Comparison of Natural Organic Matter Adsorption Capacities of Super-Powdered Activated Carbon and Powdered Activated Carbon

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Characteristics of SPAC vs. PAC
Higher Adsorption Capacity on SPAC than on PAC
For what NOM?
Why?
Suspension and solution

PAC
20 mg/L
$D_{50} = 11 \, \mu m$

SPAC
20 mg/L
$D_{50} = 0.9 \, \mu m$
PAC (D50: 12 μm)  

S-PAC (D50: 0.7 μm)
Normal PAC vs. S-PAC in terms of volumetric percentage undersize with respect to particle size.

- Normal PAC:
  - Particle size:
    - 9 μm
    - 0.7 μm
    - 0.2 μm
  - Volumetric percentage undersize:
    - 0 to 100

- S-PAC:
  - Particle size:
    - 9 μm
    - 0.7 μm
    - 0.2 μm
  - Volumetric percentage undersize:
    - 0 to 100

Grinding is indicated by a dashed line between the two curves.
Adsorption isotherms of Suwannee river NOM water on S-PAC and PAC. Contact times are 3 weeks.
Adsorption capacity on SPAC / Adsorption capacity on PAC

- SHA
- SNOM
- SFA
- Chibaberi
- Inba
- Hakucho
- Post-coagulation
Shell Adsorption Model (SAM)

NOM could adsorb near the outer surface of the adsorbent particles. The specific outer surface area (surface area per unit mass) is greater for smaller adsorbent particles. NOM adsorption capacity could be larger on S-PAC, which had a much smaller particle size than PAC.
Gradient (\( \log q_{\text{DOC}} / \log D_{50} \))

is an indicator of penetration / unpenetration

Is called **un-penetration index**.
Gradient = Unpenetration index
Molecular weight distribution

Seize-exclusion chromatogram of Chibaberi-09 water
R² = 0.36

DOC of NOM MW > 2000 Da (mg/L)

External adsorption index

Unpenetration index

R² = 0.29

DOC of NOM MW > 500 Da (mg/L)

External adsorption index

Unpenetration index

R² = 0.46

DOC of NOM MW > 1000 Da (mg/L)

External adsorption index

Unpenetration index

R² = 0.00

DOC of NOM MW > 5000 Da (mg/L)

External adsorption index

Unpenetration index
NOM that mainly adsorbs on the external surface are is UV-absorbing-NOM. For NOM that adsorbs on the external surface, UV absorbance is more appropriate NOM concentration index than DOC.
Molecular weight distribution: LC-UV detection

UV$_{260}$ (m$^{-1}$)

Molecular weight (Da)
\[ R^2 = 0.62 \]

Unpenetration index

\[ R^2 = 0.68 \]

Unpenetration index

\[ R^2 = 0.71 \]

Unpenetration index

\[ R^2 = 0.77 \]

Unpenetration index
High-MW, UV-absorbing NOM (>2000 Da) adsorb near the outer surface of the adsorbent particle.

- Low-MW, UV-absorbing NOM
- None-UV-absorbing NOM penetrate and adsorb on internal pore
Effect of cation

SNOM isotherms

Solid-phase concentration, mg/g

Liquid-phase concentration, mg/L

Mono-valent solution
K (0.49 meq/L)
+ Na (0.39 meq/L)

Di-valent solution
Ca (0.24 mM)
+ Na (0.38 mM)

Mono-valent solution
K (0.49 mM)
+ Na (0.39 mM)

SPAC
PAC

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Molecular size measurement by dynamic scattering method

SNOM, Pure water (Milli-Q)
SNOM in Na (0.4 mM)
SNOM in Na (0.4 mM) + Ca (0.025 mM)
SNOM in Na (0.4 mM) + Ca (0.25 mM)
SNOM in Na (0.4 mM) + Ca (2.5 mM)
SNOM in Na (0.4 mM) + Ca (10 mM)
SNOM in Na (0.4 mM) + Ca (25 mM)
Ca concentration, mM

In bulk water

In pore
Molecular size measurement by dynamic scattering method

- Pure water (Milli-Q)
- SNOM in Na (0.4 mM)
- SNOM in Na (0.4 mM) + Ca (0.025 mM)
- SNOM in Na (0.4 mM) + Ca (0.25 mM)
- SNOM in Na (0.4 mM) + Ca (2.5 mM)
- SNOM in Na (0.4 mM) + Ca (10 mM)
- SNOM in Na (0.4 mM) + Ca (25 mM)
- High-MW, UV-absorbing NOM (>2000 Da)
- Cation [divalent cation (Ca\(^{2+}\))]
Conclusions

Among various NOMs, UV-absorbing and high MW (> 2000 Da) adsorbs mainly on the external region of adsorbent particle.

Because the divalent cation (Ca$^{2+}$) is accumulated in the carbon pores, the NOM agglomerates at pore and do not diffuse into internal pores.

Due to it smaller particle size and larger specific outer surface area, SPAC has higher NOM adsorption capacity than PAC.

But, the extent of capacity ratio (SPAC/PAC) is dependent on NOM type.
Acknowledgements

Metawater Co., Japan.
Japan Society for the Promotion of Science
Ministry of Health, Labour and Welfare

Thank you