

GREEN SYNTHESIS OF COBALT NANOPARTICLES USING MARINE SEAWEED PIGMENTS AND ITS APPLICATIONS ON ENVIRONMENT

Submitted in partial fulfillment of the requirements for the award of
Master of Technology degree in Biotechnology

by

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**DEPARTMENT OF BIOTECHNOLOGY
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12 B Status by UGC | Approved by AICTE
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BONAFIDE CERTIFICATE

This is to certify that this Review Report is the bonafide work of Varshine K.R(41810020), who carried out the Review report entitled "**GREEN SYNTHESIS OF COBALT NANOPARTICLES USING MARINE SEAWEED PIGMENTS AND ITS APPLICATIONS ON ENVIRONMENT**" under our supervision from January 2023 to May 2023.

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ABSTRACT

Nanoparticles are largely used particles nowadays; they can be anywhere in the surroundings. Different methods to convert biomass into useful materials and products without generating pollutants will be useful for global environmental protection. The present study deals with the preparation of sorbent from a suitable activated carbon enhanced with PEG along with Cobalt nanoparticles. The sorbent thus prepared will be used for the removal of heavy metals from aqueous solutions. Factors influencing the adsorption characteristics under batch conditions were studied for chromium concentrations in range of 30 – 150 ppm. The studies were conducted to optimize the size of the adsorbent, temperature and contact time. The maximum adsorption is attained at a pH of 6.5 and a dosage of 3 g. The effective temperature for the reaction was at 37°C. The adsorption isotherms showed that the Freundlich Isotherm is a better adsorption model and the characteristic parameters were determined. The results of the kinetic models showed that the pseudo second order kinetics was found to correlate with the experimental data well. The present analysis, the Co_3O_4 combined with has an efficient adsorption for chromium.

Keywords: Cobalt nanoparticles; Seaweed; Heavy metals; Green synthesis; toxicity; adsorption studies

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ABBREVIATION

NPs	Nanoparticles
TEM	Transmission electron microscopy
XRD	X-ray diffraction
EDX	Energy dispersive x-ray
SEM	Scanning electron microscopy

CHAPTER 1

INTRODUCTION

The fundamental building blocks of nanotechnology are nanoparticles. Richard Adolf Zsigmondy made the first observation of nanoparticle sizes, which range from 1 to 100 nm and are composed of metal, metal oxides, organic matter, and carbon. (Hasan, 2015) Cells are the building blocks of existence. Nevertheless, these cell components are quite diminutive. Nanotechnology focuses on the design, production, and characterization of nanoscale particles (Cho *et al.*, 2013). Nanoparticles are fundamentally microscopic particles that behave as a singular entity based on their properties and modes of transport (Machado *et al.*, 2015). A nanoparticle matrix either dissolves, encloses, encapsulates, or binds the medication. Depending on the preparation method, nanoparticles, nanospheres, and nanocapsules can be created (Liu *et al.*, 2008).

Nanospheres are matrix systems in which the drug is physically and uniformly distributed, whereas nanocapsules are systems in which the drug is confined within a cavity and surrounded by a special polymer membrane (Ma and Manthiram, 2012). (Tiwari *et al.*, 2008). Fullerenes, carbon nanotubes, graphene, carbon quantum dots, nanodiamonds, nanohorns, nanoporous materials, core-shell nanoparticles, antimonene, silicene, MXenes, 2D MOF nanosheets, boron nitride nanosheets, layered double hydroxides, and metal-based nanomaterials are examples. We conclude by discussing the challenges and potential of nanomaterials (Talpin *et al.*, 2016) (Leveneur *et al.*, 2011).

Currently, nanotechnology is rapidly developing and permeating virtually all domains of materials chemistry. Thanks to daily advances in nanotechnology, potent characterization and synthesis techniques are now available for creating nanomaterials with better-controlled dimensions (Talpin and Shevchenko, 2016). Nanomaterials have many commercial applications, including scratch-resistant paints, surface coatings, electronics, cosmetics, environmental remediation, sporting goods, sensors, and energy storage devices (Kodama, 1999).

Due to their remarkable physical, chemical, optical, magnetic, electrical, catalytic, and electronic properties, Co₃O₄ nanoparticles are widely used in fuel cells, lithium-ion batteries, super-capacitors, field-emission materials, solar selective absorbers, pigments, electrochromic devices, gas sensors, and catalytic applications (Kim *et al.*, 2012).

Co₃O₄-NPs have recently received a great deal of attention due to their unique and significant applications. These nanoparticles are utilized in catalysis, energy storage systems, electrochromic thin films, lithium ion batteries, solar selective adsorbers, capacitors, field emission materials, and gas sensors. Singh *et al.* (2012) have described cobalt oxide composites with graphene and Co₃O₄ that increase the dimensional stability of the substrate. Cobalt nanoparticles have numerous applications, including energy storage, catalysts, contrast agents, microelectronics, and drug delivery (Thodeti *et al.*, 2016).

The four categories of techniques for preparing cobalt nanoparticles are physical, chemical, physicochemical, and biological. To surmount the unique challenges encountered during synthesis, a number of strategies must be employed. Matthias Zeisberger was able to create 10 nm-sized magnetic nanoparticles of metallic cobalt Co by utilizing XRD. In terms of specific heating power, these nanoparticles outperformed magnetic iron oxide nanoparticles (Cirri *et al.*, 2015) (Zou *et al.*, 2016).

Due to the use of sophisticated synthesis procedures, expensive apparatus, protracted reaction periods, high costs, and high synthesis temperatures, the majority of synthesis methods have been linked to a number of drawbacks. In addition, some stabilisers and surfactants used in the synthesis process have a history of being hazardous and having deleterious and carcinogenic effects, rendering the produced nanoparticles unsuitable for a variety of applications (Lue, 2007).

The aqueous extract of *Hypnea musciformis* was utilised to biosynthesize silver nanoparticles with antibacterial and antifungal properties. Kumar observed that *Sargassum tenerrimum* biosynthesized Silver Nanoparticles inhibited human

MTCC pathogenicity (Sorbiun *et al.*, 2018). (Khan *et al.*, 1019) In a single step, *Fucus spiralis* reduces aqueous chloroaurate ions during the biosynthesis of gold nanoparticles. Different shapes and diameters (5–40 nm) of biosynthesized gold nanoparticles are produced. (Mogilevsky *et al.*, 2014)

CHAPTER 2

LITERATURE REVIEW

2.1 GREEN SYNTHESIS OF COBALT AND COBALT OXIDE

Nanotechnology employs a variety of physical and chemical processes to produce nanomaterials with unique properties. Thanks to nanotechnology, we can create novel materials with dimensions (at least in one) smaller than 100 nanometer. These substances are utilised in a vast array of products, including consumer goods, nanomedicine, nanoelectronics, biomaterials, and energy production. Traditional methods for producing nanoparticles included pyrolysis and abrasion, but these processes had disadvantages such as high costs, sluggish synthesis rates, and high energy demands (Jamal *et al.*, 2015). The majority of these substances are produced through chemical processes, such as the sol gel technique and chemical reduction. However, these techniques generate hazardous byproducts and utilise noxious compounds (Majolagbe *et al.*, 2016; David *et al.*, 2019).

Co₃O₄-NPs have garnered a great deal of attention recently due to their unique and important applications. Catalysis, energy storage systems, electrochromic thin coatings, lithium ion batteries, solar selective adsorbers, capacitors, field emission materials, and gas sensors all utilise these nanoparticles. Cobalt oxide has recently been characterised in graphene and Co₃O₄ composites that increase the dimensional stability of the substrate (Wu *et al.*, 2010). (Li *et al.*, 2019)

For these purposes, millions of trees are cut down, and the leaves are left behind as bio-waste. Consequently, it is crucial to develop processes and technologies to utilise this bio-waste. To accomplish this, we used *Populus ciliata* leaves as a reducing agent to produce Co₃O₄-NPs. According to a review of relevant literature, the leaf extract of this plant has not yet been used to produce Co₃O₄-NPs (Ogundipe *et al.*, 2017; Hafeez *et al.*, 2019).

The antibacterial properties of the synthesised Co_3O_4 -NPs are evaluated against specific gram-positive and gram-negative bacterial species using a safe synthetic procedure that is economical, effective, innocuous, and environmentally benign. Peter et al. (2016) report that a number of researchers created NPs using a variety of biosynthetic techniques for this competition.

The *P.granatum* skins were collected from a nearby market in Bahawalpur, Pakistan. To eliminate contaminants, skins were sliced and rinsing with ultrapure water. 20 g of *P.granatum* skins were homogenised with 150 millilitres of water using an electric blender. The mixture was then heated to 75°C with constant stirring, chilled, and filtered. The brown filtrate was collected and used to produce cobalt oxide nanoparticles (Qureshi et al., 2015).

$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ was the precursor for the nanoparticle synthesis. This salt was dissolved in 100 ml of distilled water to create a 1 mmolar solution. For the synthesis of Co_3O_4 NPs, 30 ml of cobalt salt solution and 20 ml of pant leaf extract were combined and heated at 80 °C for three hours. The formation of Co_3O_4 -NPs was accompanied by a change in pigmentation (from light brown to dark brown). The mixture was chilled until room temperature was reached. The resultant solution was centrifuged at 15,000 rpm for 15 minutes, the supernatant was decanted, and the residue (Co_3O_4 -NPs) was baked at 60 °C (Shindy, 2017).

Using Cu Ka radiation in the range of $2\theta = 20-80$ at a scanning rate of 5 min⁻¹, XRD analysis (Bruker, German) was employed to determine the purity of the cobalt oxide NPs generated. The elements were determined using Energy Dispersive X-Ray Spectroscopy (EDX) (JEOL, Japan) analysis. The structural morphology was investigated using a scanning electron microscope (SEM) (Hitachi SX-650, Tokyo, Japan) (Lu et al., 2014) (Haider et al., 2019). Cobalt oxide nanoparticles were subjected to FTIR (Nexus 470, FTIR) analysis in the range of 500-4000 cm⁻¹ with a resolution setting of 4 cm⁻¹ in order to verify the functional biomolecules associated with them. UV-Vis spectrophotometer was used to record UV-Vis adsorption spectra (Perkin Elmer, United States). In addition, atomic force microscopy was utilised to corroborate the morphology and particle size of the synthesised cobalt oxide nanoparticles (Iqbal et al., 2015; Fultz and Howey, 2012).

One-step in-situ green synthesis comprises the processes of reduction-based nucleation and growth. The particles are formed by converting cobalt ions into neutral cobalt atoms, and then the bioactive substance in extracts stabilises them. Ellagic acid's ortho-phenolic hydroxyl group and ester oxygen atom are conjugated with the hydroxyl and carboxyl groups of phenolic compounds, which have a strong tendency to react with metals. During chelate formation, when the hydrogen is removed from the ortho position of the phenolic hydroxyl group, a semiquinone- like structure is produced. The ability of ellagic acid to shed electrons produces an H⁺ radical. This procedure reduces Co(II) to a single Co atom, resulting in the formation of nanoparticles due to the capping effect. Transmission electron microscopy (TEM) was used to learn more about the structural characteristics of artificial cobalt oxide nanoparticles (Kumar *et al.*, 2021).

2.2 MARINE SEAWEED PIGMENTS

In photosynthetic organisms, photosynthesis is a biological process that converts solar energy between 400 and 700 nm into the chemical energy required for the organism's growth and development. The pigments present in the live cells of all photosynthetic organisms play a crucial role in absorbing sunlight and transforming it into this vital energy. Depending on their specific functions, the pigments that collect light energy for chlorophyll *a* are either photosynthetic pigments (chlorophylls) or accessory pigments (phycobiliprotein) and carotenoids. (Singh *et al.*, 2021)

Natural pigments exist in a vast array of tints and have been utilized extensively throughout history. Food production, the textile and paper industries, water science and technology, and agricultural research and practice are a few noteworthy examples. Pigments exhibit beneficial biological activities as antioxidants and anticancer agents, in addition to possessing a number of essential properties that make them suitable for use in these diverse industrial contexts. Consequently, they have an excellent chance of meeting current market demands, which are increasingly focused on the health and biotechnology sectors in quest of natural substances and products with proven positive effects on human health (Cserháti, 2006).

The structural diversity of natural pigments influences their stability in various technical and environmental conditions. Liquid chromatography is the most appropriate technique for qualitatively determining and identifying a pigment, and it is used to analyze pigments in a matrix. Visible radiation interacts with sediments and macrophytes in coastal waters, altering the spectral composition and irradiance of incident light (Kannaujiya *et al.*, 2021).

Variable spectral fractions in marine vegetation determine The pigment volume and distribution within a plant determines its colour and even its classification into one of the three main phyla. In addition to significant concentrations of chlorophylls A and B, green seaweeds (phylum Chlorophyta) contain minor quantities of - carotene and xanthophylls, each of which contributes to the pigment content (Pangestuti *et al.*, 2011).

Brown seaweeds, which range in colour from yellow to olive-green to brown (phylum Ochrophyta, class Phaeophyceae), contain high concentrations of the xanthophyll fucoxanthin and low concentrations of other xanthophylls, chlorophyll a and c, and beta-carotene (Talarico *et al.*, 2000). Red seaweeds belong to the phylum Rhodophyta, which has a high concentration of phycoerythrin and phycocyanin and a low concentration of chlorophyll a, beta-carotene, and xanthophylls (Bonanno *et al.*, 2018) (Freitas *et al.*, 2022).

On an industrial scale, pigments derived from microalgae account for a respectable 31% of the 870 cosmetic patent families. Pigments have the second- largest share of the 2356 patent families for the human nutrition industry, with beta-carotene and astaxanthin at the top of the development lines. They are the substances exhibiting the greatest growth in both industries, along with proteins (Pereira *et al.*, 2015). Chlorophyll a, whose primary source is found in all oxygenic photosynthetic organisms, is the subject of the most patents (5,949). Astaxanthin ranks second (4,236 patents), closely followed by allophycocyanin, which ranks last among 67 patients (Zhao *et al.*, 2009).

2.2.1. Phycobili Protein

The preponderance of plants and phytoplankton contain chlorophylls a and b to absorb light energy. Within this wavelength range, these plants and phytoplankton are photosynthetically active, as chlorophyll a and chlorophyll b are active at wavelengths of 430 and 680 nm and 450 and 660 nm, respectively. There would be an absorption hiatus between the blue and red regions of the visible spectrum because red seaweeds contain only chlorophyll a, which limits the quantity of light that can be absorbed. Geneva (Emilsson *et al.*, 2005)

In 1883, Theodor Wilhelm Engelmann recognized PBS as the principal light-harvesting chromoprotein. PBP are essential components of red seaweed's photosynthetic light-harvesting complexes and are considered accessory pigments of chlorophyll. Obtaining PBPs is not simple and straightforward. As previously mentioned, PBP are located within the phycobilisome within the chloroplast, making it difficult to obtain PBP extracts using conventional techniques. Algae must be pretreated with the appropriate solvents and homogenized in order to discharge their contents. There are numerous extraction methods, and selecting the optimal one is crucial for maximising PBP recovery because it has a significant impact on the pigment's activity and integrity. The state of the biomass (fresh versus dry algae), the biomass/solvent ratio, the method used to disrupt cells, the solvent, the length of time and number of steps required for extraction, and the method used to store the biomass prior to extraction are some of the specific parameters that can be altered and disrupted with the proper techniques (Hsieh-Loet *et al.*, 2019).

2.2.2 Phycoerythrin

The Greek word "erythros," which means "red," contributed to the appellation of the crimson pigment Phycoerythrin (PE) (Munier *et al.*, 2013) PE is a photosynthetic pigment found in cryptomonads, red microalgae, and red macroalgae. (Goudarzi *et al.*, 2014). PE shares the characteristics of PBP that have already been described; furthermore, as a PBP and as stated previously, PE is frequently used as a natural dye in the food and cosmetics industries. In addition, PE derived from the microalgae *Porphyridium* sp. (phylum Rhodophyta) has been extensively studied and tested in the creation of foods with "special effects," such

as aesthetically pleasing cake decorations, soft drinks, and alcoholic beverages that fluoresce under specific pH values or UV light (Rossano *et al.*, 2003).(Bulavin *et al.*,2016)

Efforts akin to those in the preceding examples frequently result in a substantial number of publications promoting innovative, simple, rapid, and/or optimal techniques for phycoerythrin extraction from red seaweeds. These benefits, which are supported by this research and are undeniably replicable in the laboratory, do not always possess the same efficacy, affordability, and sustainability on an industrial scale. Takaichi *et al.* (2016) examine the techniques for extracting and purifying PE from red marine algae.

2.2.3 Phycocyanin

The name of the blue pigment, phycocyanin (PC), is partially derived from the English word "cyan," which itself comes from the Greek word "kyanos." It's noteworthy to note that each of these phrases refers to a different hue of blue: blue-green and dark blue, respectively (Eggersdorfer *et al.*, 2018). Rhodophyta, Cyanobacteria, and Cryptophyta contain R-Phycocyanin (R-PC), Bangiophyceae possess B-Phycocyanin, and PC is classed according to its source (B-PC). However, it is important to note that the majority of PC studies do not get this pigment from red algae, much less macroalgae. In reality, one of the earliest groups of prokaryotic organisms, cyanobacteria, which maintains a worldwidedistribution over a wide range and variety of aquatic and terrestrial settings, is the primary source of this blue pigment in an industrial context. An unusual red alga is the red microalgae *Cyanidium caldarium*, which is isolated from hot springs and grows under conditions of bright sunlight, high temperatures, and acidic environment. Therefore, its PC has been extracted and researched with the theorythat it may be thermostable and have unique properties in comparison to cyanobacterial pigments (Rapoport *et al.*, 2021)

In their study of the parameters influencing PC stability, Meléndez-Martínez *et al.*, 1999 identified temperature and pH as the determinants of this pigment's stability and demonstrated the capability of glucose, sucrose, and NaCl to sustain it. Alternately, thermophilic species (such as the aforementioned *Cyanidium*

caldarium) might offer more thermostable PC versions. However, trying to produce these extreme-living creatures on a big scale may present new difficulties and costs. Therefore, as suggested to generate thermostable PC in non-native hosts (Chan *et al.*, 2015)

Discussing present patterns and a projection of the PC market value primarily credits this expansion and interest to the pigment's growing acceptance (in place of synthetic substitutes) in the incorporation of therapeutic and nutritious products, but also credits it to a demand for its distinctive colour on its own. In fact, PC has a deep cobalt blue hue that is almost impossible for other natural pigments to match

2.2.4 Carotenoids

The animal kingdom is unable to produce carotenoids, a family of long conjugated isoprenoid pigments that are present throughout the vegetal kingdom as well as in fungi and photosynthetic organisms. This is likely because the necessary genes for encoding the enzymes needed for carotenoid biosynthesis have been lost through evolution (Gruszecki *et al.*, 2005). Rhodophyta has a high carotenoid content, but there are variations between the macroalgae (family Porphyridiaceae) and microalgae within the phylum. The latter contain β -carotene and lutein, whilst the former solely contain β -carotene and zeaxanthin. (Stahl and Sies, 2005).

Numerous natural sources, including fruit and vegetables, eggs, fish, algae, fungi, and yeasts, are improved nutritionally by carotenoids. There are about 50 carotenoids in the human diet. Carotenoids are also well-known in the cosmetics sector for enhancing skin health by boosting dermal protection against UV radiation. Together with other reducing agents like polyphenols and vitamins, they function as antioxidants (Kang and Sim, 2008). Additionally, carotenoids help to strengthen immune defences and play a part in lowering the prevalence of chronic illnesses and aging-related diseases like cancer, diabetes, bone, skin, and eye disorders, and inflammatory and cardiovascular diseases

2.2.5 Xanthophylls

Chemically, a 40-carbon polyisoprenoid containing cyclic structures at both ends of its conjugated chain. It shares a structure with zeaxanthin as a consequence,

but one ring's double bond is located in a different place, giving it three chiral centres as opposed to zeaxanthin's one. In terms of its chemical composition, zeaxanthin is made up of a pol (Lee *et al.*, 2014)

Zeaxanthin is regarded as a tool against tumour and cancer development due to its anti-inflammatory capability, and its use in chemotherapy may be advantageous for the patients. As a photoprotective agent, this chemical can also be used to treat eye conditions like cataracts or slow macular degeneration (Yang *et al.*, 2021). Techniques for extracting astaxanthin, particularly from the microalgae species *Haematococcus lacustris*, have improved as a result of its biotechnological potential. Solvent extraction, supercritical fluid extraction, and oil extraction are only a few of the documented extraction techniques that were found. The molecular nature of astaxanthin isomers makes it challenging to extract them using traditional techniques. In order to distinguish astaxanthin isomers such 13- cis astaxanthin, 15- cis astaxanthin, and trans-astaxanthin, numerous investigations have been carried out. A lot of the time, spectrophotometric or chromatography are used to quantify astaxanthin (Wang, *et al.*, 2008).

As a result, high performance liquid chromatography (HPLC) is the preferred technique for assessing carotenoids; for example, HPLC with chiral stationary phases is one of the most effective methods for enantiomeric separation (Liu *et al.*, 2009)

2.3 ADSORPTION OF HEAVY METALS USING COBALT OXIDE NANOPARTICLES

The expansion of industry and human activities, such as plating and electroplating, batteries, pesticides, mining, rayon production, metal rinse processes, tanning, fluidized bed bioreactors, textile production, metal smelting, petrochemicals, paper production, and electrolysis applications, there has been an increase in the presence of heavy metals in wastewater. Water tainted with heavy metals makes its way into the environment, endangering both human health and the ecosystem. The heavy metals could cause cancer and are non-biodegradable. The operational conditions (i.e., temperature, adsorbent amount, pH value, adsorption period, and initial concentration of metal ions) and the physicochemical features of adsorbent

and heavy metals define the adsorption mechanism. Typically, heavy metal ions are capable of adhering to the surface of the adsorbent (El-Sherif *et al.*, 2013)

Adding surfactant-free cobalt nanoparticles to contaminated water, waiting at least 5 seconds for the heavy metal ions to congregate around the cobalt metal nanoparticles, and then removing the cobalt metal nanoparticles coated with the heavy metal ions in the metallic or metal oxide form from the contaminated water are the steps in a process for extracting heavy metal ions from water. A suitable support material, such as sand, wood, cellulose, metallic fibers, porous ceramic, a polymer support, or glass, is used to hold the cobalt metal nanoparticles in place. It is possible to remove the heavy metal ion-coated cobalt nanoparticles using a magnetic field of up to 1 Tesla, but ideally at least 0.2 Tesla. The cobalt metal nanoparticles should ideally be clumped together (García-Niño *et al.*, 2014).

Cobalt nanoparticles could be anchored to a substrate built into a filter. Superparamagnetic characteristics may be present in the cobalt nanoparticles. Cobalt oxide may be used to cover the cobalt metal nanoparticles. Cobalt metal nanoparticles may be functionalized and stable in air (Taseidifar *et al.*, 2017) (Tjandraatmadja *et al.*, 2008).

The most popular modification processes to increase a material's specific surface area, pore structure, adsorption capacity, thermal stability, and mechanical strength include nitrogenation, oxidation, and sulfuration (Alshameri *et al.*, 2019). A list of the most recent research studies on the use of biosorption for wastewater treatment is provided. Numerous functional groups on the surface, such as carboxyl, amino, hydroxyl, phosphate, thiol, etc., hasten the biosorption process (Borba *et al.*, 2006)

In general, electrostatic interaction, aggregation, complexation/coordination, micro precipitation, ion exchange, reduction, or oxidation can occur when contaminants interact with the surface of a biosorbent. The biosorbent surface charge density and the ionisation of functional groups there are influenced by the pH of the solution (Hao *et al.*, 2016). Cations are almost stable at low pH levels and can attach to the surface of the biosorbent. On the other hand, at higher pH levels,

there is a chance of a precipitation phenomenon and a decrease in the solubility of metal cations Li,Z. et.al,.(2019)

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM

To remove the heavy metals from the waste water by synthesizing the metal oxide.

3.2 SCOPE OF THE PRESENT INVESTIGATION

Cobalt oxide is synthesized by marine seaweed then, it is characterized by instrumental analysis such as FT-IT and SEM. Finally, heavy metals from the waste water is removed by cobalt oxide. The adsorption kinetics were studied.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 SAMPLE COLLECTION

The seaweed sample was collected from Mandapam, Rameswaram Tamil Nadu.

4.2 ADSORBENT PREPARATION

Shade drying process was done for 3 days to remove the moisture content from the sample. The dried sample were powdered using a mixer grinder and finally sieved to the particle size.

4.3 SYNTHESIS OF SEAWEED

Seaweed sample was taken – 5 g and added with 50 ml of distilled water and kept in water bath for 30 min then the Boiled Sample was filtered using Whattman filter paper No.1. Cobalt oxide was weighted 5 g and added with 15 ml of filtered sample and kept in magnetic stirrer for 20 min and After the above procedure, UV reading was taken and peak was observed and the sample is centrifuged and pellet was collected. Finally, the sample was given for characterization by FT-IR.



Figure 4.3.1 Boiled seaweed pigments without filtration process



Figure 4.3.2 filtered seaweed sample

Conical flask was taken and filled with 100 ml of distilled water and 1 g of Potassium dichromate (base solution).

10 conical flask was taken, in the concentration of 1st conical flask - 1ml solution + 99ml distilled water, 2nd conical flask - 2ml solution + 98ml distilled water, 3rd conical flask - 3ml solution + 97ml distilled water, 4th conical flask - 4ml solution + 96ml distilled water, 5th conical flask - 5ml solution + 95ml distilled water, 6th conical flask - 6ml solution + 94ml distilled water, 7th conical flask - 7ml solution + 93ml distilled water, 8th conical flask - 8ml solution + 92ml distilled water, 9th conical flask - 9ml solution + 91ml distilled water, 10th conical flask - 10ml solution + 90ml distilled water.

The initial spectrophotometric reading was noted at 235 nm for all the concentrations in the conical flasks. After the first spectrophotometric reading, the activated charcoal was added in the range of 250 mg, 500 mg, 750 mg, 1.000 mg, 1.250 mg in the base solution (100 ml of Distilled water and 1 g of potassium dichromate.) The solution was centrifuged and filtered for the spectrophotometric

reading was noted at 235 nm for every 2 to 3 hours until lowest adsorption value is noted.

The lowest adsorbance value was obtained at solution where 5 mg of activated charcoal added, so the particular gram of activated charcoal was taken for the further procedure. The activated charcoal of 5 g was added in the base solution. 100 ml of distilled water and 1 g of potassium dichromate. The spectrophotometric reading was noted at 235 nm for every 2 to 3 hours after centrifugation process and the pellet was collected and FTIR analysis was done.

The pellet from synthesized sample was taken and added with PEG (0.3 g) and 2 ml of distilled water. The above solution was mixed well and kept in stirrer for few min and it is centrifuged and the pellet was collected.

5 g of activated charcoal was added with previously collected pellet and 50ml of distilled water. And kept in magnetic stirrer for about 20 h.

The next day, the solution was centrifuged and the pellet was collected for about 1 g. Finally, 100 ml of distilled water, 1 g of potassium dichromate was added. From the above solution, 10 ml was taken. In that 10 ml of solution, 90 ml distilled water, 500 mg of activated carbon and 1 g of collected pellet was added, and centrifuged for the spectrophotometric reading. The readings were performed till the adsorbance value is 0.000 for every 10 min at the range of 235 nm.

4.4 ADSORPTION STUDIES

4.4.1 Estimation of Chromium

To find the concentration of Chromium, the solutions were given for spectrophotometric analysis and from the adsorbance value concentrations of the solutions were calculated.

4.4.2 Optimization of Chromium concentration with adsorbent

10 ml of 30, 60, 90, 120 and 150 ppm of the Chromium solutions were taken and 0.5 g of the crushed powder was mixed with the solutions. The solutions were kept

for 10 min and then the solutions were filtered. The filtrate was given for spectrophotometric analysis.

4.4.3 Optimization of adsorbent size

30 ml of the solution with the optimized concentration was taken in different beakers and to it 1.5 g of the adsorbent of sizes pan and mesh no 25 and 52 are added respectively. These solutions were mixed thoroughly for 30 minutes and filtered and then given for spectrophotometric analysis.

4.4.4 Optimization of contact time

30 ml of the solution containing the optimised concentration and 1.5 g of the optimised sizes were taken in different beakers. They were kept for time durations of 30, 60, 90 and 120 minutes. The solutions were filtered and given for spectrophotometric analysis after the time period was over.

4.4.5 Optimization of temperature

To optimize the temperature 1.5 g of the optimum sized adsorbent was taken and heated in an incubator for 2 h at different temperatures, 32°C, 37°C and 45°C. The adsorbent was added to 30 ml of the solution of optimum concentration and kept for an optimum time.

4.4.6 Optimization of pH

To optimize the pH, 30 ml of the solution with optimum concentration is maintained with different pH, namely 2, 4, 6, 8 and 10. To maintain the acidic pH of 2, 4 and 6 0.01N HCl was added and to maintain the alkaline pH of 8 and 10 1M NaOH was used. 1.5 g of the optimized size adsorbent was taken and heated at the optimized temperature and added to the solutions and kept for the optimum contact time.

4.4.7 Optimization of dosage

To optimise the dosage, 1.5, 3 and 4.5g to 30 ml of the solution with optimised concentration was maintained at optimum pH. The adsorbent with optimum size was heated at optimum temperature and added to the solution. These solutions were mixed thoroughly and kept for an optimum contact time.

4.5 MODELS FOR ADSORPTION ISOTHERMS

4.5.1 Langmuir isotherm (Model 1)

The theory for Langmuir isotherms assumes monolayer coverage of adsorbate over a homogenous adsorbent surface. Therefore at equilibrium; a saturation point is reached where no further adsorption can occur adsorption takes place at specific homogeneous sites within the adsorbent by the following equation (Chenet al, 2015).

$$\frac{C_0}{m} = \frac{abC_e}{1+abC_e} \quad (1)$$

Alternate equation

$$\frac{m}{C_0} = \frac{1}{ab} + \frac{1}{C_e} \quad (2)$$

4.5.2 Freundlich isotherm (Model 2)

The theory for Freundlich isotherms describes a monolayer and multilayer coverage of adsorption over a heterogeneous surface area adsorbent (22). An adsorption isotherm is an empirical relation between the concentrations of solute on to the surface of an adsorbent to the concentration of the solute in the liquid with which it is contact.

In following equation

$$\frac{x}{m} = KC^{1/n} \quad (3)$$

Alternate equation

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log C \quad (4)$$

4.5.3 BET (Brunauer- Emmett -Teller) isotherm (Model 3)

This isotherm describes the physical adsorption of adsorbent on a solid surface and serves as the basis for an important analysis technique for the measurement of the specific surface area of a material.

In following equation.
$$q_e = \frac{K_B \times C_e \times Q_0}{(C_s - C_e) \{1 + (K_B - 1) \left(\frac{C_e}{C_s} \right)\}} \quad (5)$$

Alternate equation

$$\frac{C_e}{(C_s - C_e)q_e} = \frac{K_B - 1}{K_B \times Q_0} \times \frac{C_e}{C_s} + \frac{1}{K_B \times Q_0} \quad (6)$$

4.5.4 Tempkin Isotherm (Model 4)

This isotherm describes the effects of some indirect 1 adsorbate/adsorbate interactions on adsorption isotherms suggested that the heat of adsorption of all the molecules in the layer would decrease linearly with coverage due to these interactions.

In the following equation

$$q_e = \frac{RT}{b_T} \times \ln(K_T C_e) \quad (7)$$

Alternate equation

$$q_e = B_T \ln K_T + B_T \ln C_e \quad (8)$$

4.6 MODELS OF SORPTION KINETICS

4.6.1 Pseudo First Order Kinetics

The pseudo first order equation (Lagergren's Equation) describes adsorption in solid liquid system based on the sorption capacity of solid.

In the following equation

$$\frac{dq_t}{dt} = K_1 (q_e - q_t) \quad (9)$$

Alternate equation

$$\log(q_e - q_t) = \log q_e - \frac{K_1}{2.303} t \quad (10)$$

4.6.2 Pseudo Second Order Kinetics

The pseudo second order rate expression has been applied for analysing chemisorptions kinetics from liquid solutions.

In the following equation

$$\frac{dq_t}{dt} = K_1(q_e - q_t)^2 \quad (11)$$

Alternate equation

$$\frac{t}{q_t} = \frac{1}{K_2} + \frac{1}{q_e} t \quad (12)$$

CHAPTER 5

5.RESULTS AND DISCUSION

Seaweed sample was taken – 5 g and added with 50ml of distilled water and kept in water bath for 30mins then the heated sample was filtered using Whattman filter paper. Cobalt oxide was weighted 5 g and added with 15 ml of filtered sample and kept in magnetic stirrer for 20 min and After the above procedure, UV reading was taken and peak was observed. And the sample is centrifuged and pellet was collected. Finally, the sample was given for characterization (FT-IR).

5.1. UV- SPECTROSCOPY ANALYSIS

The amount of discrete wavelengths of UV or visible light that are absorbed by or transmitted through a sample in contrast to a reference or blank sample is measured by the analytical technique known as UV-Vis spectroscopy. The sample composition has an impact on this feature, potentially revealing what is in the sample and at what concentration. Let's first think about the characteristics of light as this spectroscopy method depends on its utilization.

The energy of light has a fixed value that is inversely proportional to its wavelength. As a result, shorter light wavelengths carry more energy while longer ones carry less. The promotion of electrons in a substance to a higher energy state, which we can observe as adsorption, requires a precise quantity of energy. In a substance, electrons in various bonding conditions require different amounts of energy to move them to higher energy states.

The generated cobalt (II) oxide nanoparticles' UV visible absorption spectra showed a peak at 530 nm.

5.2 FTIR INTERPRETATION FOR SYNTHESIS OF COBALT OXIDE

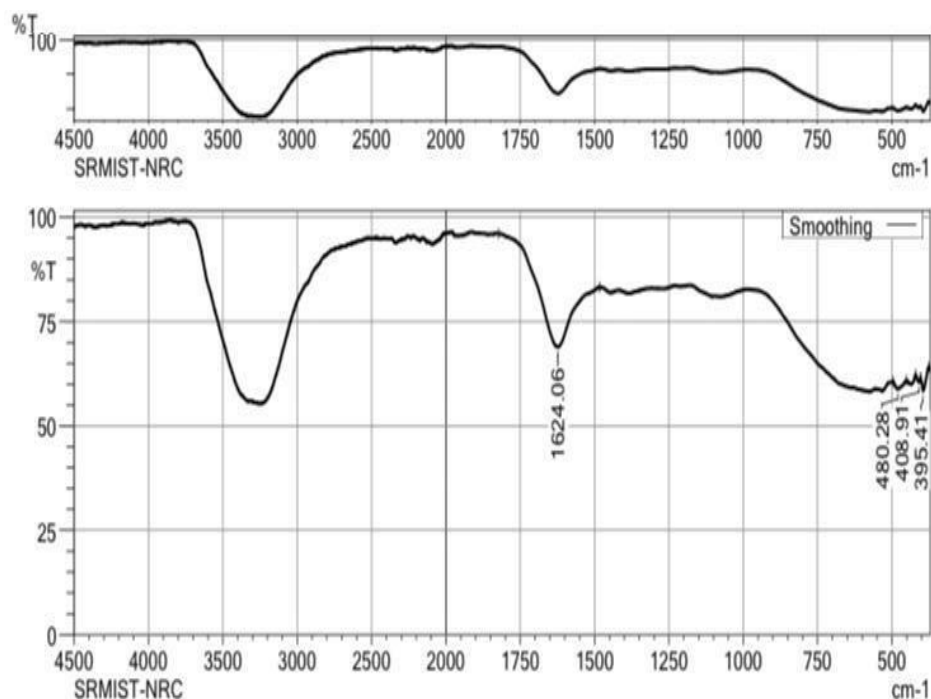


Figure 5.2 shows the FTIR result of the synthesized cobalt oxide

Table 5.2 IR spectrum table for the synthesized cobalt oxide

S.No	Wavelength Range	Peak Observed	Appearance	Functional Group	Group
1	3300-2500	3200	Strong, Broad	Carboxylic acid	O-H stretching
2	1650-1600	1624.06	Medium	Conjugated alkene	C=C Stretching

The peak obtained at wavelength 3200 has strong and broad peak, when compared with the peak obtained at the wavelength 1624.06.

Due to proton sharing with oxygen atoms that are nearby in nature, an OH group has a wide range of energy on an IR spectrum. The O-H bond has a propensity to vibrate in various locations and at various frequencies. The relationship stretches more as a result.

5.3 POTASSIUM DICHROMATE AND ACTIVATED CARBON PROCESS

Conical flask was taken and filled with 100ml of distilled water and 1 g of Potassium dichromate. (base solution)

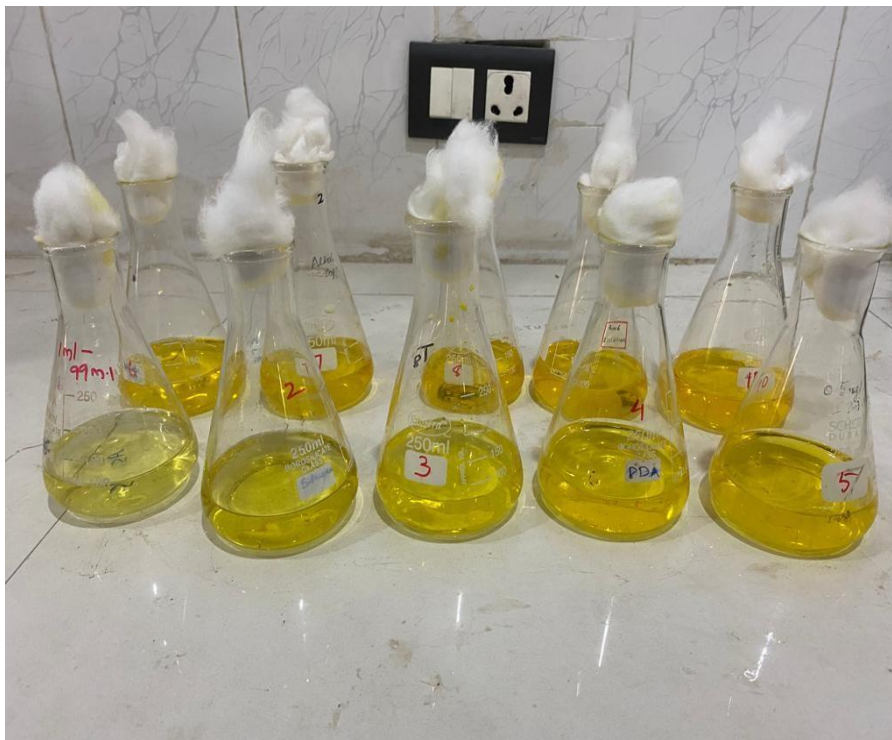


Figure 5.3 Different Concentration of the heavy metals prepared with distilled water

10 conical flask was taken, in the below concentration

1st conical flask - 1ml solution + 99ml distilled water, 2nd conical flask - 2ml solution + 98ml distilled water, 3rd conical flask - 3ml solution + 97ml distilled water, 4th conical flask - 4ml solution + 96ml distilled water, 5th conical flask - 5ml solution + 95ml distilled water, 6th conical flask - 6ml solution + 94ml distilled water, 7th conical flask - 7ml solution + 93ml distilled water, 8th conical flask - 8ml solution + 92ml distilled water, 9th conical flask - 9ml solution + 91ml distilled water, 10th conical flask - 10ml solution + 90ml distilled water

The initial spectrophotometric reading was noted for all the concentrations in the conical flasks. For the above concentrations, the spectrophotometric reading was noted at 235nm.

Table 5.3 Spectrophotometric reading of the heavy metals

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.029	7.4	14643
2	235	0.057	30.6	14646
3	235	0.098	45.5	14650
4	235	0.124	50.4	14665
5	235	0.248	65.2	14661
6	235	0.498	60.0	14646
7	235	0.569	70.0	14647
8	235	0.665	75.2	14639
9	235	0.982	80.1	14655
10	235	1.120	85.1	14651

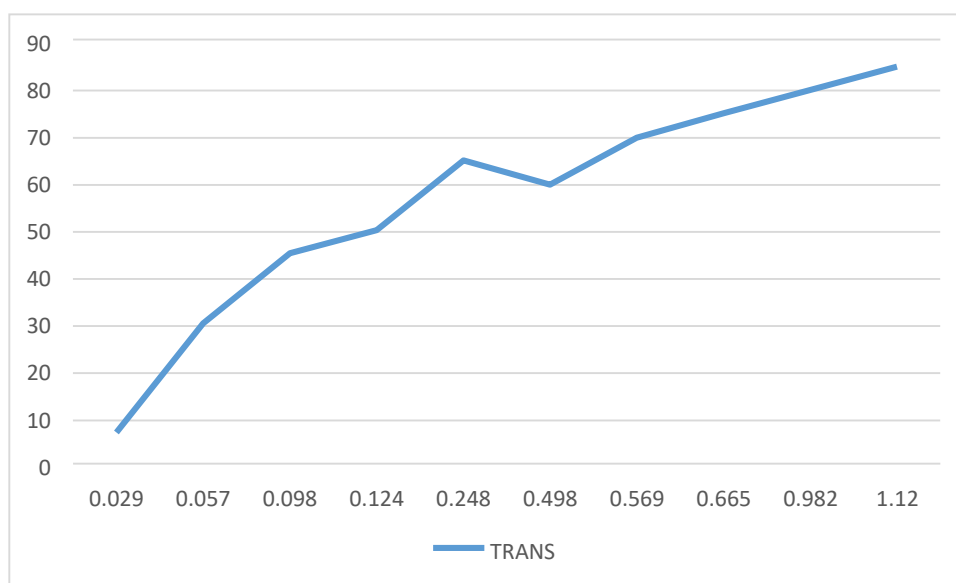


Figure 5.3.1 Spectrophotometric reading of the heavy metals

After the first spectrophotometric reading, the activated charcoal was added in the range of 250 mg, 500 mg, 750 mg, 1.000 mg, 1.250 mg in the base solution (100ml of distilled water and 1 g of potassium dichromate.)

The solution was centrifuged and filtered for the spectrophotometric reading and it was noted at 235 nm for every 2 to 3 hours until lowest adsorption value is noted.



Figure 5.3.2 Activated charcoal added to all the conical flasks

Table 5.3.1 Spectrophotometric reading of the sample after adding activated charcoal

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.198	63.4	3742
2	235	0.281	52.4	3726
3	235	0.413	38.6	3706
4	235	0.570	26.9	3689
5	235	1.120	7.6	3661

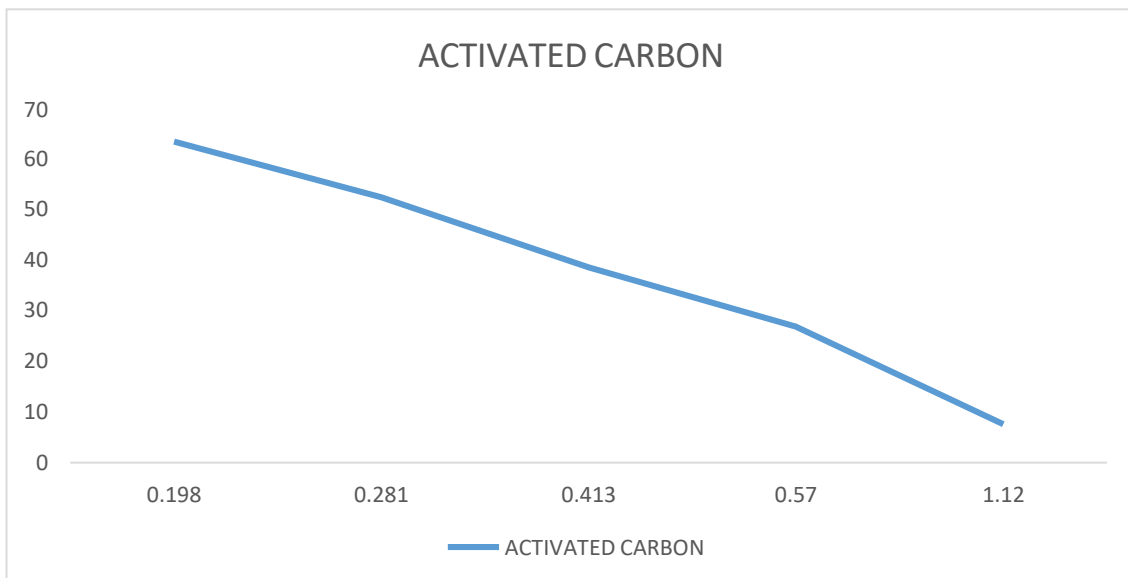


Figure 5.3.3 Spectrophotometric reading of the sample after adding activated charcoal

Table 5.3.2 Spectrophotometric reading after 1-hour time interval

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.155	100.0	14950
2	235	0.165	99.9	14927
3	235	0.308	99.9	14656
4	235	0.664	100.0	14661
5	235	0.588	100.0	14646

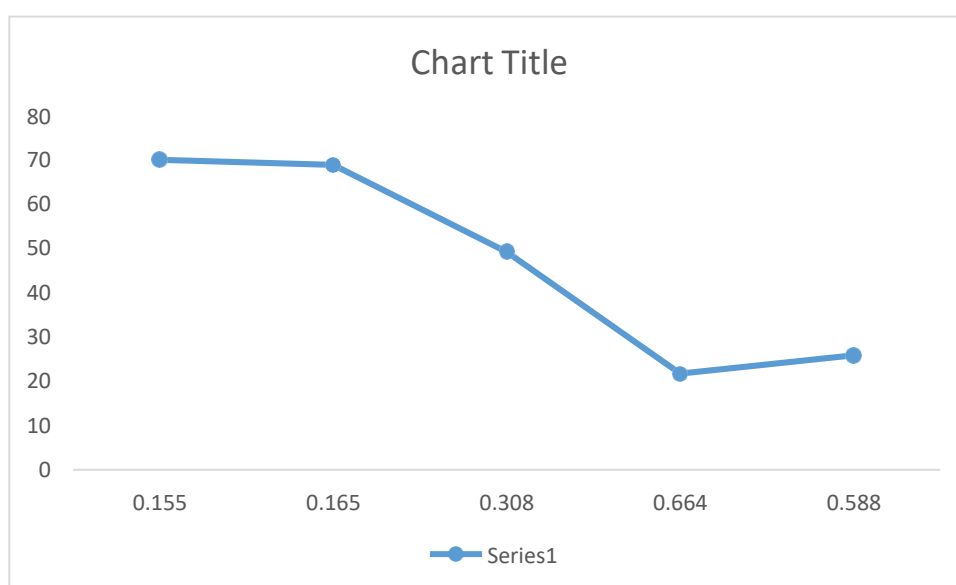


Figure 5.3.4 Spectrophotometric reading after 1-hour time interval

Table 5.3.3 Spectrophotometric reading after 2-hour time interval

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.001	99.7	14950
2	235	0.002	99.6	14936
3	235	0.002	99.5	14927
4	235	0.002	99.5	14919
5	235	0.002	99.5	14919

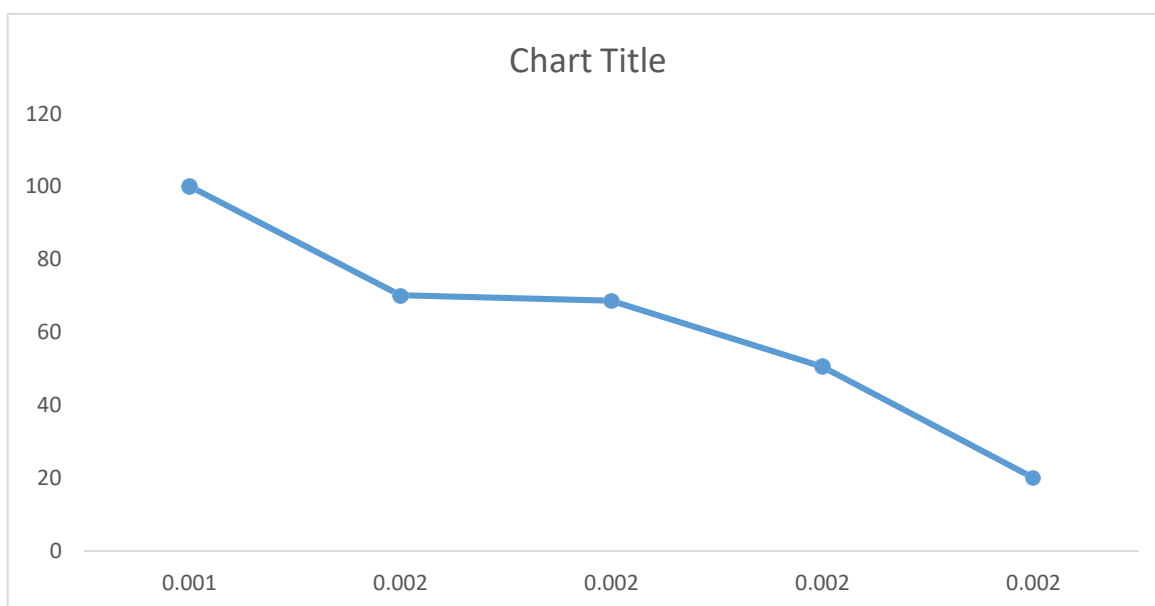


Figure 5.3.5 Spectrophotometric reading after 2 hour time interval

The lowest absorbance value was obtained at solution where 5.00 mg of activated charcoal added, so the particular gram of activated charcoal was taken for the further procedure.

The activated charcoal of 5 g was added in the base solution. 100ml of distilled water and 1 g of potassium dichromate. The spectrophotometric reading was noted at 235 nm for every 2 to 3 hours after centrifugation process and the pellet was collected and FTIR analysis was done.

Table 5.3.4 Final spectrophotometric reading of the absorbed activated charcoal

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.001	99.8	14494

Table 5.3.5 Spectrophotometric reading after 1-hour time interval

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	-0.001	100.2	14535

5.4 COATING WITH POLY-ETHYLENE GLYCOL(PEG)

The pellet from synthesized sample was taken and added with PEG(0.300gm) and 2 ml of distilled water. The above solution was mixed well and kept in stirrer for few min and it is centrifuged and the pellet was collected. 5g of activated charcoal was added with previously collected pellet and 50ml of distilled water. And kept in magnetic stirrer for about 20 hours.

The next day, the solution was centrifuged and the pellet was collected for about 1 g. Finally, 100ml of distilled water, 1 g of potassium dichromate was added. From the above solution, 10ml was taken. In that 10ml of solution, 90ml distilled water, 500mg of activated carbon and 1 g of collected pellet was added, and centrifuged for the spectrophotometric reading. The spectrophotometric reading was done till the absorbance value is 0.000 for every 10 min at the range of 235nm.



Figure 5.4 Sample with activated charcoal kept in magnetic stirrer

Table 5.4 Spectrophotometric reading after coating heavy metals

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.000	100.0	14635

Table 5.4.1 Spectrophotometric reading after 1-hour time interval

S.No	Wavelength	Absorbance	Transmittance	Energy
1	235	0.000	100.0	21565

5.5 FT-IR INTERPRETATIONS FOR HEAVY METALS AND ACTIVATED CARBON

The term "Fourier transform infrared" (FT-IR) refers to the most popular kind of infrared spectroscopy. All infrared spectroscopies operate under the premise that some IR energy is absorbed when it passes through a material. It is noted which radiation enters the sample.

For a number of reasons, FTIR is the favored approach to infrared spectroscopy. First off, the sample is not ruined. Second, it is far quicker than earlier methods. Thirdly, it is far more accurate and sensitive.

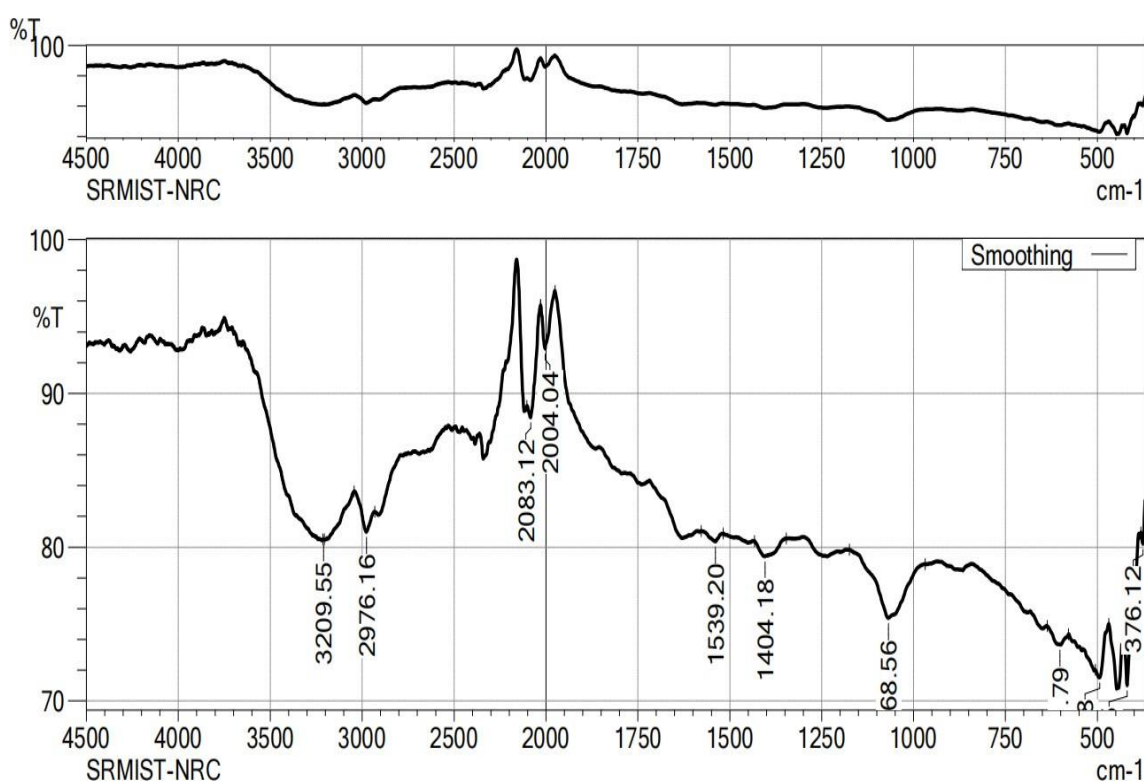


Figure 5.5 FTIR result of the heavy metals

Table 5.5 FTIR interpretation of the above result

S.No	Wavelength	Peak observed	Appearance	Group	Compound Class
1	3300-2500	3209.55	Strong, Broad	O-H Stretching	carboxylic acid
2	3000-2840	2976.16	Medium	C-H Stretching	Alkane
3	2140-1990	2083.12	Strong	N=C=S Stretching	Isothiocyanate
4	2140-1990	2083.12	Strong	N=C=S Stretching	Isothiocyanate
5	1550-1500	1539.20	Strong	N-O Stretching	Nitrocompound
6	1410-1380	1404.18	Strong	S=O Stretching	sulfonyl chloride
7	1070-1030	1068.56	Strong	S=O Stretching	Sulfoxide

The peak obtained at 3209.55 has the strong and broad appearance with O-H Bonding and carboxylic compound.

Due to proton sharing with oxygen atoms that are nearby in nature, an OH group has a wide range of energy on an IR spectrum. The O-H bond has a propensity to vibrate in various locations and at various frequencies. The relationship stretches more as a result.

There is also other peak obtained as strong appearances with various bonding and compound classes.

There is no weak appearances obtained in this FTIR interpretation.

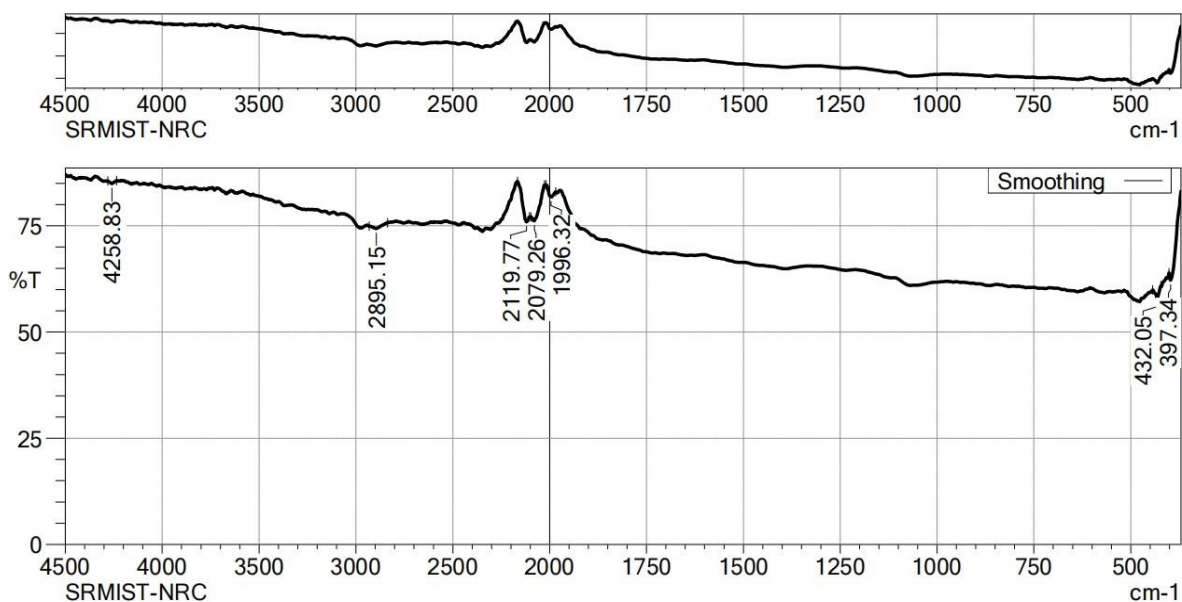


Figure 5.5.1 represents the FT-IR results of the sample after 1 hour

Table 5.5.1 FT-IR results of the sample after 1 hour

S.NO	WAVE LENGTH	PEAK OBSERVED	APPEARANCE	GROUP	COMPOUND CLASS
1	2830-2695	2895.15	Medium	C-H Stretching	Aldehyde
2	2175-2140	2119.77	Weak	C=	
3	2140-1990	2079.26	Strong	N=C=S stretching	isothiocyanate
4	2000-1650	1996.32	Weak	C-H Stretching	aromatic compound

Strong bond appears at the wavelength of 2079.26 with N=C=S bonding.

Isothiocyanate compound class also presented in this wavelength range.

Two weak bonds are appeared at the wavelength of 2119.77 and 1996.32 with different bonding and compound class each.

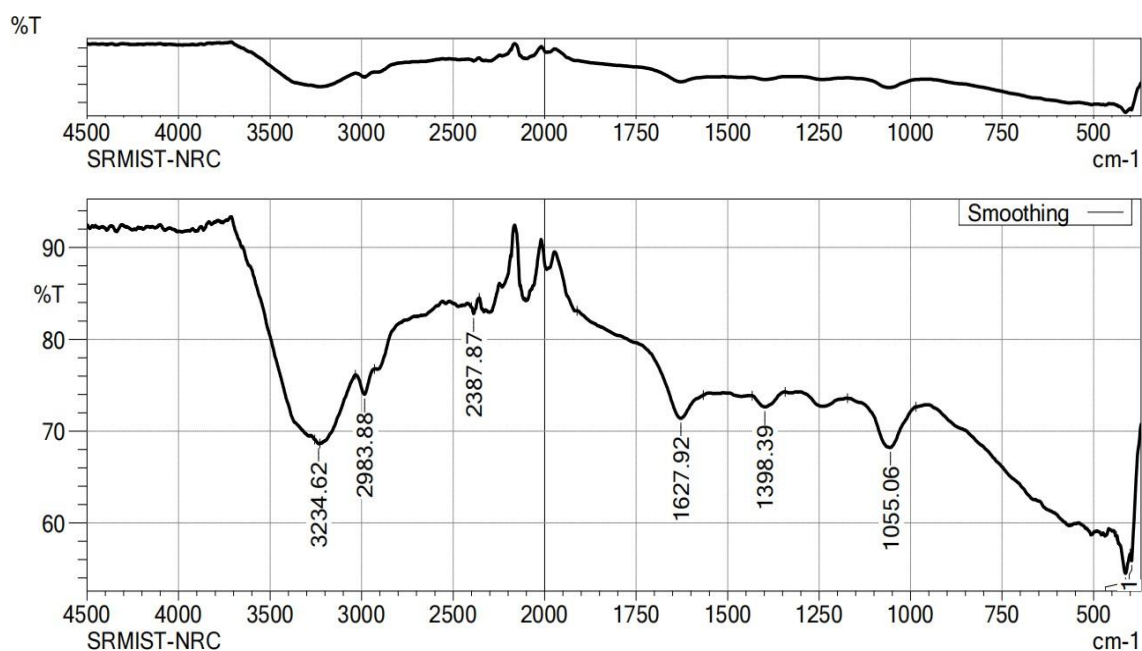


Figure 5.5.2 Shows the FT-IR result after adsorption of Chromium

Table 5.5.2 FT-IR result after adsorption of Chromium

S.No	Wavelength	Peak Observed	Appearance	Group	Compound class
1	3300-2500	3234.62	Strong, Broad	O-H Stretching	Carboxylic acid
2	3000-2840	2983.88	Medium	C-H Stretching	alkane
3	1650-1600	1627.92	Medium	C=C Stretching	Conjugated alkane
4	1425-1380	1398.39	Strong	S=O Stretching	Sulfonyl chloride
5	1050-1085	1055.06	Strong	C-O Stretching	Primary alcohol

The peak obtained at 3234.62 has the strong and broad appearance with O-H bonding and carboxylic acid are presented. The peak obtained at 2983.88 and 1627.92 has the medium appearance with different group and compound class.

The peak obtained at 1055.06 has the strong appearance with compound class of primary alcohol.

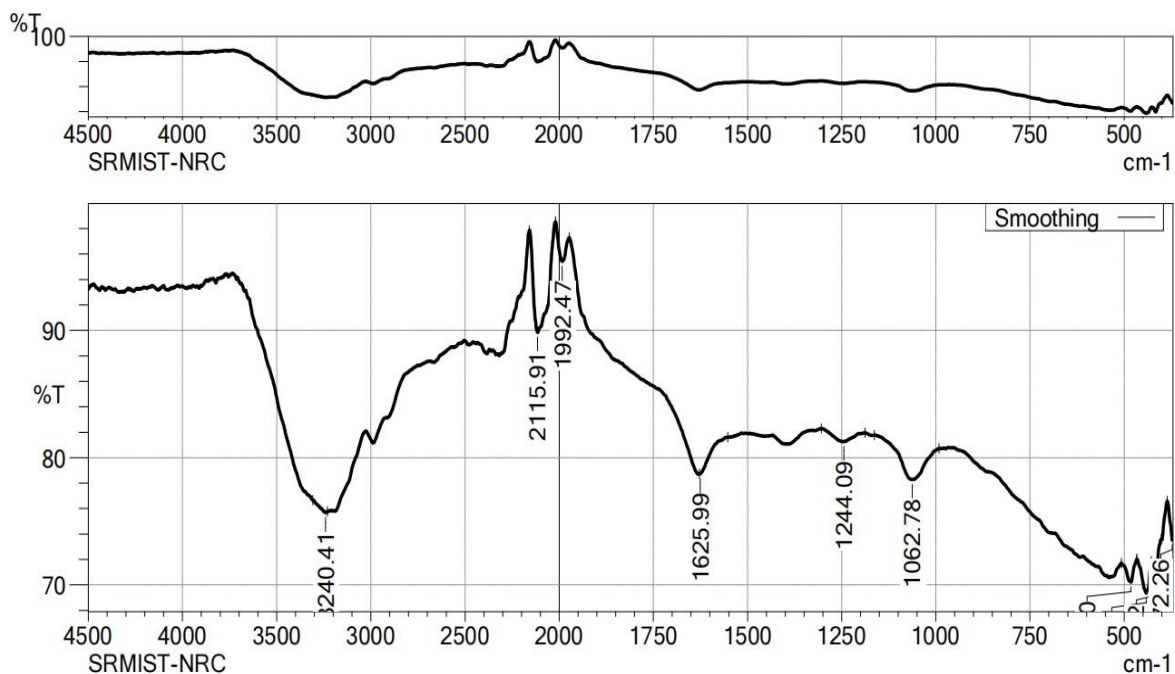


Figure 5.5.3 FTIR result after an hour of adsorption of Chromium

Table 5.5.3 Interpretation of FT-IR after 1-hour of adsorption of Chromium

S.No	Wavelength	Peak observed	Appearance	Group	Compound class
1	3300-2500	3240.41	Strong, Broad	O-H Stretching	Carboxylic acid
2	2140-2100	2115.91	Weak		alkyne
3	2000-1650	1992.47	Weak	C-H Bending	Aromatic compounds
4	1650-1600	1625.99	Medium	C=C Stretching	Conjugated alkene
5	1275-1200	1244.09	Strong	C-O Stretching	Aromatic ester
6	1070-1030	1062.78	Strong	S=O Stretching	sulfoxide

5.6 SEM ANALYSIS

A concentrated electron beam is utilized in SEM examination, a potent investigative technique, to create intricate, high-magnification images of a sample's surface topography. The interactions of the electron beam with atoms at different depths within the sample give rise to the signals that a SEM uses to create an image. Secondary electrons (SE), reflected or backscattered electrons (BSE), distinctive X-rays and light (cathodoluminescence), adsorbed current (specimen current), and transmitted electrons are only a few of the signals that are generated. All SEMs come equipped with secondary electron detectors, however it is uncommon for a single instrument to incorporate detectors for all other potential signals (Krivanek *et al.*, 2010).

In order for SEM samples to resist the high vacuum conditions and the high intensity electron beam, they must be tiny enough to fit on the specimen stage and may need specific processing to improve their electrical conductivity and stabilize them. Typically, a conductive adhesive is used to fix samples rigidly on a specimen holder or counterfoil.

A tungsten filament cathode-equipped electron gun emits an electron beam thermionically in a conventional SEM. Due to its high melting point and low vapor pressure compared to other metals, which enables electrical heating for electron emission, and due to its low price, tungsten is typically employed in thermionic electron cannons.

The nature of the SEM's probe, energetic electrons, makes it perfectly suited for probing the optical and electrical properties of semiconductor materials. The high-energy electrons from the SEM beam will introduce charge carriers into the semiconductor. As a result, electrons in the beam are promoted from the valence band to the conduction band, losing energy in the process and leaving holes in their wake.

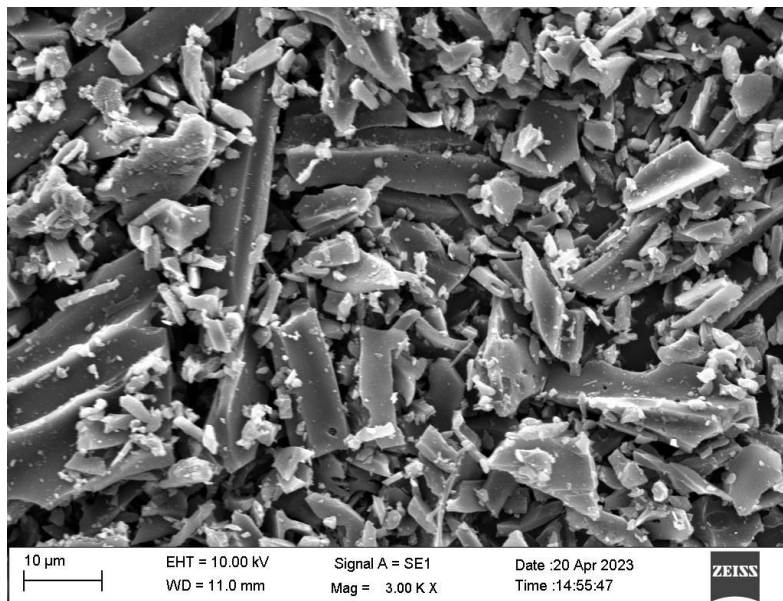


Figure 5.6 Represents the SEM result sample

There is no adsorption of activated charcoal shows in the above SEM result.

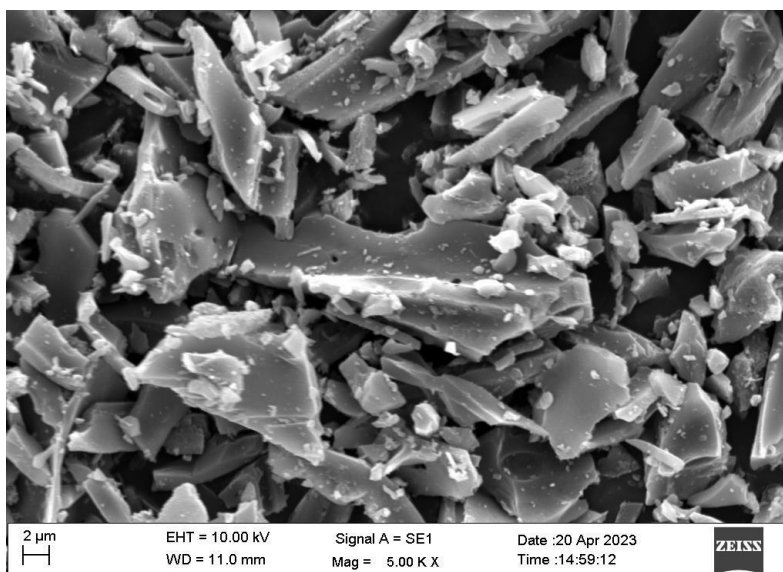


Figure 5.6.1 SEM result of sample after an hour of adding activated charcoal

There is no adsorption of activated charcoal is observed due to the absence of the pores in the above result.

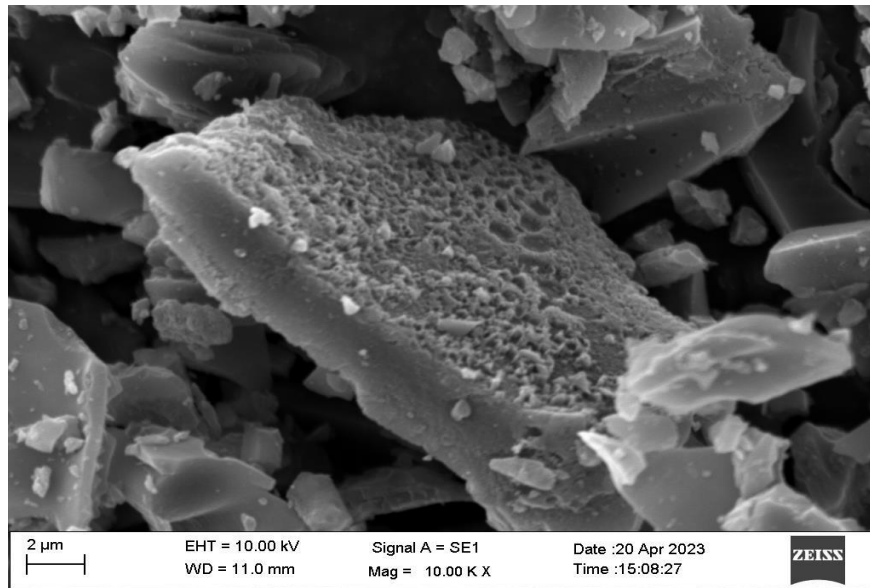


Figure 5.6.2 Adsorption of activated charcoal

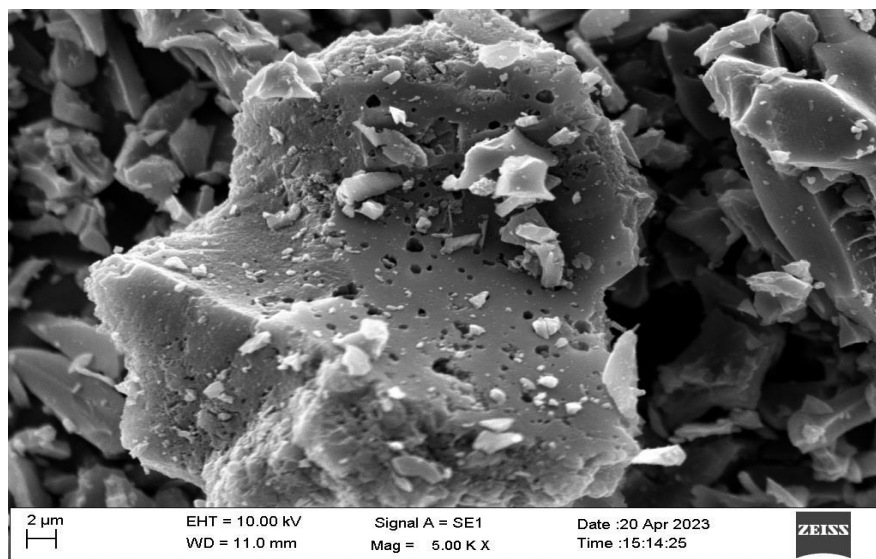


Figure 5.6.3 Adsorption of activated charcoal at higher magnification

The above pictures represent the presents of the activated charcoal due its visibility of the pores. Figure 5.6.3 shows adsorption of activated charcoal with the nanoparticles without coating.

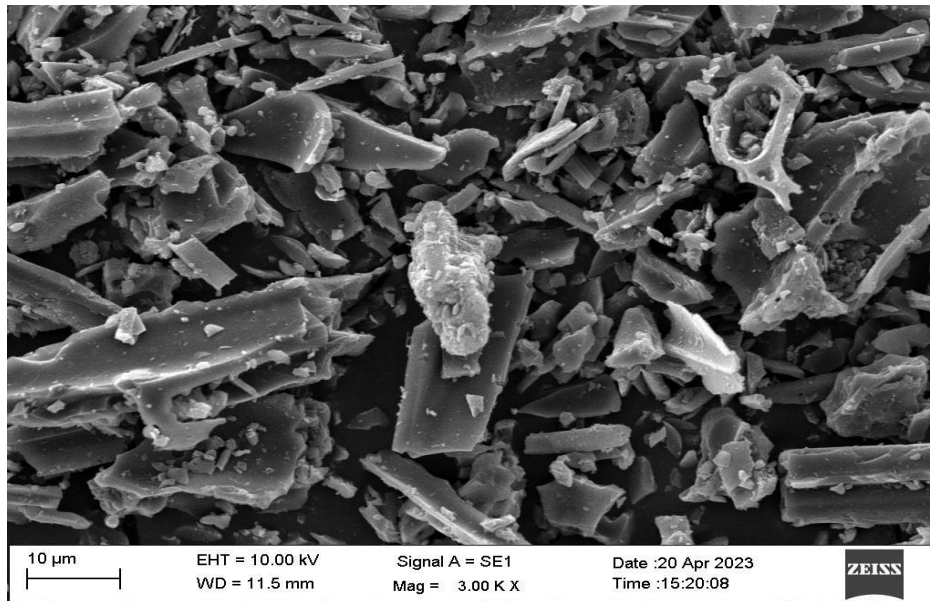


Figure 5.6.4 shows the coated nanoparticle

From the above SEM analysis result we can say that nanoparticels are coated by the heavy metals in the presence of activated charcoal.

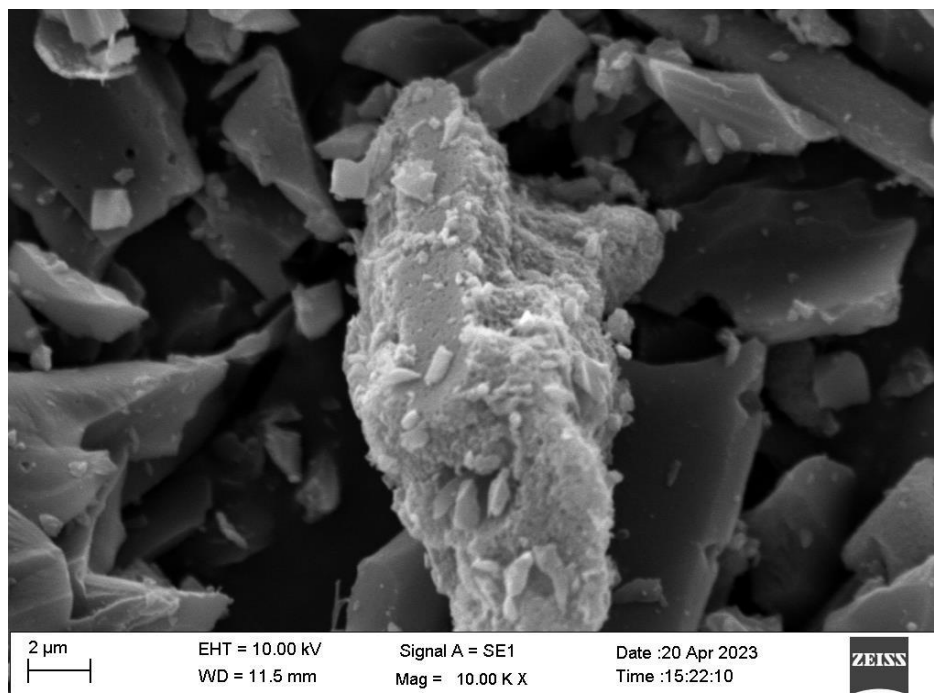


Figure 5.6.5 Coated nanoparticle at higher resolution

5.7 ADSORPTION KINETICS

5.7.1 Pseudo first order kinetics

$$\frac{dq_t}{dt} = K_1 (q_e - q_t)$$

$$\frac{dq_t}{dt} = 0.0619(118.713 - q_t)$$

$$K_1 = 0.0619 \text{ min}^{-1} \quad q_e = 118.73 \text{ mg/g}$$

5.7.2 Pseudo second order kinetics (Figure -3b)

$$\frac{dq_t}{dt} = K_2 (q_e - q_t)^2 \quad \frac{dq_t}{dt} = 0.01915(79.36 - q_t)^2$$

$$K_2 = 0.01915 \text{ g mg}^{-1} \text{ min}^{-1} \quad q_e = 79.36 \text{ mg/g}$$

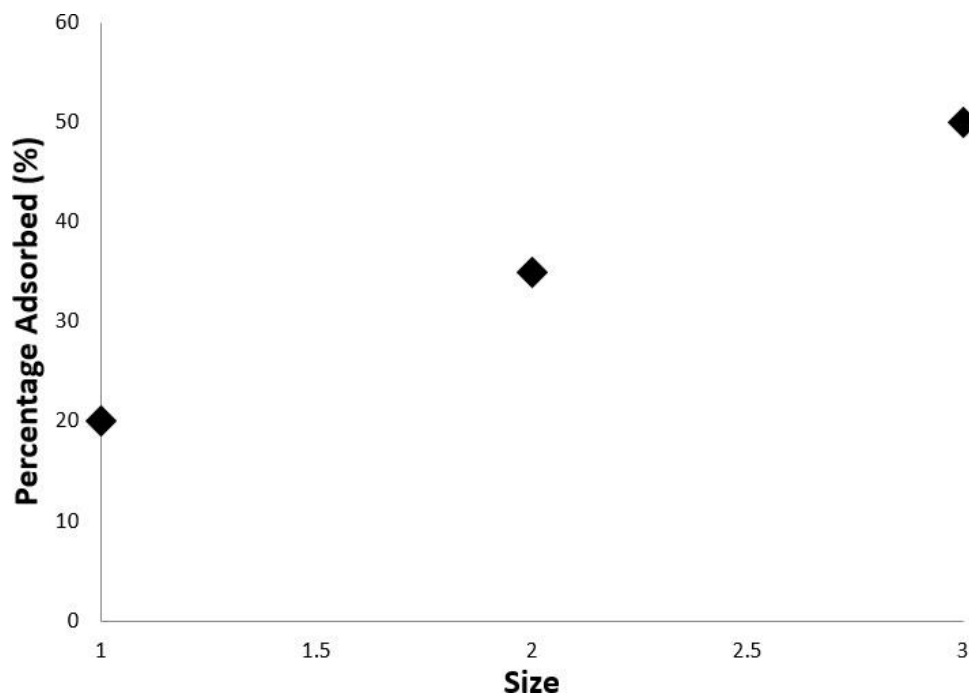


Figure 5.7.1 Influence of concentration on the adsorption

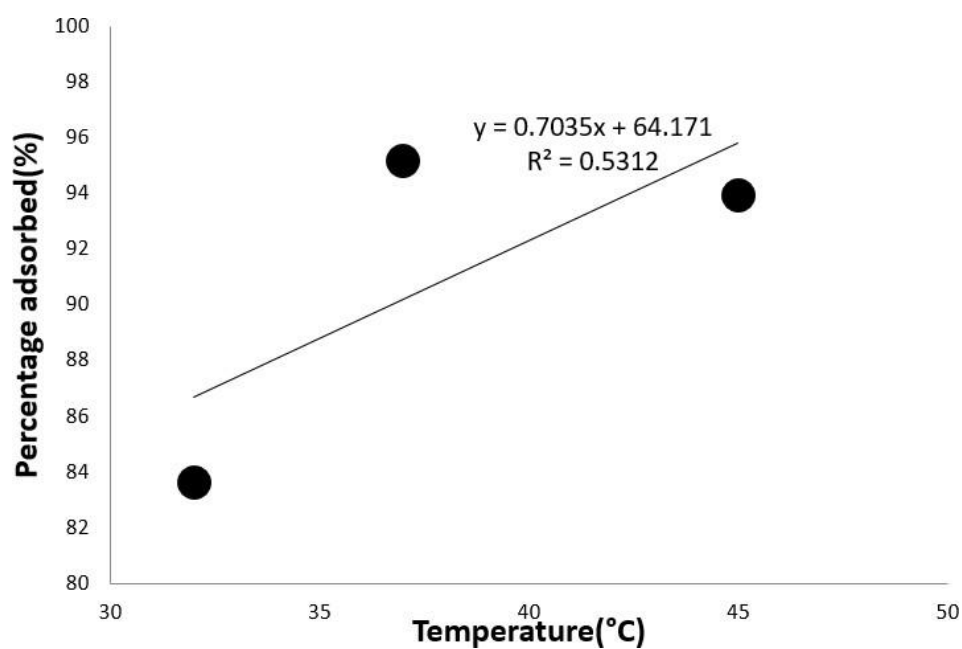


Figure 5.7.2 Influence of temperature on Chromium removal

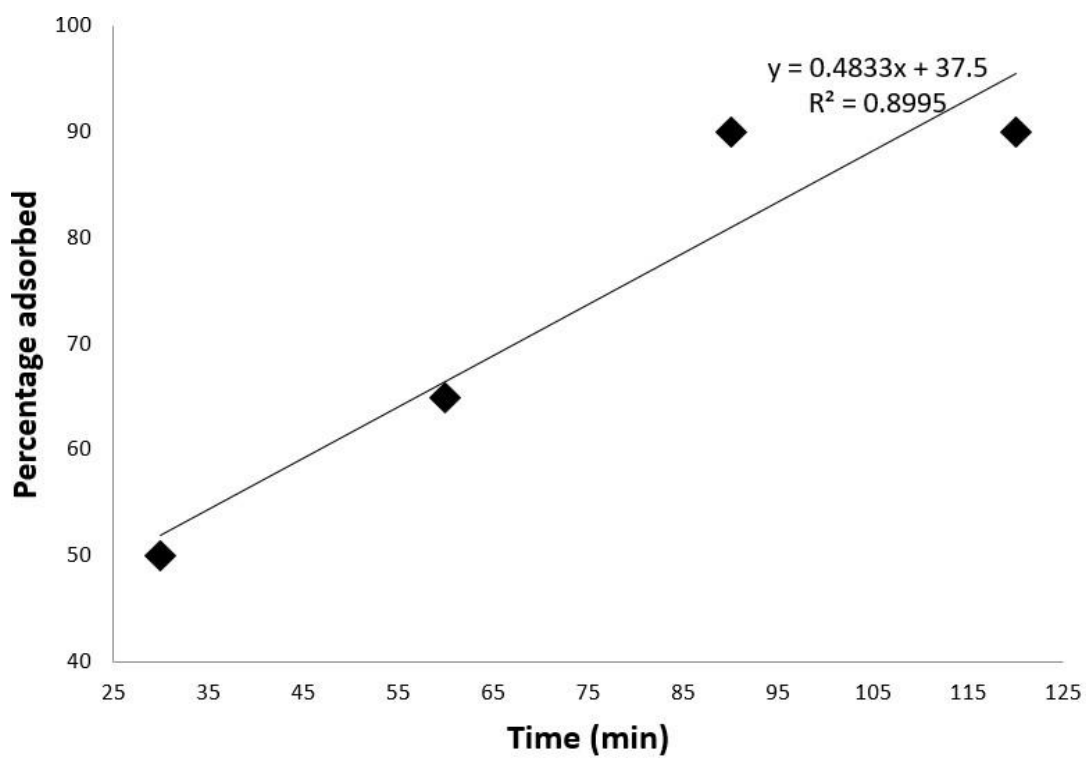


Figure 5.7.3 Influence of contact time on Chromium removal

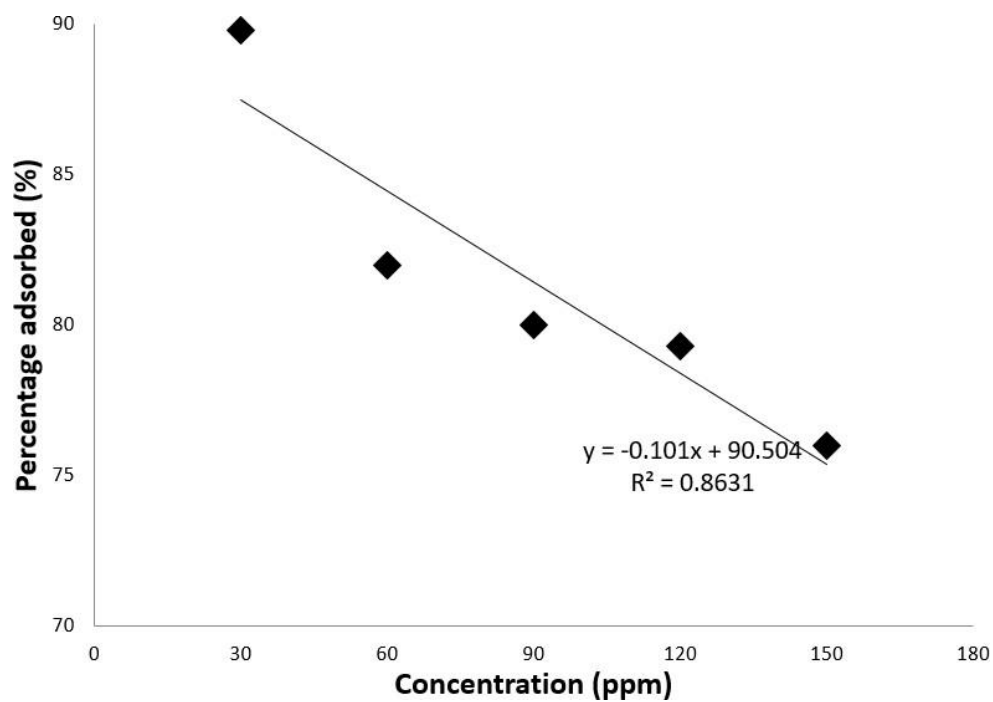


Figure 5.7.4 Influence of dosage on Chromium removal

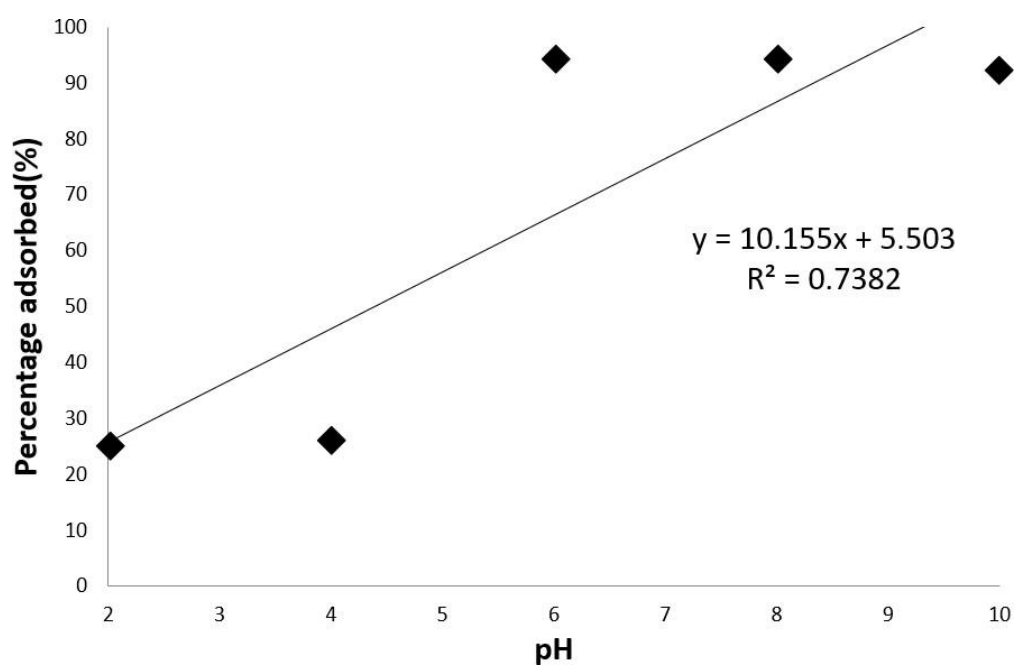


Figure 5.7.5 Influence of pH on Chromium removal,

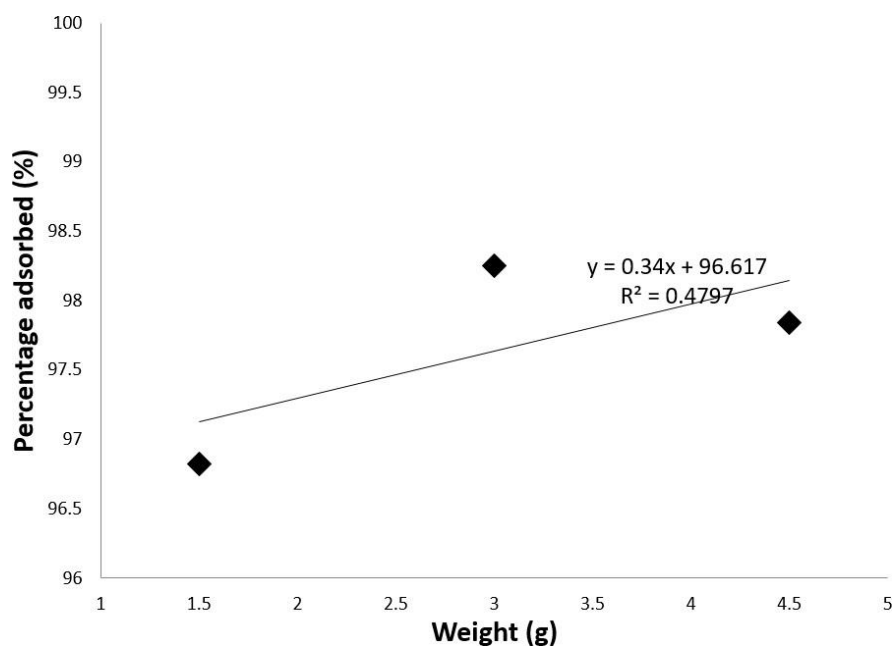


Figure 5.7.6 Influence of dosage on Chromium removal

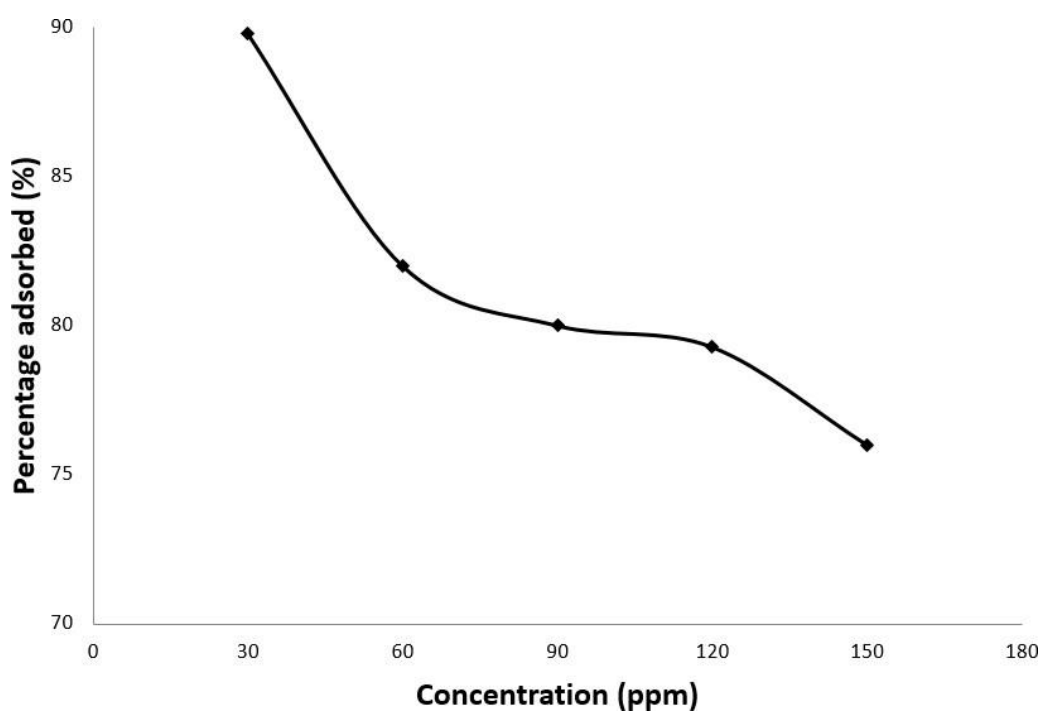


Figure 5.7.7 Langmuir Isotherm

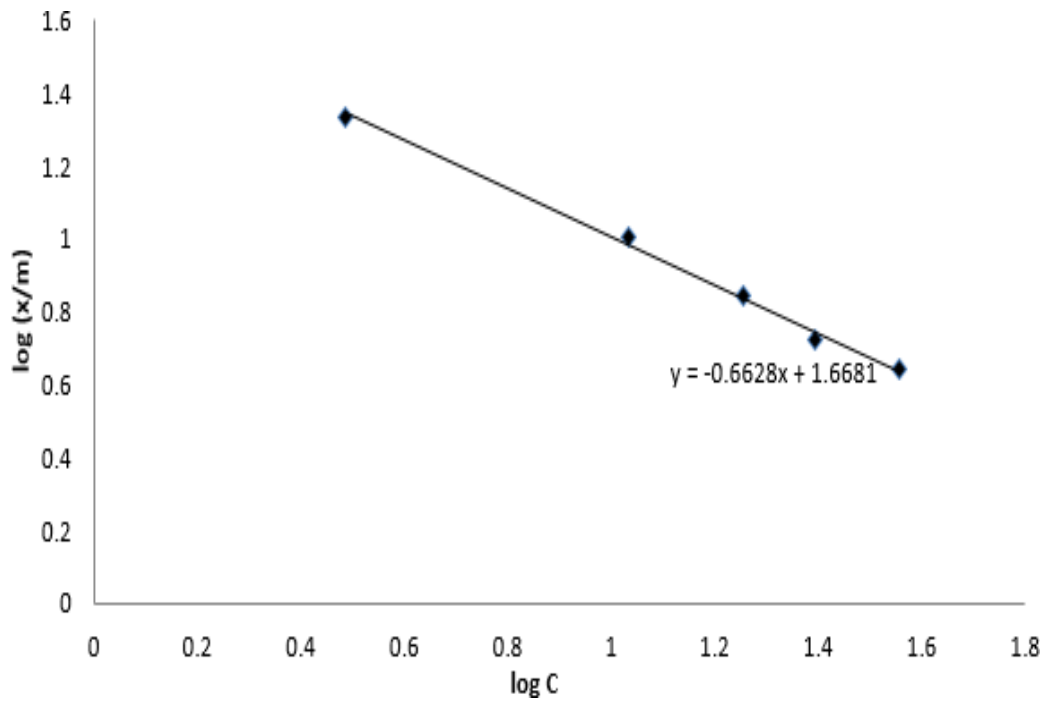


Figure 5.7.8 Freundlich Isotherm

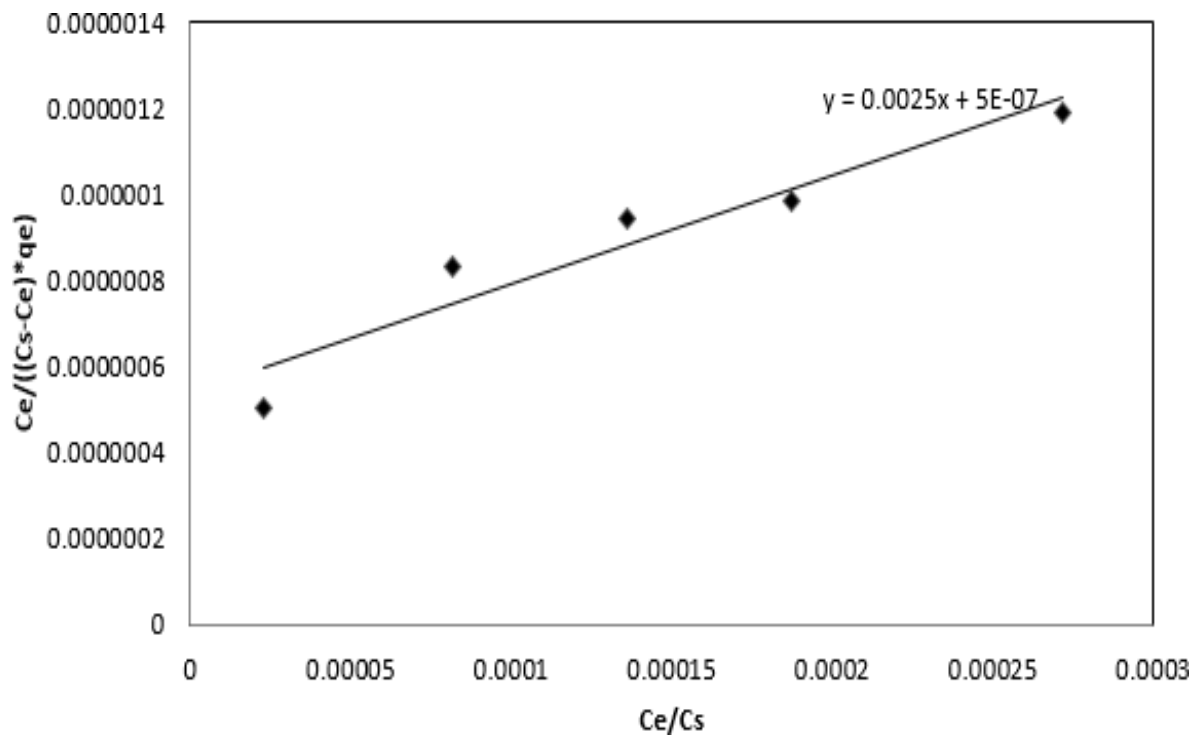


Figure 5.7.9 BET Isotherm

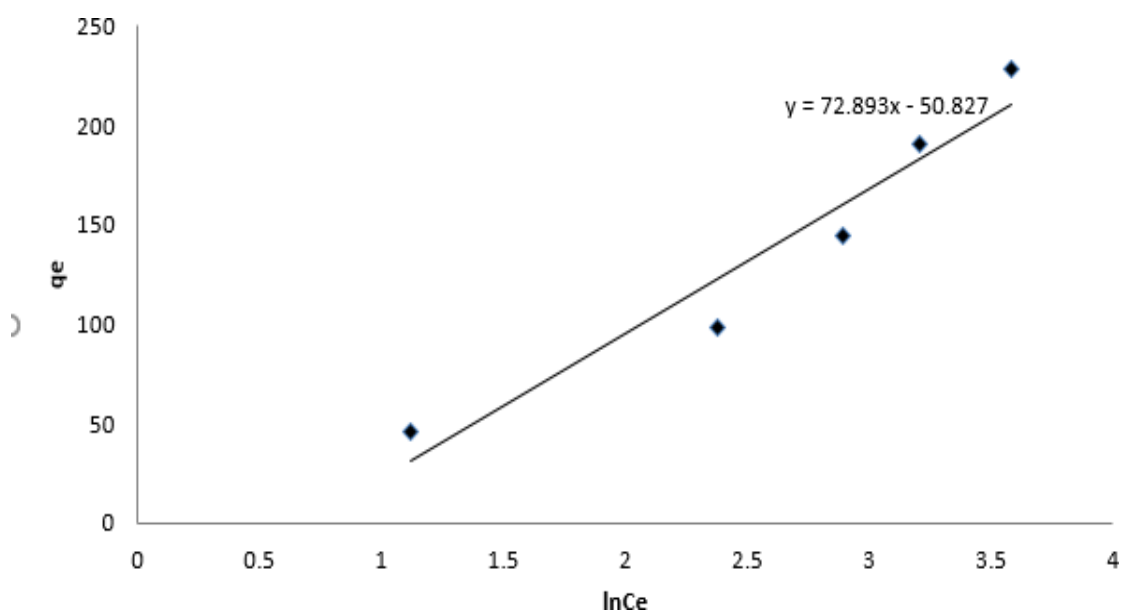


Figure 5.7.10 Temkin Isotherm

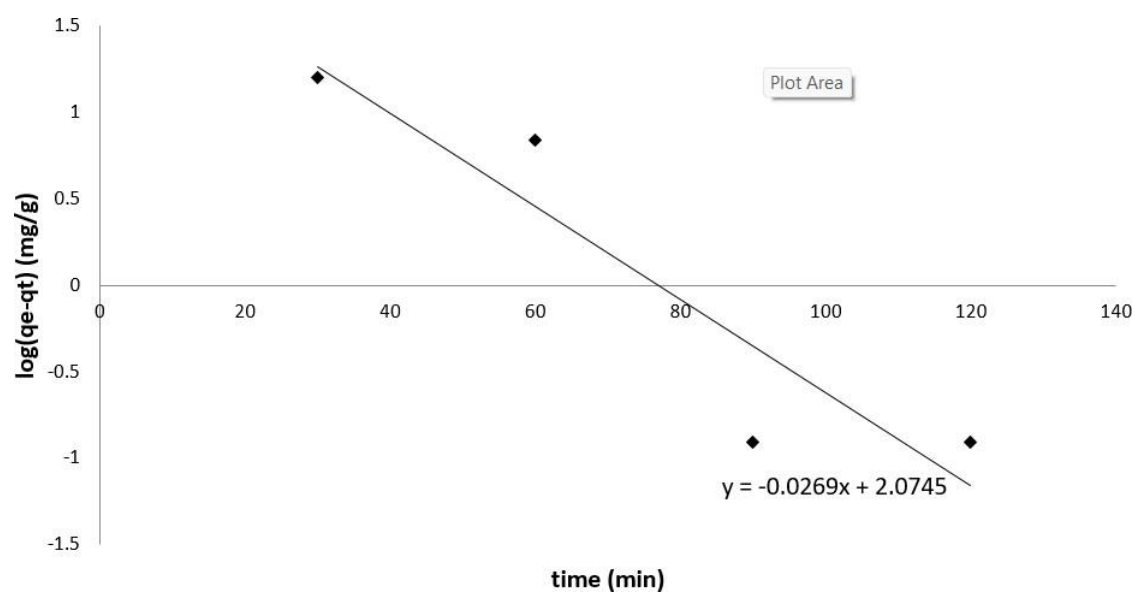


Figure 5.7.11 Pseudo first order

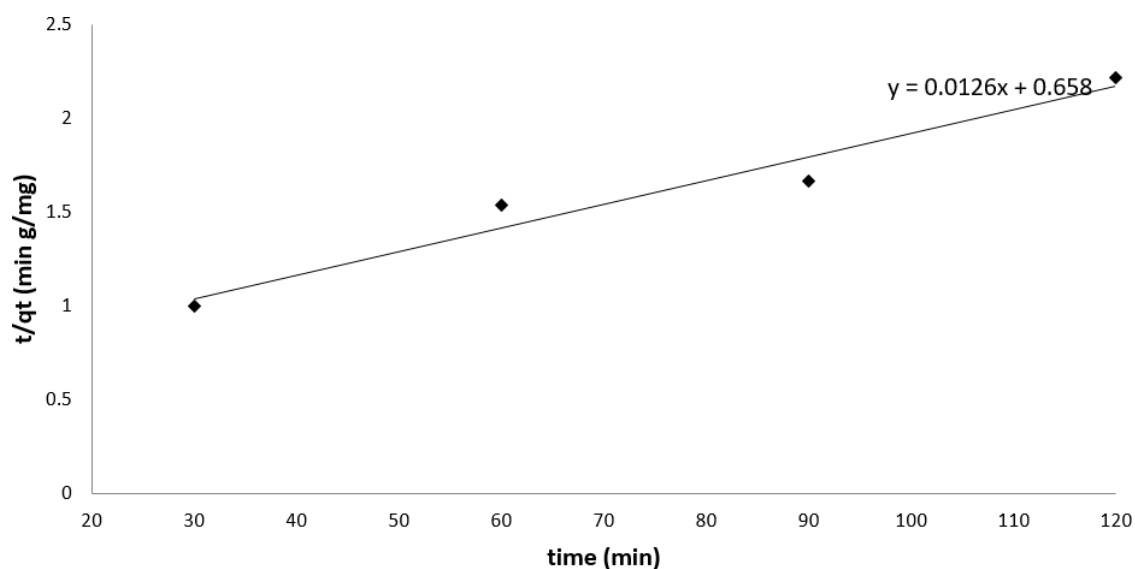


Figure 5.7.12 Pseudo second order

Table 5.7.1 Adsorption Isotherms with R^2 values

Isotherms	R^2 value
Langmuir Isotherm	0.9857
Freundlich Isotherm	0.9961
BET Isotherm	0.9172
Temkin Isotherm	0.9316

Table 5.7.2 Adsorptions Kinetics with R^2 value

Kinetics	R^2
Pseudo first order	0.8616
Pseudo second order	0.9534

Table 5.7.2 shows that the Pseudo second order is the most appropriate kinetics for the experiment because its R^2 value is 0.9961, which is closer to linearity.

On chitin and chitosan biopolymers, adsorption kinetic experiments for various metal ions were conducted. Cu ions follow pseudo second order kinetics, Pb ions follow pseudo first order, Cd ions follow pseudo second order, and Ni ions follow pseudo first order were studied, along with Cu ions on H₃PO₄- treated rice husk,

which matches the result of activated carbon with Cobalt NPs boosted by PEG. As the adsorption isotherms and adsorption kinetics were explored on these parameters, the analysis of the adsorbent under the influence of various parameters was concluded. To investigate the adsorbent's properties, instrumental analysis was performed. The research revealed that adsorption occurs at a higher rate at lower concentrations, so further research was conducted at a 30 ppm concentration.

This concentration value was used to establish the particle size of the adsorbent. As particle size decreases, surface area increases, leading to increased adsorption by tiny particles. This suggests that larger pore size have a higher adsorption capacity. Based on the concentration and dimensions, a study of the contact time was conducted. There was no longer any adsorption occurring after 90 minutes. Therefore, the optimal time for the process of adsorption has arrived. On the basis of the aforementioned characteristics, a study based on temperature was conducted. The optimal adsorption temperature was 37°C. A study of numerous pH levels revealed that a pH of 6.5 is optimal. It was determined that the optimal concentration for adsorption is 3 g per 30 ml of adsorbent. After calculating the various isotherms, the regression parameter revealed that the Freundlich isotherm best describes this adsorption. According to studies, this adsorption follows pseudo-second-order kinetics.

CHAPTER 6

6. SUMMARY AND CONCLUSION

For a healthy environment and society, it is crucial to remove heavy metal ions from wastewater. The removal of heavy metal ions from various wastewater sources has been the subject of many reported methods. These techniques could be divided into categories such as adsorption-, membrane-, chemical-, electric-, and photocatalytic-based therapies.

To remove the heavy metals from the waste water, cobalt oxide nanoparticles are used. Firstly, cobalt oxide nanoparticle is synthesized by the green method using seaweed pigments.

In this project, Potassium dichromate is used as the heavy metals and PEG (poly ethylene glycol) is used to link the activated charcoal and the heavy metal. Activated charcoal has the tendency to adsorb the heavy metals. With the interpretation of the FTIR, SEM characterization, it is confirmed that heavy metal is combined with the nanoparticle - cobalt oxide. By the adsorption of the activated charcoal. Presence of activated charcoal represents the pores.

The adsorbent was identified as a good candidate for the removal of chromium, different parameters were evaluated and the effective adsorption of the compounds. The adsorption isotherms showed that the Freundlich Isotherm is a better adsorption model and the characteristic parameters were determined. The results of the kinetic models showed that the pseudo second order kinetics was established to be related with the experimental data.

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