



MANUFACTURING GROUP

PROCESS
SOLUTIONS
FOR A CLEANER
BRIGHTER
TOMORROW

PROC-X TECHNICAL INSIGHTS

BIOCHAR & THE ISSUE OF ALUMINUM CONTAMINANTS

Characterization. Liberation. Separation. Validation.

SUSTAINABLE
MATERIALS.
CLEANER
PROCESSES.
A STRONGER
TOMORROW.



Conceptual material
illustration

Understand the material. Release the attachment. Verify the separation.

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MATERIALS
TECHNOLOGY
PEOPLE
A CLEANER TOMORROW

An educational & technical guide
Proc-X Manufacturing Group Inc.

WHY ALUMINUM MATTERS IN BIOCHAR

Quality, value, and processability begin with understanding the contaminant.

Aluminum contamination can reduce product quality, disrupt downstream processing, and limit the market value of biochar. The path to effective separation depends on one key question: is the aluminum free, attached, embedded, or mineral-bound?

CLEAN BIOCHAR

HIGHER PURITY.
HIGHER VALUE.



BIOCHAR WITH ALUMINUM CONTAMINANTS

VISIBLE ALUMINUM FLAKES
CAN REDUCE QUALITY AND
DISRUPT PROCESSING.



ALUMINUM CONTAMINANTS

FREE
ATTACHED
EMBEDDED
MINERAL-BOUND

WHY THIS MATTERS

- ✓ Product quality & specification compliance
- ⚙️ Improved downstream handling and reduced equipment wear
- 📊 Higher-value biochar and recoverable metal streams
- 🌿 Stronger environmental and commercial outcomes

WHAT THIS GUIDE COVERS

- 🧪 Characterization
- 🔍 Liberation
- ⚙️ Separation technologies
- 🛡️ Validation & safety
- 📄 A practical path to implementation

The most successful projects start with characterization, not assumptions.

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ONE CONTAMINANT, FOUR VERY DIFFERENT PROBLEMS

The separation route changes depending on how the aluminum occurs in the biochar.

01 FREE METALLIC PIECES

Loose chips, fragments, or granules that can often be separated after screening and classification.



SCREEN
CLASSIFY
REMOVE

02 ATTACHED FLAKES / FOIL

Thin metallic pieces still bonded to char surfaces; these usually require liberation before separation.



LIBERATE
THEN
SEPARATE



Before specifying equipment,
**confirm whether the target is
free aluminum removal or
reduction of total aluminum.**

03 EMBEDDED FINES

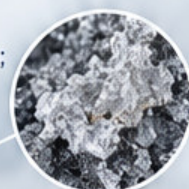
Very fine metallic particles trapped within or strongly adhered to char particles; these are the most difficult dry-separation case.



FINE PARTICLES
HARD TO LIBERATE
CHALLENGING
TO SEPARATE

04 MINERAL-BOUND ALUMINUM

Aluminum present as ash, oxide, or mineral species rather than free metal; this is a different problem than removing metallic aluminum.



ASH / OXIDE
MINERAL SPECIES
DIFFERENT
SEPARATION APPROACH

Characterization determines the process.

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CHARACTERIZATION COMES FIRST

The best separation strategy begins with disciplined material analysis.

No separator should be selected before understanding particle size, attachment mode, ash content, moisture, and whether the aluminum is metallic or mineral-bound.

Illustrative display - not sample measurements.

THE CHARACTERIZATION WORKFLOW



Representative Sampling

Obtain a truly representative sample of the material stream.



Particle Size & Visual Classification

Determine size distribution and identify key particle types.



Moisture / Ash / Bulk Density

Quantify moisture, ash content and bulk density.



SEM-EDS, XRF, ICP or equivalent elemental analysis

Understand composition and attachment mode (metallic vs. mineral-bound).



Bench Separation Trials

Evaluate separation performance and optimize conditions using Proc-X technologies.



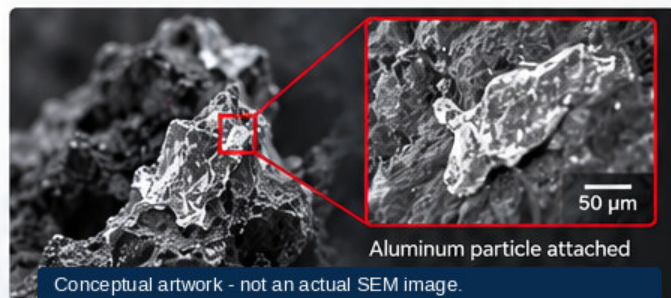
Mass Balance & Commercial Decision

Define achievable recoveries, product purity and economics to guide full-scale design.

KEY QUESTIONS



- What size fraction carries the aluminum?
- Is the aluminum free, attached, or embedded?
- How much char can be recovered at target purity?
- What is the value of the metal reject stream?



Conceptual artwork - not an actual SEM image.

TYPICAL OUTPUTS



PSD by fraction



Residual Al by fraction



Liberation observations



Pilot test direction

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WHEN THE ALUMINUM IS COARSE OR FREE

Mechanical dry separation is often the best first route.



For loose metallic particles, the combination of size classification and nonferrous separation can often deliver the cleanest and most economical result.

WHY THIS WORKS



Creates narrow, more separable size fractions



Removes unwanted ferrous contamination first



Targets conductive nonferrous metal



Produces cleaner biochar and a recoverable reject stream



IMPORTANT: conventional magnets do not remove aluminum.



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WHEN THE ALUMINUM IS FINE AND ATTACHED

Liberation becomes the decisive step.

Fine aluminum bonded to char surfaces rarely separates well without first releasing the attachment. The challenge is to detach the metal while preserving as much clean char as possible.



RECOMMENDED DEVELOPMENT PATH

- 1 Define the attachment mode and particle size**
Characterize how aluminum is bonded and its size distribution.
- 2 Trial controlled attrition or selective milling**
Use appropriate intensity to liberate aluminum without over-grinding the char.
- 3 Classify into narrow size cuts**
Create consistent size fractions for effective separation.
- 4 Test the most suitable separation technologies**
Trial air/density or suitable eddy-current methods; electrostatic separation requires material testing.
- 5 Measure purity, yield, and reject quality**
Quantify results and confirm process viability.

PRACTICAL NOTES

- Avoid over-grinding the char**
Excessive milling can destroy char structure and create new fines.
- Test more than one liberation intensity**
Optimal conditions depend on material and attachment type.
- Do not assume all fines are clean**
Fines can still carry attached aluminum and require verification.
- Validate with a full mass balance**
Account for all streams to understand true performance.

For attached contaminants, liberation testing matters more than separator brand names.



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PROC-X TECHNICAL INSIGHTS

TECHNOLOGY OPTIONS, VALIDATION & SAFETY

A successful solution must be technically effective, commercially practical, and safe to operate.

01



TECHNOLOGY OPTIONS

- Screening & classification
- Eddy current separation
- Air table / density separation
- Electrostatic separation in selected cases
- Wet or chemical routes only when justified

ADVANCED
SEPARATION
TECHNOLOGIES
REAL RESULTS.

MEASURE.
VERIFY.
OPTIMIZE.
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02



VALIDATION METRICS

- Residual aluminum in cleaned char
- Recovered char yield
- Reject stream purity
- Performance by particle-size fraction
- Complete mass balance

03



SAFETY CONSIDERATIONS

- Combustible dust review
- Fine aluminum handling controls
- Dust collection and containment
- Process housekeeping and operator protection
- Pilot testing before scale-up

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If aluminum is mineral-bound rather than metallic, the solution path may be completely different.

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FINE-PARTICLE SEPARATION

Match the method to the material - not simply the word "fine".



THREE METHODS. THREE DIFFERENT LIMITATIONS.

01 EDDY-CURRENT SEPARATION

For liberated metallic particles within a tested size range. One specialist system lists 0.5-10 mm; that is not a guarantee for micron-scale aluminum attached to char. [1]

02 AIR-TABLE / DENSITY SEPARATION

Control particle size, shape and feed presentation. A flat foil flake may behave very differently from a compact aluminum granule in an air stream. [2]

03 ELECTROSTATIC SEPARATION

A development option, not an automatic solution. Biochar conductivity varies with production conditions; do not assume the carbon is electrically insulating. [3]

Conventional magnets remove ferrous metal - not aluminum.

Sources: [1] STEINERT, EddyC FINES. [2] Triple/S Dynamics, Gravity Separators. [3] Gabhi et al., Biochar 2 (2020), 369-378. Actual feed trials are required.

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WHEN DRY SEPARATION IS NOT ENOUGH

Wet and chemical routes require a complete process assessment.

LABORATORY ROUTE SELECTION

Before equipment selection.



Conceptual system illustration

01

WET PHYSICAL

After liberation, evaluate wet gravity or flotation only where particle behavior supports separation. Confirm compatibility with water before adding liquid.

02

SELECTIVE LEACHING

May transfer aluminum into solution, depending on its chemical form. This is chemical recovery, not a clean-metal fraction. Recheck the treated char properties.

03

TOTAL SYSTEM COST

Include reagent demand, gas control, filtration, washing, drying and effluent treatment. Evaluate the whole process, not just the cleanliness of the solid.

COMPATIBILITY IS A GATE - NOT A FOOTNOTE.

Reactive aluminum fines can generate flammable gas with water and react dangerously with strong acids or bases. No unassessed washing or chemical trials. [4]

Sources: [4] ILO/WHO, ICSC 0988. Related-carbon leaching research: Yuan et al., Processes 10 (2022), 849. Related-feed studies do not establish biochar performance.

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PROVE PERFORMANCE. CLOSE THE MASS BALANCE.

A visually cleaner product is not a validated separation.

ILLUSTRATIVE DRY-BASIS EXAMPLE - NOT TEST DATA

Assumed total-aluminum assays. Every output is counted, including collector fines.

STREAM	DRY MASS (kg)	Al MASS (kg)
Feed	1,000	50.00
Product	850	4.25
Metal-rich reject	130	44.75
Collected dust / fines	20	1.00

Output check: 850 + 130 + 20 = 1,000 kg

4.25 + 44.75 + 1.00 = 50.00 kg Al

85.0%

PRODUCT MASS YIELD

850 / 1,000 x 100

0.50%

Al IN THE PRODUCT

4.25 / 850 x 100

91.5%

Al DIVERTED

(50 - 4.25) / 50 x 100

REMOVAL IS NOT THE SAME AS SALEABLE RECOVERY.

Diversion includes dust. Product yield is not carbon recovery; carbon recovery requires separate carbon assays.

Validation plan: sample each size fraction, repeat trials, report analytical uncertainty, and verify product properties. These values demonstrate calculations only; they are not a Proc-X performance claim.



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PROCESS SAFETY IS PART OF THE DESIGN

Assess the actual mixture - including the fines created by processing.



START WITH A DUST HAZARD ASSESSMENT

Characterize the feed, product and collector fines. Review explosibility and ignition sensitivity before final equipment selection. [5]



CONTROL IGNITION

Review hot char, bearings, friction, static and metal impact. Select electrical and mechanical safeguards for the assessed hazards.

LIMIT PROPAGATION

Engineer collection, containment, isolation and explosion protection as required. An ordinary dust collector is not automatically suitable.

ASSESS REACTIVITY

Before wet treatment, assess water compatibility, reaction heat and flammable-gas generation. Engineer gas handling and monitoring as needed. [4]

PLAN OPERATIONS

Address housekeeping, exposure controls, maintenance, operator training and a material-specific emergency and fire response.

ENGINEERING REFERENCE: NFPA 660 (2025)

Review the standard and local requirements for each project. This brochure is not a compliance certification. [6]

Sources: [4] ILO/WHO, ICSC 0988. [5] OSHA, Combustible Dust Technical Manual. [6] NFPA 660, 2025 edition. All equipment and microscopy artwork is illustrative, not measured test evidence.





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THE PROC-X PATH FORWARD

From material understanding to a scalable processing solution.

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REAL IMPACT.
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FEED HANDLING,
CONVEYING,
AND DOSING



SIZE REDUCTION
AND CLASSIFICATION
SUPPORT



MIXING, CONDITIONING,
AND THERMAL
PROCESSING



INSPECTION AND
QUALITY ASSURANCE



DOWNSTREAM
HANDLING AND
PACKAGING



RECOMMENDED NEXT STEPS

- 1 Define the feed and the specification target
- 2 Run characterization and bench testing
- 3 Develop a pilot separation flowsheet
- 4 Validate purity, yield, and economics
- 5 Scale to a reliable commercial system

Proc-X combines process knowledge, equipment breadth, and practical engineering to help customers convert challenging materials into cleaner, higher-value products.



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Talk to Proc-X about your biochar application.



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