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New bench scale plant for biosorption

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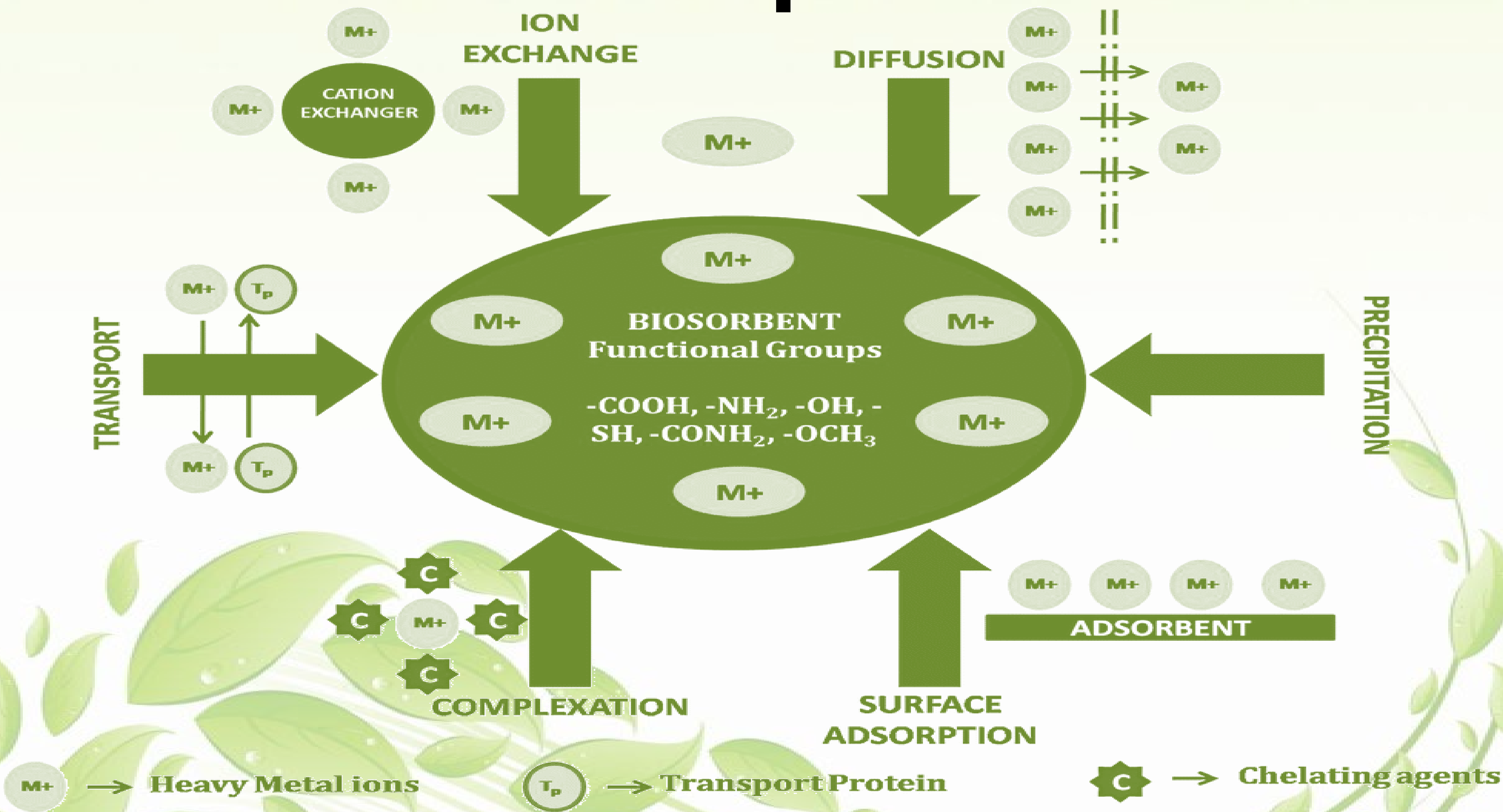
Biosorption



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Gaur, N., Flora, G., Yadav, M., & Tiwari, A. (2014). A review with recent advancements on bioremediation-based abolition of heavy metals. Environmental Science: Processes & Impacts, 16(2), 180-193.

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Biosorption – new trends

Biosorption process

Focus on: **sorbate removal**	Focus on: **biosorbent enrichment**	
Wastewater treatment **(11 993 papers)**	Biological feed supplements with micronutrients **(30 papers)**	Micronutrients fertilizer components **(29 papers)**

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Webofknowledge.com –keywoerds biosorption and wastewater, biosorption and feed supplements,biosorption and fertilizer

Potential biosorbents

BIOSORBENTS

Plants

- Leaves
- Seeds

Fungi

- Micromycetes
- Macromycetes

Algae

- Microalgae
- Macroalgae

Animal

- Bones
- Eggshells

Microbes

- Bacteria
- Archea

Waste

- Manure
- Agricultural waste

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Chojnacka, K. (2010) Biosorption and bioaccumulation–the prospects for practical applications. Environment International, 36(3), 299-307

Micronutrient fertilizer additives

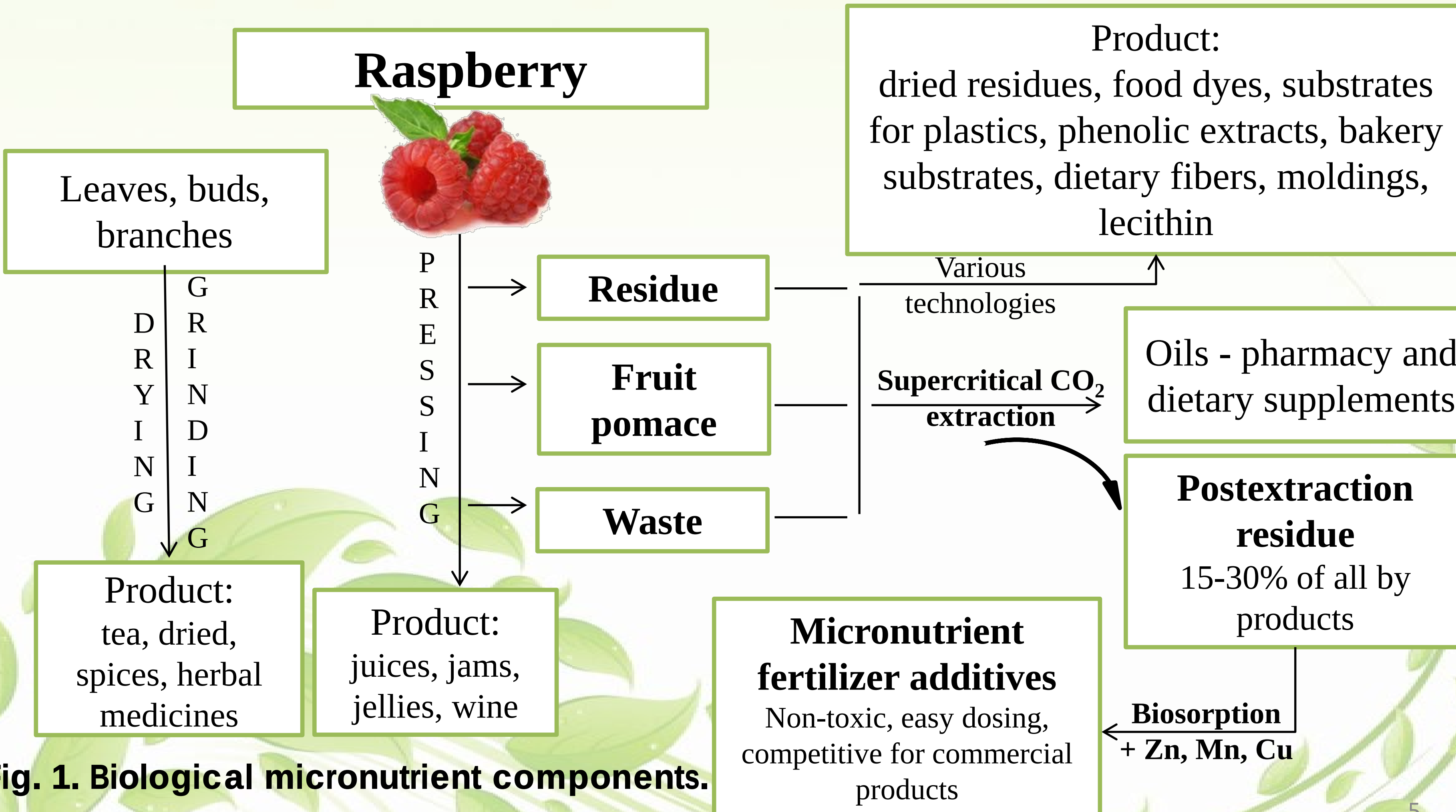
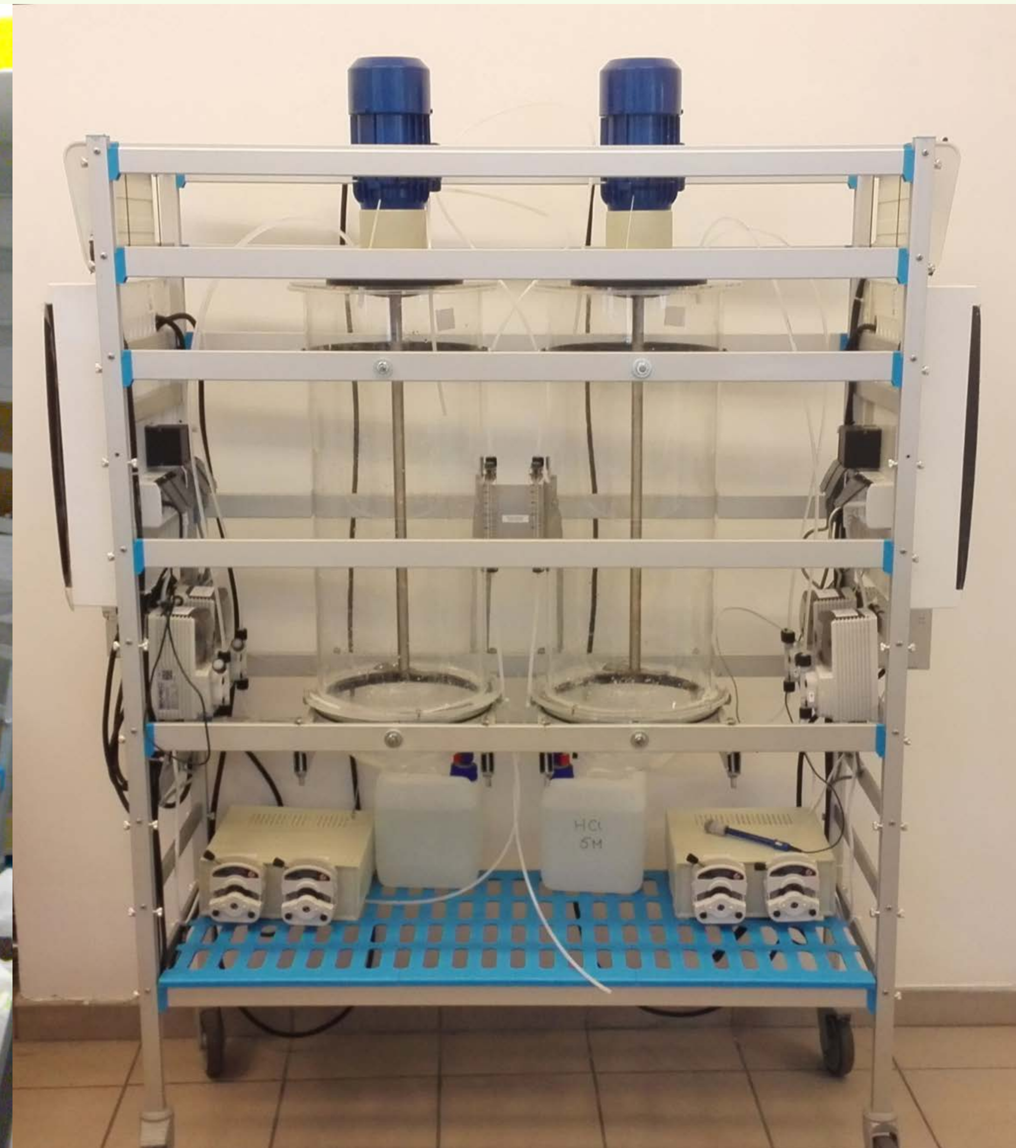


Fig. 1. Biological micronutrient components.

Chojnacka, K., Tuhy, Ł., Samoraj, M., Michalak, I., Witek-Krowiak, A. & Górecki, H. (2014) New Biological Fertilizer Components with Micronutrients by Biosorption, Fertilizer Technology: Synthesis, vol. 2, pp 376-409

Installation



Installation – stirred tank mode

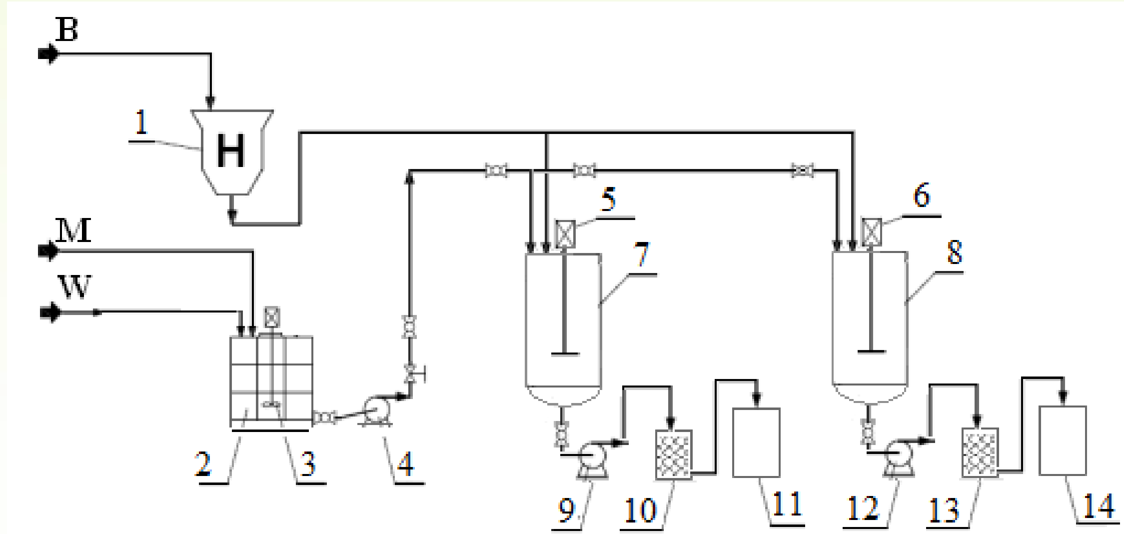


Fig. 3. Simplified scheme of the process in stirred tank mode – a system of two stirred tank reactors.

Streams:
B – Biomass,
M – Micronutrients,
W- Deionized water.

Equipment: 1 – Biomass homogenizer; 2 – Micronutrient solution tank; 3, 5, 6 – Stirrers; 4, 9, 12 – Peristaltic pumps; 7, 8 - Stirred tank reactors tank (equipped with pH regulator); 10, 13 – Biomass sedimentators; 11, 14 – Post-process tanks.

Installation – fixed bed mode

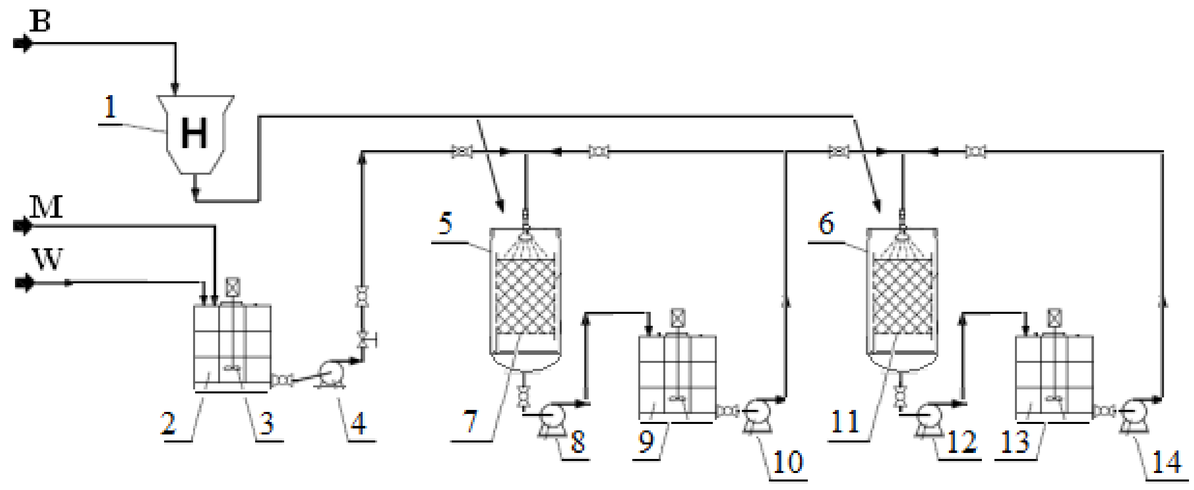


Fig. 4. Simplified scheme of the process in fixed bed mode – a system of two column reactors.

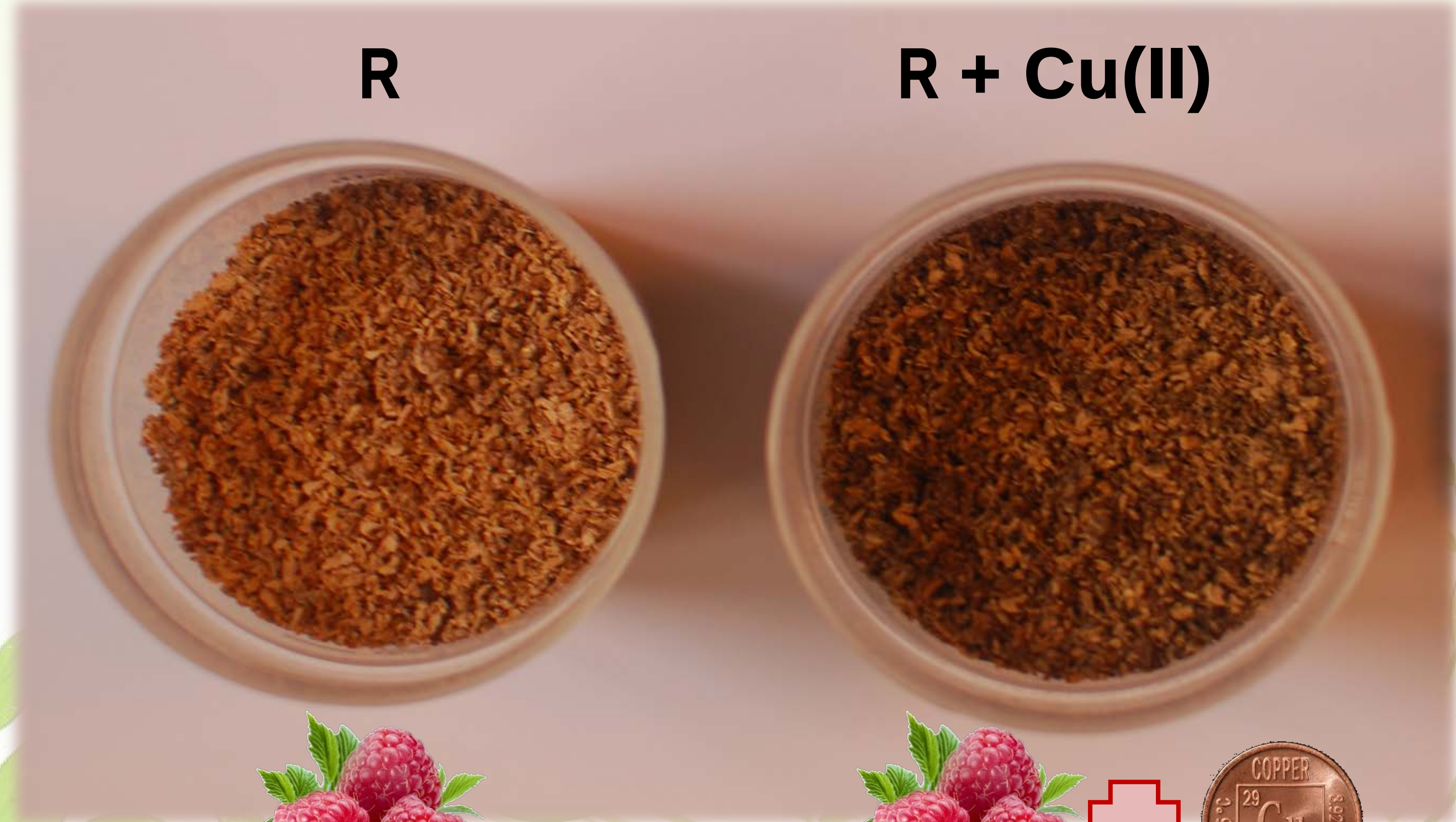
Streams: B – Biomass, M – Micronutrients, W- Deionized water.

Equipment: 1 – Biomass homogenizer; 2 – Micronutrient solution tank; 3 – Stirrer; 4, 8, 10, 12, 14 – Peristaltic pumps; 5, 6 - Reactor tanks; 7, 11 – Sieve; 9, 13 – Recirculated solution tanks (equipped with pH regulator).

Process parameters

Mode	Stirred tank	Fixed bed
Sorbate	**Cu(II) ($CuSO_4 \cdot 5H_2O$)**	
Sorbate concentration	**300 mg/L**	
Reactor volume	**70L**	
Solution volume	**50L**	**200L**
pH	**5**	
Temperature	**25^{o}C**	
Material losses	**10%**	
Volumetric flow rate	**-**	**1L/min**
Process time	**2.5h**	**6h**
Drying	**24 h, 50^{o}C**	

Final product



Results

Daily productivity

- 300–400 g at stirred tank mode
- 10–16 kg at fixed bed mode

Material loses

- 10% in both cases

Estimated 100 kg production costs

- 419$ at stirred tank mode
- 48.1$ at fixed bed mode

Multielemental content of product

Element (mg/kg)		R - natural	R + Cu – stirred tank mode	R + Cu – fixed bed mode
Micronutrients	Cu	**8.96±1.79**	**12611±2522 EC=1407**	**12808±2562 EC=1429**
	Zn	34.6±6.9	171±34	58.2±11.6
	Mn	75.9±15.2	14±3	13.3±2.660
	Fe	122±24	184±37	77±15.4
	Mo	6.54±1.31	4.41±0.88	0.247±0.049
Macronutrients	P	1551±310	797±159	1839±368
	K	2767±553	156±31 **(-94.4%)**	140±28 **(-94.9%)**
	S	1407±281	1370±274 **(-2.63%)**	925±185 **(-34.3%)**
	Ca	2502±500	585±117 **(-76.6%)**	188±38 **(-92.5%)**
	Mg	1802±360	170±34 **(-90.6%)**	209±42 **(-88.4%)**
	Na	472±94	630±126	72.8±14.6
Toxic elemenrs	Cd **(5)***	0.83±0.17	0.532±0.106	<0.03
	Ni **(60)***	<0.03	<0.03	<0.03
	As **(50)***	<0.3	<0.3	10.2±2.0
	Pb **(140)***	<0.5	19±4	7.99±1.60
	Cr **(100)***	0.117±0.023	0.616±0.123	0.655±0.131

** Act of fertilizer and fertilization, 18 June 2008, approved by Polish Ministry of Agriculture and Rural Development.*

Stirred tank mode modelling

Model	Equation	Linear form	Parameters	R^2
Pseudo-1st order	$\frac{dq_t}{dt} = k_1(q_{eq1} - q_t)$	$\ln(q_{eq} - q_t) = \ln(q_{eq1}) - k_1 \cdot t$	k_1=0.0235 (1/min) q_{eq1}=12.7 (mg/g) **$q_{ICP-OES}$=12.6 (mg/g)**	0.997
Pseudo-2nd order	$\frac{dq_t}{dt} = k_2(q_{eq2} - q_t)^2$	$\frac{t}{q_t} = \frac{1}{k_2 \cdot q_{eq2}^2} + \frac{1}{q_{eq2}} \cdot t$	k_2=0.00426 (g/mg·min) q_{eq2}=15.3 (mg/g)	0.913

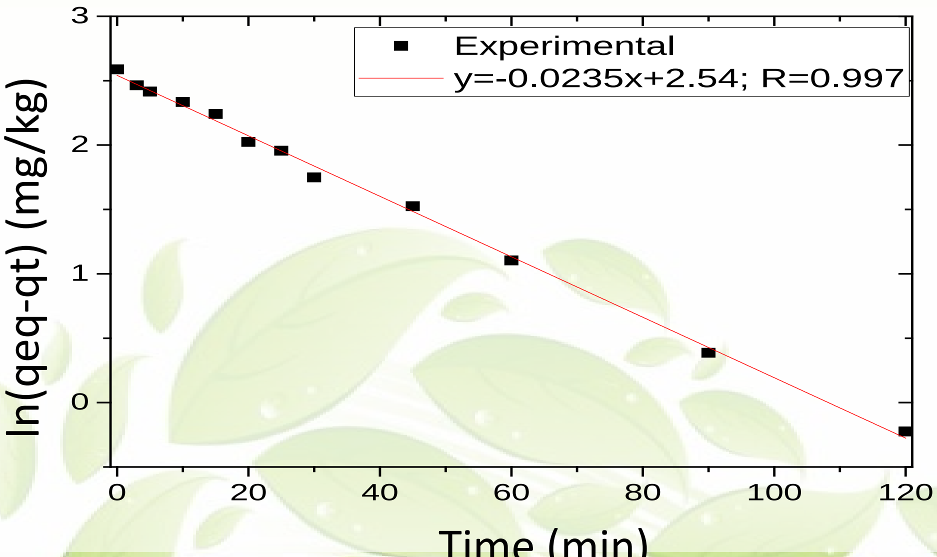


Fig.5. Pseudo-1st order model linear plot.

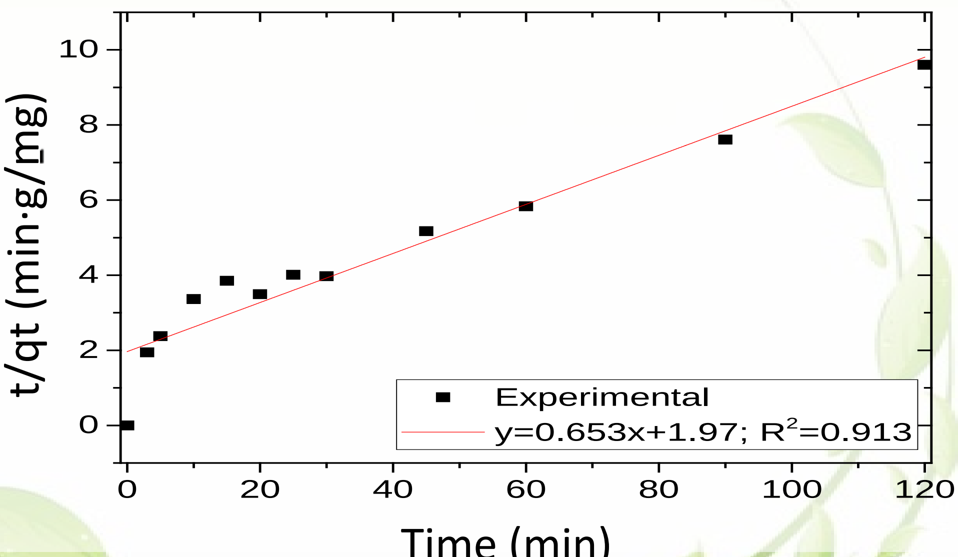


Fig. 6. Pseudo-2nd order model linear plot.

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Ho, Y. S., & McKay, G. (1998) Kinetic models for the sorption of dye from aqueous solution by wood. Process Safety and Environmental Protection, 76(2), 183-191.

Fixed bed mode modelling

Model	Equation	Linear form	Parameters	R^2
Yoon-Nelson	$\frac{C_t}{C_0-C_t} = \exp(k_{YN}t - \tau k_{YN})$	$ln\frac{C_t}{C_0-C_t} = k_{YN}t - \tau k_{YN}$	τ=105 (min) k_{YN}= 0.0078 (1/min)	0.996
Thomas	$\frac{C_t}{C_0} = \frac{1}{1+\exp\left[\left(\frac{k_{Th}q_{ex}}{Q}\right)-k_{Th}C_0t\right]}$	$ln\left(\frac{C_0}{C_t}-1\right) = \frac{k_{Th}q_{ex}}{Q} - k_{Th}C_0t$	k_{Th}= 0.0260 (mL/min mg) q_{eq}= 13.5 (mg/g) **$q_{ICP-OES}$=12.8(mg/g)**	0.996
Walborska	$\partial\frac{\partial c_b}{\partial t} + v\frac{\partial c_b}{\partial H} + \frac{\partial q}{\partial t} = D_{ax}\frac{\partial^2 c_b}{\partial H^2}$	$ln\left(\frac{c}{c_0}\right) = \frac{\beta_a c_0 t}{q} - \frac{\beta_a H}{v}$	β_a= 0.181 (1/min) q= 17.5 (mg/g)	0.935
Adams-Bohart	$\frac{C_t}{C_0} = \exp\left(k_{AB}C_0t - k_{AB}N_0\frac{z}{U_0}\right)$	$ln\left(\frac{C_t}{C_0}\right) = k_{AB}C_0 - k_{AB}N_0\frac{z}{U_0}$	N_0 = 17500 (mg/L) k_{AB} = 0.0103 (mL/min mg)	0.935

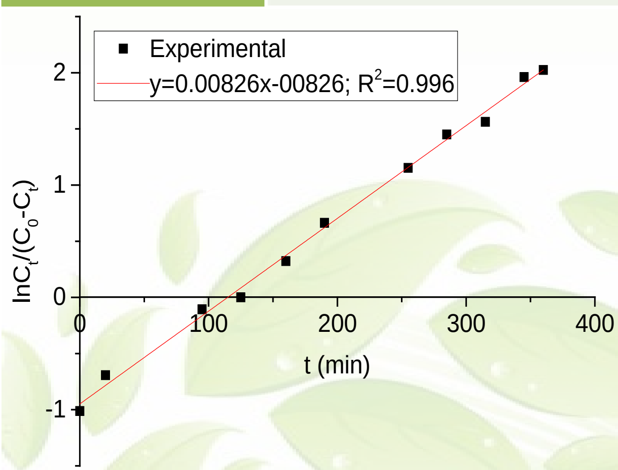

Fig. 7. Yoon-Nelson model linear plot vs. experimental data.

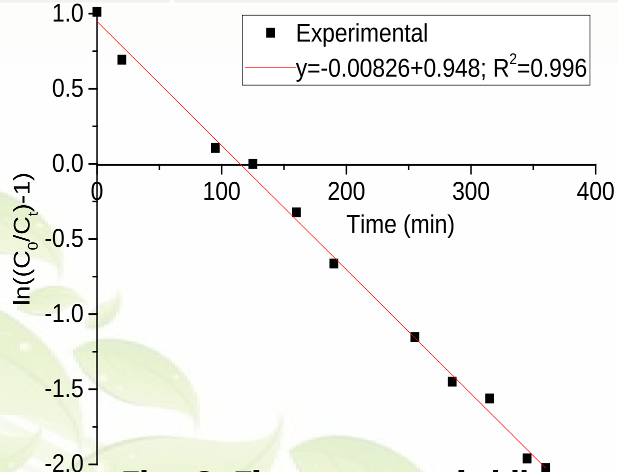

Fig. 8. Thomas model linear plot vs. experimental data.

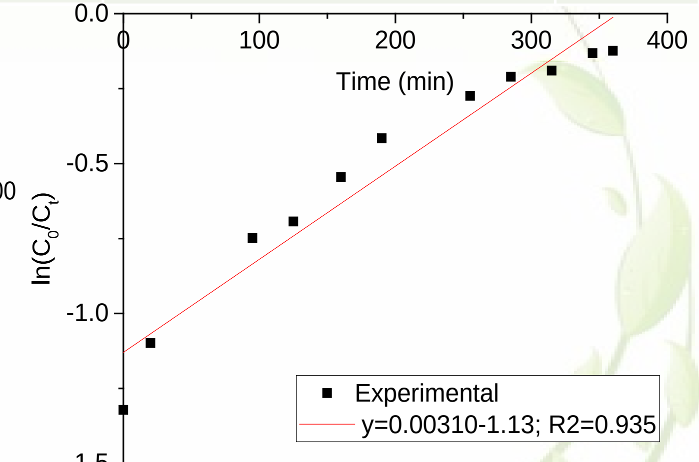

Fig. 9. Adams-Bohard, Walborska model linear plot.

Saadi, Z., Saadi, R., & Fazaeli, R. (2013) Fixed-bed adsorption dynamics of Pb (II) adsorption from aqueous solution using nanostructured γ-alumina. Journal of Nanostructure in Chemistry, 3(1), 48

Conclusions

- New bench scale installation for biosorption and comparison of two possible process mode was presented with kinetics description
- New eco-friendly micronutrient fertilizer additives with copper based on raspberry seeds were produced and multielemental content was determined after sample mineralization
- The material losses in the process were about 10% for fixed bed and stirred tank reactors
- The cost of the utilization of berries seeds to micronutrient fertilizer components in fixed bed mode was much lower (48.1 $/100 kg) than in stirred tank mode (419 $/100 kg)
- New installation is an efficient tool in biosorption studies and enables investigation of parameter influence in a wide range

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Perspectives

Selection of the process parameters
(and minor modifications of installation)

Vegetation tests of new product
(TF determination and comparison with commercial products)

Scale up to pilot plant scale
(transfer proven solutions)

UNIVERSITY of LIFE SCIENCES in Lublin

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Thank you for your attention!

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