2026 Volume: 02 Issue: 11 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-23

ACTIVATED CHARCOAL IN THE ELIMINATION OF PHARMACEUTICALS AND TOXIC SUBSTANCES: UNDERLYING MECHANISMS, PHARMACOKINETIC BEHAVIOUR AND CLINICAL THERAPEUTIC UTILIZATION

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Article Received: 01 October 2026
Article Revised: 20 October 2026
Published on: 10 November 2026

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DOI: https://doi-doi.org/101555/ijrpa.8945

ABSTRACT

Activated charcoal represents a highly porous carbon-based adsorbent employed in clinical toxicology to diminish the gastrointestinal absorption of specific pharmaceuticals and toxic agents during poisoning incidents. Its extensive surface area facilitates the adsorption of numerous organic compounds. **Multiple-dose activated charcoal (MDAC)** may augment the elimination of medications by disrupting enterohepatic recirculation and facilitating the transfer of drugs into the intestinal tract. Nevertheless, its efficacy is contingent upon the substance in question, the timing of administration and the patient's clinical status. It **demonstrates reduced effectiveness against alcohols, lithium, iron** and numerous inorganic substances. **Potential adverse effects encompass emesis, aspiration, constipation and intestinal obstruction.** Appropriate administration protocols are critical for ensuring both the safety and efficacy of poisoning management interventions.

KEYWORDS: Activated charcoal, drug adsorption, toxicology, drug elimination, pharmacokinetics, multiple-dose activated charcoal, enterohepatic recirculation, poisoning.

1.INTRODUCTION

1.1 DEFINITION OF CHARCOAL AND ACTIVATED CHARCOAL

Charcoal is manufactured through the thermal decomposition of organic substances under conditions of restricted oxygen availability. Activated charcoal is subjected to specialized thermal or chemical treatment processes that generate an extensive network of microscopic pores and substantially expand its surface area. Within pharmaceutical toxicology, this material serves to diminish the gastrointestinal absorption of pharmaceuticals and toxic substances and when administered in repeated doses, it facilitates the accelerated elimination of designated medications.

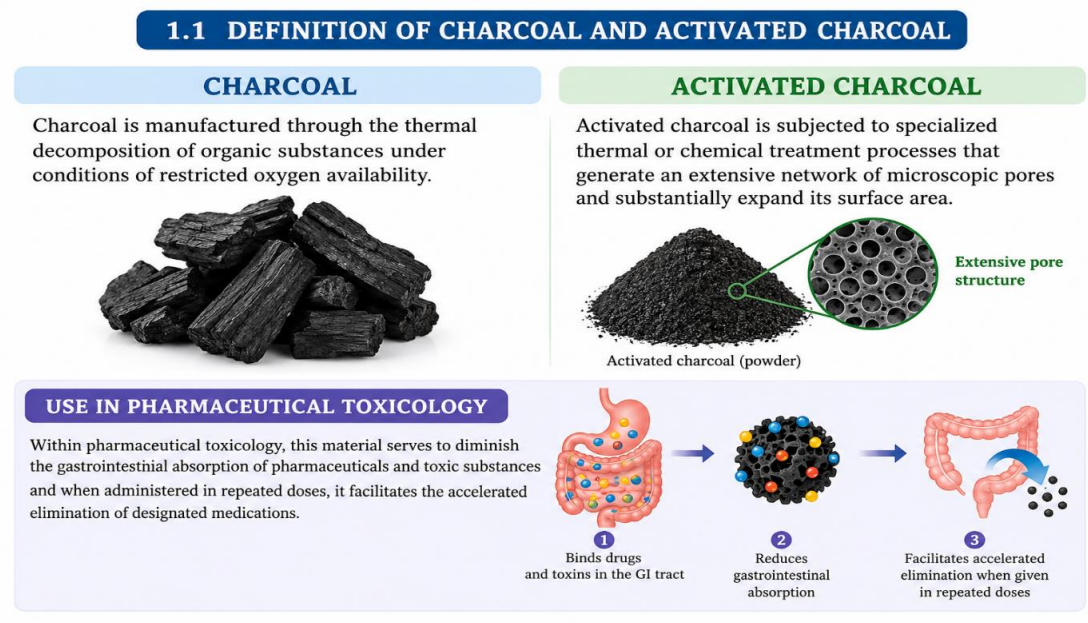

Figure 1: Different Between Charcoal Vs Activated Charcoal.

1.2 HISTORICAL BACKGROUND

Activated charcoal has served as a therapeutic agent in the management of poisoning cases throughout history. The twentieth century witnessed its emergence as a significant adsorbent material, attributed to its expansive surface area and capacity to bind numerous organic compounds. Contemporary clinical practice employs activated charcoal judiciously, with selection criteria encompassing the specific nature of the toxin, the interval elapsed since ingestion, the patient's respiratory status, and a comprehensive assessment of anticipated therapeutic benefits relative to potential adverse effects.

1.3 IMPORTANCE IN TOXICOLOGY

Activated charcoal possesses considerable clinical significance owing to its ability to reduce systemic exposure to certain toxic compounds before their absorption into the circulatory system. Its primary benefits include:

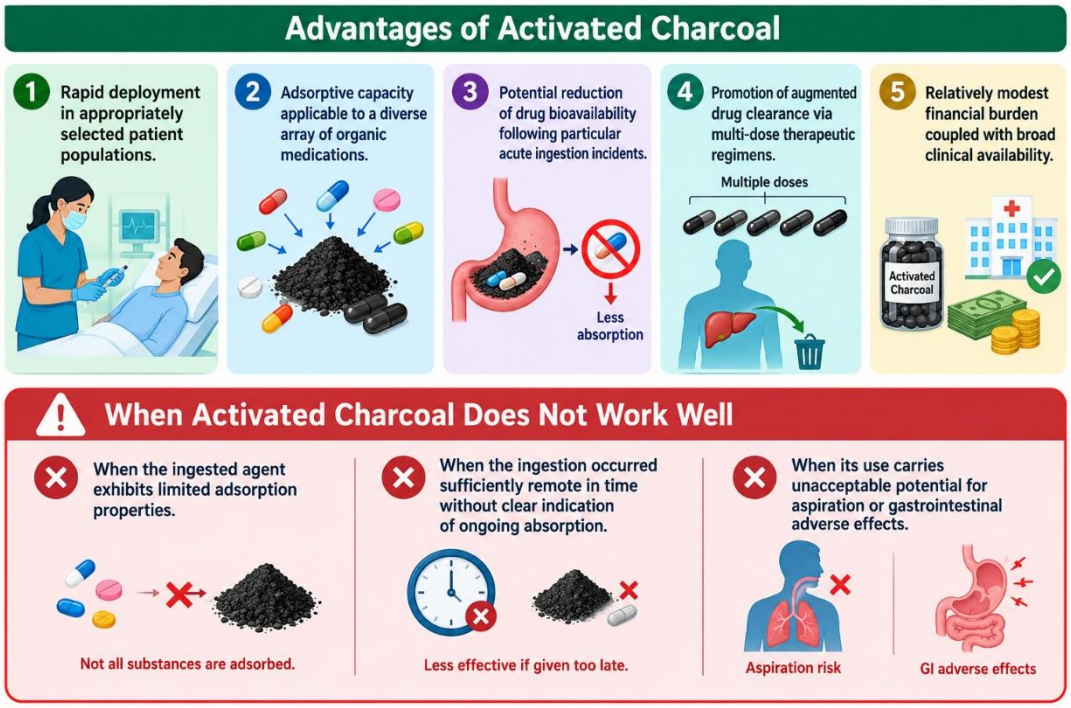

Figure 2: Role for Activated Charcoal.

2. TYPES OF CHARCOAL

2.1 ORDINARY CHARCOAL

Conventional charcoal is manufactured through the thermal treatment of wood, coconut husks, or comparable organic substances in an oxygen-restricted environment. The resulting product's surface characteristics and internal pore configuration are determined by both the source material and the production methodology employed. Due to its lack of optimization for pharmaceutical applications, ordinary charcoal is unsuitable as a substitute for pharmaceutical-grade activated charcoal in the clinical management of poisoning cases.

2.2 ACTIVATED CHARCOAL.

- Activated charcoal is manufactured through the enhancement of porosity and surface area in standard carbon materials.
- Physical activation: Carbonized material undergoes heating with steam or carbon dioxide under elevated temperatures.

➢ Chemical activation: The material is subjected to treatment with activating chemicals, subsequently heated, and comprehensively washed.

➢ These methodologies generate pores and surface functional groups that enhance the adsorption capacity for various substances.

2.3 POWDERED AND GRANULAR ACTIVATED CHARCOAL:

POWDERED ACTIVATED CHARCOAL (PAC): Comprises minute particles possessing a comparatively extensive external surface area and expedited adsorption kinetics. Pharmaceutical-grade powdered formulations are routinely employed in the management of acute poisoning cases.

GRANULAR ACTIVATED CARBON (GAC): Constitutes larger particulate matter and is primarily utilized in aqueous purification applications, industrial filtration operations, and adsorption column systems.



Figure 3: Granular activated carbon (GAC) and Powdered activated carbon. (PAC)

2.4 PHYSICOCHEMICAL PROPERTIES

Activated charcoal possesses an extensive surface area coupled with a porous architecture that facilitates the adsorption of pharmaceutical agents and toxic substances. The pores are categorized as follows:

✓ Micropores: Dimensions below 2 nm

✓ Mesopores: Dimensions ranging from 2–50 nm

✓ Macropores: Dimensions exceeding 50 nm

The carbon-based composition of its surface and the presence of functional groups significantly determine adsorption characteristics. Adsorption capacity is influenced by multiple parameters, including pH levels, temperature conditions, ionic strength, and the molecular composition of the target substance. While it effectively adsorbs numerous organic

pharmaceutical compounds, it demonstrates limited binding affinity for certain small molecules, highly polar substances, and inorganic materials.

3. STRUCTURE AND SURFACE PROPERTIES

3.1 CARBON STRUCTURE: Activated charcoal is predominantly composed of carbon atoms organized in disordered, aromatic, graphene-resembling strata. In contrast to graphite, this material exhibits structural irregularities and an extensive network of pores, which generate a substantial internal surface area capable of facilitating the adsorption of appropriate molecular species.

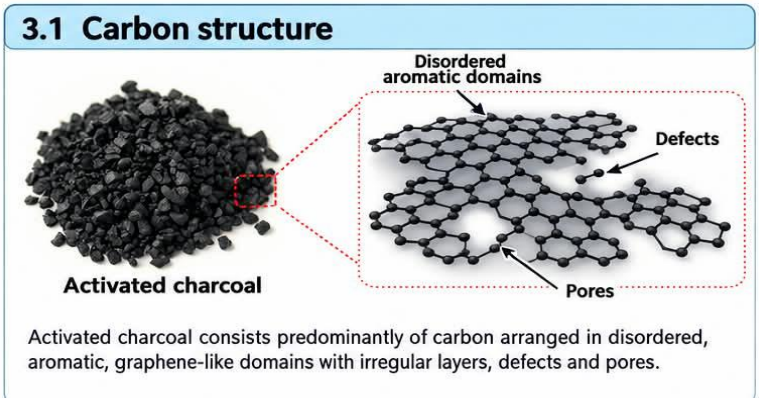

Figure 4: Carbon Structure.

3.2 POROSITY: The pore structure of activated charcoal is classified by width: micropores measure less than 2 nm, mesopores range from 2–50 nm, and macropores exceed 50 nm. Micropores typically contribute substantially to overall adsorption capacity, while larger pores facilitate molecular transport through the internal pore network. The optimal pore size distribution is contingent upon the dimensions and properties of the target compound.

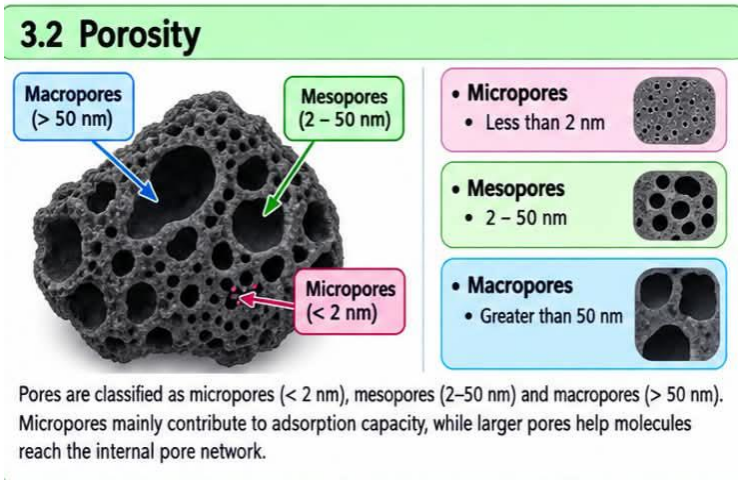

Figure 5: porosity of activated charcoal.

3.3 SURFACE AREA: Activated carbon can achieve a specific surface area ranging from hundreds to more than one thousand square metres per gram, contingent upon its composition and activation methodology. Certain specialized materials demonstrate even higher measured values. This extensive internal surface enables substantial interaction between the carbon matrix and dissolved molecules. However, a high surface area alone does not ensure effective adsorption of all pharmaceuticals; chemical affinity and pore accessibility remain equally critical factors.

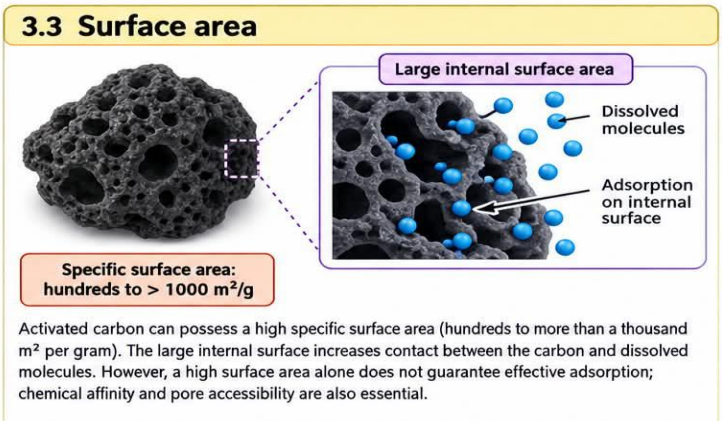

Figure 6: surface area.

3.4 ADSORPTION SITES: Activated charcoal removes pharmaceutical compounds from solution by binding them to its carbon matrix through non-covalent mechanisms, including van der Waals forces, hydrogen bonding, and ionic interactions. The spatial distribution and density of these binding sites directly influence both the quantity of drug molecules that can be retained and the specificity of the adsorption process.

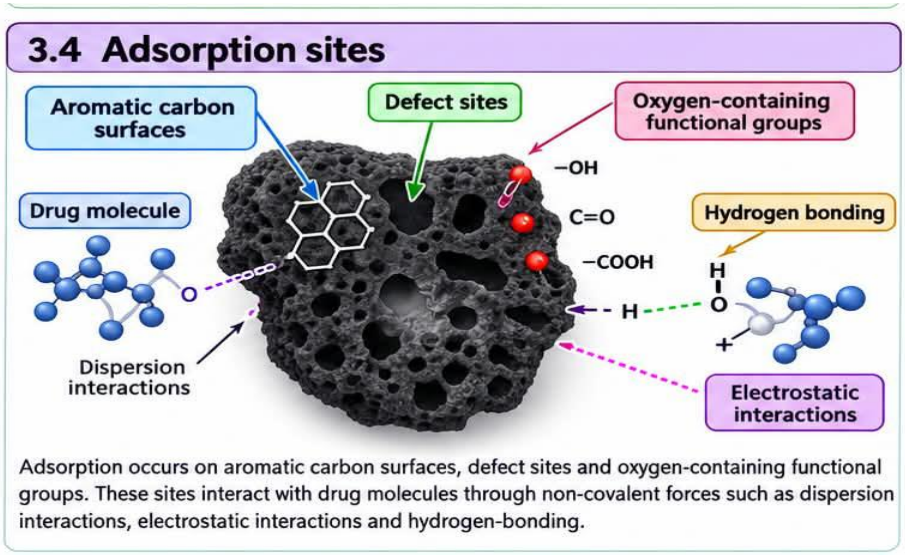

Figure 7: Adsorption sites of Activated Charcoal.

4. MECHANISM OF DRUG ADSORPTION

4.1 PHYSICAL ADSORPTION

Adsorption represents the accumulation of molecules at a surface. It is distinct from absorption, wherein a substance penetrates the bulk of another material. Activated charcoal predominantly binds susceptible drugs and toxins to its internal surfaces. The resulting drug–charcoal complex typically remains within the gastrointestinal tract and is excreted in faeces.

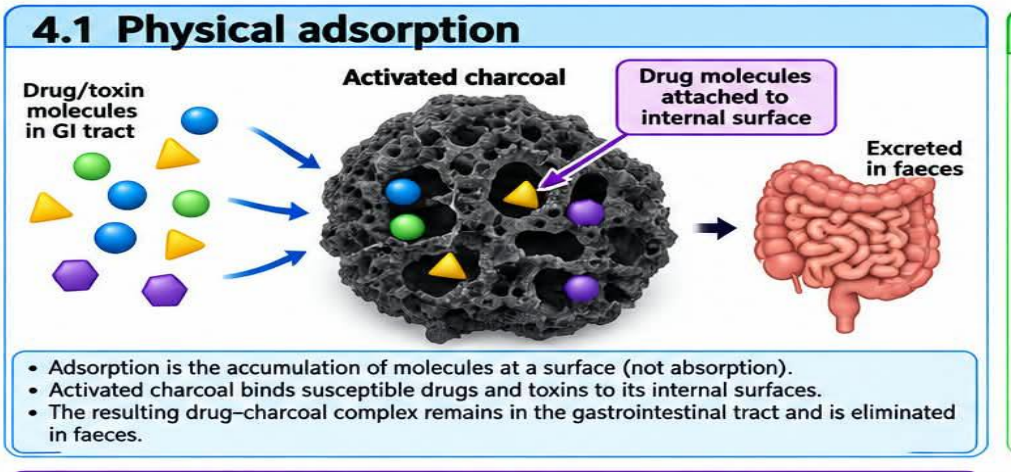

Figure 8: Physical Adsorption.

4.2 HYDROPHOBIC INTERACTIONS: Numerous organic drugs possess hydrophobic regions that interact favourably with carbon-rich surfaces. Hydrophobic interactions can substantially contribute to the adsorption of lipophilic compounds, although this relationship is not invariable and is contingent upon molecular structure and solution conditions.

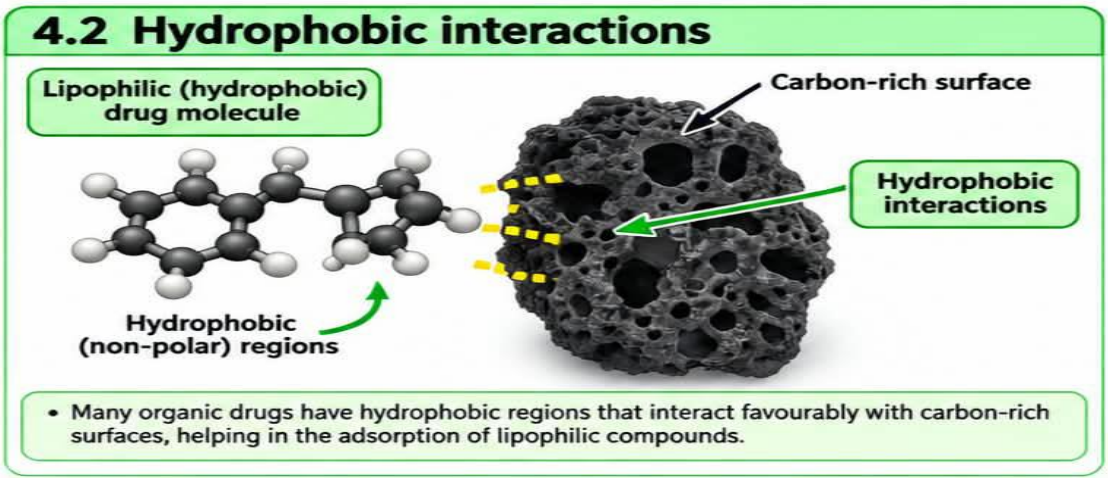

Figure 9: Hydrophobic Interactions

4.3 VAN DER WAALS AND OTHER INTERACTIONS: Dispersion forces, frequently termed London dispersion forces, facilitate interactions between adsorbate molecules and the carbon surface. Contingent upon the compound, supplementary contributions may originate from aromatic interactions, electrostatic effects, and hydrogen bonding. These interactions are predominantly non-covalent. Their cumulative strength establishes whether a molecule is retained on the adsorbent under gastrointestinal conditions.

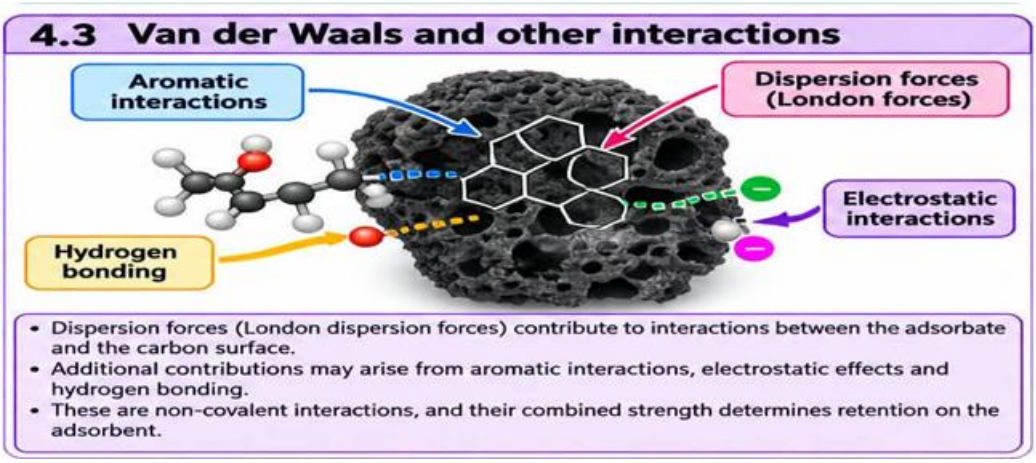

Figure 10: Vander Waals force and other interactions.

4.4 EFFECT OF PH AND DRUG PROPERTIES: The medium's pH influences both the ionization state of pharmaceutical compounds and the surface charge characteristics of activated charcoal, thereby modulating the adsorption process. Additional determinants of adsorption include molecular dimensions, aromatic structure, lipophilicity, polarity, and the accessibility of porous structures. Consequently, activated charcoal exhibits differential adsorption capacity across various pharmaceutical agents.

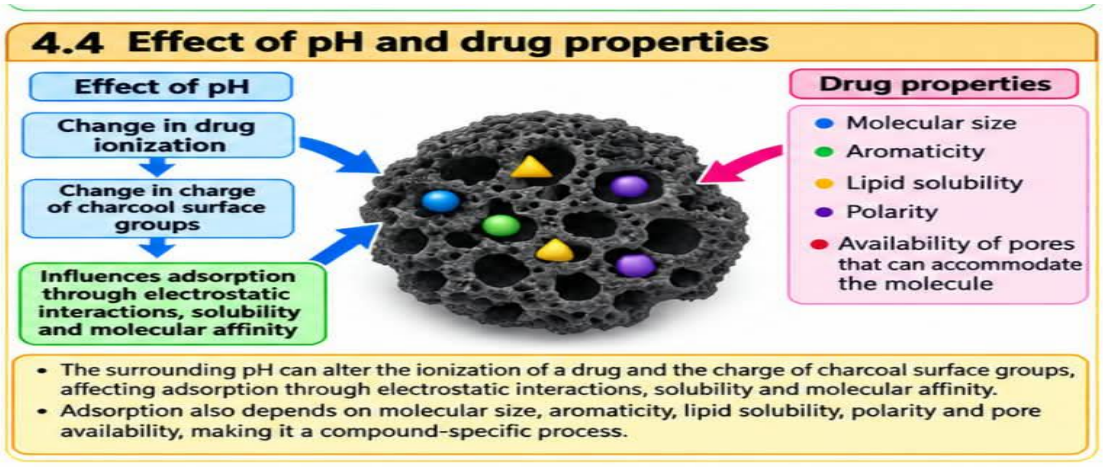

Figure 11: Drug properties and effects of pH.

5. CHARCOAL AND GASTROINTESTINAL EXCRETION

5.1 REDUCTION OF DRUG ABSORPTION: Upon oral administration, pharmaceutical agents typically dissolve within gastrointestinal secretions and may penetrate the intestinal epithelial barrier to enter systemic circulation. Activated charcoal possesses the capacity to adsorb suitable pharmaceutical molecules within the gastrointestinal lumen, thereby diminishing the quantity accessible for absorption.

5.2 BINDING OF DRUGS IN THE GASTROINTESTINAL TRACT: Pharmaceutical Sequestration within the Gastrointestinal System: Activated charcoal functions through adsorption mechanisms to bind pharmaceutical agents within the intestinal environment, thereby diminishing their unbound concentration and facilitating enhanced surface attachment.

5.3 PREVENTION OF ENTEROHEPATIC AND ENTEROGASTRIC REABSORPTION: Disruption of Enterohepatic Circulation: Certain pharmaceutical agents undergo excretion via biliary pathways or translocation from the circulatory system into the gastric compartment, subsequently undergoing reabsorption into the systemic circulation. Activated charcoal functions through adsorptive mechanisms within the gastrointestinal tract, thereby inhibiting reabsorption and facilitating accelerated elimination of these substances. This pharmacological principle constitutes a fundamental component of multiple-dose activated charcoal (MDAC) therapeutic protocols.

5.4 ENHANCED ELIMINATION: Gastrointestinal Dialysis: Repeated administrations of activated charcoal bind pharmaceutical substances within the intestinal tract, maintaining diminished drug concentrations and facilitating the continued movement of medications from the circulatory system into the gastrointestinal compartment. This mechanism substantially improves pharmaceutical elimination in select cases of poisoning, contingent upon the specific agent involved.

6. PHARMACOKINETICS

Table 1: Pharmacokinetics For Activated Charcoal.

Pharmacokinetic parameter	Effect of activated charcoal
Absorption	May reduce absorption of susceptible substances when administered at an appropriate time
Distribution	Does not directly remove drug already distributed into tissues
Elimination	Multiple doses can enhance elimination of certain drugs in selected cases.
Bioavailability	May decrease the bioavailability of an adsorbed drug.
Metabolism	Does not directly metabolise drugs.
Half-life	May shorten the apparent elimination half-life of some drugs when MDAC is effective.
Systemic absorption of charcoal	Negligible; charcoal acts primarily within the gastrointestinal tract.

7. MULTIPLE-DOSE ACTIVATED CHARCOAL (MDAC)

7.1 PRINCIPLE: Multiple-dose activated charcoal consists of the successive giving of activated charcoal following a primary exposure. It is mainly aimed at reducing absorption, MDAC can promote the removal of certain drugs that are already circulating.

7.2 MECHANISM

- Disruption of enterohepatic recycling.
- Disruption of enterogastric circulation.
- 3.Gastrointestinal dialysis involves promoting drug movement from the bloodstream into the intestines through adsorption in the intestinal lumen.

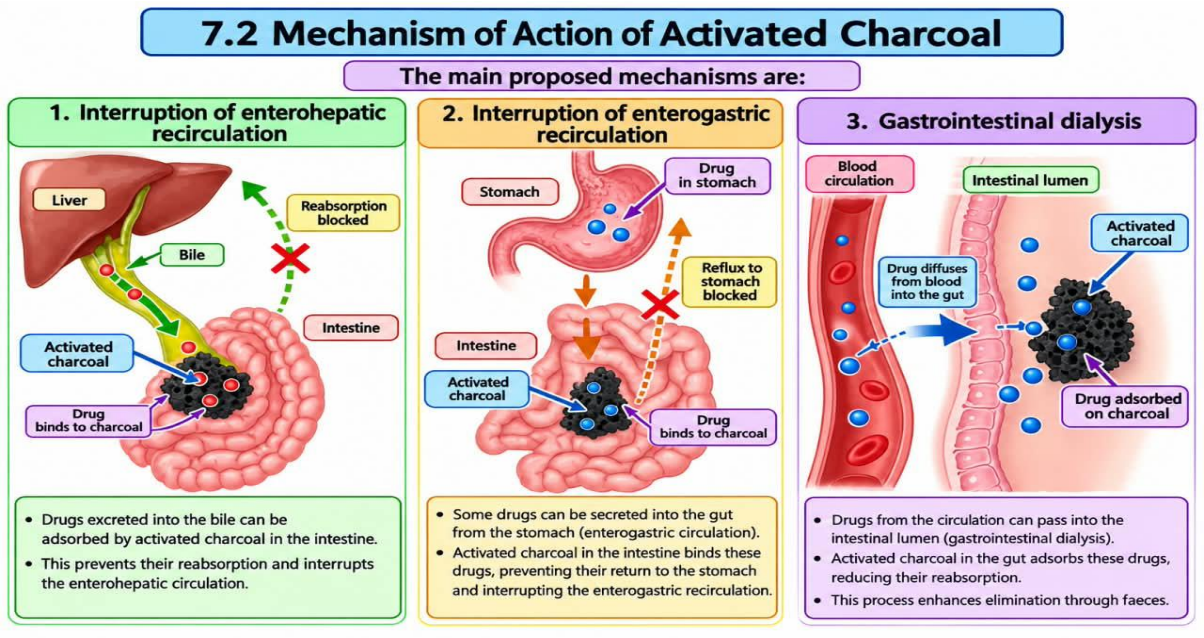

Figure 12: Core MOA of activated charcoal.

7.3 DRUGS FOR WHICH MDAC MAY BE CONSIDERED

Table 2: A summary table of drugs for which MDAC- Multiple-dose activated charcoal (MDAC) may be considered:

Substance category	Expected adsorption	Important Effective
Carbamazepine	Generally good	MDAC may be considered in selected poisonings.
Phenobarbital	Generally good	MDAC may enhance elimination in selected cases.

Theophylline	Generally good	MDAC may be useful in severe poisoning under specialist guidance.
Salicylates	Variable to useful	Clinical assessment and other treatments may be required.
Alcohols, including ethanol	Poor	Activated charcoal is not an effective treatment for alcohol poisoning.
Lithium	Poor	Other treatment approaches may be required.
Iron salts	Poor	Charcoal is not effective for iron poisoning.
Strong acids and alkalis	Not appropriate	Charcoal is not a suitable treatment for corrosive ingestion.

7.4 LIMITATIONS

Table 3: Limitations of activated charcoal.

Application	Role of activated charcoal	Limitation
Acute oral drug overdose	May reduce gastrointestinal absorption of selected drugs	Benefit depends on the substance, timing and clinical circumstances.
Selected severe poisonings	MDAC may enhance elimination of certain drugs	Requires toxicology guidance and monitoring.
Toxin removal research	Used as an adsorbent in experimental systems	Laboratory results do not establish clinical effectiveness.
Water and air purification	Removes selected contaminants through adsorption	This is an environmental use, not a medical treatment.

8. FACTORS AFFECTING CHARCOAL ADSORPTION

8.1 Molecular size: Extremely large molecules might be filtered out by smaller pores, yet adsorption can still take place in available larger pores.

8.2 Lipid solubility: Numerous lipophilic organic substances exhibit advantageous adsorption due to interactions with carbon-rich surfaces.

8.3 pKa and ionization: The pKa of a medication, along with the surrounding pH, influences the ratio of ionized to unionized molecules. Ionization may alter solubility, electrostatic interactions, and affinity for the carbon surface.

8.4 Dose of charcoal: The ratio of charcoal to drug quantity affects the adsorption capacity that is available. An increased quantity might enhance binding when adsorption sites are

scarce, but additional charcoal does not guarantee a proportionate increase in clinical advantage.

8.5 Contact time: Timely administration may be especially beneficial since less medication has had the opportunity to enter the bloodstream. In certain poisonings, delayed absorption can happen based on the formulation and conditions of the gastrointestinal tract.

8.6 Gastric contents and co-ingested substances: Food, gastrointestinal contents, and other concurrently ingested substances may compete for adsorption sites .Formulations with sustained release and agents that slow gastric emptying can also influence the clinical time frame in which charcoal might be beneficial.

9. THERAPEUTIC APPLICATIONS:

- **9.1 ACUTE POISONING:** One dose of activated charcoal might be appropriate after a possibly harmful intake of a substance that charcoal can adsorb, if given with a secure airway. The choice must consider the potential seriousness of poisoning, the quantity consumed, the duration since contact, and the risks associated with treatment.
- **9.2 DRUG OVERDOSE:** Activated charcoal could decrease absorption following an overdose with certain analgesics, antidepressants, anticonvulsants, and other organic medications. Efficacy differs depending on the compound and formulation; it is incorrect to assume that all members of a therapeutic class are absorbed equally.
- **9.3 SELECTED TOXIN ELIMINATION:** Frequent use of charcoal can enhance the removal of specific severe toxins, such as carbamazepine, phenobarbital, theophylline, dapsone, or quinine.
- **9.4 ENTEROHEPATIC RECIRCULATION:** This system may help enhance the removal rate in specific situations. Activated charcoal serves as a supplement to supportive care and specific antidotes when necessary.
- **9.5 DENTAL PRODUCTS:** It absorbs plaque, stains, toxins and bad breath causing bacteria from teeth and gums.

10.ACTIVATED CHARCOAL IN DENTAL PRODUCTS

Many oral hygiene products, including toothpastes, tooth powders, mouthwashes, and toothbrush-related goods, include activated charcoal. Claims of tooth whitening, stain removal, and oral detoxification are the main reasons for its popularity. However, there is little scientific proof to back up many of these assertions, and charcoal products should be assessed for safety, abrasively, and effectiveness.

Differentiating between regular charcoal used as fuel or in other industrial uses and activated charcoal, a highly porous and adsorptive type of carbon, is crucial in dentistry.

10.1 Dental products containing charcoal

Charcoal toothpaste



Figure 13: Tooth Paste Mixed with Activated Charcoal.

- Promoted for eliminating external stains from coffee, tea, and tobacco.

Could offer certain mechanical stain removal, based on its composition and abrasiveness.

- Does not consistently whiten inherent tooth staining.

The presence of fluoride is crucial for preventing cavities; charcoal cannot replace fluoride.

- **Charcoal tooth powder:** Utilized as a powder for scrubbing surfaces and eliminating stains.
- The potential wear of enamel and dentin is influenced by its particle size, hardness, concentration, and formulation.
- Homemade powders that are not standardized can exhibit inconsistent abrasivity and varied composition.



Figure 14: Tooth Powder Mixed with Activated Charcoal.

Charcoal mouthwash



Figure 15: Mouth Wash Mixed with Activated Charcoal.

10.2. Advertised for freshening breath and cleaning the mouth

• There is inadequate evidence for clinically significant whitening or plaque reduction specifically from charcoal.

• Activated charcoal can adsorb specific substances, which may encompass active components in a formulation.

Charcoal-infused toothbrushes

• Utilize bristles claimed to be infused with charcoal.

• Their efficacy mainly relies on brushing method, bristle structure, and plaque elimination

• There is a lack of strong, high-quality evidence that toothbrushes with charcoal-infused bristles are more effective than standard toothbrushes.

• Function of Charcoal in Toothpaste and Its Fundamental Mechanism.



Figure 16: Toothbrush Made with Activated Charcoal.

11. MECHANISM OF CHARCOAL IN TOOTHPASTE

1.ADSORPTION — THE PRIMARY PROPOSED MECHANISM

Activated charcoal has many pores and features a significant surface area. These surfaces have the ability to draw in and hold specific molecules and compounds via physical and chemical interactions.

Compounds associated with stains might adhere to the surface of the charcoal. Certain impurities might become confined within its pores.

• The efficiency relies on the surface chemistry of the charcoal, its formulation, and the duration of contact.

2. PHYSICAL ELIMINATION OF SUPERFICIAL BLEMISHES.

Toothpaste with charcoal frequently includes abrasive substances. While brushing, these particles, together with the toothbrush and additional abrasives in the formula, aid in eliminating surface deposits and external stains from coffee, tea, or tobacco. Noteworthy: This effect could stem more from mechanical wear than from the adsorption characteristics of charcoal.

3.RESTRICTED IMPACT ON INHERENT STAINING

Intrinsic stains exist inside the tooth's composition, which includes enamel and dentin. charcoal typically cannot infiltrate the tooth and chemically lighten these stains. Consequently, it does not consistently alter the innate base colour of teeth.

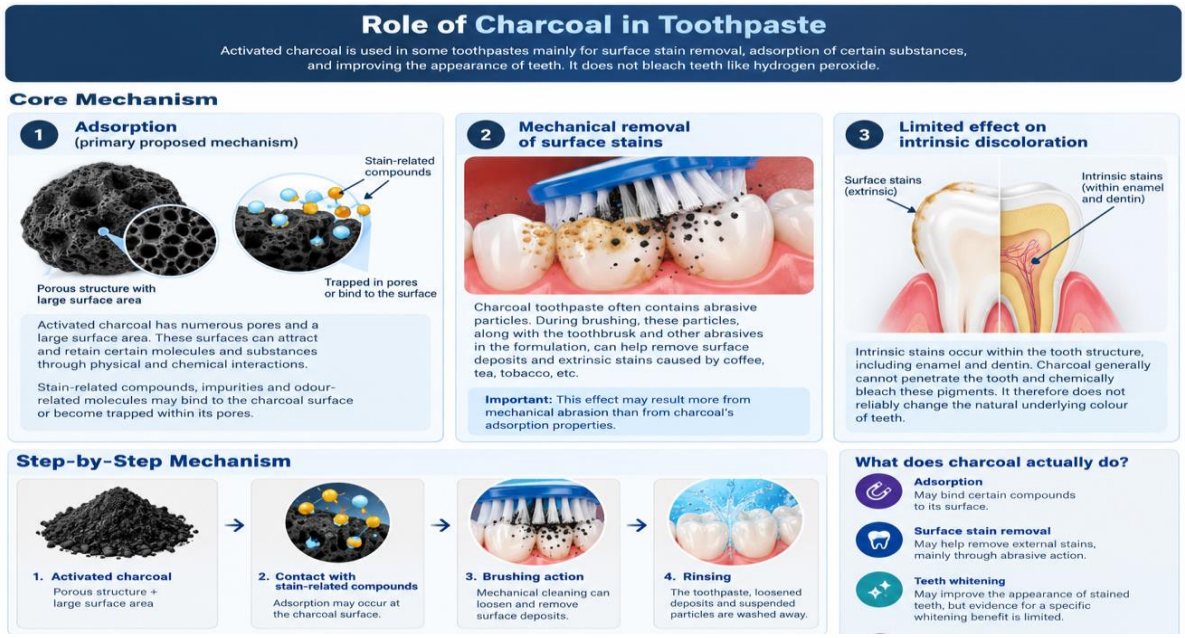

Figure 17: Dental Product Mechanism for Activated Charcoal.

Table:4 - Potential Applications of Activated Charcoal in Dentistry: Proposed Mechanisms, Evidence, and Limitations.

Application	**Proposed mechanism**	**Evidence and limitations**
Extrinsic stain removal	Adsorption and mechanical removal of surface deposits	May remove some surface stains but is not superior to conventional toothpaste in available studies.
Tooth whitening	Adsorption of coloured compounds and abrasive cleaning	Evidence does not establish reliable whitening of intrinsic discoloration.
Plaque control	Proposed adsorption of organic material and microorganisms	Adequate evidence of superior plaque removal or antimicrobial benefit is lacking.
Halitosis management	Proposed adsorption of Odor-producing compounds	Clinical effectiveness of charcoal mouthwashes has not been adequately demonstrated.

Table: 5- Suggestions for Improvement in Charcoal Toothpaste Products and Marketing Strategies.

S. No.	Improvement Area	Current Problem	Suggested Improvement	Expected Result
1	Product Quality	Limited product benefits	Improve cavity protection and enamel care	Better oral health and trust
2	Ingredients	Strong taste or artificial ingredients	Offer herbal and mint-based options	Greater customer preference
3	Packaging	Ordinary packaging	Use attractive, recyclable packaging	Improved brand image
4	Brand Awareness	Low brand recognition	Promote through TV and social media	Increased brand awareness
5	Pricing	High price or poor value	Introduce affordable pack sizes	More customers
6	Customer Satisfaction	Customer complaints	Improve quality and customer support	Higher satisfaction
7	Product Variety	Limited product options	Offer whitening, sensitivity, and herbal variants	Wider customer base
8	Advertising	Less effective promotion	Use dentist-approved educational campaigns	Increased credibility
9	Customer Loyalty		Introduce loyalty points and discounts	Improved customer retention
10	Environmental Sustainability	Excessive plastic packaging	Use recyclable materials and reduce packaging	Better environmental image
11	Distribution	Limited availability	Expand availability in pharmacies and retail stores	Increased sales
12	Innovation	Similar products to competitors	Develop distinctive features based on customer needs	Competitive advantage

12. ADVERSE EFFECTS AND SAFETY

12.1 VOMITING: It develop following administration, especially when large doses are administered or when preparations demonstrate poor tolerability. The occurrence of vomiting may diminish the quantity of charcoal that remains in the gastrointestinal tract and elevate the potential for aspiration complications.

12.2 CONSTIPATION: Constipation represents a documented adverse effect of concern. Vigilant monitoring is essential when administering multiple doses, particularly in patients presenting with diminished gastrointestinal motility.

12.3 ASPIRATION: The inhalation of charcoal particles into the respiratory tract may result in significant pulmonary complications. Individuals experiencing diminished consciousness, convulsive episodes, or compromised airway protection face elevated risk.

12.4 INTESTINAL COMPLICATIONS: Uncommon yet severe adverse outcomes . The likelihood of occurrence may be elevated in individuals presenting with compromised intestinal motility, pre-existing obstruction, or those receiving repeated doses despite clinical unsuitability

12.5 CONTRAINDICATIONS AND PRECAUTIONS

Critical contraindications and precautions encompass:

- An unprotected airway or substantial aspiration risk.
- Suspected gastrointestinal obstruction, perforation, or ileus.
- Ingestion of a substance for which charcoal offers no meaningful benefit.
- Situations in which administration may interfere with necessary treatment or increase harm.

Table: 6 Substances Poorly Adsorbed by Activated Charcoal: Clinical Significance and Reasons.

S. No.	Substance	Adsorption by Activated Charcoal	Clinical significance	Reason
1.	Alcohols (ethanol and methanol)	Poorly adsorbed.	Activated charcoal is ineffective; appropriate supportive care and antidotally treatment may be required.	Small molecular size and physicochemical properties limit effective adsorption
2.	Lithium	Poorly adsorbed	Activated charcoal is ineffective; haemodialysis may be required in severe poisoning	Lithium is a small inorganic ion.
3.	Inorganic	Generally,	Specific assessment and	Many inorganic salts and

	substances	poorly adsorbed	appropriate treatment are necessary.	metals have limited affinity for charcoal surfaces.
4.	Corrosive substances	Not a suitable routine treatment	Management requires specialist guidance and appropriate supportive care.	Administration may increase vomiting and aspiration risk and complicate clinical evaluation.
5.	Other substances with low adsorption	Varies by compound	Substance-specific evidence should guide treatment decisions.	Adsorption depends on molecular size, chemical structure, ionization, and pore accessibility.

13. CHARCOAL COMPARED WITH OTHER ELIMINATION METHODS

Table 7: Comparison of Charcoal and Other Methods of Eliminations.

Sno	Method	Mechanism of Action	Main application	Limitations
1.	Gastric lavage	Removes stomach contents using a tube and fluid.	Considered only in exceptional cases of poisoning under expert guidance.	Invasive procedure with limited evidence of benefit and risk of serious complications.
2.	Activated charcoal	Adsorbs certain drugs and toxins within the gastrointestinal tract	Used in selected cases of acute poisoning involving adsorbable substances. metals; aspiration risk exists.	Ineffective for many substances, including alcohols and
3.	Urinary alkalinization	Sodium bicarbonate raises urine pH, increasing renal elimination of certain weak acids.	Used particularly in selected cases of salicylate poisoning.	Requires clinical monitoring; unsuitable for every toxicant
4.	Haemodialysis	Removes certain toxic substances from the blood through a semipermeable membrane	Severe poisoning involving dialyzable substances, such as selected cases of lithium or salicylate toxicity.	Effectiveness depends on toxicant properties, clinical condition, and availability.
5.	Hemoperfusion	Blood passes through an adsorbent-containing cartridge that binds selected toxic substances.	Used in specific poisoning situations when appropriate and available.	Limited role in contemporary practice; depends on the toxicant and availability of alternatives.

14. MODERN DERIVATIVES:

14.1 MODIFIED ACTIVATED CHARCOAL: Investigation of engineered activated carbons seeks to alter surface composition, pore architecture, and selective adsorption capacity. Chemical modification of surfaces can strengthen interactions with specific compound categories or optimize functionality within particular aqueous environments.

14.2 NANOSTRUCTURED CARBON MATERIALS: Nanostructured carbon materials, encompassing carbon-based porous materials and specific nanocarbons, are currently under examination for applications in adsorption, separation, and environmental remediation. Prior to clinical implementation, it is essential to establish nanomaterial biocompatibility, gastrointestinal interactions, potential systemic absorption, and clearance mechanisms.

14.3 FUNCTIONALIZED ADSORBENTS: Functionalized adsorbents are engineered with specific chemical moieties intended to enhance their affinity toward target molecules.

14.4 NOVEL DRUG AND TOXIN REMOVAL SYSTEMS: Investigation into sophisticated porous materials, polymer-carbon composite systems, and selective sorbent technologies may facilitate the advancement of novel detoxification methodologies.

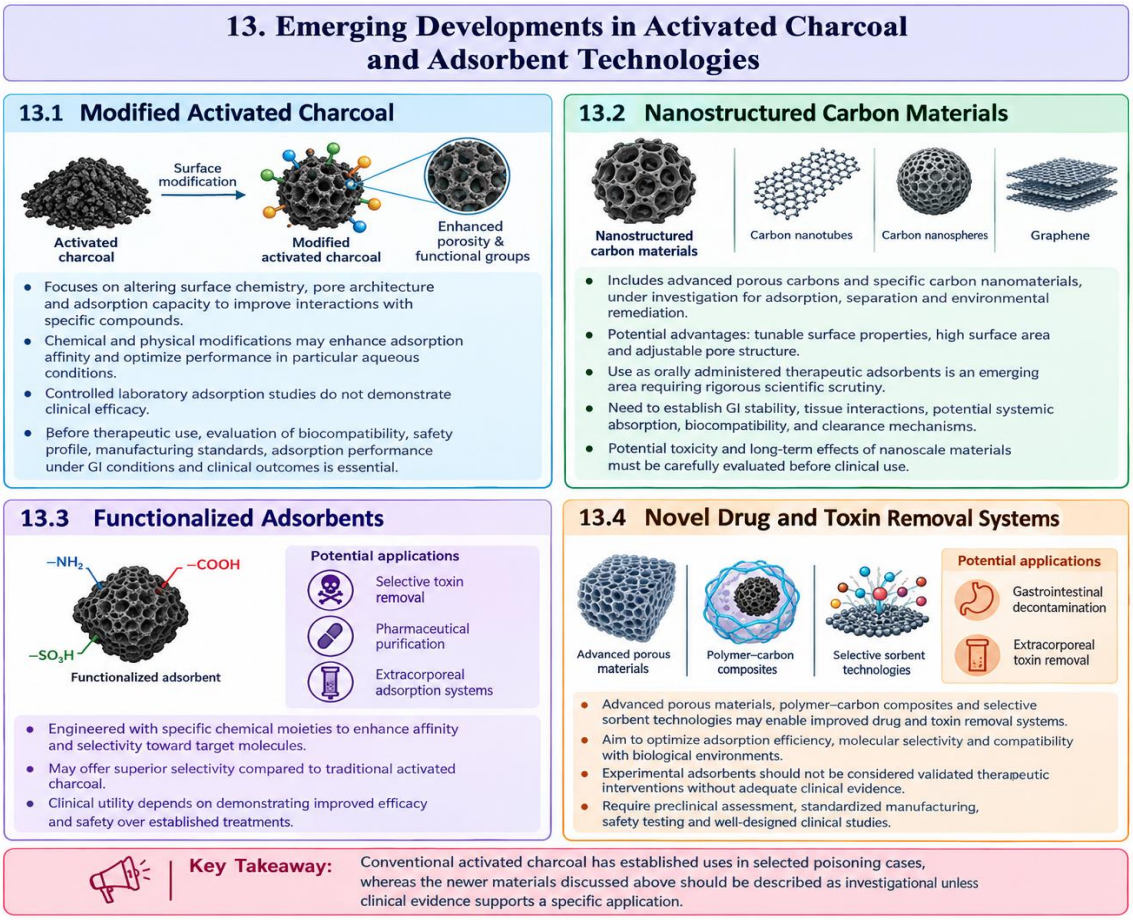

Figure 18: Pharmaceutical Development for Activated Charcoal.

15. FUTURE PERSPECTIVES

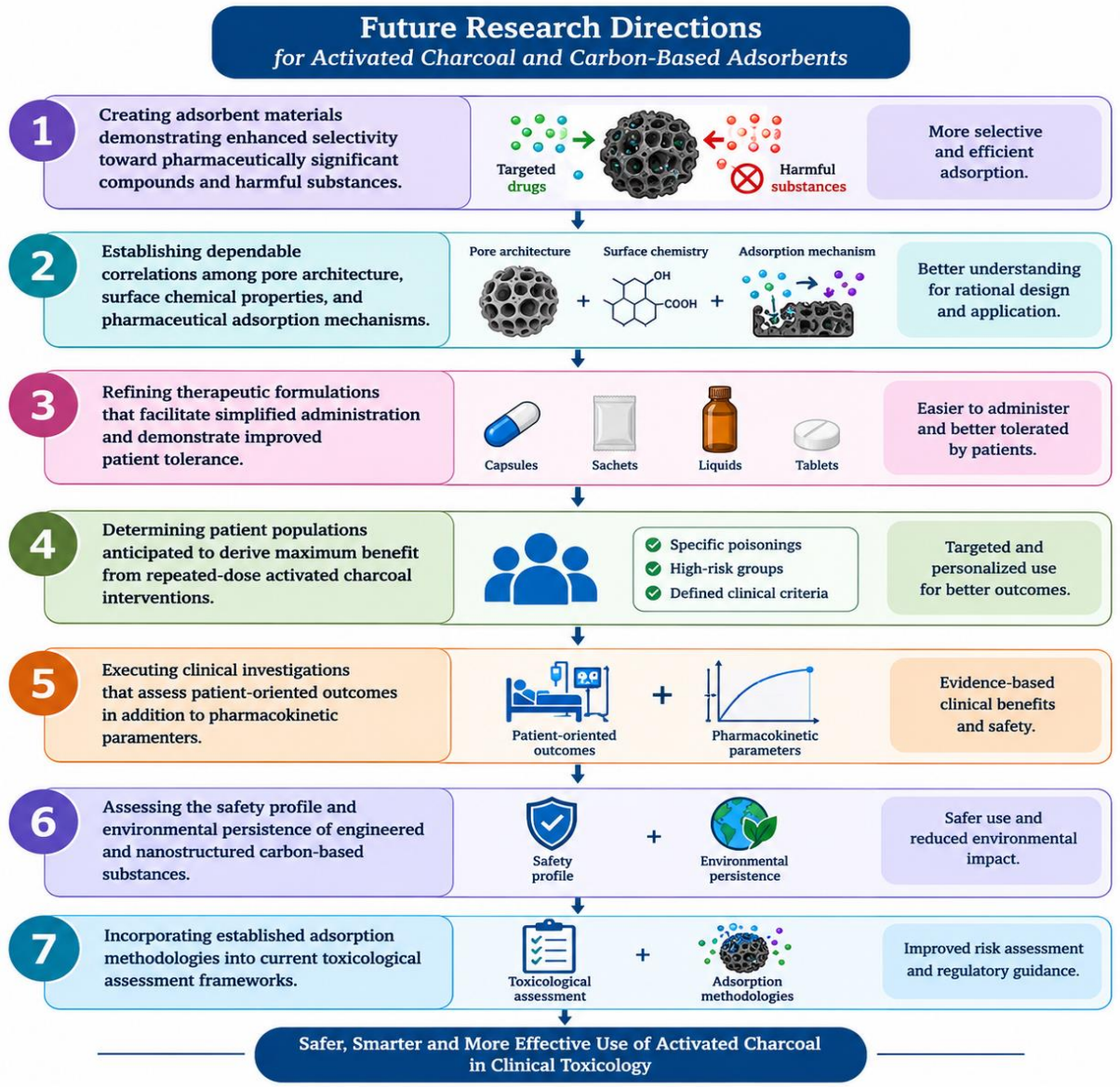

Figure 19: future perspective directions for activated charcoal and carbon-based adsorbents.

16. CONCLUSION

Activated charcoal is an important gastrointestinal adsorbent used in certain acute poisonings. Its porous structure helps reduce drug absorption, while multiple-dose administration can enhance the elimination of certain drugs. However, its effectiveness depends on the substance, timing and patient condition. It is ineffective for alcohols, lithium, iron, and many inorganic compounds. Aspiration and intestinal complications are major safety concerns. Future targeted adsorbents may improve toxin removal, but further research is required.

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