Research in Environmental Engineering: Where Environmental and Mathematical Researchers Can Collaborate?

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Vilnius Gediminas Technical Universitety (VilniusTech)

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I am greatful to…

…be praeities – nėra ateities…

Prof. habil. dr.
Donatas Butkus

Prof. dr.
Arvydas Lietuvninkas

Šviesios atminties prof. habil. dr. **Pranas Baltrėnas**

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EU challenges for environmental engineering science

- Climate neutrality and Zero pollution in the EU by 2050.
- Among the goals of zero pollution by 2030
  - 55 percent reduce the health effects of air pollution (premature deaths)
  - 25 percent reduce the number of EU ecosystems where air pollution threatens biodiversity
  - 50 percent reduce the loss of nutrients, the use of chemical pesticides <...>.
  - <...> 50 per cent – to reduce the amount of final municipal waste and significantly reduce the total generated waste.

JRC 2022

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Research interests

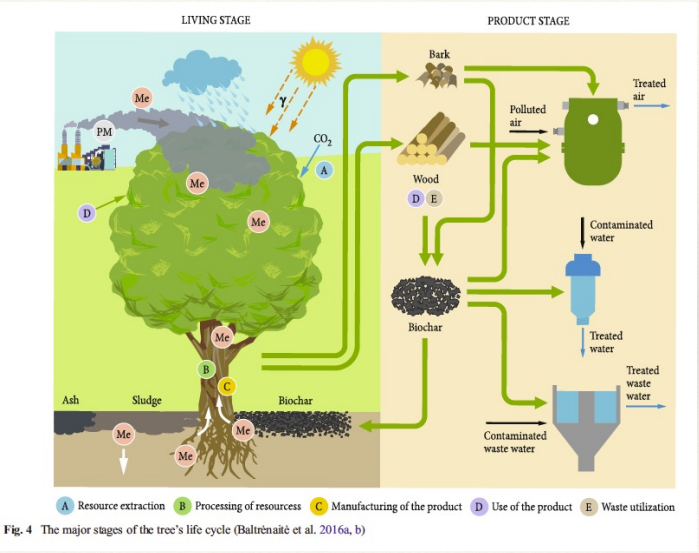

Fig. 4 The major stages of the tree's life cycle (Baltrėnaitė et al. 2016a, b)

Baltrėnaitė et al. 2016

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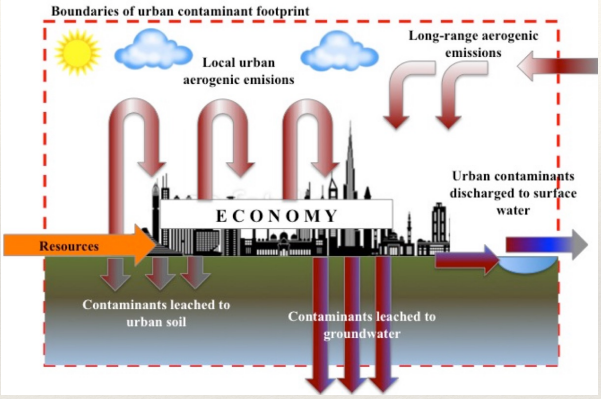
Increased economy and urban activities magnify the effect



Urban contaminant footprint

(introduced by Baltrėnaitė et al. 2018)

- Although urban areas cover less than 3% of the global terrestrial surface, cities are responsible for 78% of carbon emissions, 60% of residential water use, 76% of wood use on the global scale (Grimm et al. 2008).
- High health risks of exposure to residence soils would be expected after 150 years of accumulation under the current urban environment.

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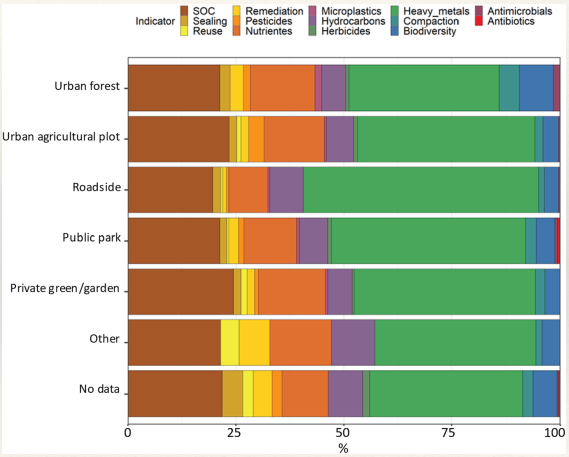
Increased economy and urban activities magnify the effect _EU context

- Percentage of soil threats identified per land cover in European Union countries during our study (n = 603) (Binner et al. 2024)
- potentially toxic elements (*heavy metals*) from former anthropogenic activities are prone to mobility at heavy rain and flooding conditions



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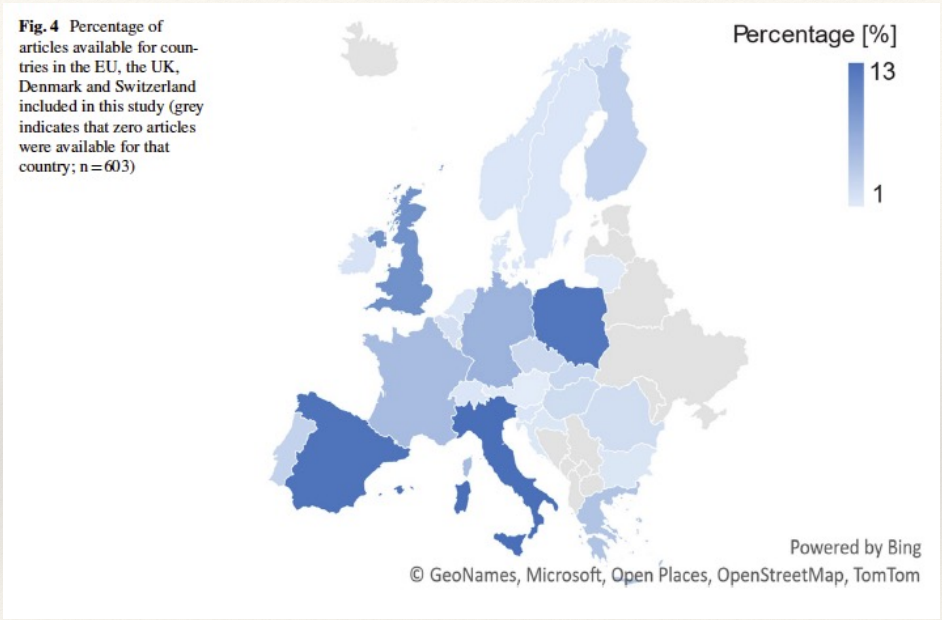

Fig. 4 Percentage of articles available for countries in the EU, the UK, Denmark and Switzerland included in this study (grey indicates that zero articles were available for that country; n = 603)

Binner et al. 2024

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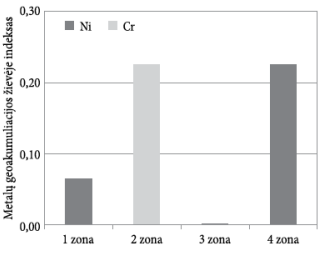
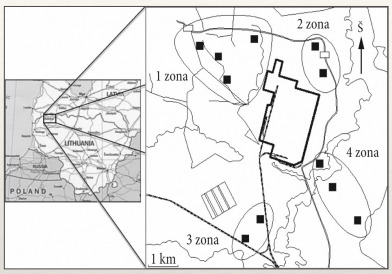
Environmental quality evaluation



2.16 pav. Skirtingų AB „ORLEN Lietuva“ įtakos zonų metalų geoakumuliacijos pušies žievėje teigiamos indekso $I_{geo,b}$ reikšmės



Sniego, dirvožemio, samanų ir pušies žievės ėminių ėmimo vietos AB „ORLEN Lietuva“ įtakos zonoje. Kontrolinė aikštelė yra10 km į vakarus nuo įmonės (paveiksle nepavaizduota)

2.16 lentelė. Geoakumuliacijos indekso $I_{geo,dt}$ reikšmės, užtaršos klasės ir užtaršos laipsnis (Müller 1981)

Geoakumuliacijos indeksas ($I_{geo,dt}$)	Užtaršos klasė	Užtaršos laipsnis
<0	0	Beveik neužteršta
0–1	1	Mažai ar vidutiniškai užteršta
1–2	2	Vidutiniškai užteršta
2–3	3	Vidutiniškai ar labai užteršta
3–4	4	Labai užteršta
4–5	5	Labai ar ypač užteršta
>5	6	Ypač užteršta

Baltrėnaitė et al. 2014, 2016a,b

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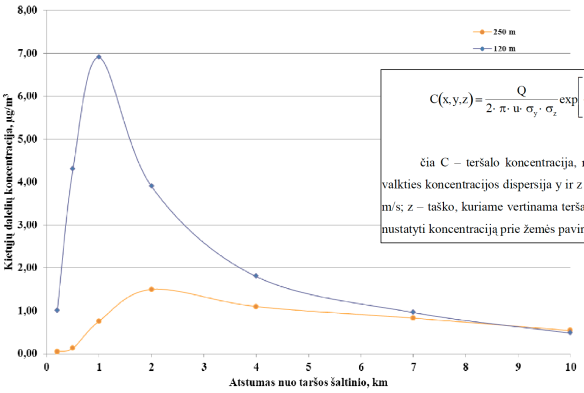
Aerogenic particle transport



$$C(x,y,z) = \frac{Q}{2 \cdot \pi \cdot u \cdot \sigma_y \cdot \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}\right)\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{(z-H)^2}{\sigma_z^2}\right)\right] + \exp\left[-\frac{1}{2}\left(\frac{(z+H)^2}{\sigma_z^2}\right)\right]\right\}, \quad (3.1)$$

čia C – teršalo koncentracija, mg/m^3; Q – emisijų iš kamino greitis, mg/s; σy, σz – teršalų valkties koncentracijos dispersija y ir z ašimis, H – efektinis taršos šaltinio aukštis, m; u – vėjo greitis, m/s; z – taško, kuriame vertinama teršalų koncentracija, altitudė nuo žemės paviršiaus (m) (jei norima nustatyti koncentraciją prie žemės paviršiaus, tai z = 0); y – teršalų valkties išplitimas y ašies atžvilgiu.

3.35 pav. Kietųjų dalelių koncentracijos pasiskirstymo pokyčiai priklausomai nuo taršos šaltinio aukščio

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Phytotechnologies

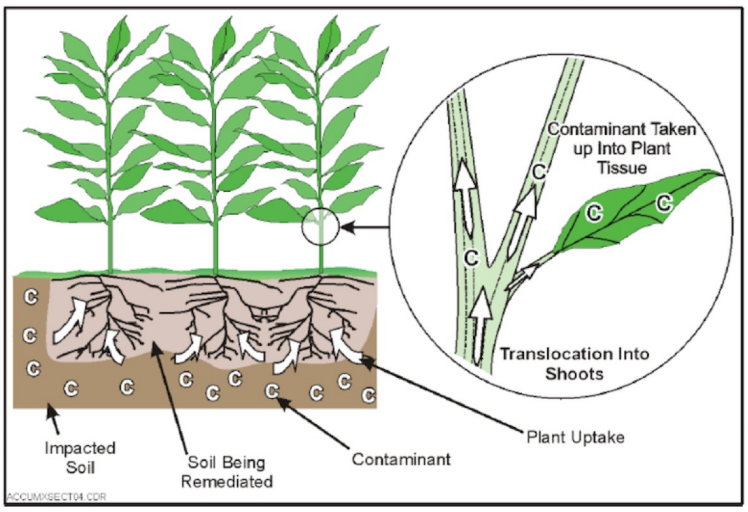

Figure 1-3 Phytoaccumulation of Inorganics

Source: Interstate Technology and Regulatory Cooperation Work GroupInterstate Technology and Regulatory Cooperation Work Group

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Metal plant uptake model

- The model also assumes that metal uptake depends on root density. Plant metal-uptake causes a change in soil metal concentration (mg/kg) at depth ***(d)***, and this change is estimated as:

$$\Delta[M]_z = \frac{1}{\rho_z}\int_0^\tau R_z TC\phi dt$$

- where $\Delta[M]_z$ – change in metal concentration (mg/kg) at depth z; ρ_z – bulk density of the soil (g/cm^3) at depth z; t – time (days); R_z – root density fraction (root mass at depth z)/(total root mass)

Robinson et al. 1993

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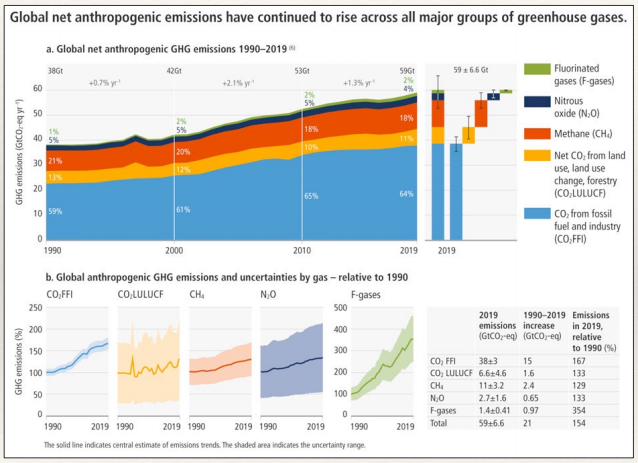
Climate change burden



- Solutions are available for all sectors to halve emissions by 2030 and about 40–70% by 2050
- Among the methods for reducing carbon emissions, biochar technologies are also distinguished (0.3-6.6 Gt CO_2/year).

Tarpvyriausybinė klimato kaitos grupė 2022

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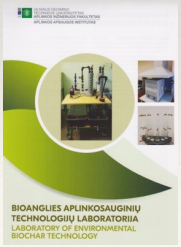
Biochar



- Biochar is a heterogeneous material rich in aromatic carbon and mineral substances. Under controlled conditions, using clean technologies, biochar is produced by the pyrolysis method from biomass and used for a purpose that limits its rapid mineralization in the form of CO_2, and the final purpose of using biochar is soil improvement.

Lehmann and Joseph 2010; EBC 2012

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Benefits of biochar

- Converting about 1% of annual total CO_2 uptake by vegetation to biochar would reduce anthropogenic C emissions by 10%
- In the soil, biochar from wood waste is about 100 times more stable than from animal waste or straw
- Up to 50% biochar has a positive effect on plants in the growing medium after replacing peat
- Up to 1% biochar in the growing medium is sufficient to protect against plant diseases
- Incorporating biochar into soil can reduce the uptake of metals, about 70% Cd, 40% Zn and Pb, into plants (e.g. rice roots)

Šaltinis: Lehmann and Joseph 2010; EBC 2012

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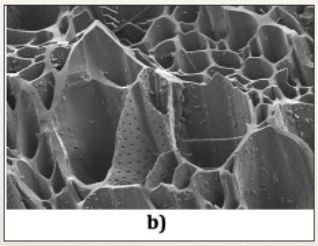
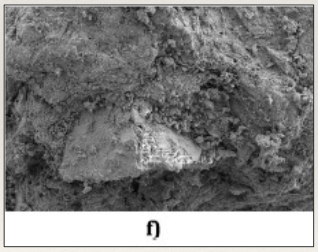
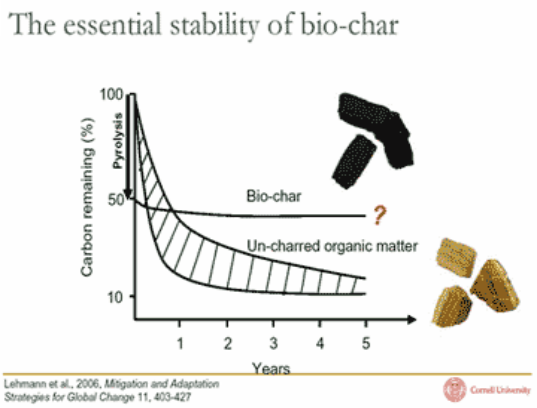




- Scanning electron microscope images (magnification 2000 times, scale 10 microns) of biochar produced from: b) pine wood sawdust at 700°C; f) city sewage sludge 700°C



Baltrėnaitė et al. 2017

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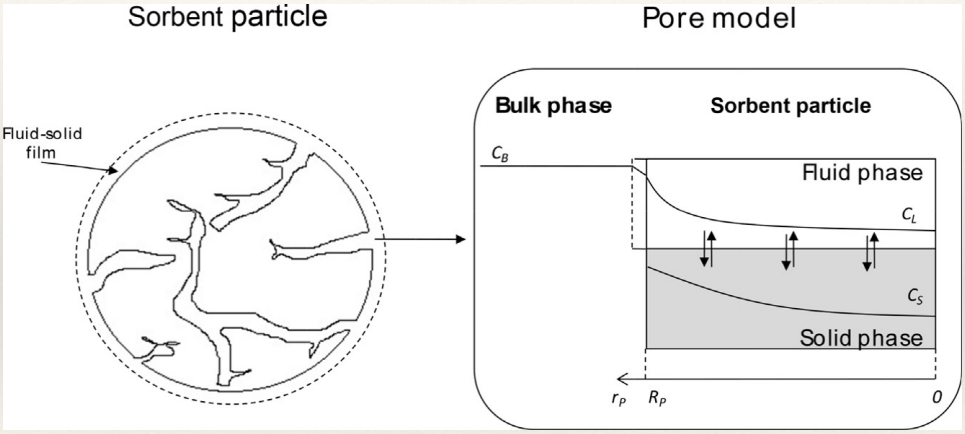
Dynamic intraparticle model



Russo et al. 2015

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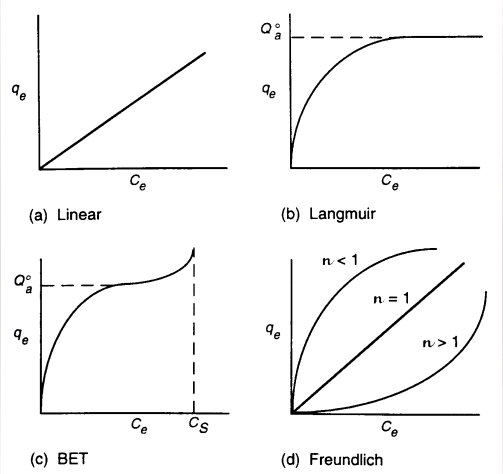
Isotherm models



Isotherms describe the equilibrium relationship between two quantities:

q_e – the mass of sorbed contaminant per mass of sorbent, and

C_e – the equilibrium concentration of contaminant in the fluid (mass or molar concentration in water, or mass concentration or partial pressure in air)

q_e / C_e – relationships depend on the type of adsorption that occurs, multi-layer, chemical, physical adsorption, etc.

Isotherms are empirical, include data that can be obtained only from experiment. 4 main forms of isotherms are: Linear(Henry's), Langmuir, Freundlich, BET

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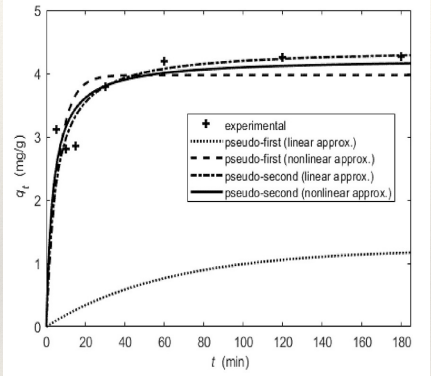
Dynamic intraparticle model



The pore volume and surface diffusion model consists of equations 2 and 3:

$$\frac{\partial C_B(t)}{\partial t} = -k_m A\left(C_B(t) - C_L(t, R_p)\right), \quad \text{(Eq. 2)}$$

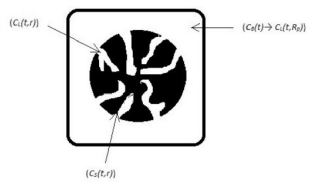


Fig. 2. The conceptual scheme about transfer of potentially toxic elements from the bulk phase to the particle: $C_L(t,r)$ represents the diffusion from the surface to the centre of the particle; $C_B(t) \rightarrow C_L(t, R_p)$ represents the diffusion of the solute from the bulk liquid to the surface of the particle; $C_S(t,r)$ represents the diffusion on the inner surface of the particle.

$$\varepsilon\frac{\partial C_L(t,r)}{\partial t} + (1-\varepsilon)\frac{\partial C_S(t,r)}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(\varepsilon D_p r^2 \frac{\partial C_L(t,r)}{\partial r} + (1-\varepsilon)D_S r^2 \frac{C_S(t,r)}{C_L(t,r)}\frac{\partial C_L(t,r)}{\partial r}\right), \quad \text{(Eq. 3)}$$

where km is the external mass transfer coefficient, $A = \frac{mS}{V}$, m is the mass of adsorbent, S is the external surface area per mass of adsorbent, V is the volume of solution, Rp is the particle radius, ε is the particle porosity, r is the particle radial direction, Dp is the pore diffusivity and DS is the surface diffusivity. The initial and boundary conditions for this system are described by Eqs. (4)–(6):

E. Baltrėnaitė-Gedienė et al. / Chemosphere 245 (2020) 125562

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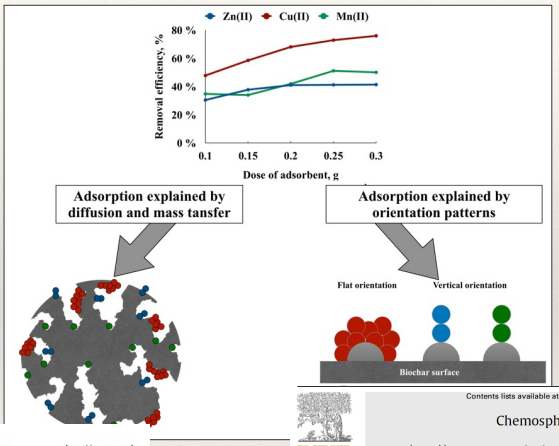
Metal adsorption by biochar



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ISSN: 1392-6292
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Numerical Analysis of Liquid-Solid Adsorption Model

Teresė Leonavičienė, Raimondas Čiegis, Edita Baltrėnaitė and Valeriia Chemerys

Contents lists available at ScienceDirect
Chemosphere
journal homepage: www.elsevier.com/locate/chemosphere

Comparison of CU(II), MN(II) and ZN(II) adsorption on biochar using diagnostic and simulation models

Edita Baltrėnaitė-Gedienė [a,*], Teresė Leonavičienė [b], Pranas Baltrėnas [a]
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[b] Department of Mathematical Modelling, Vilnius Gediminas Technical University, Saulėtekio al. 11, Vilnius, Lithuania

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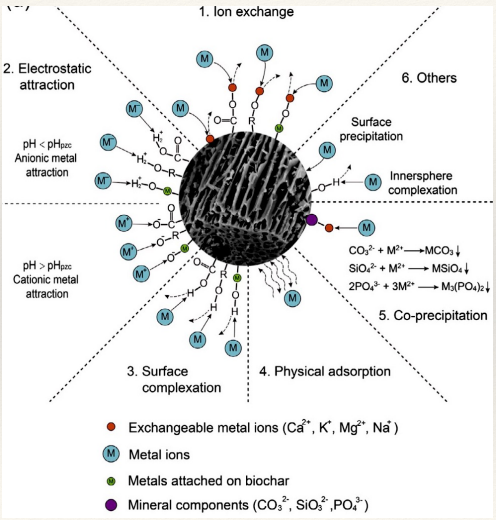
Adsorption mechanism



- For inorganics (e.g. metals) the possible adsorption mechanisms usually involve:
- electrostatic attraction
- ion-exchange
- physical adsorption
- surface complexation and/or precipitation and others (Tan et al. 2015).

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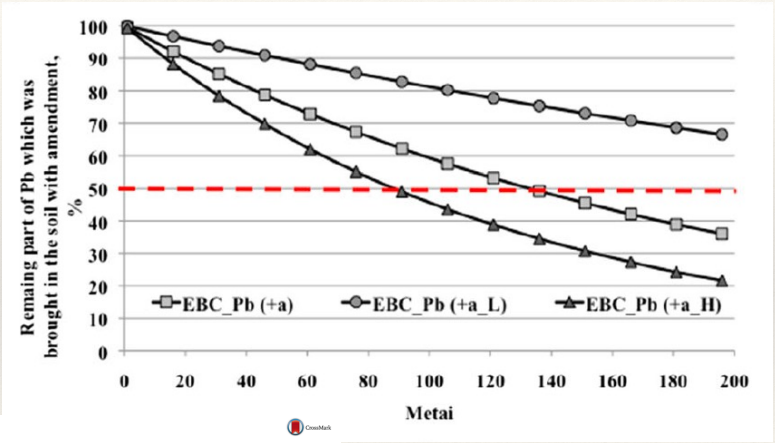
Pb remaining in soil after biochar addition



Environ Model Assess
DOI 10.1007/s10666-016-9505-7

Modelling the Balance of Metals in the Amended Soil for the Case of 'Atmosphere–Plant–Soil' System

Edita Baltrėnaitė[1] · Arvydas Lietuvninkas[2] · Pranas Baltrėnas[1]

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Biochar for biofiltration

- Baltrėnas P, **Baltrėnaitė E** (2019) A vertical biofilter-adsorber. EU patent No. 3072576.
- Baltrėnas P, **Baltrėnaitė-Gedienė E** (2019) A biofilter - adsorber. München: European Patent Office. No. EP2826543.

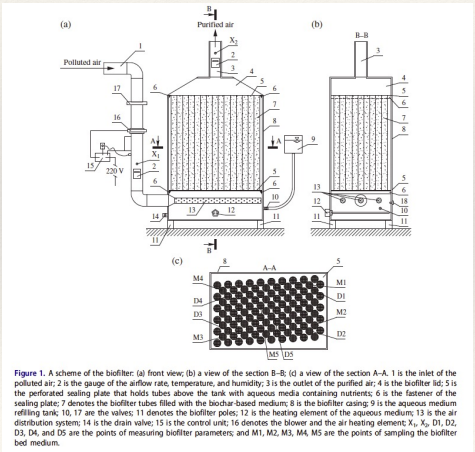

Figure 1. A scheme of the biofilter: (a) front view; (b) a view of the section B–B; (c) a view of the section A–A. 1 is the inlet of the polluted air; 2 is the gauge of the airflow rate, temperature, and humidity; 3 is the outlet of the purified air; 4 is the biofilter lid; 5 is the perforated sealing plate that holds tubes above the tank with aqueous media containing nutrients; 6 is the fastener of the sealing plate; 7 denotes the biofilter tubes filled with the biochar-based medium; 8 is the biofilter casing; 9 is the aqueous medium refilling tank; 10, 17 are the valves; 11 denotes the biofilter poles; 12 is the heating element of the aqueous medium; 13 is the air distribution system; 14 is the drain valve; 15 is the control unit; 16 denotes the blower and the air heating element; X_1, X_2, D1, D2, D3, D4, and D5 are the points of measuring biofilter parameters; and M1, M2, M3, M4, M5 are the points of sampling the biofilter bed medium.

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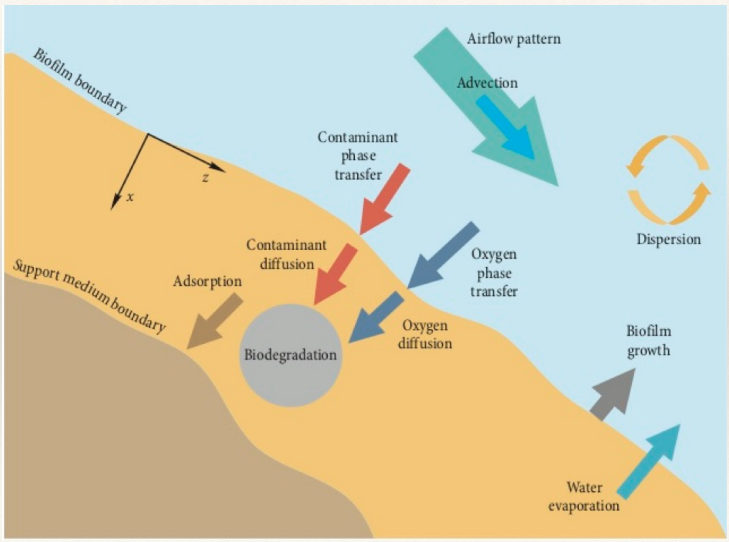
Biofiltration



(according to Devinny, Ramesh 2005)

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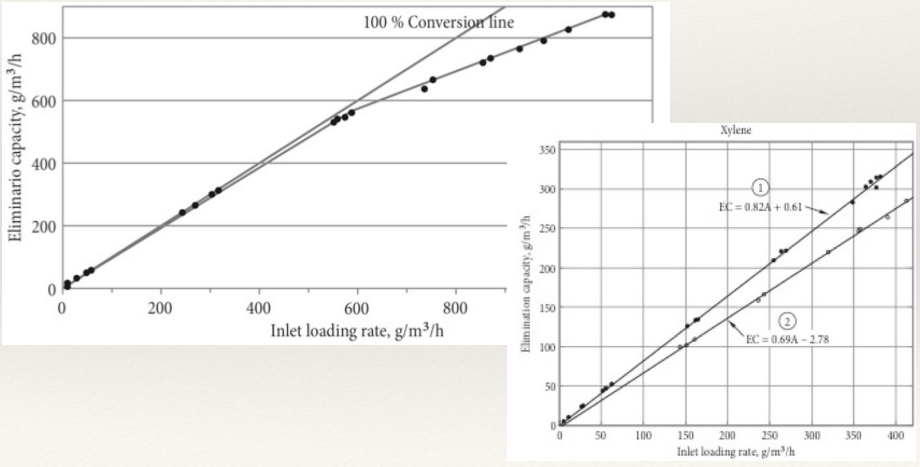
- Influence of inlet load rate on the elimination efficiency and elimination capacity (example of toluene, media – wood biochar)



Baltrėnaitė et al. 2016

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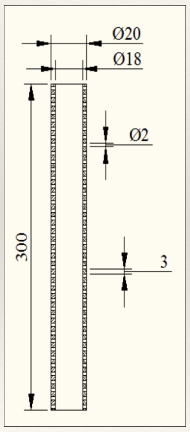
Journal of the Air & Waste Management Association

A biochar-based medium in the biofiltration system: Removal efficiency, microorganism propagation, and the medium penetration modeling

Pranas Baltrėnas, Edita Baltrėnaitė, Jonas Kleiza & Jurgita Švedienė



The penetration coefficient of the packing material

Assuming that the packing material of the tube makes a porous medium through which the polluted air gets through and with reference to Darcy's law, the basic vectorial relation of laminar filtration was obtained as follows:

$$v = -\frac{k}{\mu}\text{grad}p \qquad (1)$$

where $v = (u, v, w)$ (m/sec) is a vector of the filtration rate, μ is the coefficient of the dynamic viscosity of the supplied air (Ns/m^2), p is pressure (Pa), and k is the penetration coefficient of the porous medium (m^2). Since movement is only in one direction, i.e., along the tube, supposedly, in the direction of the Ox axis, eq 1 is scalar:

$$u = -\frac{k}{\mu}\frac{\partial p}{\partial x} \qquad (2)$$

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PFAS

- Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic chemicals used throughout society. However, they are increasingly detected as environmental pollutants and some are linked to adverse effects on human health.
- Per and poly-fluoroalkyl substances (PFAS) are all around us:
  - Coating of non-stick cookware, smartphone screens, weatherproof clothing, and stain-resistant textiles, in microchips, jet engines, cars, batteries, medical devices, refrigerator systems
- Most PFAS are also easily transported in the environment, covering long distances away from the source of their release.
- PFAS have been frequently observed to contaminate groundwater, surface water and soil. Cleaning up polluted sites is technically complex and costly. If releases continue, they will accumulate in the environment, drinking water and food.
- Natural processes cannot break apart their strong C-F bonds

ECHA 2024

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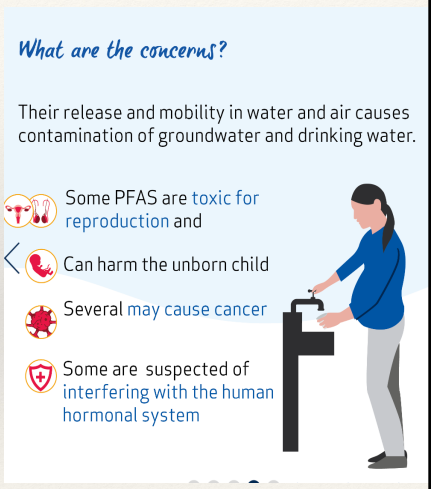
Challenges of PFAS

- In 2023 the European Chemicals Agency (ECHA) published a proposal initiated by environmental agencies of **Denmark, Germany, the Netherlands, Norway and Sweden** to restrict the manufacture of more than **12,000 substances** collectively known as 'forever chemicals'.
- After PFASs escape from factories, homes and vehicles into the environment, they add to the growing pollution problem.
- **Ten of thousand of tonnes of PFASs** are emitted annually in Europe alone
- Restrictions with the grace period, some permanent exceptions (including fluorinated drugs, such as Prozac), and particular environmental technologies (including (bio)char-based systems) are among PFAS managing strategies in the agendas of environmental regulatory institutions



ECHA 2024

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PFAS in environment-human continuum: from global risk to local management

SEMINAR – 19 October 2023

SI. Swedish Institute

ACHIEVING ZERO PFAS

2024 09–2026 09

The project aims to guide PFAS management via the collaboration of cross-sectorial stakeholders and cross-border cooperation among the Baltic region partners with support to Ukraine

Prof Dr Edita BALTRĖNAITĖ-GEDIENĖ
Lithuanian team leader
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SRK II 308

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Communication to public, S4P

- Member of the Natural and Technical Sciences Committee of the Lithuanian Science C...
- 2 EU patents, 5 Lithuanian patents
- Panevėžys district Smilgiai High school students are awarded Prof. Pranas Baltrėnas prize for the outstanding environmental project
- Established by the Vydūnas Youth Foundation of the USA and awarded to VilniusTech Faculty of Environmental Engineering students, Dr. Arūnas and Irena Draugeliai scholarship
- Oak Tree and nominal audience – in the memory of **Prof. Dr Habil Pranas Baltrėnas**





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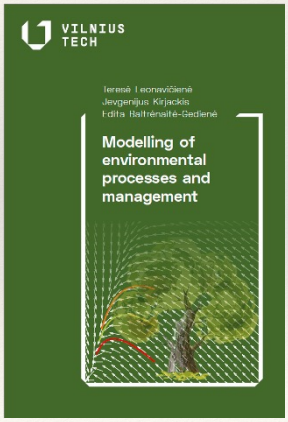
EU project, Erasmus+

- Vilnius Gediminas University of Technology (VILNIUS TECH) participated in the ERASMUS+ project GEOCLIC (Geospatial Engineering for Climate Change Adaptation of Coastal Ecosystems /GEOCLIC). The project aimed to modernize and increase the internationality of bachelor's, master's, and doctoral degree studies in monitoring and protecting coastal ecosystems using new technologies in Azerbaijan, Kazakhstan, and Turkmenistan.

Co-funded by the Erasmus+ Programme of the European Union



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Thank you

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