Activated Carbon Technical White Paper

Activated carbon, as a porous carbon material with highly developed pore structure, ultra-large specific surface area, and excellent adsorption performance, is a core adsorbent material inindustrial environmental protection, exhaust gas treatment, water treatment, food and pharmaceutical, and air purification fields. It is widely used in VOCs treatment, paint mist purification, industrial wastewater deep treatment, drinkingwater purification, odor removal, solvent recovery and other scenarios. With the advancement of the "dual carbon" goal, stricter environmental policies, and the upgrading of industrial fine production, activated carbon hasbecome a key consumable for environmental governance and process optimization, and its performance directly determines the governance efficiency, operating cost, and compliance level.

This white paper systematically covers the adsorption principle, raw material classification, production process, core performance indicators, product forms,selection logic, application scenarios, installation and maintenance, regeneration technology, and industry trends of activated carbon. Combined with GB/T30202-2023 "Coal-Based Granular Activated Carbon", LY/T 3284-2021 "Activated Carbon for Industrial Organic Exhaust Gas Purification — Technical Specificationsand Test Methods", and other national and industry standards, this white paper provides professional, precise, and actionable technical references for enterprises in areas such as activated carbon selection, system design, environmental compliance, and costoptimization, helping enterprises achieve efficient governance, stable operation,and overall goals of cost reduction and efficiency improvement.

I. Adsorption Principles and Core Value of Activated Carbon

The core function of activated carbon is to efficiently capture organic pollutants, odors, heavy metals, pigments, VOCs, paint mist particles, and other impurities in gases and liquids through physical adsorption (van der Waals forces) and chemical adsorption (surface functional group bonding),achieving purification, separation, recovery, and decolorization functions. Its essence is to provide enormous specific

surface area through a porous structure, providing adsorption sites for pollutant molecules to achieve efficient and stable purification.

Adsorption Mechanism — Physical Adsorption (van der Waals Forces): Activated carbon surface and pollutant molecules are bonded through intermolecular forces,with no chemical reaction, reversible, fast adsorption speed, suitable for most organic gases and small molecule pollutants (such as VOCs,formaldehyde, benzene series, paint mist particles).

Chemical Adsorption (Surface Functional Groups): Activated carbon surfaces contain hydroxyl, carboxyl, phenolic, and other functional groups, which react chemically with pollutants to form chemical bonds;strong adsorption force, irreversible, suitable for heavy metals, acidic/alkaline gases, and highly polarorganic substances.

Core Value — High-efficiency Purification: Specific surface area up to 800–2000 m^2/g, with micropores (<2 nm), mesopores (2–50 nm), andmacropores (>50 nm) hierarchically distributed, capable of precisely capturing pollutants of different sizes; VOCs removal rate ≥90%, heavy metal adsorptionrate ≥95%.

Strong Adaptability: Suitable for gas phase (exhaust gas, air), liquid phase (wastewater, drinking water), solid phase (decolorization, deodorization)

for all scenarios; pore structure and surface properties can be customized.

Economic and Environmentally Friendly: Long service life, strong regenerability, no secondary pollution. Compared to catalytic combustion, photo-catalytic oxidation, and other processes,

operating costs reduced by 40%–60%.

Process Assurance: Provides stable purification for coating, chemical, food, pharmaceutical, and other industries; protects downstream equipment and improves

product quality; meets environmental emission requirements.

II. Raw Material Classification and Characteristics

The performance of activated carbon is determined by raw materials, activation process, and pore structure. The mainstream raw materials are divided into four major categories, suitable for different working conditions.

Coal-Based Activated Carbon (Most Common)

Made from anthracite, bituminous coal, and lignite through carbonization and activation. Advantages: low cost, high strength, wear resistance,

stable pore structure, strong gas-phase adsorption capacity (VOCs, paint mist, odors). Disadvantages: high ash content, fewer surface functional groups, weaker liquid-phase adsorption (decolorization, heavy metals). Applications: industrial exhaust gas treatment, VOCs purification, paint mist filtration,air purification, solvent recovery.

Fruit Shell Activated Carbon (Coconut Shell/Walnut Shell, High-End)

Made from coconut shell, walnut shell, and apricot shell through high-temperature activation. Advantages: well-developed micropores, large specific surface area (1000–1500 m^2/g), high strength, low ash content, fast adsorption speed, excellent regeneration performance. Disadvantages: high cost, limited production. Applications: drinking water purification, food decolorization, pharmaceutical refining, gold extraction, high-end exhaust gas treatment.

Wood-Based Activated Carbon (Wood Chips/Bamboo Charcoal, Liquid Phase Specific)

Made from wood, wood chips, and bamboo through chemical activation (phosphoric acid, zinc chloride). Advantages: well-developed mesopores,strong decolorization ability, rich surface functional groups, excellent liquid-phase adsorption. Disadvantages: low strength, easy to pulverize, not heat-resistant. Applications: food and beverage decolorization, industrial wastewater deep treatment, pharmaceutical decolorization, pigment removal; National Standard Information Public Service Platform.

Special Activated Carbon (Customized)

Coconut Shell Columnar/Granular: High strength, high iodine value, suitable for high-flow-rate exhaust gas, continuous production.

Honeycomb Activated Carbon: Honeycomb structure, low airflow resistance, large packing volume, suitable for high-volume exhaust gas, low-concentration VOCs.

Modified Activated Carbon: Silver-loaded, copper-loaded, acid-base modification to improve adsorption of heavy metals, formaldehyde, and hydrogen sulfide.

III. Production Process

Physical Activation Method (Mainstream, Gas-Phase Specific)

Carbonization: Raw materials are carbonized at 600–800°C under oxygen-free conditions to remove volatile matter and form initial pores.

Activation: At 800–1000°C, water vapor and CO_2 are introduced to react with carbon to expand pores and form well-developed micro/mesopores. Advan-

tages: no chemical residues, high strength, suitable for gas-phase adsorption.

Chemical Activation Method (Liquid-Phase Specific)

Impregnation: Raw materials are soaked in activating agents such as phosphoric acid and zinc chloride.

Carbonization and Activation: Heating at 400–600°C; activating agents dehydrate and expand pores, forming mesopore-rich structures. Advantages: mesopore-

rich, strong decolorization, suitable for liquid-phase applications.

Emerging Technologies (Microwave/Plasma Activation)

Microwave activation completed in 5–15 minutes; efficiency improved by 80%, energy consumption reduced by 45%; specific surface area reaches 2600–2900

m^2/g, suitable for high-end customized products.

IV. Core Performance Indicators

1. Iodine Adsorption Value (mg/g) — Micropore Capacity (Gold Standard)

Definition: The amount of iodine adsorbed per gram of activated carbon, reflecting the development of micropores (<2 nm) and the adsorption capacity for small molecules (VOCs, formaldehyde)

adsorption capacity.

National Standard: Industrial VOCs treatment ≥1100 mg/g (GB/T 30202-2023).

Grades: Standard ≥800, Premium ≥1000, High-End ≥1200.

2. Carbon Tetrachloride (CTC) Adsorption Rate (%) — Gas-Phase Adsorption Capacity

Definition: Indicator of gas-phase adsorption capacity, applicable to VOCs and exhaust gas treatment.

National Standard: Industrial exhaust gas specific ≥70% (GB/T 12496.5).

3. Specific Surface Area (BET, m²/g) — Total Adsorption Capacity

Definition: Total surface area per unit mass of activated carbon.

National Standard: Industrial qualified ≥1000, high-end ≥1200.

4. Strength/Abrasion Resistance (%) — Durability

Definition: Resistance to crushing and abrasion.

National Standard: Granular carbon ≥95% (ball-disk method).

5. Ash Content (%)

Coal-based ≤15%, wood-based ≤5% (GB/T 30201-2013).

6. Moisture Content (%)

Industrial ≤5%, food grade ≤10%.

7. Methylene Blue Adsorption Value (mg/g) — Mesopore Capacity

Definition: Development of mesopores (2–50 nm) and adsorption capacity for large molecules (dyes, organic wastewater).

Applications: Wastewater treatment, decolorization.

8. Bulk Density (g/L)

Coal-based: 500–600, coconut shell: 400–500.

9. Particle Size (mesh/diameter)

Granular: 8–18 mesh, 18–30 mesh.

Columnar: 1.5–4 mm.

V. Product Forms and Application Scenarios

1. Granular Activated Carbon (Most Common)

Forms: Columnar (1.5–4 mm), granular (8–30 mesh).

Advantages: High strength, moderate airflow resistance, good regenerability, suitable for medium-to-high concentration VOCs, paint mist, and exhaust gas treatment.

Applications: Paint booth exhaust, coating line VOCs, chemical exhaust gas, solvent recovery.

2. Honeycomb Activated Carbon (High Air Volume Specific)

Forms: Honeycomb shape, pore diameter 2–5 mm.

Advantages: Low airflow resistance (<600 Pa), large packing volume, treatment air volume 500–20,000 m³/h.

Applications: Low-concentration, high-volume exhaust gas, workshop ventilation, odor treatment.

3. Powdered Activated Carbon (Liquid-Phase Specific)

Forms: Powder.

Advantages: Large specific surface area, fast adsorption speed, strong decolorization.

Applications: Industrial wastewater, food decolorization, drinking water deep treatment; National Standard Information Public Service Platform.

4. Fibrous Activated Carbon (High-End)

Forms: Fiber, felt.

Advantages: Extremely fast adsorption speed, easy regeneration, suitable for precision purification.

Applications: Pharmaceuticals, electronics, precision instruments, high-end air purification.

VI. Selection Logic and Adaptation Principles

1. Selection by Application Scenario

VOCs/Paint Mist Exhaust Gas (Coating, Spray Booths): Choose coal-based columnar/granular (iodine value ≥1000, CTC ≥70%,

strength ≥95%).

High-Volume, Low-Concentration Exhaust Gas (Workshop Ventilation): Choose honeycomb activated carbon (iodine value ≥650, airflow resistance <600 Pa).

Industrial Wastewater, Decolorization, Heavy Metals: Choose wood-based/coconut shell powder (methylene blue ≥150 mg/g, well-developed mesopores).

Drinking Water, Food, Pharmaceuticals: Choose coconut shell granular (iodine value ≥1100, ash ≤5%, heavy metals compliant).

2. Selection by Operating Parameters

Concentration: High concentration (>500 mg/m³) → granular carbon; Low concentration → honeycomb carbon.

Air Volume: High volume → honeycomb carbon; Medium-to-low volume → granular carbon.

Flow Rate: Granular carbon 0.2–0.6 m/s; Honeycomb carbon <1.2 m/s.

Temperature: ≤120°C → standard; 120–200°C → heat-resistant modified.

Humidity: High humidity → moisture-resistant modified; Low humidity → standard.

3. Selection by Performance Indicators (Industrial Exhaust Gas)

Iodine value ≥1000 mg/g (VOCs adsorption).

CTC ≥70% (gas-phase adsorption).

Strength ≥95% (wear-resistant, not easily pulverized).

Ash content ≤15% (coal-based).

VII. Installation, Operation, Maintenance, and Regeneration Standards

1. Installation Standards

Granular Carbon: Fill evenly, thickness 400–500 mm, moderate compaction, prevent short-circuit flow.

Honeycomb Carbon: Vertical installation, sealed between layers, avoid air leakage.

Pre-filtration: Install paint mist filter cotton and primary efficiency filter screens to prevent dust and paint residue from blocking pores.

Air Speed Control: Granular carbon 0.2–0.6 m/s; Honeycomb carbon <1.2 m/s.

2. Replacement Cycle Determination

Standard: Granular carbon 3–6 months; Honeycomb carbon 6–12 months (depending on concentration and air volume).

Saturation Signals: Exhaust outlet concentration exceeds standard, obvious odor, airflow resistance increases 2–3 times.

3. Routine Maintenance

Weekly: Check airflow resistance, concentration, and dust blockage.

Monthly: Clean pre-filters, inspect carbon layer, prevent short-circuit flow.

Prohibited: Water washing, sun exposure, high-temperature baking (destroys pore structure).

4. Regeneration Technology (Cost Reduction and Efficiency Improvement)

Thermal Regeneration: High-temperature desorption at 800°C, restores adsorption capacity (regeneration rate ≥80%).

Steam Regeneration: Water vapor desorption, suitable for VOCs and solvent recovery.

Chemical Regeneration: Acid-base and solvent elution, suitable for heavy metals and organic wastewater.

VIII. Typical Industry Application Solutions

1. Coating/Spray Booth Exhaust Gas Treatment (VOCs + Paint Mist)

Solution: Paint mist filter cotton (pretreatment) → Granular activated carbon (coal-based columnar, iodine value ≥1000).

Effect: VOCs removal rate ≥90%, paint mist interception ≥95%, service life 3–6 months.

2. Industrial VOCs Exhaust Gas (Chemical, Printing, Electronics)

Solution: Honeycomb activated carbon (high air volume) + Granular activated carbon (high concentration).

Effect: Compatible with air volume 500–20,000 m^3/h, concentration 50–1,000 mg/m^3, stable compliance.

3. Industrial Wastewater Deep Treatment (Printing & Dyeing, Chemical, Electroplating)

Solution: Powdered activated carbon (wood-based/coconut shell).

Effect: COD removal rate ≥75%, heavy metal removal ≥95%, decolorization rate ≥90%.

4. Drinking Water/Food Decolorization (Tap Water, Beverages, Food)

Solution: Coconut shell granular activated carbon.

Effect: Removes residual chlorine, odors, heavy metals, and color; complies with drinking water standards.

IX. Technology Development Trends

1. High Performance

Ultra-high iodine value: ≥1300 mg/g, specific surface area ≥1800 m²/g.

Precise pore control: Micropore/mesopore/macropore grading, adaptable to different pollutants.

2. Multi-Functional Composite

Modified activated carbon: Silver-loaded, copper-loaded, acid-base modification, integrated adsorption + catalysis.

Composite materials: Activated carbon + molecular sieve, activated carbon + catalyst, improving adsorption efficiency.

3. Green and Environmentally Friendly

Regeneration technology: Thermal, steam, and chemical regeneration; regeneration rate ≥80%.

Eco-friendly raw materials: Biomass, waste wood, straw, reducing coal dependence.

4. Intelligence and Digitalization

Online monitoring: Concentration, airflow resistance, temperature, real-time alerts.

AI Optimization: Automatic adjustment of air volume, replacement cycles, precision maintenance.

X. Conclusion

As the core adsorbent material in industrial environmental protection and purification, the performance of activated carbon directly determines governance effectiveness, operatingcosts, and environmental compliance. With the accelerating

transformation toward industrial greening and intelligent development, high-performance, multifunctional, customized, and recyclableactivated carbon has become the inevitable choice of the industry, and is a key support for achieving the "dual carbon" goal and promoting high-quality industrial development.

This white paper systematically covers the technical principles, performance indicators, selection logic, operation and maintenance standards, and industry applications of activated carbon.Combined with the latest national standards and industry trends, it provides enterprises with a comprehensive technical reference throughout the entire process.