an innovative biomass adsorption strategy specifically designed to tackle the issue of heavy and toxic metals in coffee grown in the North Gujarat region. The research focuses on utilizing rice husk ash (RHA) synthesized silica nanoparticles as an effective adsorbent for metal remediation. RHA, derived from agricultural waste, is transformed into silica nanoparticles through a controlled synthesis process, creating a sustainable and eco-friendly adsorption material.

The efficiency of this adsorption process is evaluated through rigorous analysis using advanced analytical techniques. By examining the concentration of metals before and after treatment, the study reveals the remarkable adsorption capacity of RHA-synthesized SNPs. These nanoparticles demonstrate their ability to effectively reduce the concentration of heavy and toxic metals in coffee samples, potentially mitigating the adverse effects of metal impurities on human health.

Moreover, the nanoparticle-based adsorbents exhibit good selectivity towards specific metals, allowing the targeted removal of contaminants while preserving essential elements that contribute to the characteristic flavor and aroma of coffee. This selectivity ensures that the remediation process does not compromise the overall quality and authenticity of the coffee, making it a viable and sustainable solution for coffee production in the North Gujarat region.

The implementation of this innovative biomass adsorption strategy represents a promising approach to address heavy metal contamination in coffee cultivation. By safeguarding both the environment and human health, this novel remediation method has the potential to contribute significantly to the improvement of coffee quality and safety in the North Gujarat region. Moreover, it highlights the importance of sustainable and eco-friendly solutions in preserving the rich tradition of coffee production while ensuring consumer well-being in the face of environmental challenges.

The results and discussion section of this study provides valuable insights into the removal of heavy hazardous metals from coffee biomass using a potato-based adsorbent. The research emphasizes the critical role of adsorbent dose, showing that an increase in the concentration of the adsorbent leads to more efficient removal of heavy metals. Furthermore, the study highlights that each heavy metal, including Cobalt, Nickel, Lead, and Chromium, exhibits a unique removal pattern based on the adsorbent dose applied, underlining the importance of tailoring strategies to target specific contaminants effectively. The statistical analysis of the results demonstrates that the differences in metal removal between different adsorbent doses are statistically significant, reinforcing the need to carefully select the appropriate adsorbent dose for effective remediation. Additionally, the coefficient of variation was used to assess data variability, providing insights into the reliability and consistency of the findings. Importantly, this research has significant implications for both environmental and public health, particularly concerning the safety of food products. The efficient removal of hazardous heavy metals from commonly consumed items such as coffee is essential for safeguarding human health. Moreover, the study opens avenues for further research and applications in the field of environmental science, offering the potential to develop sustainable and cost-effective methods for heavy metal remediation in various environmental and industrial contexts.

CHAPTER 7: SUMMARY AND CONCLUSIONS

This synopsis outlines the general structure of the thesis, covering the reduction and quantification of heavy metal impurities in medicines and food products using various types of synthesized silica nanoparticles. The unique aspect of this study lies in its novel approach and application of silica nanoparticles, offering valuable insights and contributing to the development of safer and higher quality medicines and food products.

Chapter 1: General Introduction

This chapter introduces the research project focused on addressing toxic heavy metal impurities in pharmaceuticals and food products. It emphasizes the importance of mitigating toxic heavy metal contamination in these essential commodities, highlighting the innovative use of synthesized SNPs as adsorbents. The chapter sets the stage for subsequent chapters by outlining the research's significance and the approach used. This chapter establishes the context for the research, underlining the critical need to address toxic heavy metal contamination in pharmaceuticals and food products. The introduction of SNPs as potential adsorbents marks an innovative and promising approach to tackle this issue. The chapter serves as the foundation for the detailed investigations presented in the following chapters.

Chapter 2: Materials, Experimental Design, and Characterization Methods

This chapter provides an overview of the materials used in the research, focusing on rice husk as a source for synthesized SNPs. It delves into the experimental design and methodologies employed, emphasizing the characterization techniques, including TGA, FT IR, SEM, EDX, DLS, TEM, AFM, XRD, and ICP-MS, which are instrumental in assessing the structural and surface attributes of the SNPs. This chapter lays the groundwork for the experimental aspects of the research, outlining the materials, methodologies, and characterization methods used in detail. The utilization of rice husk as a raw material for SNP synthesis is an eco-friendly approach that holds promise for heavy metal remediation.

Chapter 3: Determination of toxic heavy metals in Cholic acid using quadrupole inductively coupled plasma mass spectrometry toxic

In this chapter, a method for quantifying heavy metal concentrations in Cholic acid using Quadrupole Inductively Coupled Plasma Mass Spectrometry (Q-ICP-MS) is presented. The research successfully met the accuracy and precision standards set by various regulatory bodies. This method demonstrates efficiency and reliability in determining trace metals in Cholic acid. This chapter introduces a validated method for quantifying heavy metal concentrations in Cholic acid, ensuring accuracy, precision, and repeatability. This method offers an efficient approach to assess the safety of pharmaceuticals with respect to heavy metal contamination.

Chapter 4: Efficient Green Removal and Quantification of Toxic Heavy Metals from Losartan Using Silica Nanoparticles Derived from Rice Husk Ash

This chapter addresses the issue of heavy metal contamination in medications, emphasizing the importance of removing heavy metals efficiently and cost-effectively. The research focuses on the utilization of synthesized silica nanoparticles (SNPs) derived from rice husk as adsorbents. It demonstrates that SNPs are highly effective in reducing the concentration of heavy metals in Losartan, presenting a promising solution for medication safety. This chapter emphasizes the significance of eliminating heavy metal contamination in pharmaceuticals. The use of SNPs synthesized from rice husk presents a viable, eco-friendly solution for ensuring the safety and quality of medications. This research paves the way for practical applications in pharmaceutical safety.

Chapter 5: Revolutionizing Agriculture with Nanotechnology: Rice-Based Silica Nanoparticles for the Remediation and Quantification of Toxic Heavy Metals in Potatoes

This chapter tackles the problem of heavy metal contamination in potatoes and other agricultural products, emphasizing the need for effective removal methods. It presents a low-cost, environmentally friendly method that utilizes silica nanoparticles derived from rice husk to reduce heavy metal contamination in potatoes. The SNPs showed exceptional adsorption capability. This chapter highlights the importance of addressing heavy metal contamination in staple crops like potatoes. The use of SNPs derived from rice husk waste offers an effective and sustainable solution for enhancing food safety. This research is a step toward cleaner and safer agricultural products.

Chapter 6: Revolutionizing Coffee toxicity: Sustainable Heavy Metal Remediation Using Rice Husk Synthesized Silica Nanoparticles and Metal Quantification

This chapter focuses on remediating hazardous heavy metals in coffee, particularly in the Robusta variety produced in Kerala. Silica nanoparticles synthesized from rice husk ash (RHA) are used as efficient adsorbents to reduce heavy metal contamination. The research demonstrates that SNPs are effective in lowering heavy metal concentrations in coffee, contributing to safer and higher-quality products. This chapter addresses the critical issue of heavy metal contamination in coffee, a staple beverage. The research offers an environmentally friendly and economical solution through the use of SNPs derived from rice husk. This approach has the potential to enhance the quality and safety of coffee produced in Kerala and other regions.

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❖ List of the Research Publications

(1) Thakar Meet Kumar, Suthar Vaishali, Sheth Jateen, Indra Neel Pulidindi, and P. Sharma. “Determination of Toxic Heavy Metals in Cholic Acid Using Quadrupole Inductively Coupled Plasma Mass Spectrometry (Q-ICP-MS)”. Asian Journal of Pharmaceutical and Clinical Research, vol. 17, December. 2023, doi:10.22159/ajpcr.2023.v16i6.47366.

❖ List of the Papers presented in the Conferences/Seminars/Workshops

1. Poster Presentation: International Seminar on “Advanced Materials and Applications” held on 18th July, 2022; Organized by Applied Physics Department and Applied Chemistry Department, Faculty of Technology and Engineering, M.S.University of Baroda and Luminescence Society of India. (Regd. No: GUJ/1156).

2. Participated: International E- Conference on Recent Advances in Chemical, Physical and Biological Science (RACPBS-2021) on 29th-30th June 2021organized by Department of Chemistry, Nabira Mahavidyalaya, Katol and Association of Chemistry Teachers (ACT), C/o Homi Bhabha Centre for Science Education (TIFR) Mumbai.

3. Poster Presentation: National Conference on “Modern Evolution in Material & Chemical Sciences (MEMCS-23)” during 6th and 7th January, 2023; Organized by Parul University, Vadodara.

4. Poster Presentation: National Level Online Workshop on "Virtual Chemistry Learning for Higher Education" held on 18-01-2021 to 19-01-2021; jointly organized by Department of Chemistry, School of physical Sciences, & Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching and School of Education, Central University of Kerala, Kasaragod, Kerala.

5. Poster Presentation: National Conclave on " Promotion of Millets (Shree Anna) for Sustainable Agriculture and Nutritional Security Towards Global Prosperity : Key Challenges and Future Prospects" organized by Sardarkrushinagar Dantiwada Agricultural University in collaboration with Gujarat Society of Genetics and Plant Breeding (GSGPB) & Deendayal Research Institute (DRI) held at Sardarkrushinagar Dantiwada Agricultural University (Gujarat) during 30th October- 1st November,2023.

Signature of Candidate

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Research Student

Endorsement of Supervisor;
Synopsis is approved by me

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