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ALMOND SHELL CARBON AS AN ADSORBENT: A COMPARATIVE STUDY ON ADSORPTION OF DIBASIC ACIDS

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Abstract

The development of sustainable, low-cost adsorbents from agricultural waste has emerged as a key strategy in wastewater treatment. Almond shell carbon (ASC), derived from lignocellulosic biomass, shows potential as an efficient adsorbent due to its porosity, high carbon content, and surface functional groups. This study investigates the adsorption behaviour of four common dibasic acids—oxalic acid, malonic succinic and glutaric acid—onto ASC and compares its performance with commercial wood-based activated carbon. Batch adsorption experiments were conducted to examine the effects of pH, adsorbent dosage, contact time, and initial concentration. Adsorption isotherms were analyzed using Langmuir and Freundlich models. The results demonstrated that ASC exhibits strong adsorption capacity for acids, outperforming wood carbon in several parameters. The study highlights almond shell carbon as a promising eco-friendly alternative for organic acid removal in wastewater treatment applications.

1. Introduction

Industrial effluents from food processing, textiles, pharmaceuticals, and chemical industries often contain dibasic organic acids such as oxalic acid, malonic succinic and glutaric acid. Their discharge into aquatic environments poses environmental challenges, including increased acidity, alteration of biochemical oxygen demand (BOD), and potential toxicity to aquatic organisms. Adsorption onto activated carbon remains one of the most effective approaches for the removal of organic contaminants from water.

The use of agricultural by-products for activated carbon production is gaining attention because of its sustainability, cost-efficiency, and waste-to-resource benefits. Almond shells, rich in lignin and cellulose, represent a suitable precursor for high-quality activated carbon. This study examines the adsorption performance of almond shell carbon (ASC) for the removal of dibasic acids and compares its efficacy with that of commercial wood carbon.

2. Materials and Methods

2.1 Preparation of Almond Shell Carbon

Almond shells were washed, dried, crushed, and sieved. Chemical activation was performed using phosphoric acid (H_3PO_4) followed by carbonization at 450–500°C. The resulting carbon was washed to neutral pH and dried.

2.2 Adsorption Studies: Batch equilibrium studies at varying concentrations, pH, and temperature. Isotherm models: Langmuir, Freundlich.

ADSORBENT USED

Fig.1 almond nut shell, Fig.2 crushed almond Nut shell Fig.3 almond nut shell carbon

2.3 Preparation of Solutions and Procedure:

Materials Used: Almond shell carbon, Di basic acids (oxalic acid, malonic succinic and glutaric acid), NaOH, Phenolphthalein, Stoppered bottle, Burette, Pipette, Funnel, Conical flask.

PROCEDURE:

Prepared aqueous solution of acids into numbered flask as labelled, the total volume of each solution is 50ml taken in Stoppard bottles. Transfer 10ml of the solution from each bottle into the conical flask. Add 2-3 drops of Phenolphthalein indicator and titrate against NaOH. Once the end point is reached, read the burette reading. The volume of baseV_1. Calculate the actual concentration of oxalic acid C_1 in the flask number 1 to 5 respectively, and write it down in the table. Using practical balance weigh 5 portions of walnut shell carbon, each portion1 gram. Placed Almon shell carbon into numbered flask into stoppered bottle and shake them, wait for 20 minutes, the process of adsorption is in progress. Mix the mixtures for several times by shaking the flask. (The process of adsorption is a function of times it is important to put on ion feel into flask at the same time to provide adsorption for the same period in each flask). Filter the mixtures into clean and dry flask to avoid disturbing effect of adsorption of acid into filtering paper, remove away the first portion of filtration approximate of 5ml. Determine the final concentration of acid C, in each of the flask after adsorption from each solution, pipette out 10ml of oxalic acid solution and transfer it to clean and dry conical flask. To this conical flask containing oxalic acid solution at 2 to 3drops of Phenolphthalein indicator. Now, titrate this solution against NaOH in the burette, note down the burette reading. The volume of base V_2

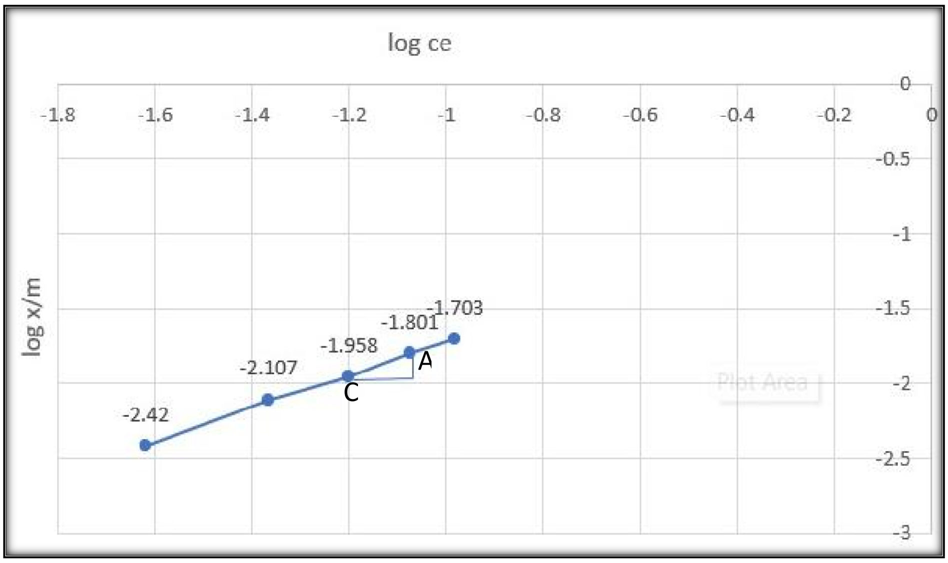
PROCEDURE TABULAR COLUMN: -Dilution of acids

Bottle No.	Vol. of acid added (0.1N)	Volume of water added in ml	Amount of Almond shell nut shell carbon added in gm
1	50	00	1
2	40	10	1
3	30	20	1
4	20	30	1
5	10	40	1

TABULAR COLUMN:

SI. NO	Initial concentration of Oxalic acid(Co)	Vol. of titrant taken in ml	Amount of almond shell Carbon added in	Burette reading	Ce = B.R*0.1/10Eq.con.of	X=Co-Ce/20 Amount adsorbed in moles	x/m	Log(x/m)	Log Ce	Ce (x/m)
1	0.5	10	1	10.4	0.104	0.0198	0.0198	-1.703	-0.982	0.0020
2	0.4	10	1	8.4	0.084	0.0158	0.0158	-1.801	-1.075	0.0013
3	0.3	10	1	6.3	0.063	0.011	0.011	-1.958	-1.200	0.0006
4	0.2	10	1	4.3	0.043	0.0078	0.0078	-2.107	-1.366	0.0003
5	0.1	10	1	2.4	0.024	0.0038	0.0038	-2.420	-1.619	0.00009

GRAPH: FREUNDLICH ADSORPTION ISOTHERM (OXALIC ACID)



Scale= X-axis – 1 unit =0.2cm; Y- axis - 1 unit=0.5cm

SLOPE= AB/BC

= (-1.801)-(-1.958)

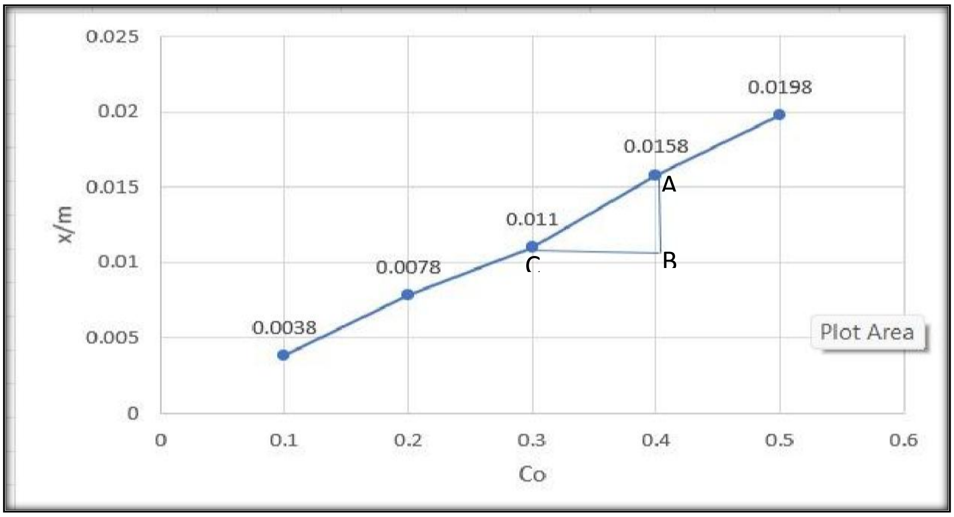
(-1.1)- (-1.2)

= 0.17

0.1

= 1.57

GRAPH: LANGMUIR ADSORPTION ISOTHERM (OXALIC ACID)



Scale= X-aixs – 1 unit =0.1cm; Y- axis - 1 unit=0.005cm

SLOPE= AB/BC

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$$= \frac{(0.0158)-(0.011)}{(0.4)-(0.3)}$$

$$= 0.0048$$

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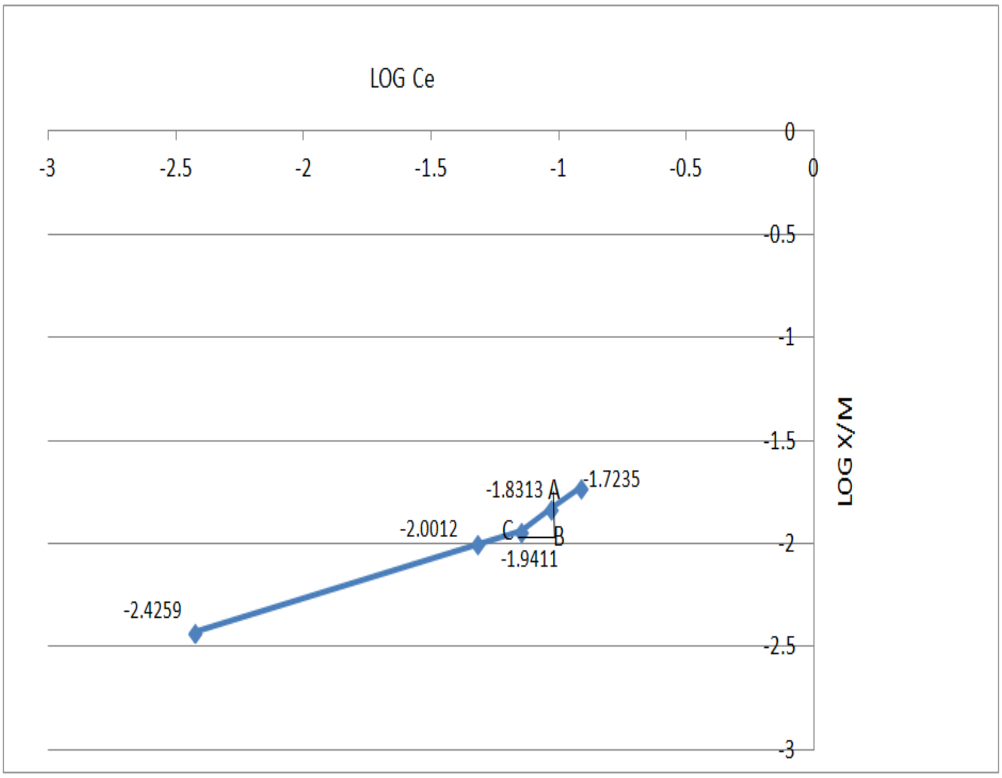
TABULAR COLUMN: -

SI. NO	Initial concentration of Malonic acid(Co)	Vol. of titrant taken in ml	Amount of almond shell Carbon added in gm	Burette reading	Ce = B.R*0.1/10Eq.con.of acid	X=Co-Ce/20 Amount adsorbed in	x/m	Log(x/m)	Log Ce	Ce (x/m)
1	0.5	10	1	12.2	0.122	0.0189	0.0189	-1.7235	-0.91364	0.00230
2	0.4	10	1	9.3	0.093	0.01535	0.01535	-1.83138	-1.03151	0.00142
3	0.3	10	1	7.7	0.071	0.01145	0.01145	-1.9411	-1.14874	0.00081
4	0.2	10	1	4.8	0.048	0.0076	0.0076	-2.0012	-1.3187	0.00036
5	0.1	10	1	2.5	0.025	0.00375	0.00375	-2.4259	-2.4259	0.000093

GRAPH: FREUNDLICH ADSORPTION ISOTHERM (MALONIC ACID)

Scale= X-axis – 1 unit =0.5cm Y- axis - 1 unit=0.5cm



SLOPE= AB/BC

= (-1.8313)-(-1.9411)

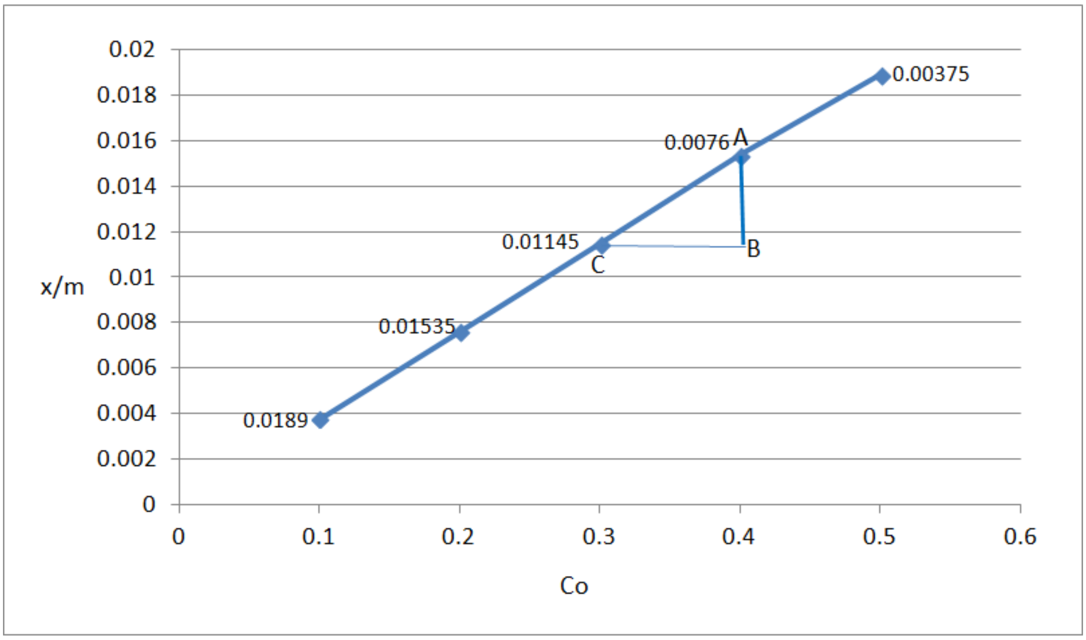
(-1.2)- (-1.3)

= 0.1098

0.1

= 1.098

GRAPH : LANGMUIR ADSORPTION ISOTHERM (MALONIC ACID)



Scale= X-axis – 1 unit =0.1cm Y- axis - 1 unit=0.002cm

SLOPE= AB/BC

SLOPE = (0.0076)-(0.01145)

(0.4)-(0.3)

= 0.00385

0.1

= 0.096

TABULAR COLUMN: -

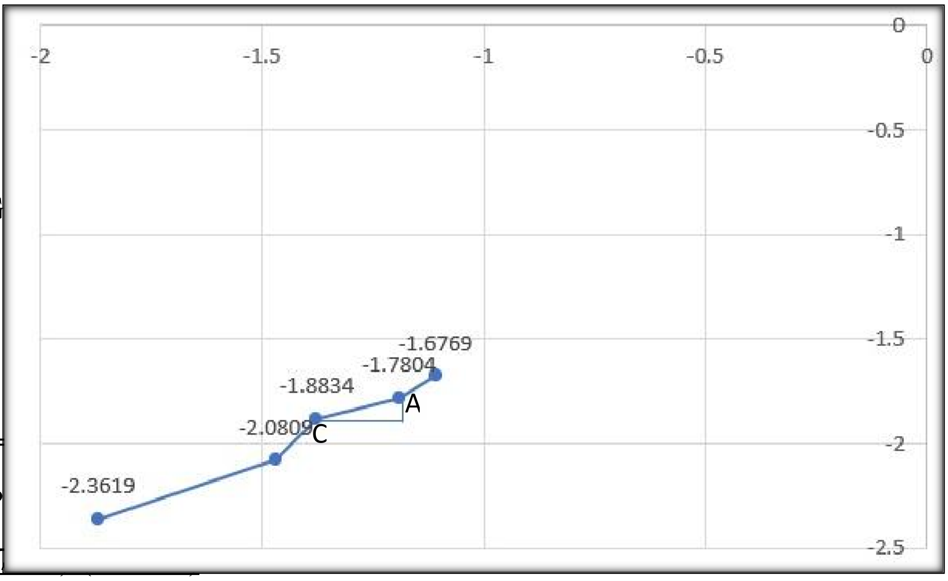
SI. NO	Initial concentration of Succinic acid(Co)	Vol. of titrant taken in ml	Amount of almond shell Carbon added in gm	Burette reading	Ce = B.R*0.1/10Eq.con.of acid in mol/dm^3	X=Co-Ce/20 Amount adsorbed in moles	x/m	Log(x/m)	Log Ce	Ce (x/m)
1	0.5	10	1	8.2	0.082	0.0209	0.0209	-1.6769	-1.0861	0.00171
2	0.4	10	1	7.6	0.076	0.0162	0.0162	-1.7804	-1.1191	0.00123
3	0.3	10	1	6.8	0.068	0.0116	0.0116	-1.8824	-1.2674	0.00788
4	0.2	10	1	3.4	0.034	0.0083	0.0083	-2.0804	-1.4685	0.000282
5	0.1	10	1	1.5	0.015	0.00425	0.00425	-2.3619	-1.8239	0.000063

GRAPH: FREUNDLICH ADSORPTION ISOTHERM (SUCCINIC ACID)

LOG Ce

L O G

X/M



Scale=

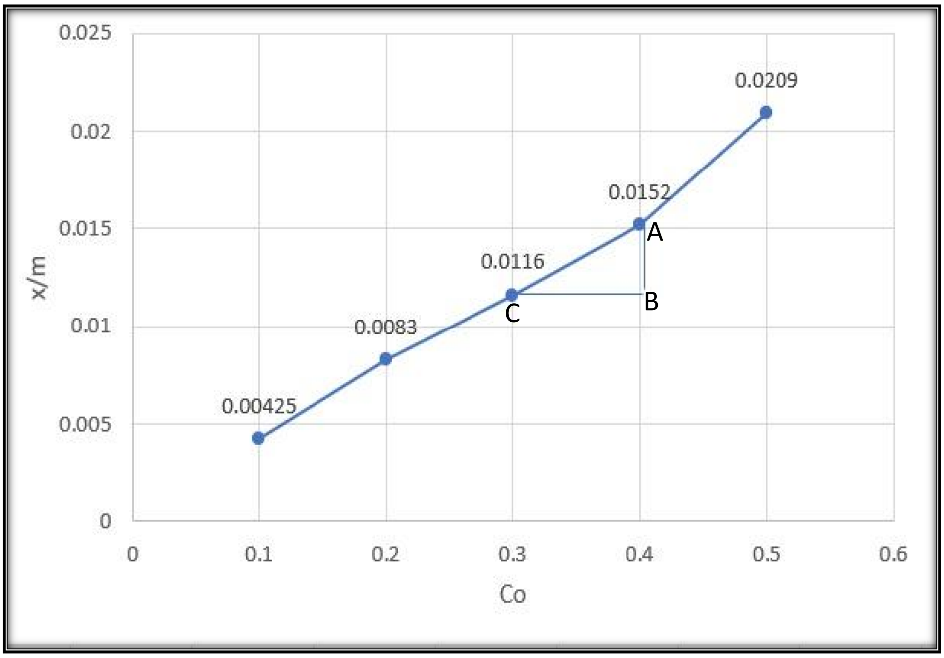
SLOP

= (-1.7

(-1.2)-(-1.4)

= 0.103/0.2 = 0.515

GRAPH: LANGMUIR ADSORPTION ISOTHERM (SUCCINIC ACID)



Scale= X-axis – 1 unit =0.1cm; Y- axis - 1 unit=0.005cm

SLOPE= AB/BC

= (0.0152)-(0.0116)/(0.4)- (0.3)

= 0.0036

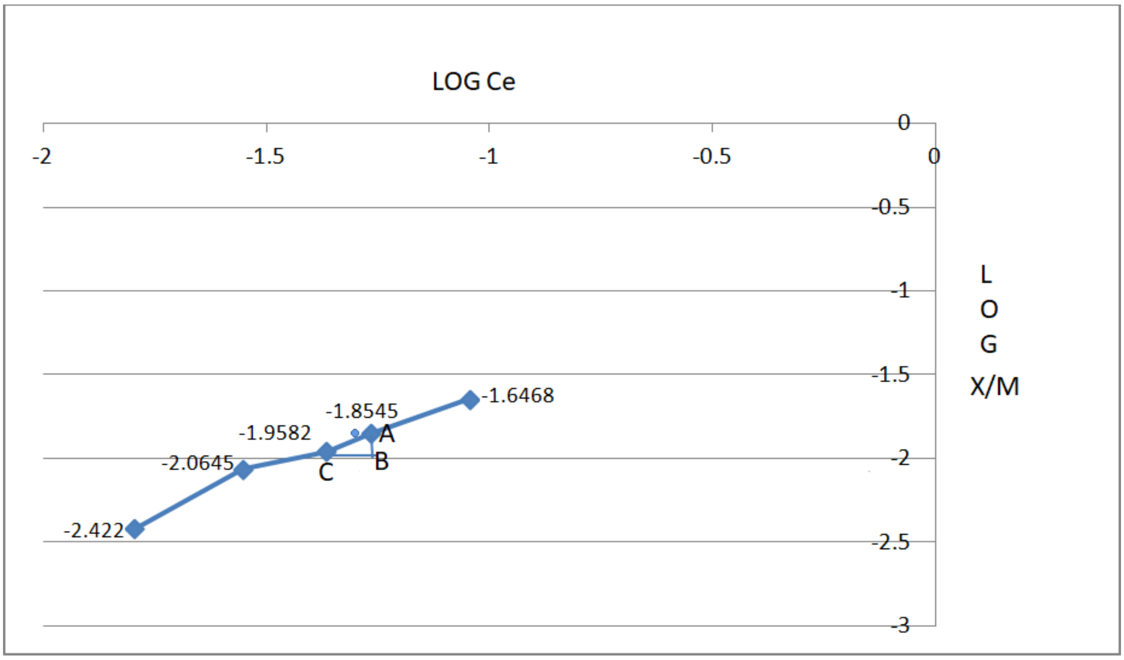
0.1

= 0.036

TABULAR COLUMN: -

SI. NO	Initial concentration of Glutaric acid(Co)	Vol. of titrant taken in ml	Amount of almond shell Carbon added in gm	Burette reading	Ce = B.R*0.1/10Eq.con.of acid	X=Co-Ce/20 Amount adsorbed in	x/m	Log(x/m)	Log Ce	Ce (x/m)
1	0.5	10	1	9	0.09	0.0205	0.0205	-1.688	-1.045	0.00184
2	0.4	10	1	6.5	0.085	0.01575	0.01655	-1.82	-1.267	0.0013
3	0.3	10	1	4.3	0.43	0.01285	0.01285	-0.189	-1.366	0.0005
4	0.2	10	1	2.8	0.028	0.0086	0.0086	-2.065	-1.552	0.00024
5	0.1	10	1	1.6	0.016	0.0042	0.0042	-2.376	-1.795	0.00006

GRAPH: FREUNDLICH ADSORPTION ISOTHERM (GLUTARIC ACID)



Scale= X-axis – 1 unit =0.5cm Y- axis - 1 unit=0.5cm

SLOPE= <u>AB/BC</u>

= (-1.8545)-(-1.9582)

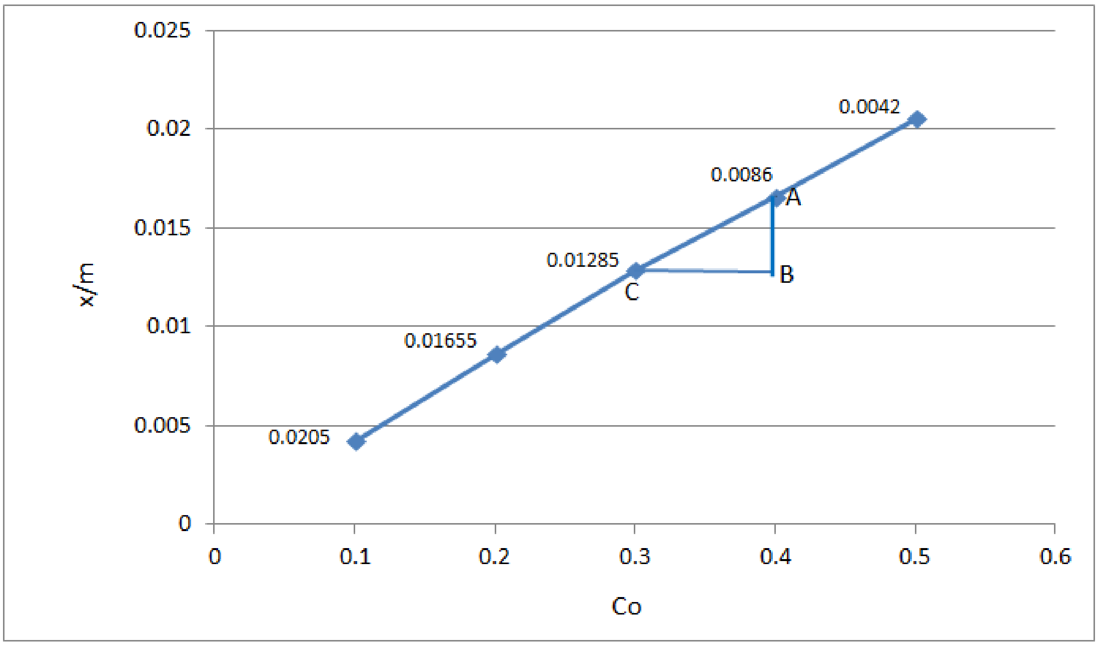
(-1.9)- (-1.8)

= 0.1037

0.1

= 1.037

GRAPH: LANGMUIR ADSORPTION ISOTHERM (GLUTARIC ACID)



Scale= X-axis – 1 unit =0.1cm Y- axis - 1 unit=0.005cm

SLOPE= <u>AB/BC</u>

= <u>(0.0086)-(0.01285)</u>

(0.4)- (0.3)

= <u>0.00425</u>

0.1

= 0.0425

3. Results and Discussion

3.1 Effect of Contact Time

Maximum adsorption occurred within 120–150 minutes. Oxalic acid showed the fastest adsorption due to its smaller molecular size.

3.2 Effect of Initial Concentration

Adsorption capacity increased with concentration but % removal decreased after equilibrium due to saturation of active sites.

3.3 Effect of pH

Optimal adsorption was observed at pH 2–3 because dibasic acids remain mostly protonated, increasing affinity for ASC.

3.4 Adsorption Isotherms

- **Langmuir isotherm showed better correlation ($R^2 > 0.97$)** for oxalic and succinic acids, indicating monolayer adsorption.
- **Freundlich model** fitted better for maleic and malonic acids, suggesting heterogeneous adsorption sites

3.5 Comparative Study

Dibasic Acid	**Adsorption Efficiency**	**Best-Fit Model**
Oxalic	Very High	Langmuir
Succinic	High	Langmuir
Malonic	Moderate	Freundlich
Glutaric	Moderate—Low	Freundlich

Oxalic acid showed the strongest interaction because of its highest acidity and ability to form stable surface complexes.

4. Conclusion

Almond shell carbon is an effective, eco-friendly, and economical adsorbent for removing dibasic acids from aqueous solutions. Its performance is comparable to commercial activated carbons. Oxalic and succinic acids exhibit stronger adsorption, following Langmuir monolayer behavior, while maleic and malonic acids show heterogeneous adsorption.

The results support the use of almond shell carbon in wastewater treatment facilities for organic acid removal.

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