



Orange Peel as a Green Adsorbent for Wastewater Treatment

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ABSTRACT: This abstract will briefly examine the process of treating wastewater with natural adsorbents and discuss its operation. Impurities must be removed from wastewater through treatment before being discharged into the environment. When using traditional methods, applying procedures requiring a significant amount of energy and chemical input is frequently necessary. On the other hand, naturally occurring adsorbents have garnered much attention because they are inexpensive, highly efficient, and positively affect the environment. The surface of the adsorbent material is where contaminants adhere to and are pulled to as part of the adsorption process. There are a variety of elements that influence the adsorption capacity of an adsorbent. These factors include the chemical composition, surface area, porosity, and functional groups on the surface. The effectiveness of adsorption is also significantly influenced by many other factors, such as pH, temperature, contact time, and the percentage of starting pollutant concentration.

Introduction: As a result of its remarkable ability to dissolve in a wide range of different substances, water has been given the moniker of "universal solvent." Only one substance can exist in all three physical states—gas, liquid, and solid—and always takes on more than one form. This substance is the only one that can exist in all three of these states. Water makes up a significant portion of the Earth's surface and the human body, albeit to diverse degrees. It is a component required to keep life occurring [1]. On the other hand, this material is a liquid at room temperature and has no noticeable aroma or taste. It is an essential substance that is utilized in a big way. The overall volume of the hydrosphere is approximately 96.4%, comprised of oceans and seas, with underground water accounting for around 1.68% of the total volume. Icy and snow make up more than two percent of the total. In addition, the earth's surface freshwater, saline lakes, and inland oceans together account for 0.059% of the total water

on the planet. Even though some water is in the air and everything is alive, it is only in tiny amounts.

All forms of life need to have access to aqueous solutions. It is distinguished from other substances by its range of exceptional features. The majority of this stuff is odorless, and it appears to be clear for the most part. A significant amount of water is discharged into the environment after it has been used in residential and commercial settings. For many decades, the effluent from the textile industry has been the primary contributor to the pollution of water sources. This is the text you entered: "[2]." The term "pollutant" describes a substance when its environmental concentrations exceed specified standards [3]. "Pollution" is the phrase that is used to characterize this action or occurrence. The term "water pollution" refers to the problem of hazardous compounds in water sources, which may disrupt the lives of aquatic organisms. These can be



lakes, streams, seas, groundwater, or oceans. They can also be groundwater. Increases in population and industrialization are two of the most important causes that contribute to the contamination of water [4]. Pollution is detrimental to all life forms since it unintentionally discharges pollutants that are not wanted into the water. Water hyacinth and Nipa pose a threat; industrial waste is deposited into our seas,

1.1 SURFACE WATER POLLUTION

Surface water refers to the natural features of the earth's surface. These water features include rivers, lakes, lagoons, and seas. Surface water contamination occurs when hazardous substances come into contact with the water, dissolve in the water, or physically mix with the water [6].

1.2 GROUNDWATER POLLUTION

The pollution of groundwater typically continues for a considerable amount of time. Bacteria and chemicals are examples of the many contaminants that have the potential to contaminate groundwater. When sewage that has not been cleaned is discharged on land, seepage pits, or septic tanks, the groundwater becomes contaminated [7]. When poisonous and carcinogenic industrial waste products can escape into the environment without regulation and when nitrogen-based fertilizers are used excessively, groundwater can become polluted.

1.3 TYPES OF WATER POLLUTANTS

Various types of water pollutants are classified as:

1.4 ORGANIC POLLUTANT

All waste elements and organic stuff are included in its composition. There are various sources, including the decomposition of dead plants and animals, paper mills, tanning activities, meat packing facilities, industrial leftovers from food processing, and household animal waste. Biological activity, including that of bacteria, causes it to go through a process known as biodegradation, ultimately leading to its disintegration or decomposition. Through the consumption of oxygen from synthetic organic molecules, it leads to a reduction in the amount of oxygen present in water [8]. Synthetic organic chemicals are compounds that include carbon atoms and are referred to by that terminology.

pollution of groundwater occurs during drilling, flooding during the rainy season carries waste deposits into our water, heavy metals, radioactivity, burning coal-producing plants, mining, eroded sediments, deforestation, oil spills, building lavatories and visionaries over streams or even the sea, high population density, oil spills, and other factors (5)

Most organic molecules found in water are synthetic substances produced due to human activities [9]. Leachate from landfills, industrial chemicals, plastics, pesticides, and solvents were some of the pollutants that contributed to the contamination.

1.5. INORGANIC POLLUTANTS

Mineral acids, inorganic salts, trace elements, metals, complexes of metal-organic compounds, cyanides, and sulfates are just some of the many different types of chemicals that can be discovered in these contaminants. It is possible that they were damaging to aquatic life and put people in danger of becoming ill. Most heavy metals are estimated to be hazardous to human health and ecosystems [10]. The following elements are classified as heavy metals: nickel, cobalt, lead, arsenic, cadmium, zinc, iron, manganese, titanium, vanadium, and chromium. Heavy metals pose a threat to human health when they are exposed to them. They possess qualities that cause cancer. Extreme metal poisoning can hurt a person's cardiovascular system, gastrointestinal system, kidneys, liver, endocrine glands, bones, and lungs, among other organs. Diseases of the cardiovascular system and injury to the central nervous system are two other potential effects [11]. Many degenerative conditions that impair these particular biological systems have been connected to prolonged exposure to heavy metals, which may raise the risk of certain cancers. These ailments have been associated with the presence of heavy metals. Following is a list of heavy metals that, if present in human bodies, can have significant adverse effects on human health.

Heavy metals toxic to humans, such as lead, cadmium, copper, mercury, and arsenic, are the most dangerous to human health [12]. These metals have been the focus of significant research, and organizations such as the World Health Organization routinely evaluate the dangers they present to human



health [13]. Heavy metal intoxication can cause damage to a wide variety of organs and systems, including the central nervous system, the central nervous system, the heart, the lungs, the gastrointestinal tract, the kidneys, the liver, the endocrine glands, and the bones. Exposure to heavy metals over an extended period has been associated with a variety of degenerative conditions that impact the same physiological systems, and it may even increase the risk of some cancers [14]. The Table 1 is a comprehensive list of heavy metals harmful to human health.

Table 1. Heavy metals and related Health issues

HEAVY METALS	
Lead	Kidney damage, brain damage in fetal.
Zinc	State of depression, increased thirst, complete or partial paralysis.
Nickel	Nausea, coughing, carcinogenic, dermatitis, chronic asthma.
Chromium	Headache, nausea, vomiting, diarrhea
Cadmium	Kidney failure, carcinogenic, renal disorders
Mercury	Rheumatoid arthritis, kidney problems, and circulatory and nervous system disorders.

HEAVY METAL – CHROMIUM

Chromium is harmful to aquatic creatures. The production of both chromium (VI) and chromium (III) results in chromium (VI), which is more hazardous than chromium (III) [15]. Due to human and industrial activities, chromium can be found in shallow surface water and groundwater. People who work with steel and textiles are particularly at risk from chromium (VI), a significant health concern. The electrical and electronic sectors have severe regulations on using chromium (VI)

species. Industrial effluent is an important entry point for hazardous metals and their compounds into untreated water supplies. Chromium (VI) compounds include chromium elements in the +6 oxidation state. Chromium is a metallic element with hardness, brittleness, and a shiny look. The item has a glossy finish and has a silvery gray color. While it maintains its resistance to oxidation in air, it undergoes combustion when exposed to heat, producing green chromic oxide. Chromium, which is inherently unstable when exposed to oxygen, quickly forms a thin oxide film in some uses, such as anti-corrosion treatments, conservation coatings, colors for textiles, and wood preservation. There are multiple possible states for compounds containing hexavalent chromium. Chromate pigments made of hexavalent chromium compounds are used in many polymers, paints, dyes, and inks. To make surface coatings like paints and primers more corrosion-resistant, chromates are added to them. Furthermore, electroplating metal components with chromic acid creates a protective or decorative layer. When you do "hot work," such as welding stainless steel or melting chrome metal, you run the risk of hexavalent chromium. In these cases, chromium does not start in a hexavalent form. However, oxidation transforms chromium into its hexavalent form due to the process's high temperature. Precipitation, coagulation, filtering, and separation of chromium by settling coagulants are the typical steps in the conventional method for chromium removal from water and wastewater. Adsorption is a practical and economical alternative to traditional procedures as they are ineffective in removing Cr (VI).

Human health is severely harmed by chromium. Renal tubular necrosis is caused by acute chromium poisoning [16]. Cancers of the respiratory tract are caused by chronic chromium exposure. Causes ulcers and upset stomachs. Pulmonary issues lung cancer. The compromised immune system and Damage to the kidneys and liver [17].

WASTEWATER TREATMENT FOR REMOVING POLLUTANTS

BIOLOGICAL METHODS

In this process, bacteria have a role in the sedimentation of solution solids, which is an important step. Conventional approaches to wastewater treatment



include utilizing stabilization ponds, trickling filters, and activated sludge [18].

Utilizing microbes to aerate and mix the organic material, which assists it in decomposing as it travels through the treatment process, and then separating the solids is the most frequent procedure. Activated sludge is the most popular technique. The aeration basin is regularly restocked with bacteria that include "activated sludge" to speed up the process of decomposing organic waste and moving forward leisurely and unhurriedly. Filters 3–10 are often made up of beds of coarse media, often made of plastic or stones. After the wastewater is sprayed into the air and seeps through the press, the organic compounds are broken down by the bacteria in the wastewater. Once the effluent that the trickling filters have collected has been released at the bottom, it will proceed through sedimentation. The performance of lagoons and stabilization ponds is notoriously poor, and they are also recognized for their low efficiency and lengthy processing periods. The treatment of a wide variety of wastewater compositions is made possible by utilizing biological techniques. How sunlight, bacteria, algae, and oxygen interact with one another is necessary for their proper functioning.

A recent study on the biosorption technique [19] focused on removing heavy metals from industrial wastewater by utilizing adsorbents, which are products derived from agricultural waste.

Nevertheless, its application is frequently constrained by technological constraints. It is necessary to have a vast plot of land to conduct biological therapy, which is influenced by factors such as how sensitive it is to variations in illumination, which chemicals are harmful, and how little flexibility there is in design and operation. To add insult to injury, conventional methods to remove pigment are insufficient when it comes to biological treatment.

PHYSICO CHEMICAL METHODS

The most common applications of physical separation techniques include utilizing metal particles, whether individual particles or particles that incorporate metals. Mechanical screening, flotation, hydrodynamic classification, gravity concentration, electrostatic separation, magnetic separation, and attrition scrubbing are some of the steps involved in the process. To

recover heavy metals and pigments from wastewater, some typical chemical techniques that can be utilized include ion exchange, chemical precipitation, flotation, adsorption, electrochemical deposition, and photocatalysis [20]. Additional chemical processes that can be used include flotation

1.7.3 CHEMICAL PRECIPITATION METHOD

Because of its straightforward and successful operation, chemical precipitation is widely used in the industry to remove heavy metals from inorganic wastewater. This is achieved through the use of chemical precipitation. The usual chemical precipitation procedures produce insoluble residues in the form of heavy metal hydroxides, sulfides, carbonates, and phosphates. These residues are harmful to the environment. These methods accomplish their goals by inducing dissolved metals to react with the precipitant, ultimately leading to the precipitation of insoluble metals.

1.7.4 ELECTROCHEMICAL TREATMENTS

The electrostatic interaction between pollutants and coagulant-flocculant agents is characterized by the coagulation-flocculation process, which is indicated by the measurement of zeta potential (ζ), the foundation of the process. The coagulation process decreases the overall surface charge of the colloidal particles, which is done to achieve stability through electrostatic repulsion. Flocculation is a process that causes particles to impact and interact with inorganic objects, continually increasing particles' size [21].

The inclusion of organic monomers results in the formation of polymers being produced. The process of filtration, straining, or floating can be utilized to efficiently eliminate or separate individual particles. This effectively causes the particles to aggregate into larger particles that are referred to as flocculates.

1.8 ADSORPTION

As a result of the accumulation of a liquid or gaseous solute on the surface of a solid or liquid (referred to as the adsorbent), a thin layer of atoms or molecules is formed, which is referred to as the adsorbate. Adsorption is a term that describes the process. Adsorption is a process utilized extensively in various natural systems, including chemical, biological, and physical ones. Additionally, it is applied in commercial



applications for multiple products, such as activated charcoal, synthetic resins, and water filtration. Adsorption is currently considered an appropriate approach for wastewater treatment because it is both cost-effective and user-friendly simultaneously. The removal of metal ions from a wide variety of industrial effluents is often accomplished through the use of a technology known as adsorption.

Metal ions in the solution are carried to the surface of the adsorbent material during the adsorption process. Once there, they stick to the functional group located on the surface of the adsorbent material through a combination of chemical and physical attraction. Several other functional groups, including amine, carboxyl, amide, sulphonic, and others, are also responsible for enhancing the adsorption of metal ions.

DYNAMICS OF ADSORPTION

The adsorption dynamics are commonly acknowledged to involve the following sequential steps:

The process of moving adsorbate molecules from the bulk solution to the outer surface of the adsorbent through diffusion over the liquid boundary layer.

The ensuing steps in the adsorption dynamics are widely recognized as:

The adsorbate is transferred through diffusion across the liquid boundary layer from the bulk solution to the outer surface of the adsorbent.

Interstitial (interphase) mass transfer occurs as molecules move from the adsorbent's external surface to the porous structure's internal surface via pore diffusion.

Dispersion of particles on the surface within the porous structure

Three potential adsorption processes exist: batch, semi-batch, and continuous. Adsorption primarily occurs at the molecular level due to favorable interactions between the surface and the adsorbed groups. Adsorption can take on several shapes depending on the type of intermolecular attraction force involved.

Physisorption refers to adsorption, where molecules are attracted to a surface through weak van der Waals forces.

Chemisorption refers to the process in which molecules or atoms are adsorbed onto a solid surface through chemical bonding.

1.8.2 PHYSICAL ADSORPTION

When the adsorbate sticks to the surface primarily due to weak intermolecular interactions, precisely Vander Waals forces, which are responsible for the non-ideal behavior of natural gases, a phenomenon known as physisorption occurs. This phenomenon is also commonly referred to as physical adsorption. Only in environments with low quantities of the drug does adsorption for the substance take place. Molecular structures in the gas phase can produce numerous adsorption layers if the conditions are favorable. Commercial adsorbents use the process of physical adsorption to link their surfaces.

1.8.3 CHEMICAL ADSORPTION

It's adsorption when the adsorbent and adsorbate are involved in a chemical reaction. Adsorbate can be a monolayer. It is applied to catalytic processes. Electronic bonds (covalent or ionic) are formed by the adsorbate's intense contact with the substrate surface. Activated adsorption is another name for chemical adsorption.

SCOPE AND OBJECTIVES

Scientists commonly employ adsorption techniques to extract heavy metals from wastewater; activated carbon is one of the most common adsorbents. The water and wastewater treatment industries utilize activated carbon extensively, yet it is still quite expensive. Many people are interested in finding cheaper alternatives to activated carbon that you can buy at the store. One reason for this is the urgent need for a dependable and affordable way to purge polluted water of heavy metals [22]. Therefore, it is critical to investigate the adsorption capabilities of orange peel for heavy metal removal [23]. Our primary goal is to explore the utilization of less expensive natural adsorbents to remove chromium from wastewater.

MATERIALS

Orange peel shown in Figure 1, using its extracts, functions as an adsorbent that aids in the absorption of chromium (VI) [24]. Orange is an alternative to iron ions in wastewater that is both aesthetically beautiful



and economically efficient [25]. Orange peels have several benefits to the health of the skin. There are a lot of people who throw away orange peels because they are unaware of the multiple benefits that they provide. The primary components of orange peels are cellulose, pectin, hemicellulose, and lignin. Each of these components has functional groups that have the potential to serve as sites for the binding of metals [26]. It is the neighboring market that provides the natural adsorbent that is harvested



FIGURE 1: Raw orange peel

ADSORBENT PREPARATION

After being broken up into smaller pieces, the orange peel was left out in the sun for three weeks to make it dry. A thorough cleaning was performed on the dried orange peel by washing it with two liters of distilled water. This was done to eradicate any harmful contaminants. After undergoing a procedure that included cleaning, filtration, and oven drying for twenty-four hours at temperatures ranging from sixty to seventy degrees Celsius, the orange peels were finally ready for consumption. Following drying, the orange peels were ground into a fine powder and then stored as orange peel powder shown in Figure 2.



FIGURE 2: Orange peel powder

PREPARATION OF CARBONIZED CHARCOAL

The powder made from orange peel was then stored in a muffle furnace after being carbonized for forty-five minutes at five hundred degrees Celsius. It was decided to collect the carbonized powder and store it safely. In the subsequent step, it is utilized in the process of characterization.

PREPARATION OF ACTIVATED CHARCOAL

Following filtration, the H₂SO₄ and orange peel powder mixture was placed in an oven for twenty-four hours before storage. Activating the organic orange powder required a series of washes with distilled water and an additional wash with a conditioner. This was the first phase in the process. The activated charcoal that was created was utilized for the characterization experiments.

PREPARATION OF STOCK SOLUTION

Distilled water dissolved 2.772 grams of potassium dichromate (K₂Cr₂O₇) in 500 milliliters of water. This resulted in the production of the stock solution. An application of diphenyl carbazide solution was the reagent that was utilized for the elimination of chromium. Following the preparation of a solution consisting of 0.25 grams of 1,5-diphenyl carbazide, which was subsequently stored, the substance was dissolved in 50 milliliters of acetone.

ADSORPTION EXPERIMENT

2.1 REMOVAL OF HEAVY METAL CAN BE STUDIED UNDER VARIOUS PARAMETERS

2.1.1 EFFECT OF INITIAL CONCENTRATION

Different concentrations of the manufactured adsorbent were tested to determine its effectiveness at adsorbing substances. Samples of carbonized and activated orange peel were combined with 0.5 grams of adsorbent at concentrations of 2 parts per million, 4 parts per million, six parts per million, and eight parts per million. After that, the mixture was shaken for a time equaling two hours. Following that, the solution was filtered, and the obtained liquid was collected to determine the heavy metals that had attached themselves to the adsorbent.



2.1.2 EFFECT OF TEMPERATURE

Using temperatures of 500, 600, 700, and 800 degrees Celsius, the adsorption capabilities of the adsorbent were evaluated to determine how effective they were. At a concentration of one hundred parts per million (ppm), the adsorbent extracted from the carbonized and activated orange peel samples was combined with and weighed 0.5 grams. The concentration remained the same throughout the board, regardless of the temperature variation. The solutions that had been made were shaken for two hours to promote their agitation. Following two hours, the solutions were subjected to filtration, and the produced filtrate was gathered to determine whether or not heavy metals had been adsorbed onto the adsorbent.

2.1.3. EFFECT OF CONTACT TIME

The effectiveness of the created adsorbent was evaluated for various contact times, including 15, 30, 45, and 60 minutes. After being carbonized and activated, the sample adsorbent made from orange peel (0.5 grams) was combined with a 100 times more concentrated solution. It took two hours for the solution to be stored in a shaker after it had been prepared. After two hours, the solution was subjected to filtration, and the produced filtrate was gathered to determine whether or not heavy metals had been adsorbed onto the adsorbent.

2.1.4. EFFECT OF ADSORBENT DOSAGE

By combining samples of carbonized and activated orange peel at a concentration of 100 parts per million (ppm) and allowing them to come into contact with one another for thirty minutes, the adsorbent's ability to adsorb was evaluated at dosages of 0.5 grams, 1 gram, 1.5 grams, and 2 grams. The concentration and the contact duration were held at the same level throughout this particular instance. One and only one variable was the amount of adsorbent used. It was necessary to collect the filtrate after the solution was subjected to thorough filtration for approximately thirty minutes to determine whether heavy metals had been adsorbed on the adsorbent.

2.1.5. EFFECT OF PH

We tested the created adsorbent to determine how well it absorbed substances at various concentrations and pH

levels. A period of thirty minutes of shaking was followed by adding two parts per million at a pH of five, four parts per million at a pH of six, six parts per million at a pH of seven, and eight parts per million at a pH of eight. After thirty minutes, the solution was filtered, and the resulting filtrate was utilized to analyze the adsorption of heavy metals onto the adsorbent.

CHARACTERISATION STUDIES

Several techniques were utilized to evaluate the adsorption of heavy metals on the adsorbent. These techniques included FTIR analysis, UV data analysis, scanning electron microscopy photographs taken before and after adsorption, and EDAX images.

FT- IR ANALYSIS

In Figure 3, an FT-IR spectrum of the biosorbent made from carbonized orange peel is visually presented. The stretching vibration of the C-H bonds in the alkanes is responsible for the maximum amount of adsorption that occurs at 2990.09 cm⁻¹. This vibration induced the highest level of adsorption. There is a correlation between the stretching vibration of carboxylic groups' C=O bonds and the prominent peak found at a wavenumber of 1764.55 cm⁻¹. The stretching vibration of the C-H bonds in the aromatic molecule is represented by the signal detected at 1242.9 cm⁻¹ in the adsorbent made from carbonized orange peel molecules. It has been determined that the peak that was noticed at a wavenumber of 1377.89 cm⁻¹ is connected with the stretching vibration of NO₂. The C-F bond stretching in alkyl and alkyl halide compounds corresponds to the peak that may be found at 1055.84 cm⁻¹.

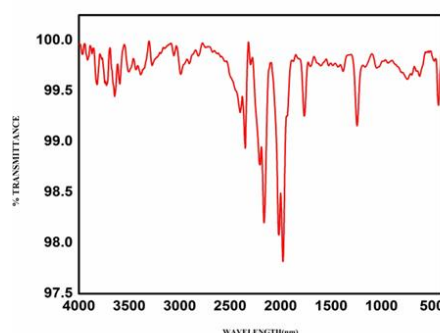


FIGURE 3: FT-IR SPECTRA OF CARBONIZED ORANGE PEEL

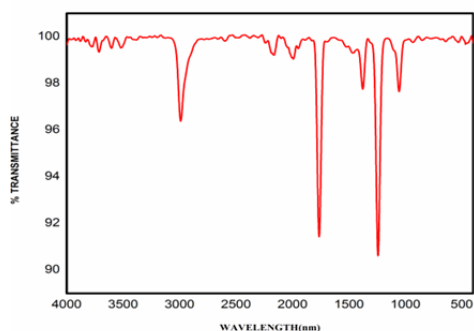


FIGURE 4: FT-IR SPECTRUM OF ACTIVATED ORANGE PEEL

The Fourier transform infrared spectra of the biosorbent made from activated orange peel are shown in Figure 4. The fact that the maximum absorption was found at a wavenumber of 2349.84 cm^{-1} proves that the C-O bond is present. When the activated orange peel adsorbent is examined, the peak at 2204.24 cm^{-1} is associated with the C=C stretching vibration. The C-C bond's vibrational motion is approximately 2164.7 cm^{-1} , corresponding to the highest vibrational motion. The aromatic molecule is also connected to the peak at around 2016.21 cm^{-1} . At about 1976.68 cm^{-1} , the aromatic component's peak can be found. There is a correlation between the peak absorption at a wavenumber of 1765.51 cm^{-1} and the stretching vibration of the C=O relationship. The signal detected at a frequency of 1241.93 cm^{-1} indicates the adsorption of the carbonyl functional group that is present in the ester. The peak that can be found at 433.905 is a representation of the C-C cycloalkane bond.

PREPARATION OF CALIBRATION CURVE

EFFECT OF INITIAL ION CONCENTRATION

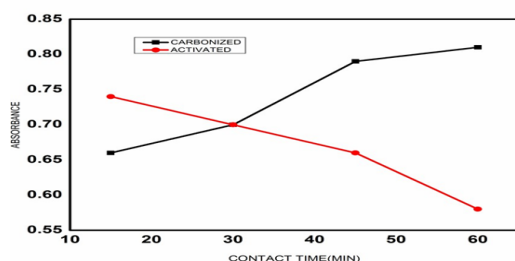


FIGURE 5: Calibration curve for initial ion concentration

Through the examination of many concentrations of stock solutions, a calibration curve in FIGURE 5 for the influence of initial ion concentration was established through a study. The concentrations of stock solutions that were examined were two ppm, four ppm, six ppm, and eight ppm. The absorbance measurements were done at a wavelength of 560 nm, and the numbers supplied are accurate. The data above was utilized to generate the calibration curves for carbonized and activated orange peel.

EFFECT OF TEMPERATURE

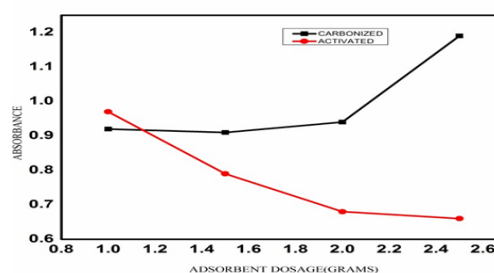


FIGURE 6: Calibration curve for the effect of temperature

A calibration curve shown in figure 6: was constructed to examine the impacts of different temperatures (500, 600, 700, and 800 degrees Celsius). An assessment of the absorbance was conducted at a wavelength of 560 nm. The calibration curve was constructed using the data obtained from carbonized and activated orange peel.

EFFECT OF CONTACT TIME

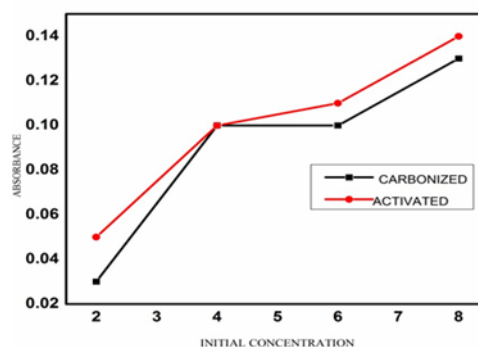


FIGURE 7; Calibration curve for the effect of contact time



Plotting the calibration curve shown in figure 7 allowed for analyzing the impact of various contact times (15, 30, 45, and 60 minutes). At 560 nm, the absorbance values were measured. These data were used to build the carbonized and activated orange peel calibration curve.

EFFECT OF ADSORBENT DOSAGE

The calibration curve shown in figure 8 was constructed to demonstrate the influence of different amounts of adsorbent (0.5g, 1g, 1.5g, and 2g). The absorbance readings were measured at a wavelength of 560 nm. The data above were used to construct the carbonized and activated orange peel calibration curve.

EFFECT OF pH

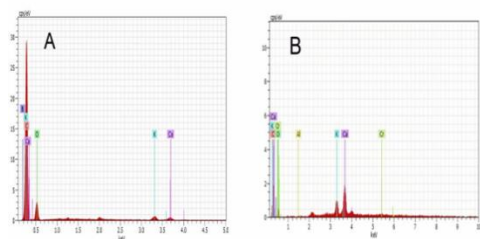


FIGURE 9: Calibration curve for the effect of pH

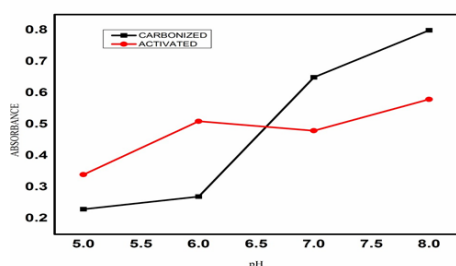


FIGURE 8: Calibration curve for the effect of adsorbent dosage

We analyzed the calibration curve shown in figure 9 to assess the influence of different pH levels (5, 6, 7, and 8). The absorbance readings were measured at a wavelength of 560 nm. The data above were used to construct the carbonized and activated orange peel calibration curve.

SEM (SCANNING ELECTRON MICROSCOPE) ANALYSIS

Figure 10 exhibits scanning electron microscopy images of a carbonized orange peel (A) before and (B) after adsorption. Figure 14 depicts the scanning electron microscope (SEM) images of an active orange peel. Image (A) shows the orange peel before adsorption, whereas image (B) shows it after adsorption. The adsorption process may be observed by comparing the photographs taken before and after adsorption, which clearly show the presence of chromium, a heavy metal, being adsorbed onto the surface of the adsorbent. The form of the adsorbent changes both before and after the heavy metal chromium adsorption. The EDAX research shows definitive evidence of chromium adsorption on the orange peel adsorbent, further supporting its credibility.

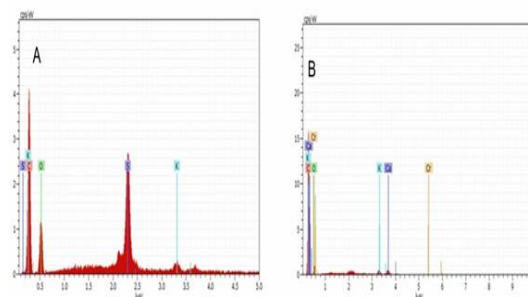


FIGURE 10: SEM images of the activated orange peel (A) before and (B) after adsorption

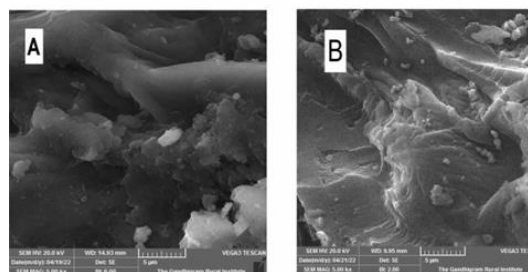


FIGURE 11 : EDAX images of the carbonized orange peel (A) before and (B) after adsorption.

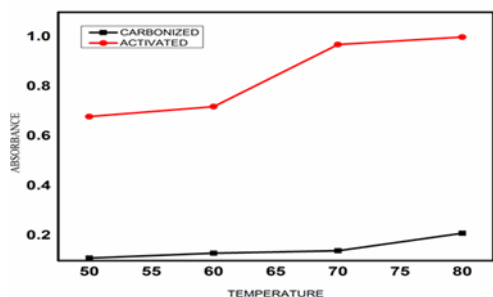


FIGURE 12: EDAX images of the Activated orange peel (A) before and (B) after adsorption.

Figure 11 and 12 presents the EDAX analysis results for the carbonized orange peel, showing the findings before (A) and after (B) adsorption. Figure 16 depicts the active orange peel adsorbent (A) in its initial state and (B) after the adsorption process. The EDAX investigation revealed that the adsorbent included adsorbed calcium, carbon, potassium, oxygen, and chromium components. The presence of a chromium peak, together with other elements, confirmed the adsorption of Cr (VI) onto the adsorbent.

4. COMPARISON OF CONCENTRATION OF CHROMIUM ADSORPTION IN THE CARBONIZED AND ACTIVATED ORANGE PEEL SAMPLES

4.1 EFFECT OF INITIAL CONCENTRATION

TABLE 2: Effect of initial concentration on carbonized and activated orange peel.

INITIAL CONCENTRATION OF HEAVY METAL (ppm)	FINAL CONCENTRATION OF HEAVY METAL IN CARBONIZED SAMPLE (ppm)	FINAL CONCENTRATION OF HEAVY METAL IN ACTIVATED SAMPLE (ppm)
2	0.012	0.0111
4	0.022	0.0242
6	0.026	0.032

8	0.032	0.1371
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The initial concentration of metal ions shown in table 2 influenced the elimination of chromium (VI). Increasing concentrations of 2 ppm, four ppm, 6 ppm, and eight ppm are used in the experiment. The concentration of chromium adsorption in the carbonized and activated orange peel samples rises with the stock solution concentration.

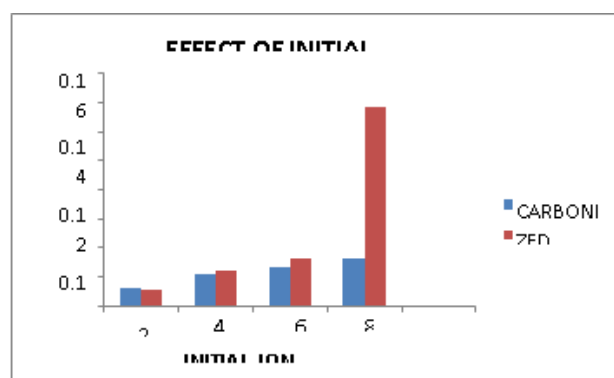


FIGURE 13: Effect of initial concentration

The graph in Figure 13 indicates the presence of the heavy metal Cr adsorbed on the activated carbonized material. The sample that has been activated has a concentration of eight parts per million, which is the highest possible concentration. The result demonstrates that the adsorbent has the highest capacity to adsorb the heavy metal chromium at its maximum concentration.

4.2 EFFECT OF TEMPERATURE

TABLE 3: Temperature's impact on activated and carbonized orange peel

Temperature's impact on activated and carbonized orange peel is shown in Table 3. The influence of temperature is one of the criteria used to determine heavy metal adsorption on the adsorbent. Samples of carbonized and activated orange peel were used in the experiment, which was conducted at temperatures of 500, 600, 700, and 800 degrees Celsius. In this case, the stock solution's concentration stays constant as the temperature rises. The carbonized and activated orange peel samples exhibit increased adsorbent content with temperature.



INITIAL CONCENTRATION OF STOCK SOLUTION (ppm)	TEMPERATURE (0C)	FINAL CONCENTRATION OF HEAVY METAL IN ACTIVATED SAMPLE (ppm)	FINAL CONCENTRATION OF HEAVY METAL IN CARBONIZED SAMPLE (ppm)
100	50	0.0125	0.068
	60	0.0151	0.072
	70	0.0163	0.097
	80	0.0236	0.1

		(PPM)	(ppm)
100	15	1.211	0.592
	30	1.2844	0.568
	45	1.4495	0.528
	60	1.4862	0.464

The adsorption of the heavy metal chromium on the adsorbent is influenced by the contact time, shown in table 4, which is one of the determining factors. The adsorption concentration on carbonized orange peel exhibits a positive correlation with the duration of contact. Concurrently, increased contact duration decreases the concentration of Cr adsorption on activated orange peel. This is due to the limited capacity of the activated orange peel's surface to absorb heavy metals. Consequently, the quantity of actively present orange peel decreases.

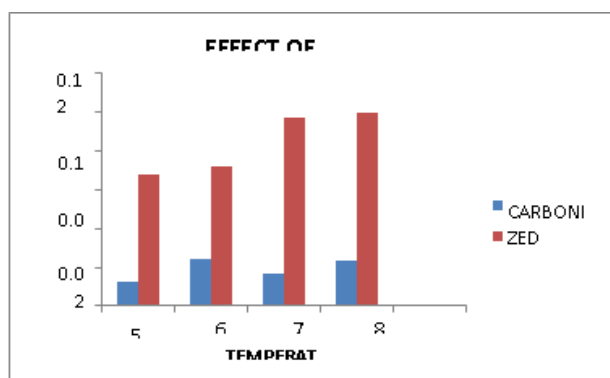


FIGURE 14: Effect of temperature

The concentration rises with temperature, shown in figure 14. According to the graph The activated orange peel adsorbent exhibited maximal heavy metal adsorption at a temperature of 800 c.

EFFECT OF CONTACT TIME

TABLE 4: Impact of contact duration on activated and carbonized orange peel.

INITIAL CONCENTRATION OF STOCK SOLUTION (ppm)	TIME (MINUTES)	FINAL CONCENTRATION OF HEAVY METAL IN ACTIVATED SAMPLE	FINAL CONCENTRATION OF HEAVY METAL IN CARBONIZED SAMPLE
100	15	1.211	0.592
	30	1.2844	0.568
	45	1.4495	0.528
	60	1.4862	0.464

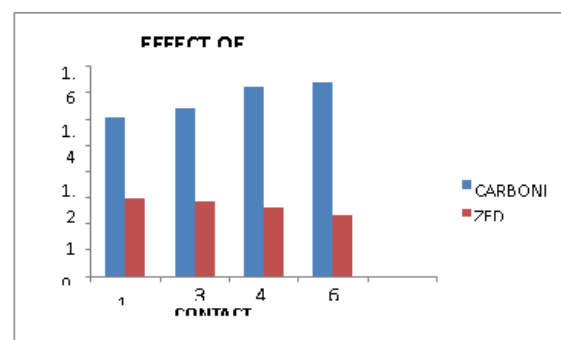


FIGURE 14: Effect of contact time

The graph as shown in figure 14 illustrates a positive correlation between the duration of contact and the concentration of heavy metals in the carbonized orange peel. Conversely, the concentration of heavy metal adsorption in the activated orange peel decreases. The highest elimination level occurs when the carbonized orange peel is left for 60 minutes.

4.4 EFFECT OF ADSORBENT DOSAGE

Heavy metal chromium removal can be investigated with adsorbent dosages of 0.5g, 1g, 1.5g, and 2g. As the weight of the adsorbent grows, its adsorption capacity also increases. As the number of adsorbents rises, the adsorption capacity of activated orange peel decreases. Augmenting the quantity of adsorbent leads to a greater surface area or an increased



number of adsorption sites for a given initial adsorbate concentration. Subsequently, the adherence of metal ions to the surface may be the underlying cause.

TABLE 5: Effect of adsorbent dosage on carbonized and activated orange peel.

INITIAL CONCENTRATION OF STOCK SOLUTION (ppm)	ABSORBENT DOSAGE (GRAMS)	FINAL CONCENTRATION OF HEAVY METAL IN ACTIVATED SAMPLE (ppm)	FINAL CONCENTRATION OF HEAVY METAL IN CARBONIZED SAMPLE (ppm)
100	0.5	0.6344	0.6689
	1	0.6375	0.5448
	1.5	0.6482	0.4689
	2	0.8206	0.4551

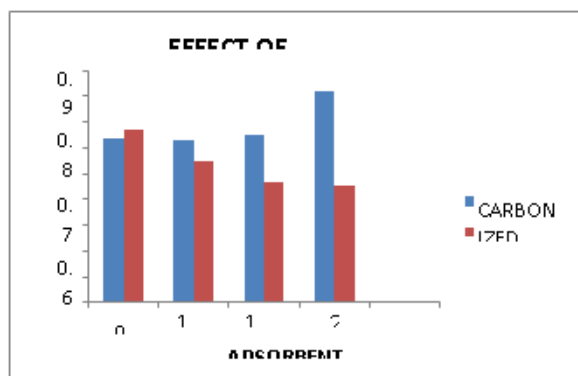


FIGURE 15: Effect of adsorbent dosage

Effect of adsorbent dosage on carbonized and activated orange peel is shown in table 5. The graph as shown in figure 15, illustrates that the adsorption of chromium increases with a higher dose of carbonized orange peels, whereas chromium adsorption in activated orange peels decreases. Therefore, when a dosage of 2g is used, the maximum adsorption occurs on both adsorbents.

4.4 EFFECT OF PH

TABLE 6: Effect of pH on carbonized and activated orange peel.

INITIAL CONCENTRATION OF STOCK SOLUTION (ppm)	pH	FINAL CONCENTRATION OF HEAVY METAL IN ACTIVATED SAMPLE (ppm)	FINAL CONCENTRATION OF HEAVY METAL IN CARBONIZED SAMPLE (ppm)
2	5	0.023	0.034
4	6	0.027	0.051
6	7	0.3037	0.224
8	8	0.3058	0.268

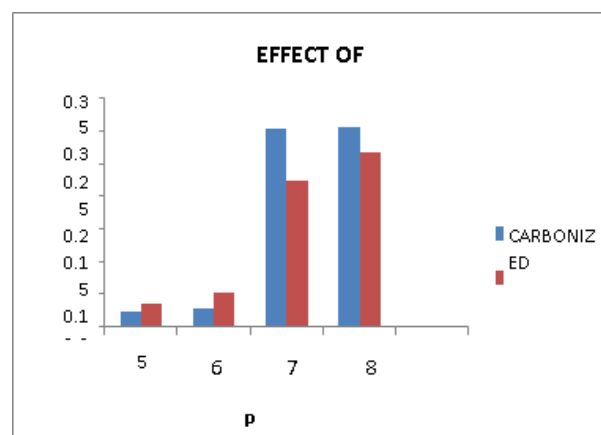


FIGURE 16: Effect of pH

The maximum concentration of chromium adsorption occurs at pH 8.

5. CONCLUSION:

It is possible to conclude that orange peel has significant potential as an adsorbent for the adsorption of Cr (VI) ions. This conclusion may be reached by considering other aspects, such as the initial ion concentration, contact time, temperature, adsorbent dosage, and pH. According to recently discovered research, the potential of activated orange peel to adsorb heavy metal Cr is significantly higher than that of



carbonized orange peel. It has been demonstrated that activated carbon generated from orange peel has a solid capacity to extract the abundant element chromium from wastewater applications. Because of its large surface area and high porosity, activated biomass can absorb pollutants effectively. The pH of the solution significantly impacts the surface characteristics of the adsorbent. As a result, it has a substantial effect on the effectiveness of the chromium removal process. Activated orange peel was used to achieve the highest chromium adsorption at a pH of eight, which led to selecting the primary solution as the ideal condition for adsorption. The results of our research indicate that the adsorption process using orange peel is efficient and shows promise as a technology that is both cost-effective and effective in removing heavy metals.

References.

1. Goldhaber S.B., 2003. Trace element risk assessment: Essentiality vs. toxicity Regul. Toxicol. Pharmacol., 38 (2) , 232-242,
2. Valentine Rupa A., Manikandan D., 2007. Photocatalytic degradation of tetracycline dye using TiO₂ catalyst: Salt effect and kinetic studies Indian Journal of Chemical Technology 14 (1), 71-77
3. Keshawy M., Fathy M., Gaffer A., Hosny R., Abdel Moghny T., Low-cost Bio-Adsorbent based on Amorphous Carbon Thin Film/chitosan composite for removal of Methylene Blue Dye: Kinetic and Isotherm. Egypt. J. Chem. 2019, 62, 2313–2329.
4. Arif A., Malik M. F., Liaqat S., Aslam A., Mumtaz K., and Afzal A., (2020). 3. Water Pollution and Industries. Pure Appl. Biol. (PAB) 9 (4), 2214–2224.
5. Brown J., and Clasen T. (2012). High Adherence Is Necessary to Realize Health Gains from Water Quality Interventions. PLoS ONE 7 (5), e36735–9. doi:10.1371/journal.pone.0036735
6. Dasgupta P., (2004). Valuing Health Damages from Water Pollution in Urban Delhi, India: a Health Production Function Approach. Envir. Dev. Econ. 9 (1), 83–106. doi:10.1017/s1355770x03001098
7. Gundry S., Wright J., and Conroy R., (2004). A Systematic Review of the Health Outcomes Related to Household Water Quality in Developing Countries. J. Water Health 2 (1), 1–13. doi:10.2166/wh.2004.0001
8. Barkay T., Gillman M., Turner R.R., 1997. Effects of dissolved organic carbon and salinity on bioavailability of mercury. Appl Environ Microbiol. 63:4267–4271.
9. Geldreich E.E., 1978. Bacterial populations and indicator concepts in feces, sewage, stormwater, and solid wastes. In: Berg G., editor. Indicators of viruses in water and food. Ann Arbor: Ann Arbor Science Publishers, 51–97.
10. El-Nemr M.A., El Nemr A., Hassaan M.A., Ragab S., Tedone L., De Mastro G., Pantaleo A., Microporous Activated Carbon from Pisum sativum Pods Using Various Activation Methods and Tested for Adsorption of Acid Orange 7 Dye from Water Molecules 2022, 27, 4840.
11. L. Li, S. Wang X., Shen and M. Jiang, Environ. Sci. Pollut. Res., 2020, 27, 18392 —18402
12. Apostoli P., Catalani S., Metal ions affecting reproduction and development Met. Ions Life Sci., 8 (2011), pp. 263-303
13. L.u. Cai, X.-K. Li, Y.e. Song, M.G. Cherian Essentiality, toxicology and chelation therapy of zinc and copper Curr. Med. Chem., 12 (23) (2005), pp. 2753-2763,
14. Gibb H.J., et al. "Lung cancer among workers in chromium chemical production." American Journal of Industrial Medicine (AJIM) 38.2 (July 7, 2000): 115-126.
15. Hasanein P., Emamjomeh A., Beneficial effects of natural compounds on heavy metal-induced hepatotoxicity Diet. Interv. Liver Dis. Foods, Nutr. Diet., Suppl. 345–355 (2019),
16. Hayes R.B., Review of occupational epidemiology of chromium chemicals and respiratory cancer. Sci Total Environ 1988; 71:331–9.
17. Thomas Liborio DesMarias, Max Costa, Mechanisms of chromium-induced toxicity,



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for wastewater treatment, Volume 8, September 2023, 100111

18. Orhon D., (2015) Evolution of the activated sludge process: the first 50 years. *J Chem Technol Biotechnol* 90(4):608–640.
19. Kuyucak N., Feasibility of biosorbents application. In: Volesky B., editor. *Biosorption of heavy metals*. Boca Raton: CRC Press; 1990. pp. 371–378. [
20. Valentine Rupa A., Vaithyanathan R., Sivakumar T., Noble metal modified titania catalysts in the degradation of Reactive Black 5: a kinetic approach, *Water Sci Technol* (2011) 64 (5): 1040–1045.
21. Global Health and Education Foundation (2007). *Conventional Coagulation-Flocculation-Sedimentation. Safe Drinking Water is Essential*. National Academy of Sciences. Retrieved on 2007-12-01.
22. Rajkumar V., Raikar and Swati Patil et al. (2015); ‘Comparative Study on Efficiency of Natural Adsorbents in Removal of Chromium,’ *International Journal of New Technologies in Science and Engineering*, Vol. 2, Issue. 1, 2015, ISSN2349-0780.
23. O. A. Ekpete et al. (2010); ‘Adsorption of Chromium (VI) and Zinc (II) Ions on the Skin of Orange Peels (*Citrus sinensis*),’ *Journal of Nepal Chemical Society*, vol. 26, pp. 31 -3.
24. Acar F. N., & Malkoc E., The chromium (VI) removal from aqueous solutions by *Fagus orientalis* L. *Bioresour. Technol.* 94(1), 13–15 (2004).
25. Asmaa Khalil, Mohamed Salem, Safaa Ragab, Orange peels magnetic activate carbon (MG-OPAC) composite formation for toxic chromium absorption from wastewater, *Scientific Reports* volume 13, Article number: 3402 (2023)
26. Kritika S. Sharma., Kajal Panchal., Monika Chhimwal., Dinesh Kumar Integrated detection and natural remediation technology as a low-cost alternative