Adsorption for wastewater treatment and water purification

Part 2:

Low-cost adsorbents for wastewater treatment applications

Circular Economy for Water

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Content and questions considered:


Illustration: Tatiana Samarina

- ✓Conventional and emerging pollutants
- ✓Adsorbents characteristics and adsorption capacities
- ✓Methods and techniques applied
- ✓Source of low-cost raw materials for adsorbent production
- ✓Simplest variations of layouts with adsorption

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Conventional and emerging pollutants

Deteriorating of natural waters:

- anthropogenic activities
- population growth
- unplanned urbanization
- rapid industrialization
- unskilled utilization of water sources

Conventional pollutants

Nutrients – forms of phosphorous and nitrogen;
Dyes and surfactants;
Heavy metals;
Bacteria and viruses
Compounds polycyclic aromatic hydrocarbons.

Emerging pollutants

Biorecalcitrant compounds, micro/nanoplastic compounds of drugs, pharmaceuticals and personal care products, plasticizers, fire retardants, endocrine disrupting chemicals, etc.

Read more:

https://www.sciencedirect.com/science/article/pii/S2095633915000039#:~:text=Emerging%20pollutants%20(EPs)%20are%20defined,(or)%20human%20health%20effects.

https://www.sciencedirect.com/science/article/pii/B978044453199500052X

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Low-cost adsorbents in water remediation techniques:

Cost-effective adsorbents for nutrient removal

Abundant and low cost source

Natural zeolites and clays
Industrial wastes and by-products
Agricultural residues
Bio-based materials

Manufacturing and remediation process

Ease of handling
Low energy consumption
Low GHG emission
High capacity and short removal time

Zero-waste

Waste produced

Regeneration
Recycling
Reuse in other application

Commercial adsorbents:

Activated carbons (PAC/GAC)
1200-3000 EUR/ton
GHG emission; energy demand;
loss of adsorbent on reg.stage;
utilization problems

Ion-exchange resins (polymers)
1700-3000 EUR/ton
energy demand; organic solvents;
utilization problems

Zeolites (natural minerals)
600-1500 EUR/ton
unsteady quality; limit abundances

Sands, gravels, etc.
50-350 EUR/ton
low capacity and nonspecific treatment

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Read more:
https://www.tandfonline.com/doi/abs/10.1080/10643380801977610

Sources of low-cost raw materials for adsorbent production

- agricultural and household wastes- e.g. fertilizer industry waste;
- industrial by-products - fly ash, steel industry wastes, aluminium industry wastes;
- sludges;
- sea materials - chitosan and seafood processing wastes, seaweed and algae;
- soil and ore materials - clays, zeolites, sediment and soil, and ore materials;
- novel low-cost adsorbents - peat moss, other industry waste such as those from leather industry and paper industry.

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Adsorbents characteristics and adsorption capacities

Adsorption – process that allow to collect one of the component (**adsorbate**) contained in liquid, for instance in mine effluent, on the solid surface (***adsorbent***).

To describe particular behavior of adsorbate on chosen adsorbent, an equilibrium model is used. Such model is called **isotherm** of adsorption.

There are plenty of those have been proposed, but the main their application is to express the amount of adsorbate to be adsorbed per unit of adsorbent as a function of concentration.

Isotherms could be different forms, which reflects processes and limitation steps

Isotherms:

- Need to be determined for particular stream treated
- Are used for calculations and design of treatment systems

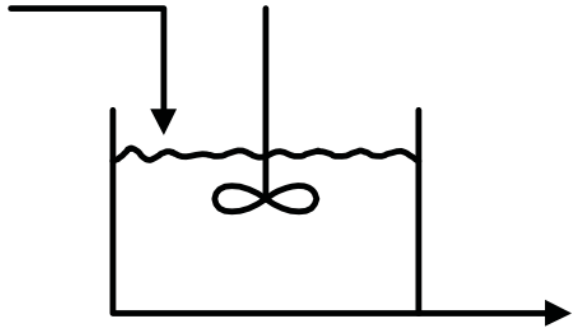
Read more:

N. Ayawei, A. N. Ebelegi, and D. Wankasi, “Modelling and Interpretation of Adsorption Isotherms,” *J. Chem.*, vol. 2017, p. 3039817, Sep. 2017, doi: 10.1155/2017/3039817. https://www.hindawi.com/journals/jchem/2017/3039817/

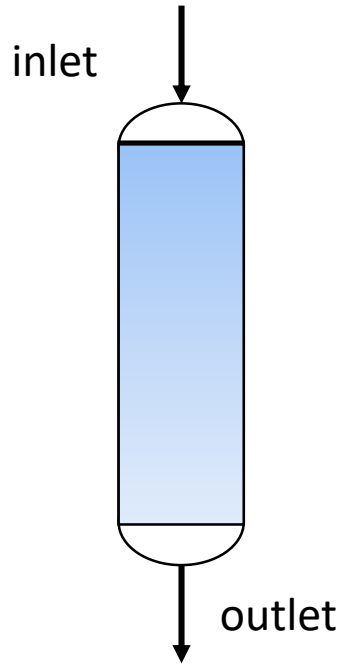
Mahmoud, Dalia Khalid et al. “Langmuir model application on solid-liquid adsorption using agricultural wastes: Environmental application review.” (2012). https://www.academia.edu/3042397/Langmuir_model_application_on_solid_liquid_adsorption_using_agricultural_wastes_Environmental_application_review

Simplest variations of layouts for wastewater treatment

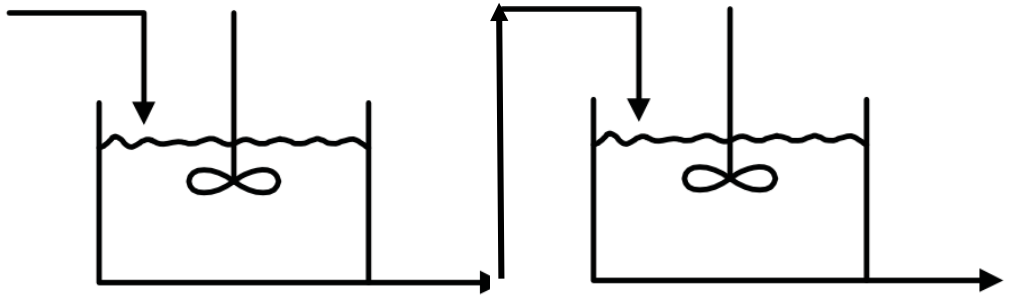
a completely mixed flow reactor (CMFR)



a column contactor



Both variants could be used in the cascade



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Example of process calculation

An mine wastewater contains 10 mg/L of undesired contaminant, and is going to be treated by adsorption. 95% removal is required to reach safe discharge limit. The wastewater is discharged at a rate of 100 000 L/day. Calculate the mass of adsorbent requirement for treatment in a ***completely mixed flow reactor***, if Freundlich isotherm given

$q = 5.1C^{0.87}$, the q is adsorption capacity, mg/g and C is concentration, mg/L.

- ***Calculating the capacity*** of adsorbent at desired concentration (0.5 mg/L, 95% removed):

$q=5.1*0.5^{0.87}=5.1*0.547=$**2.79 mg adsorbat/ g adsorbent**

- Calculating of ***contaminant load***

$Q=(C_o-C_{in})*$ rate(L/day)=9.5 mg/L*100000 L/day=950 g/day

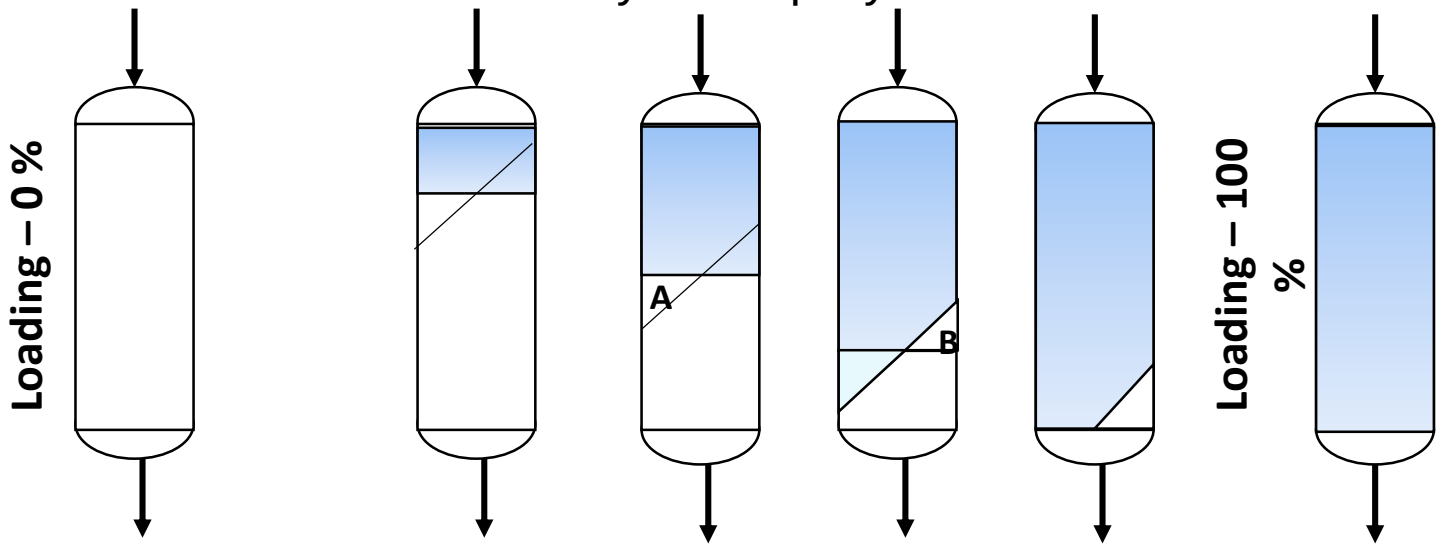
- ***Mass of adsorbent needed***

M=Q/q=950 000 mg/day : 2.79 mg/g = **340.5 kg/day**

Active zones at various times during adsorption and the breakthrough curve

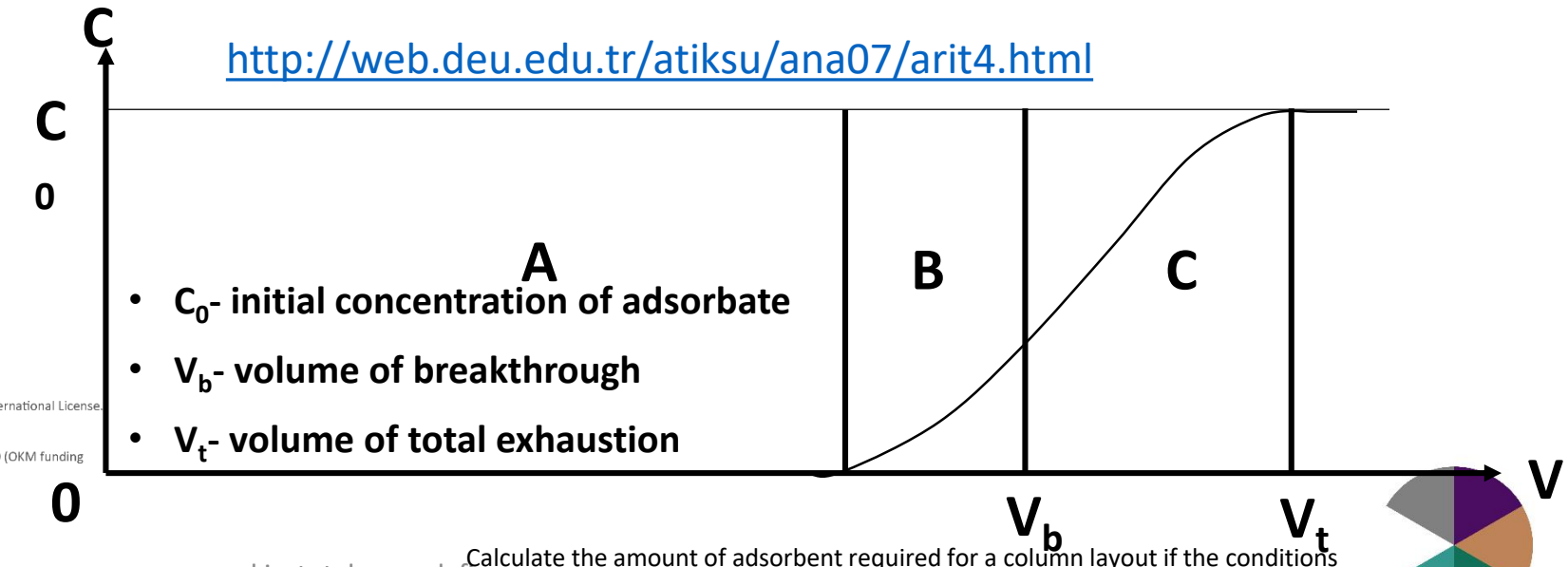
Mass transfer zone, MTZ, part of a column where the solute is most effectively and rapidly adsorbed .

This zone moves downward with a constant velocity as the upper regions become saturated.



To design a column accurately, a test column **breakthrough curve** for the stream of interest and the chosen adsorbent need to be used.

http://web.deu.edu.tr/atiksu/ana07/arit4.html



- C_0- initial concentration of adsorbate
- V_b- volume of breakthrough
- V_t- volume of total exhaustion

Calculate the amount of adsorbent required for a column layout if the conditions and isotherm are the same as for the example given above?

Content bullets and conclusions:

- Adsorption is powerful tool for water purification and waste management;
- There is a need to develop more efficient selective, inexpensive and eco-friendly low cost adsorbents;
- Low cost adsorbents can be used for wastewater management in small communities and remote areas;
- Continuous process can be used for adsorption process;
- Regeneration of adsorbents could decrease the overall expenditures of technology

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1 op:n Adsorption for wastewater treatment and water purification.

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