Removal of Heavy Metal Ion from Industrial Wastewater Using Agro Based Adsorbent, Orange Peels: An Experimental Study

A Report
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Under the guidance of

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CERTIFICATE

This is to certify that the thesis titled **'Removal of Heavy Metal Ion from Industrial Wastewater Using Agro Based Adsorbent, Orange Peels: An Experimental Study'** submitted by **AshishSahu(R900211038), PrageetKaushik (R900211039), Samarth Gupta (R900211042), GauravWadhwa (R900211037)** , to the University of Petroleum & Energy Studies, for the award of the degree of **BACHELOR OF TECHNOLOGY** in Chemical Engineering with Specialization in Refining And Petrochemicals is a bonafide record of project work carried out by them under our supervision.

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NOMENCLATURE

AC	Activated Carbon
BAD	Bio Adsorbent
PBR	Packed Bed Reactor
FBR	Fluidized Bed Reactor
MCL	Maximum Contamination Limit

Abstract

Rapid expansion of chemical industries in recent years has led to increase in generation of industrial effluents which contain toxic heavy metals. Heavy metals pose a threat to the aquatic life system when disposed into water bodies even in low concentrations. Removal of these toxic heavy metal ions from waste water is important for environmental pollution control. The discharge of heavy metals in to aquatic ecosystems has become a matter of concern in India over the past few decades. In particular, Chromium (VI) compounds, which are used as corrosion inhibitors in the manufacture of pigments, metal finishing and chrome plating, production of stainless steel, leather tanning, and preservation of woods, have been proven to be carcinogenic.

Traditionally, packed bed reactors are used to remove the heavy metal ions from the industrial effluents. The fluidized bed reactors (FBRs) offer better operational properties and are economically viable than packed bed reactors (PBRs). The most commonly used adsorbent in industries is activated carbon. However, owing to high costs of the adsorbent many industries refrain from treating the effluent prior to its disposal. In order to reduce the operational costs of the process, bio-adsorbents are used to supplement activated carbon for removal of heavy metal ions. Orange peels have already been used as alternate adsorbents in FBRs at laboratory level and up to 80% of metal removal has been achieved. Utilization of orange peels as an adsorbent in conjunction with activated carbon can significantly reduce the operating costs for removal of heavy metal ions from industrial effluents.

Keywords: Heavy Metals, Environmental Pollution Control, Chromium (VI) Compounds, Carcinogenic, Bio-adsorbents, Orange Peels, Fluidized Bed Reactors.

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CHAPTER 1

<u>INTRODUCTION</u>

Rapid growth of industrial activities in recent years led to increase of industrial wastes such as heavy metal and dyes in the environment, mainly in the aquatic systems.

Heavy metals are considered as hazardous pollutant because of their toxicity even at low concentrations. Removal of these toxic heavy metal ions from waste water is important for environmental pollution control. The discharge of heavy metals in to aquatic ecosystems has become a matter of concern in India over the past few decades. These pollutants are introduced into the aquatic systems significantly as a result of various industrial operations.

Industrialization in India gained a momentum with initiation of five year developmental plan in the early 50's. The pollutants consist of lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, gold, silver, copper and nickel. These toxic materials may be derived from mining operations, refining ores, sludge disposal, fly ash from incinerators, the processing of radioactive materials, metal plating, or the manufacture of electrical equipment, paints, alloys, batteries, pesticides and preservatives.

Various techniques have been employed for the treatment of metal bearing industrial effluents, which usually include precipitation, ion exchange, membrane and electrochemical technologies. But these techniques are expensive and not environment friendly.

Therefore, the search for efficient, eco-friendly and cost effective remedies for waste water treatment is the need of the hour.

1.1 OBJECTIVE

- ➢ To identify heavy metal ion for removal from industrial effluents.

- ➢ To identify a suitable bio-adsorbent for removal of identified heavy metal ion.

- ➢ To model a fluidized bed adsorption tower using a bio-adsorbent.

- ➢ To prepare the identified bio-adsorbent.

- ➢ To demonstrate removal of heavy metal ions from industrial effluents.

1.2 WORK PLAN

➤ Classification of various heavy metals generally found in wastewater. Identification of the metal most prominently found.

➤ Identification of the bio-adsorbent to be used and its method of preparation.

➤ Modeling of a fluidized bed adsorption tower for treatment of wastewater containing metallic impurities.

➤ Experiments to be conducted on the apparatus to monitor and analyze various process variables.
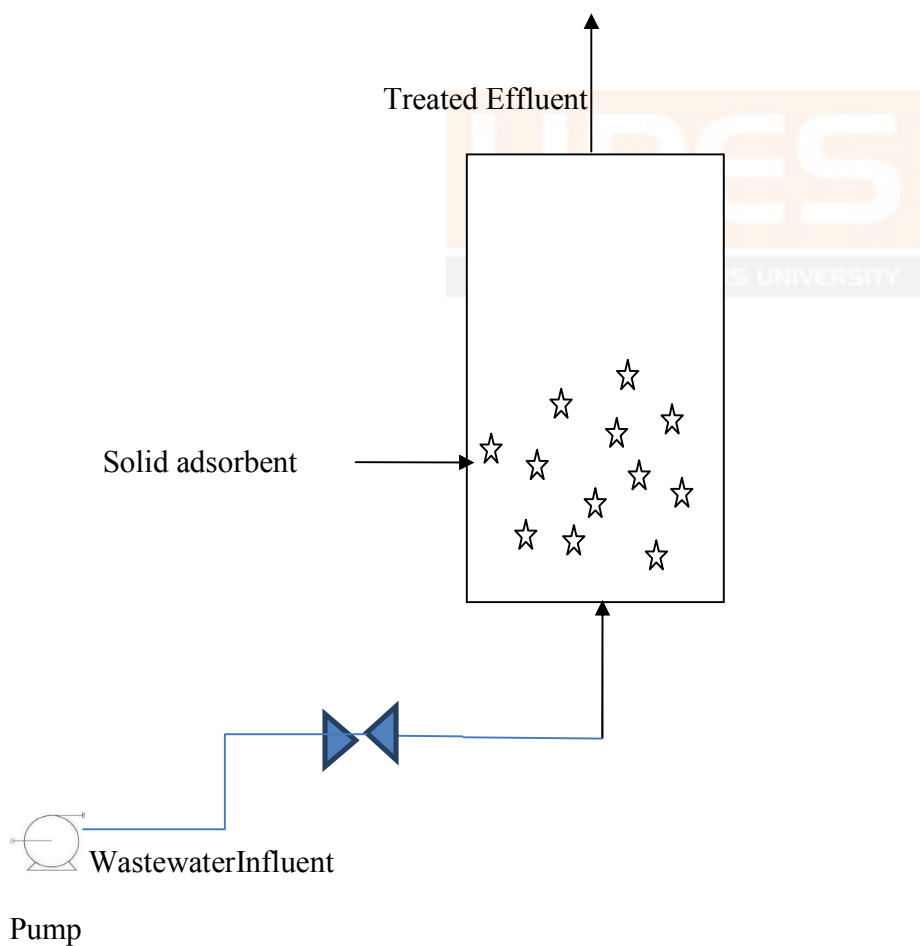
Fig. 1: Block Diagram of the Process

1.3 TIMELINE

September	• Synopsis of the project to be submitted
October	• Literature survey to be completed
November	• Project design for bio-adsorbent identification and initial report to be submitted to the mentor.
January	• Modelling and Fabrication of the adsorption coloumn.
Feburary	• Preparation of Adsorbent.
March	• Experiments done with the apparatus and analysis of the data gathered

CHAPTER 2

LITERATURE REVIEW

2.1 Heavy Metal Ion

Heavy metals are generally considered to be those whose density exceeds 5 g per cubic centimeter. A large number of elements fall into this category, but the ones listed in Table 1 are those of relevance in the environmental context [1].

Table 1: The MCL standards for the most hazardous heavy metals (Babel and Kurniawan, 2003).

Heavy metal	Toxicities	MCL (mg/L)
Arsenic	Skin manifestations, visceral cancers, vascular disease	0.050
Cadmium	Kidney damage, renal disorder, human carcinogen	0.01
Chromium	Headache, diarrhea, nausea, vomiting, carcinogenic	0.05
Copper	Liver damage, Wilson disease, insomnia	0.25
Nickel	Dermatitis, nausea, chronic asthma, coughing, human carcinogen	0.20
Zinc	Depression, lethargy, neurological signs and increased thirst	0.80
Lead	Damage the fetal brain, diseases of the kidneys, circulatory system, and nervous system	0.006
Mercury	Rheumatoid arthritis, and diseases of the kidneys, circulatory system, and nervous system	0.00003

Chromium being highly carcinogenic, it was the metal most focused on. Exposure to chromium (VI) compounds (sodium chromate) via inhalation or intratracheal or intrabronchial implantation caused benign and/or malignant lung tumors in rats and/or mice. Chromium (VI) compounds are widely used as

corrosion inhibitors, in the manufacture of pigments, in metal finishing and chrome plating, in stainless steel production, in leather tanning, and in wood preservatives [2].

Table 2: Some Chromium (VI) compounds [2]

Compound	Formula	Molec. wt.	Density (g/cm3)	Melting pt.	Dec.
Calcium chromate	CaCrO4	156.1	2.89	NR	NR
Potassium chromate	K2CrO4	194.2	2.73	975°C	NR
Lead chromate	PbCrO4	323.2	6.12	844°C	Yes
Potassium dichromate	K2Cr2O7	294.2	2.68	398°C	~500°C
Sodium chromate	Na2CrO4	162.0	2.72	792°C	NR
Sodium dichromate	NaCr2O7	262.0	2.52	357°C	400°C

Heavy metal removal from inorganic effluent can be achieved by conventional treatment processes such as chemical precipitation, ion exchange, and electrochemical removal. These processes have significant disadvantages, which are, for instance, incomplete removal, high-energy requirements, and production of toxic sludge [3].

Recently, numerous approaches have been studied for the development of cheaper and more effective technologies, both to decrease the amount of wastewater produced and to improve the quality of the treated effluent. Adsorption has become one of the alternative treatments, in recent years, the search for low-cost adsorbents that have metal-binding capacities has intensified. The adsorbents may be of mineral, organic or biological origin, zeolites, industrial byproducts, agricultural wastes, biomass, and polymeric materials [3]

Table 3: Sodium Chromate (http://en.wikipedia.org/wiki/Sodium_dichromate)

Properties	
Chemical formula	$Na_2Cr_2O_7$
Molar mass	261.97 g/mol (anhydrous) 298.00 g/mol (dihydrate)
Appearance	bright red
Odor	Odorless
Density	2.52 g/cm^3
Melting point	356.7 °C (674.1 °F; 629.8 K)
Boiling point	400 °C (752 °F; 673 K) decomposes
Solubility in water	73 g/100 mL at 25 °C
Solubility in other solvents	soluble in methanol, ethanol
Refractive index(n_D)	1.661 (dihydrate)

2.2 Fluidized Bed Adsorption Column [6]

A fluidized bed adsorption column is a type of adsorption column that can be used to carry out a variety of multiphase chemical reactions. In this type of adsorption column, a fluid (gas or liquid) is passed through a granular solid material (usually a catalyst) at high enough velocities to suspend the solid and

cause it to behave as though it were a fluid. Uniform particle mixing, uniform temperature gradients and ability to operate reactor in continuous state are some of its advantage which make it one of the widely used equipment in today's industrial world.

The solid substrate (the catalytic material upon which chemical species react) material in the fluidized bed column is typically supported by a porous plate, known as a distributor. The fluid is then forced through the distributor up through the solid material. At lower fluid velocities, the solids remain in place as the fluid passes through the voids in the material. This is known as a packed bed adsorption column. As the fluid velocity is increased, the column will reach a stage where the force of the fluid on the solids is enough to balance the weight of the solid material. This stage is known as incipient fluidization and occurs at this minimum fluidization velocity. Once this minimum velocity is surpassed, the contents of the column bed begin to expand and swirl around much like an agitated tank or boiling pot of water. The column is now a fluidized. Depending on the operating conditions and properties of solid phase various flow regimes can be observed in this fluidized adsorption column.

2.2.1 Applications

In textile industry the wastewater is treated in these adsorption columnby adsorbing the effluent on the adsorbent and decolorizing the wastewater. Fluidized bed adsorption column allow for a cleaner, more efficient process than previous standard adsorption technologies.

2.2.2 Advantages

- ➢ Uniform Particle Mixing: Due to the intrinsic fluid-like behavior of the solid material, fluidized beds do not experience poor mixing as in packed bed columns. This complete mixing allows for a uniform product that can often be hard to achieve in other column designs.

- ➢ Uniform Temperature Gradients: Many chemical reactions require the addition or removal of heat. Local hot or cold spots within the adsorption column, often a problem in packed beds, are avoided in a fluidized situation. In other column types, these local temperature differences, especially hotspots, can result in product degradation.

➢ Ability to Operate the Column in Continuous State: The fluidized bed nature of these adsorption column allows for the ability to continuously withdraw product and introduce new reactants into the reaction vessel.

2.2.3 Disadvantages

➢ Increased Column Vessel Size: Because of the expansion of the bed materials in the reactor, a larger vessel is often required than that for a packed bed column. This larger vessel means that more must be spent on initial capital costs.

➢ Particle Entrainment: The high gas velocities present in this style of column often result in fine particles becoming entrained in the fluid. These captured particles are then carried out of the column with the fluid, where they must be separated. This can be a very difficult and expensive problem

➢ Pumping Requirements: The requirement for the fluid to suspend the solid material necessitates that a higher fluid velocity is attained in the column. In order to achieve this, more pumping power and thus higher energy costs are needed.

2.3 Adsorbent

The orange peel used in this demonstration is to be collected from local fruit shops. The collected peels are to be washed with permuted water several times to remove dirt particles and water soluble materials. The washing process has to be continued till the wash water contains no colour.The washed materials are to be completely dried in an air oven at 105-110°C till the peels are completely dry. The dried peels are then acid washed in 10% (by v/v) Acetic acid solution. The product of acid wash is to be dried in Oven again at 105-110°C until it can be grinded into fine powder using a simple mixer-grinder.

The products so obtained were sieved to desired particle size of 600 microns -2mm. Then, this product has to be stored in a vacuum desiccator until required.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Identification Of Metal Ion

3.1.1

Industry identified - Cheviot International Ltd.

Industry type   - Leather tanning industry

Products   - Sheep leather, Buff leather and Goat leather

3.1.2 Composition of Industrial Wastewater

The wastewater produced by a tannery (including preparation of the hides) has a high chloride content (up to 5 g Cl/L). It contains a high concentration of COD (about 1500 – 2500 mg/L), a high amount of settable substances (10 – 20 g/L) and emulsified fat, and tends to form foam. The dichromate content can reach a peak value of 2000 mg/L. So the tannery wastewater is a killer to the water environment if it is discharged without good treatment.[11]

Chromium is identified as a Heavy Metal ion to be removed.

3.2 DESIGN of MODEL

- ➢ Plywood for assembling the different parts of the model on the stand.
- ➢ Transparent fiber column holds the distributor, and the reactor bed (solid phase) for adsorption. Transparency is required for acute observation of the fluidization of the bed.
- ➢ Fiber pipe connectors are used at the base and the top of the column. These provide the inlet and outlet to the reactor connecting it to the pump and effluent tank.
- ➢ Fiber pipe connections are made to connect the diaphragm pump to the influent tank. Connections from pump to inlet are also done.
- ➢ Similar connections are done to connect the compressor and air inlet.
- ➢ Rota meter would control the inlet flow rates of liquid phase into the reactor system.
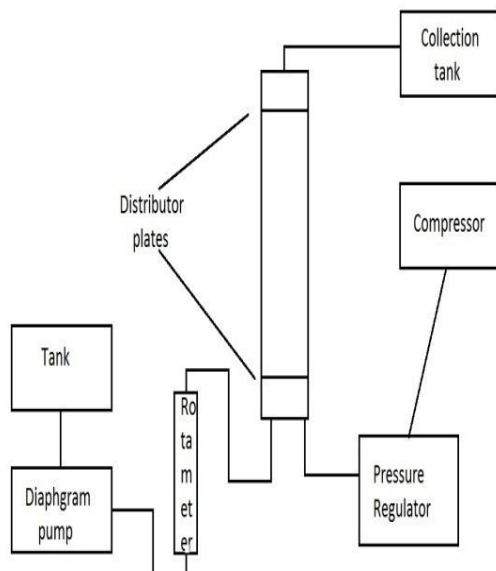- ➢ Pressure Gauge is used for controlling air flow and pressure.

Fig. 2:Layout Of The Model

3.2.1 Specifications

1. Column

Internal diameter = **25 mm**

Outer diameter = **32mm**

Thickness = **7 mm**

2. Pipes

Internal diameter = **6mm**

Outer diameter = **8mm**

3. Pump

Type**: Diaphragm Pump**

Capacity = **1 lit/min**

4. Distributor Plate

Size = **100 microns**

5. Rota meter

For liquid, Capacity = **10 lpm**

Fig. 3: Experimental Setup

3.3 Calculations for Model

For a three phase fluidized Adsorption tower,

$$\Delta P \cong (\rho_s \epsilon_s + \rho_L \epsilon_L + \rho_G \epsilon_G) Hg$$

Where,

ρ_s = density of solids (1.2 gm. $/cm^3$)

ρ_L = density of liquids (1 gm. $/cm^3$)

ρ_G = density of air (0.00129 gm. $/cm^3$)

ϵ_s = void fraction of solid

ϵ_L = void fraction of liquid

ϵ_G = void fraction of gas

For minimum fluidization velocity,

Using Sang et al (1989),

For

0.003 < V_{SL} < 0.05 m/s   and V_{SG} < 0.08 m/s

$$(V_{SL})_m = (V_{SL})_{mo} [(1- (3.76) ((V_{SG})^{0.33}(\mu_L)^{0.23} (d_p)^{0.21}(\rho_{s-}\rho_L)^{-0.42}]$$

Here,

V_{SG} = 0.065 m/s which is less than 0.08m/s

$$(V_{SL})_{mo} = \frac{33.7\,\mu_L}{d_p\rho_L} \left[(1 + \frac{(3 \times 6 \times 10^{-5} \times g \times \rho_L(\rho_{s-}\rho_L)d_p{}^3)}{(\mu_L)^2})^{0.5} - 1 \right]$$

Putting values,

$$(V_{SL})_{mo} = \frac{33.7\,(8.9\,X\,0.001)}{0.12\,X\,1} \left[\left(1 + \frac{(3\,x\,6\,x\,10^{-5}\,x\,981\,x\,1(0.2)0.12^3)}{(8.9\,X\,0.001)^2}\right)^{0.5} - 1\right]$$

$(V_{SL})_{mo}$ = 4.68 cm/s or 0.046 m/s

So,

$(V_{SL})_m$ = 0.0276 m/s

Now.

For bed expansion,

using Saberia-Broudjenni et al 1984

$$\epsilon = (14\phi_S)^{-3} \left(\frac{V_{SL}}{(V_{SL})_{mo}}\right)^{0.27} (1 + 0.07 Re_{LG}^{0.34})$$

where,

ϕ_S =   Sphericity factor

Re_{LG} = Reynolds' number

Now,

$$\phi_S = \frac{(2d_1)^2}{(d_p^2 + 2d_p)}$$

Putting values.

ϕ_S = 0.0119

Also,

$$Re_{LG} = \frac{\rho_L X V_{SG} X d_p}{\mu_L} = \frac{1\,X\,0.065\,X\,0.12}{8.9\,X\,0.001} = 1.2$$

Hence, the flow is turbulent.

Now,

$\epsilon_s = 0.34$

So, the slip velocity of gas is

$U_{GL} = 0.017(\rho_L V_{SG}{}^2)^{0.45}$

$\quad = 0.00145$ m/s

Now,

$\epsilon_L = (\frac{V_{SG} - U_{GL}}{V_{SG} + V_{SL}}) = 0.45$

$\epsilon_G = (\frac{V_{SV} - U_{GL}}{V_{SG} + V_{SL}}) = 0.19$

Therefore finally,

Putting in the first equation:

$\Delta P \cong (\rho_s \epsilon_s + \rho_L \epsilon_L + \rho_G \epsilon_G)$ Hg

$\quad = (1.2 \text{ X } 0.34 + 0.19 \text{ X } 0.0012 + 0.45 \text{ X } 1) 50.981$

$\quad = 2000.12$ gm. $/cm^2$

3.4 PREPARATION OF ADSORBENT

➢ Orange peels were taken and washed thoroughly.

➢ Then they were kept for Dehydration in oven at a temperature of $105 - 110\ ^{o}$ C, for $4 - 5$ hours.

➢ In the next step they were washed with dil. CH_3COOH (10% V/v).

➢ Further they were again dehydrated in the same manner as before.

➢ Then they were to be grinded.

➢ Sieving is done to obtain particles of ranges: 0.6mm to 1.18mm

 1.18mm to 2mm

Greater than 2mm

Table 4: Preparation of samples to be used in the experiments :

| Sample	Size	Activated Carbon (%)	Bio-adsorbent (%)
Sample 1	0.6 – 2 mm	100	0
Sample 2	0.6 -1.18mm	50	50
Sample 3	1.18 – 2 mm	50	50
Sample 4	0.6 -1.18mm	75	25
Sample 5	1.18 – 2 mm	75	25
Sample 6	0.6 – 2 mm	0	100

3.5 EXPERIMENTS AND OBSERVATIONS

3.5.1 Test runs

➤ Test runs have been conducted on the different samples prepared.

➤ Each test run was conducted as a batch process.

➤ Time taken for each run was 30 mins.

➤ Samples (around 50 ml) were collected after the treatment of samples in the test runs.

3.5.2 Titration

Titrations were conducted on all the six samples collected from the test runs using Ferrous Ammonium Sulphate as aknown solution and Di-Phenyl Amine as an indicator. Reactions in the titrations are:
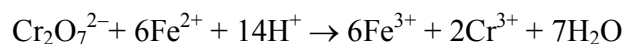
Dichromate ion reduces to two chromium(III) ions. This reaction requires 6 electrons and 14hydrogen ions:
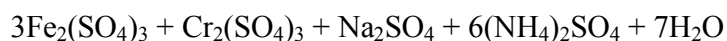
$$Cr_2O_7^{2-} + 14H^+ + 6\ e^- \rightarrow 2Cr^{3+} + 7H_2O$$
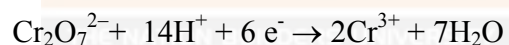
Only one electron is necessary to reduce Fe(III) to Fe(II)

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$
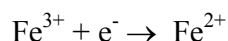
Therefore, 1 mole of $Cr_2O_7^{2-}$ (oxidizing agent) reacts with 6 moles of Fe^{2+} (reducing agent) to form 6 moles of Fe^{3+} and 2 moles of Cr^{3+}. Thus, in net ionic form:

$$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$

The molecular form ofthe reaction equation can be written as:

$$Na_2Cr_2O_7 + 6Fe(NH_4)_2(SO_4)_2 + 7H_2SO_4 \rightarrow$$
$$3Fe_2(SO_4)_3 + Cr_2(SO_4)_3 + Na_2SO_4 + 6(NH_4)_2SO_4 + 7H_2O$$
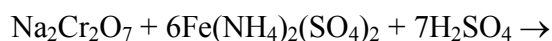
The observations were recorded

Fig. 4: Bio-Adsorbent

Fig. 5:Effluent samples of Exp 1 to 6 (L to R)

3.6 OBSERVATIONS

- For unknown solution of $Na_2Cr_2O_7$

  Normality = N_1
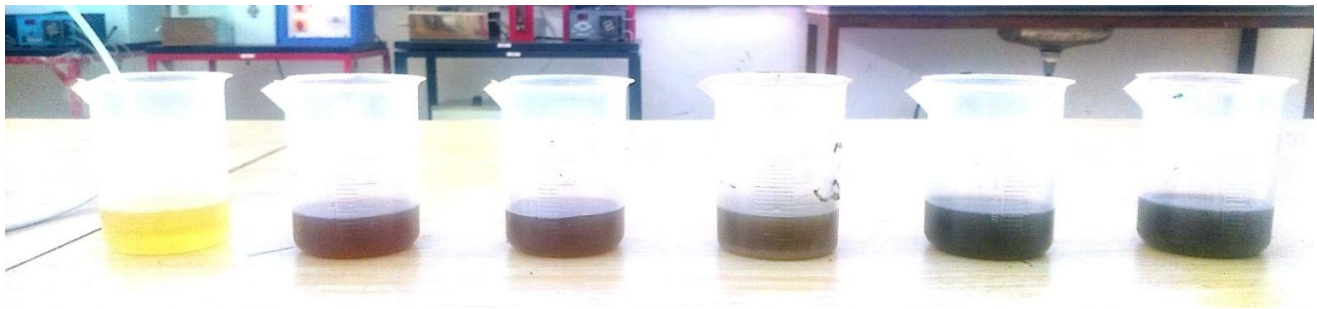
  Volume   = V1 = 10mL   (for each titration)

- For known solution of Ferrous Ammonium Sulphate (F.A.S)

  Normality = N_2 = N/40

  Volume   = V_1 (in burette for titration)

- Indicator:

  Di-Phenyl Amine (DPA)
  (Dissolved in glacial H_2SO_4)

For $Na_2Cr_2O_7$,

Molecular weight = 262 amu
        N-Factor   = 6
         Equivalent weight = 43.66

Table 5: Observation Table:

Exp. No.	Dosage	Time (mins.)	Size	Initial B.R	Final B.R	Vol. of FAS Used
1.	100% A.C	30	0.6mm – 2mm	0	5.9	5.9
				5.9	11.7	5.8
				11.7	17.5	5.8
2.	100% B.A.D	30	0.6-2	0	13.8	13.8
				13.8	27.6	13.8

3.	50% A.C – 50% B.A.D	30	1.18 - 2	0	11.9	11.9
				11.9	23.6	11.7
				23.6	35.3	11.7
4.	50%A.C – 50% B.A.D	30	0.6- 1.18	0	11.2	11.2
				11.2	22.3	11.1
				22.3	33.4	11.1
5.	75%A.C – 25% B.A.D	30	1.18– 2	0	9.1	9.1
				9.1	18.2	9.1
6.	75% A.C - 25% B.A.D	30	0.6– 1.18	0	8.5	8.5
				8.5	16.8	8.3
				16.8	25.1	8.3
7.	75% A.C.- 25% B.A.D	60	0.6– 1.18	0	3.6	3.6
				3.6	7.0	3.4
				7.0	10.4	3.4

3.7 CALCULATIONS

3.7.1 Experiment 1

Sample tested: 100% A.C. (0.6mm – 2mm)

After titration,
$N_1V_1 = N_2V_2$

Where,

N_1 = Normality of $Na_2Cr_2O_7$ (unknown solution)
V_1 = Volume of unknown solution
N_2 = Normality of Ferrous Ammonium Sulphate (known solution)
V_2 = Volume of known solution

Now,

Normality of unknown solution = N_1
Volume of unknown solution   = V_1 = 10mL
Normality of known solution   = N/40
Volume of known solution   = V_2 = 5.8 mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (5.8)

N_1 = 0.0145N

Strength = (Normality) x (Equivalent Weight)

= (0.0145) x (43.66)

= 0.63307 gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

= (0.8244) x (0.63307)= 0.5219 gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

= 2.43 – 0.63307

= 1.79693 gm/L

% Removal = (1.4781/2) x (100)

= 73.91%

3.7.2 Experiment 2

Sample tested: 100% B.A.D (0.6mm – 2mm)

Normality of unknown solution = N_1
Volume of unknown solution = V_1 = 10mL
Normality of known solution = N/40
Volume of known solution = V_2 = 13.8mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (13.8)

N_1 = 0.0345N

Strength = (Normality) x (Equivalent Weight)

= (0.0345) x (43.66)

= 1.50627gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

= (0.8244) x (1.50627)

= 1.24177 gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

= 2 – 1.24177

= 0.75823gm/L

% Removal = (0.75823/2) x (100)

= 37.91%

3.7.3 Experiment 3

Sample tested: 50% A.C, 50% B.A.D (1.18mm – 2mm)

Normality of unknown solution = N_1
Volume of unknown solution = V_1= 10mL
Normality of known solution = N/40
Volume of known solution = V_2= 11.7mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (11.7)

N_1 = 0.02925N

Strength = (Normality) x (Equivalent Weight)

   = (0.02925) x (43.66)

   = 1.27706gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

   = (0.8244) x (1.27706)

        = 1.05281gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

   = 2 – 1.05281

   = 0.94719gm/L

% Removal = (0.94719/2) x (100)

   = 47.36%

3.7.4 Experiment 4

Sample tested: 50% A.C, 50% B.A.D (0.6mm - 1.18mm)

Normality of unknown solution = N_1
Volume of unknown solution = V_1 = 10mL

Normality of known solution   = N/40
Volume of known solution   = V_2 = 11.1mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (11.1)

N_1 = 0.02775N

Strength = (Normality) x (Equivalent Weight)

    = (0.02775) x (43.66)

    = 1.21157 gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

    = (0.8244) x (1.21157)

    = 0.99882 gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

    = 2 – 0.99882

    = 1.00118 gm/L

% Removal = (1.00118/2) x (100)

    = 50.06%

3.7.5 Experiment 5

Sample tested: 75% A.C, 25% B.A.D (1.18mm – 2mm)

Normality of unknown solution = N_1
Volume of unknown solution   = V_1 = 10mL
Normality of known solution   = N/40
Volume of known solution   = V_2 = 9.1 mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (9.1)

$N_1 = 0.02275N$

Strength = (Normality) x (Equivalent Weight)

   = (0.02275) x (43.66)

   = 0.99326 gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

   = (0.8244) x (0.99326)

   = 0.81884 gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

   = 2 – 0.81884

   = 1.18116 gm/L

% Removal = (1.18116/2) x (100)

   = 59.06%

3.7.6 Experiment 6

Sample tested: 75% A.C, 25% B.A.D (0.6mm – 1.18mm)

Normality of unknown solution = N_1

Volume of unknown solution   = V_1 = 10mL

Normality of known solution   = N/40

Volume of known solution   = V_2 = 8.3 mL

Since $N_1V_1 = N_2V_2$

N_1 x (10) = N/40 x (8.3)

$N_1 = 0.02075N$

Strength = (Normality) x (Equivalent Weight)

$$= (0.02075) \times (43.66)$$

$$= 0.9059 \text{ gm/L}$$

Concentration of dichromate ion = (weight fraction) x (Strength)

$$= (0.8244) \times (0.9059)$$

$$= 0.74682 \text{ gm/L}$$

Now,

Removed Concentration = Initial concentration – Final Concentration

$$= 2 - 0.74682$$

$$= 1.25318 \text{ gm/L}$$

% Removal = (1.25318/2) x (100)

$$= 62.66\%$$

3.7.7 Experiment 7

Sample tested: 75% A.C, 25% B.A.D (0.6mm – 1.18mm)

Normality of unknown solution = N_1
Volume of unknown solution   = V_1 = 10mL
Normality of known solution   = N/40
Volume of known solution   = V_2 = 3.4 mL

Since $N_1V_1 = N_2V_2$

$N_1 \times (10) = N/40 \times (3.4)$

$N_1 = 0.0085N$

Strength = (Normality) x (Equivalent Weight)

= (0.0085) x (43.66)

= 0.3711gm/L

Concentration of dichromate ion = (weight fraction) x (Strength)

= (0.8244) x (0.3711)

= 0.3059gm/L

Now,

Removed Concentration = Initial concentration – Final Concentration

= 2 – 0.3059

= 1.6941gm/L

% Removal = (1.6941/2) x (100)

= 84.71%

3.8 COST ESTIMATION

3.8.1 FOR ACTIVATED CARBON

Cost of 1 Kg Activated Carbon = Rs 2000

3.8.2 FOR BIO-ADSORBENT (Prepared from orange peels)

Here,

1. Oven Power Rating (used for drying) = 1.8 KW

2. Oven Capacity = 2 Kg

3. Cost of Acetic Acid = Rs 50/Kg

Initially,
Weight of orange peels = 2Kg

After Drying,
Weight of orange peels = 609.6 gm.

After acid wash & drying again,
Weight of orange peels = 591.9 gm.

After grinding and sieving, adsorbent in the size range of 0.6-2mm was selected.
Weight of orange peels = 401.4 gm. ≈ 400 gm.

Therefore 2Kg orange peels, 400 gm. adsorbent was obtained.

Costs incurred:

Cost of orange peel = Rs 0 (Collected from fruit vendors)

Cost of acetic acid = Rs 6 (120mL used for treatment of 500gm. orange (peels) (i)

Total drying time = 8 hours

Cost of electricity per unit = Rs 4

Cost of operating oven = (1.8) X (8) X (4) = Rs 57.60   (ii)

Operational cost for preparation of 400 gm. adsorbent = (i) + (ii)

$$= Rs\ 63.60$$

Operational cost for preparation of 1Kg adsorbent = Rs 159

Miscellaneous costs involved = Rs 50

Total cost for preparation of 1Kg adsorbent = Rs 209

In the experiments, only 15gm adsorbent was used at a time. So,

1. Cost of 100% AC = Rs 30
2. Cost of 100% BAD = Rs 3.13

Therefore, cost of 75% AC + 25% BAD = RS 23.28 ≈ Rs 23.3

Difference in costs = 30 – 23.3

$$= Rs\ 6.7$$

Percentage difference in costs = (6.7/30) X (100)

$$= 22.33\%$$

3.8.3 OPERATION COSTS

A. 30 min. operation:

1. Power consumption of pump = 10W/hour
2. Power of compressor= 2.2KW/hour

Therefore, electricity consumption charges:

For Pump,
$C_p = (0.01)\ X\ (0.5)\ X\ (4) = Rs\ 0.02$

For Compressor,

Cc = (2.2) X (0.5) X (4) = Rs 4.4

Therefore, **total operating and testing costs = Rs 4.42**

        B. For 60 min. operation:

For Pump,

Cp = (0.01)X (1) X (4) = Rs. 0.04

For Compressor,

Cc = (2.2) X (1) X 4 = Rs 8.8

Therefore, **total operating and testing costs = Rs 8.84**

3.8.4 TESTING COST

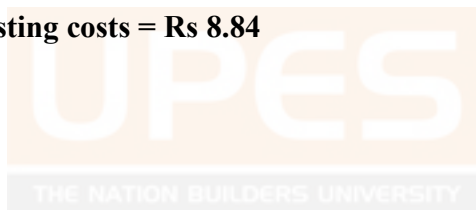**Table 6: Testing Cost:**

Experiment No.	Amt. of FAS Used (gms)	Cost of FAS Used
1	0.058	0.03
2	0.138	0.069
3	0.117	0.059
4	0.111	0.055
5	0.091	0.045
6	0.083	0.040
7	0.017	0.0085

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Amount Of Removal

- **ExperimentNo.- 1**(Sample tested: 100% Activated Carbon):

  Size: 0.6mm – 2mm

    1. Amount of dichromate removed = 1.79693 gm/lit.
    2. Percentage removal   = 73.91%

- **Experiment No.- 2**(100% Bio-Adsorbent):

  Size: Average (600μm -2mm):

    1. Amount of Dichromate removed = 0.75823 gm/lit.
    2. Percentage Removal   = 37.91%

- **Experiment No.- 3**(50% Activated Carbon – 50% Bio- Adsorbent)

  Size: 1.18mm – 2mm

    1. Amount of Dichromate removed = 0.94719 gm/lit.
    2. Percentage Removal   = 47.36%

- **Experiment No.- 4** (50% Activated Carbon – 50% Bio- Adsorbent):

  Size: 0.6mm – 1.18mm

    1. Amount of Dichromate removed = 1.00118 gm/lit.
    2. Percentage Removal   = 50.06%

- **Experiment No.- 5**(75% Activated Carbon – 25% Bio-Adsorbent):

  Size: 1.18mm -2 mm

    1. Amount of Dichromate removed = 1.18116 gm/lit.

2. Percentage Removal   = 59.06%

➤ **Experiment No.- 6** (75% Activated Carbon- 25% Bio-Adsorbent):

Size: 0.6mm -1.18mm

1. Amount of Dichromate removed = 1.25318 gm/lit.
2. Percentage Removal   = 62.66%

➤ **Experiment No.- 7** (75% Activated Carbon- 25% Bio-Adsorbent):

Size: 0.6mm -1.18mm

1. Amount of Dichromate removed = 1.6941gm/lit.
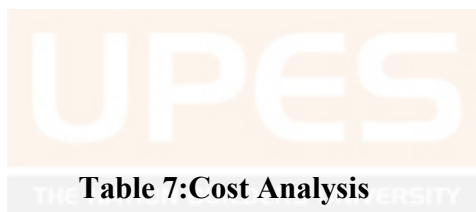2. Percentage Removal   = 84.71%

4.2 Cost Estimation

Table 7:Cost Analysis

Experiment No.	Dosage (%)	Particle Size (in mm)	Adsorbent Cost (INR)	Operation Cost (INR)	Testing Cost (INR)	Total Cost (INR)
1	100 AC	0.6-2	30	4.42	0.03	34.45
2	100 BAD	0.6-2	3.135	4.42	0.069	7.624
3	50 BAD - 50 AC	1.18-2	16.57	4.42	0.059	21.049
4	50 BAD - 50 AC	0.6- 1.18	16.57	4.42	0.055	21.045
5	25 BAD - 75 AC	1.18-2	23.3	4.42	0.045	27.765
6	25 BAD - 75 AC	0.6-1.18	23.3	4.42	0.04	27.76
7	25 BAD - 75 AC	0.6-1.18	23.3	8.84	0.0085	32.148

CHATER 5

CONCLUSIONS & RECOMMENDATIONS

The batch study of removal of Di-chromate (2gm/ltr.) using pure activated carbon, pure bio- adsorbent (Orange peel) and combination of both, was carried out. The result shows that the metal removal rate was higher (73.19%) in case of 100% AC, followed by combination of 75% AC-25% BAD to (62.66%) and 50% AC-50% BAD to (50.06%). The percentage metal removal in case of pure bio-adsorbent is 37.91%. The effect of particle size of bio-adsorbent shows that the removal was 62.66% for the particle size of 0.6-1.18 mm , followed by 59.06% for the particle size 1.18-2 mm.

The cost estimation data shows that the adsorbent cost is reduced by 22.33 % for 75% AC-25% BAD when compared to 100%AC and the total process cost is reduced by 19.42 %.

It is recommended from the study that more reduction is possible with increase in the batch time of the process.

The process needs to be studied on continuous basis with the automation of existing experimental setup which will lead to understand the actual behaviour of removal of Dichromate ion.

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