Yeast-based magnetic bionanocomposite for the removal of Zn(II) in aqueous medium

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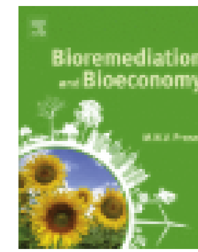
An important field!!!

Bioremediation and Bioeconomy
2016, Pages 569-588



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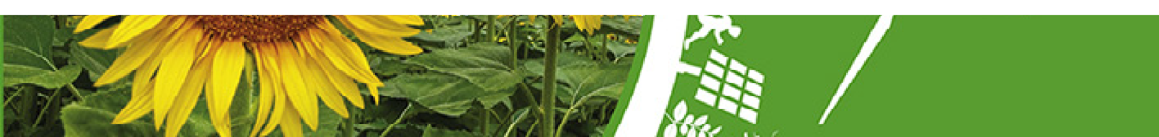

Biosorption by yeast-based material

CHEMICAL ENGINEERING COMMUNICATIONS
https://doi.org/10.1080/00986445.2019.1615468

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Synthesis, characterization, and application of yeast-based magnetic bionanocomposite for the removal of Cu(II) from water

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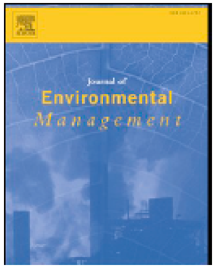

Research article

A comparison study of cleanup techniques for oil spill treatment using magnetic nanomaterials

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Seattle Times, 2012)

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US mining sites dump 50 million gallons of fouled wastewater daily

By Matthew Brown Published 2:24 pm PST, Wednesday, February 20, 2019

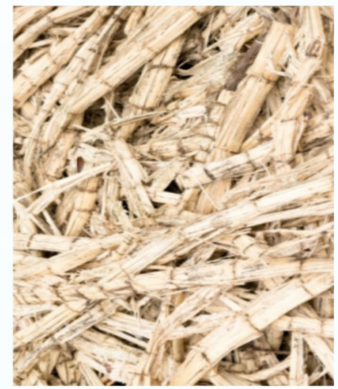
Photo: Matthew Brown / Associated Press 2018

The quality of water resources

- impact caused by human activities

Biosorption

Adsorption using biological waste – Biomass



Advantages

- **Favorable economic value**
- **High capacity for the removal of contaminants**
- **Renewable resources**

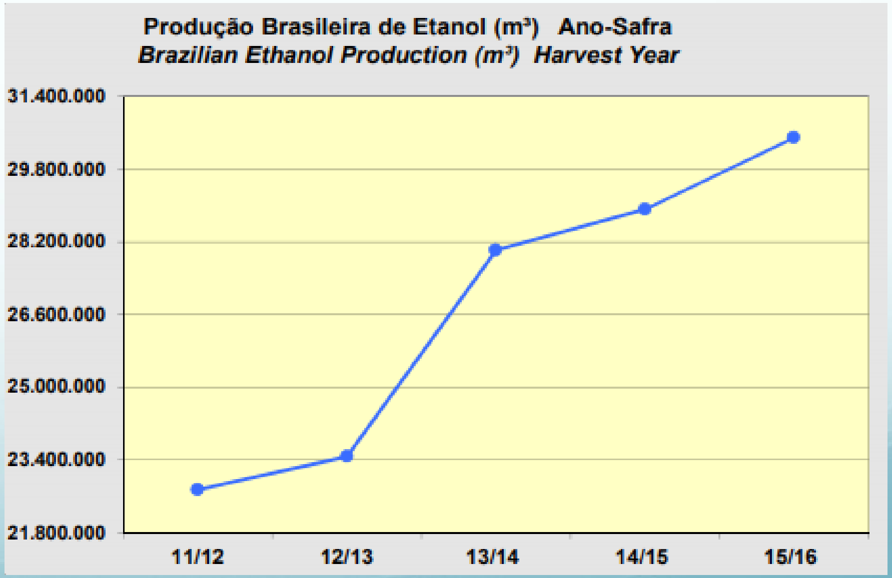
Yeast biomass

- Rich in sorption sites (carboxylic, phosphates, hydroxyls groups) for accumulation of contaminants;

- Widely used in fermentative process.

30 g for each L of alcohol

900,000 ton/year!!!



Source: Brazil, MAPA, 2017.

Ferromagnetic Nanoparticles (Fe_3O_4)

- Superparamagnetics properties:
  - Smaller size;
  - Greater interaction;
  - Magnetized particles throughout the struture with the same intensity.

- It can improve the adsorption capacity of biomass (hydroxyls groups);

- It facilitates the removal from the medium.

Goals

This work proposes to:

- synthesize, characterize, and evaluate a nanomodified yeast biosorbent for the sorption of Zn(II) in aqueous environments;

- to compare *in natura* biomass and synthesized magnetite composite to investigate the effect of magnetization in the efficiency of sorption.

Synthesis of ferromagnetic nanoparticles (coprecipitation method)

Synthesis of ferromagnetic nanoparticles (coprecipitation method)

$$Fe^{2+}_{(aq)} + 2\,Fe^{3+}_{(aq)} + 8\,OH^{-}_{(aq)} \xrightarrow{\text{30 min}} Fe_3O_{4(s)} + 4H_2O_{(l)}$$

$$Fe^{2+}_{(aq)} + 2\,Fe^{3+}_{(aq)} + 8\,OH^{-}_{(aq)} \rightarrow Fe_3O_{4(s)} + 4H_2O_{(l)}$$

Impregnation of nanoparticles to yeast biomass

Impregnation of nanoparticles to yeast biomass

$$Fe_3O_{4(s)} + YB_{(s)} \xrightarrow{\text{30 min; 80 °C}} YB\text{-}Fe_3O_{4(s)}$$

$$Fe_3O_{4(s)} + YB_{(s)} \rightarrow YB\text{-}Fe_3O_{4(s)}$$

Yeast biomass (YB)

+

Fe_3O_4 (MNP)

=

Composite (YB-MNP)

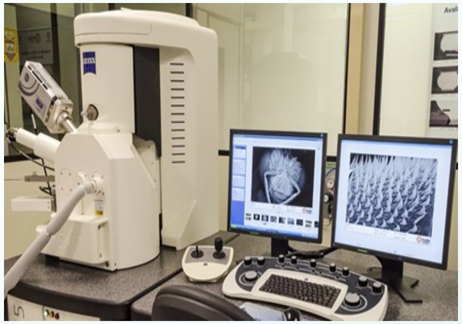
Characterization of adsorbents

- **X-Ray Diffraction (XRD)**

Identification of crystalline structures of the materials;

- **Scanning Electron Microscopy (SEM)**

It is possible to obtain external images showing the surface of the materials;

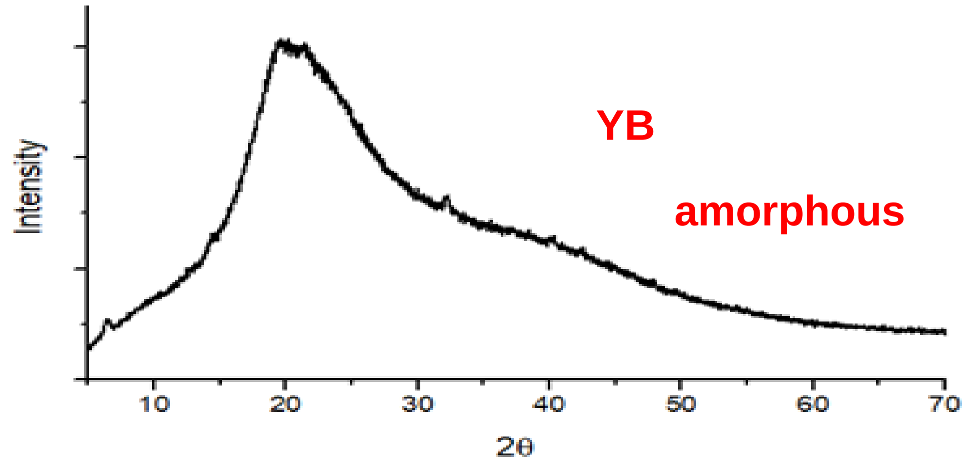


- **Fourier Transform Infrared Spectroscopy (FTIR)**

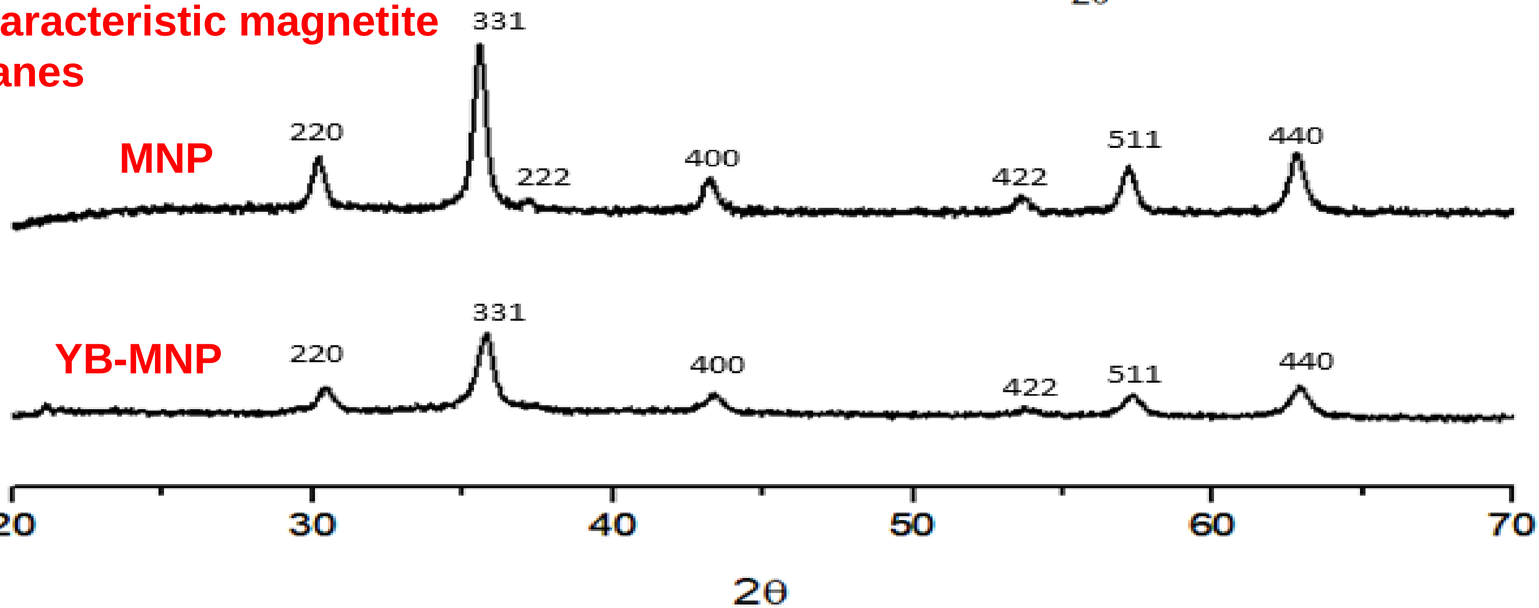
Detects the absorption in a characteristic region, identifying the functional groups in the materials.

X-Ray Diffraction (XRD)

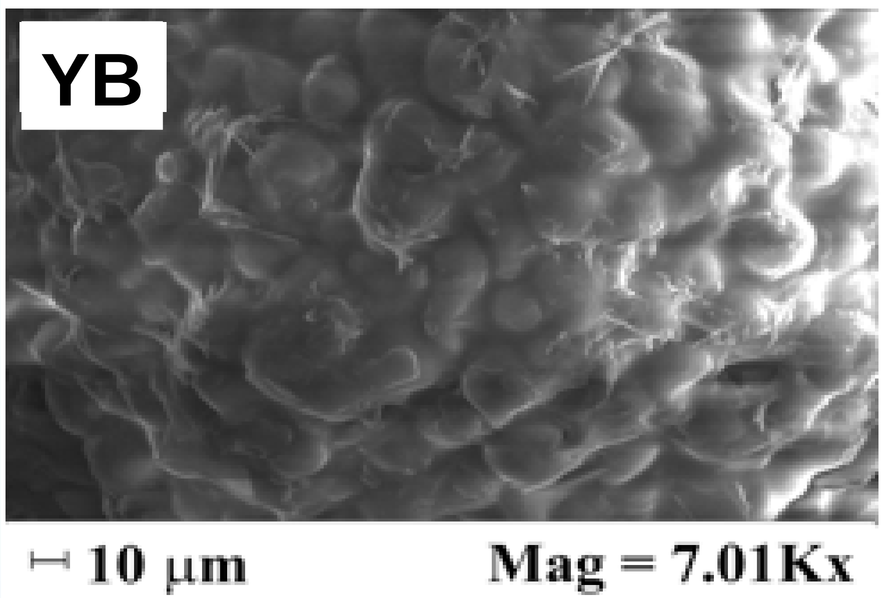
YB – yeast biomass
MNP – magnetic nanoparticles
YB-MNP – magnetic composite

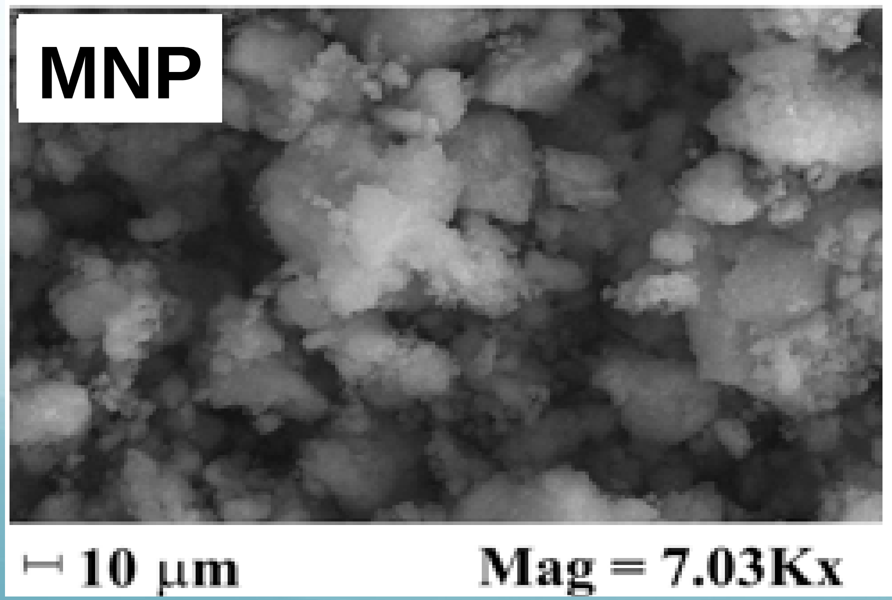


Peaks attributed to characteristic magnetite planes



Scanning Electron Microscopy (SEM)

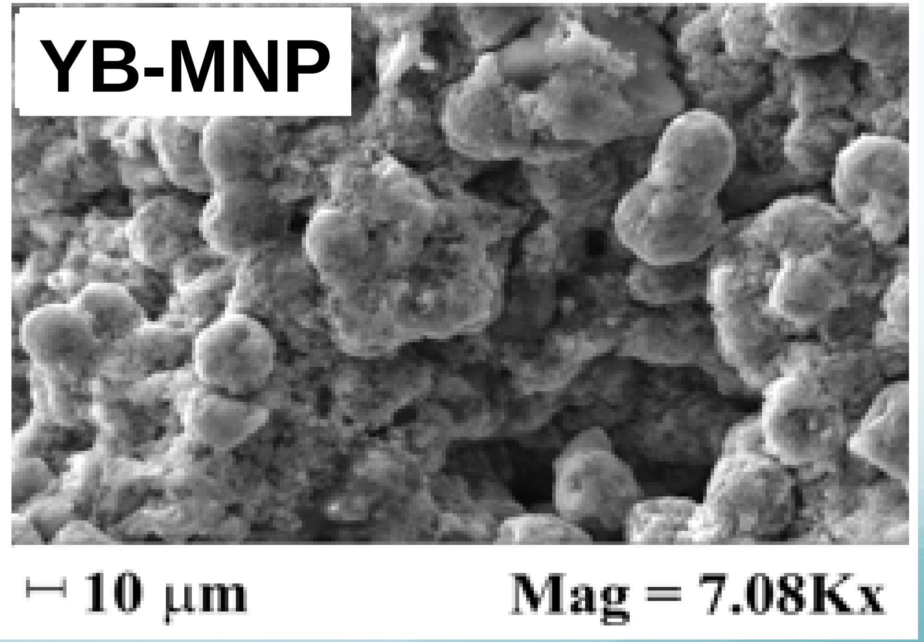




YB – yeast biomass

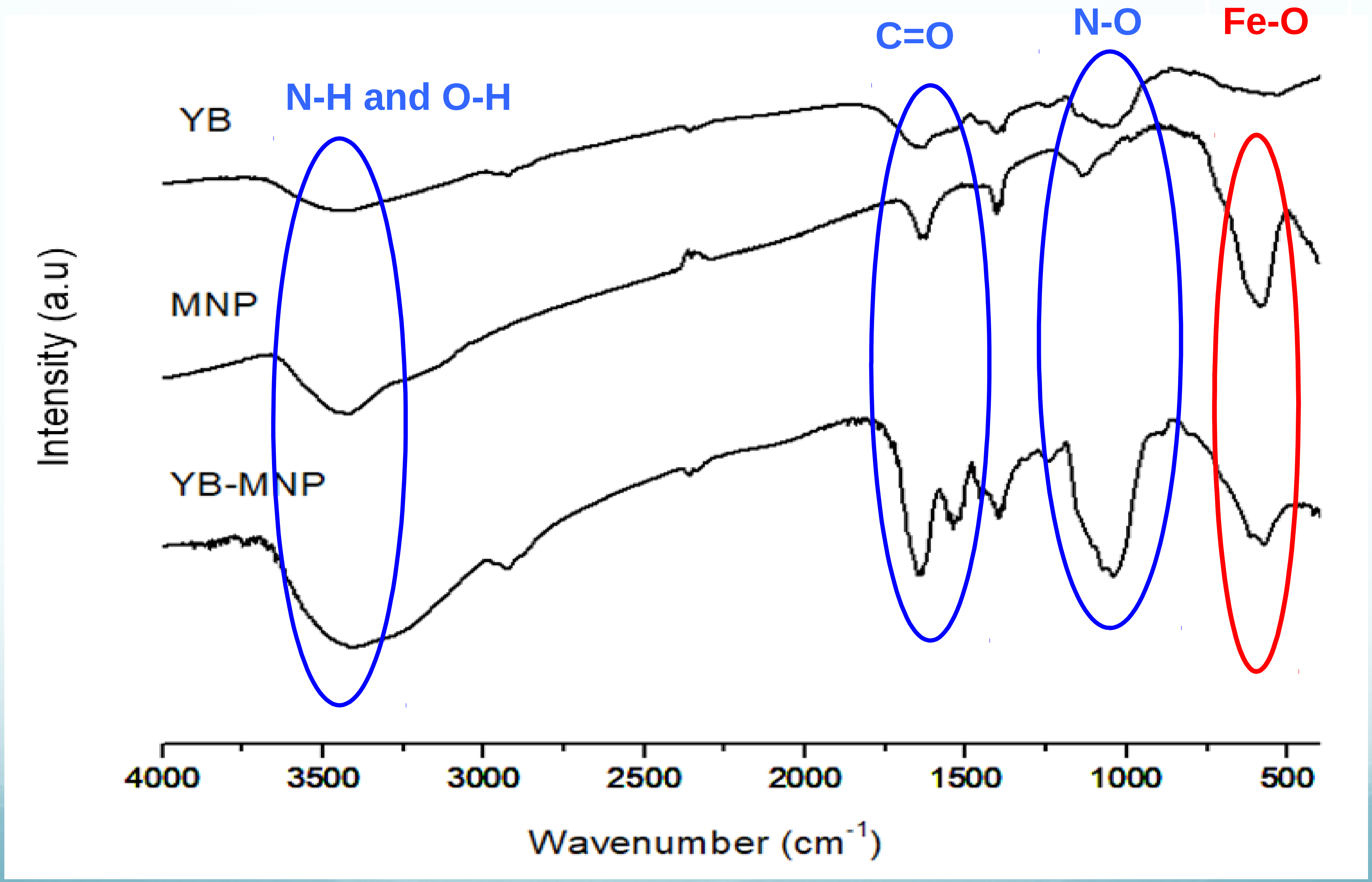
MNP – magnetic nanoparticles

YB-MNP – magnetic composite



Source: Debs et al., 2019.

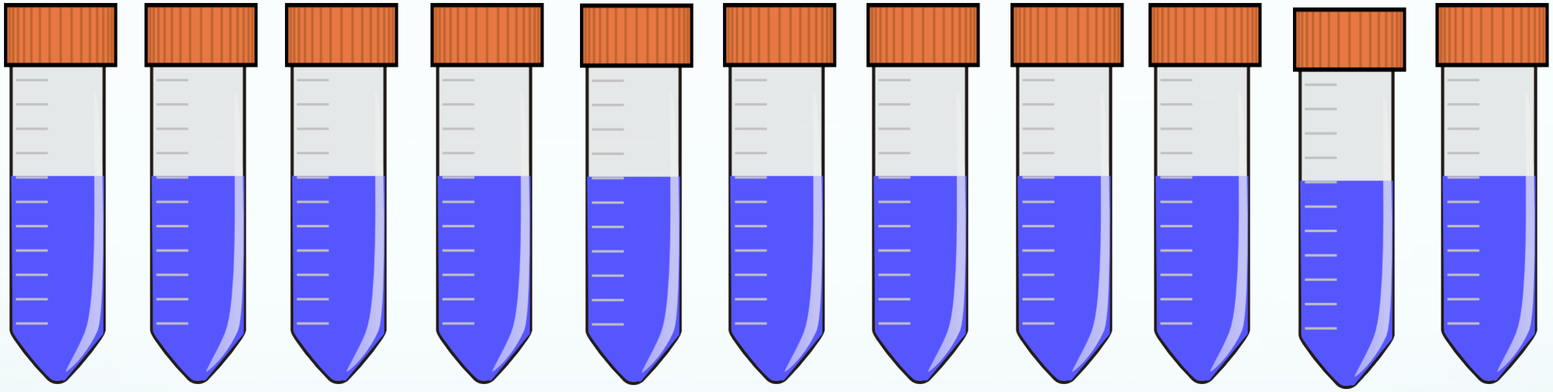
Fourier Transform Infrared Spectroscopy (FTIR)



Point of zero charge (pH_{PZC})

10 mg of YB or YB-MNP + 10 mL of NaCl 0.1 mol/L

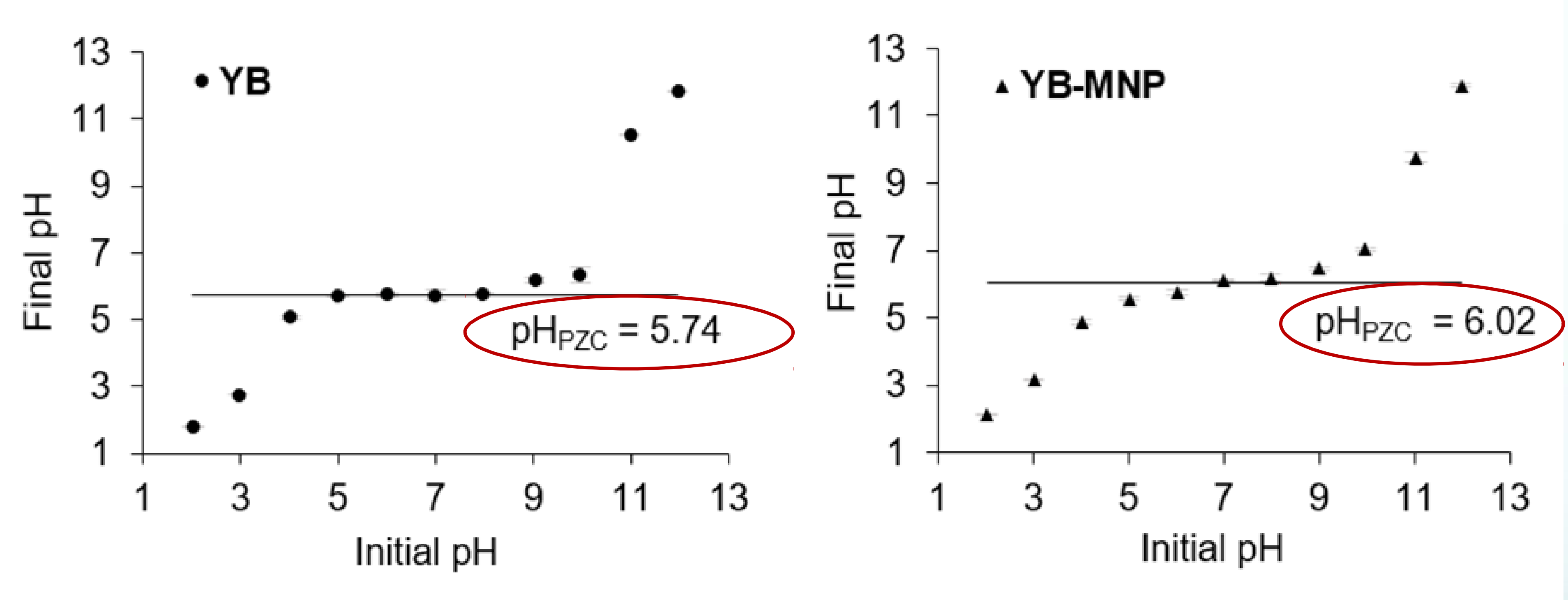
Stirring at 185 rpm for 24 h



pH 2 3 4 5 6 7 8 9 10 11 12

Initial pH *vs* final pH

Point of zero charge (pH_{PZC})

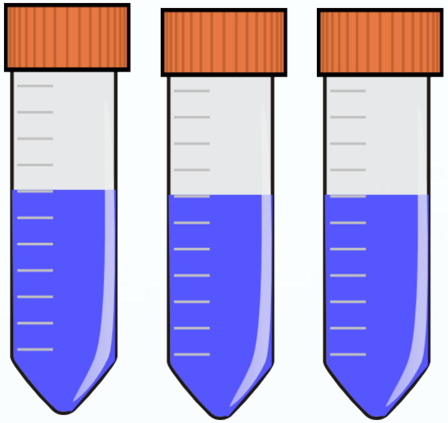


- ✓ **Negative charges on the surface of the biosorbent (above pH_{PCZ})**
- ✓ **Favors the adsorption of Zn(II)**
- ✓ **Best adsorption is expected at pH higher than pH_{PCZ}.**

pH assessment

500 mg of YB or YB-MNP

10 mL of 100 mg/L Zn(II)



pH 5.5 6.0 6.5

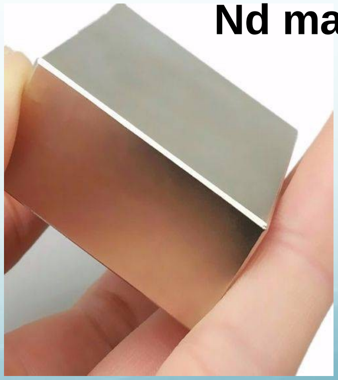
Stirring at 185 rpm for 10 min

Zn determination by Flame Atomic Absorption Spectrometry

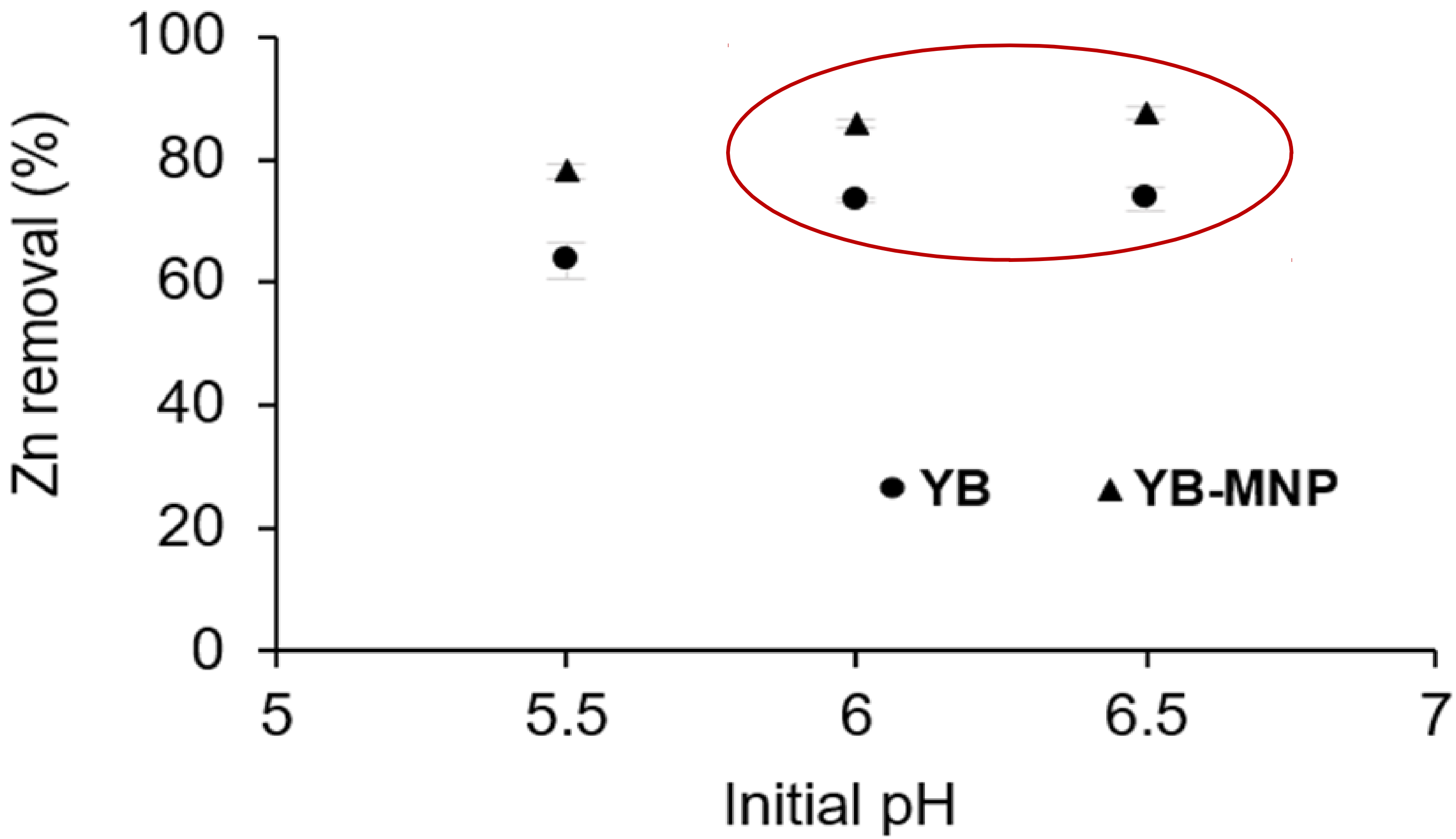
YB

YB-MNP

Nd magnet



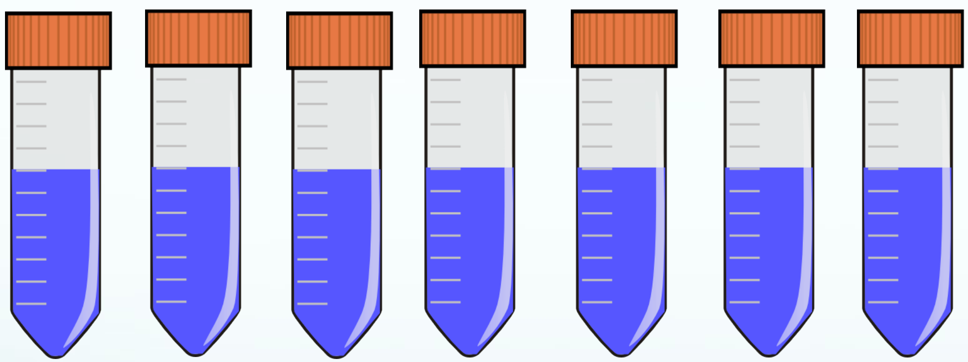
pH assessment



Kinetics studies

200 mg of YB or YB-MNP **10 mL of 100 mg/L Zn(II)**

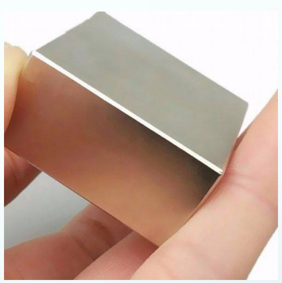
Stirring at 185 rpm at pH 6.0



t, min **5** **10** **30** **60** **90** **120** **150**

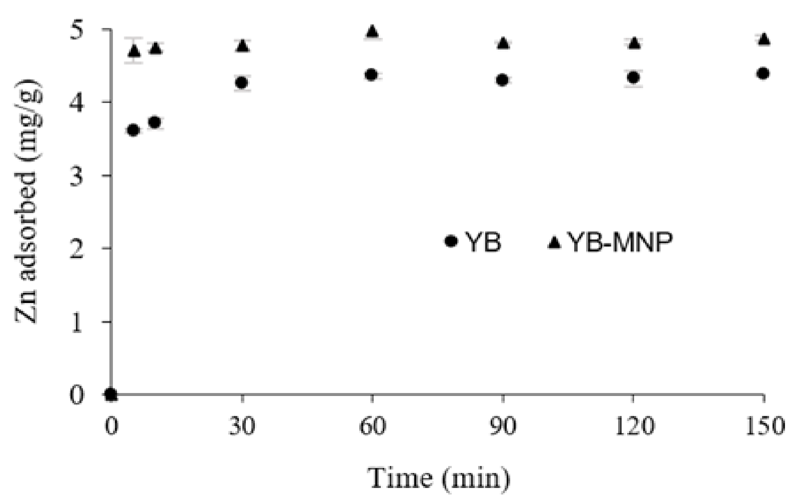
YB → **centrifugation**

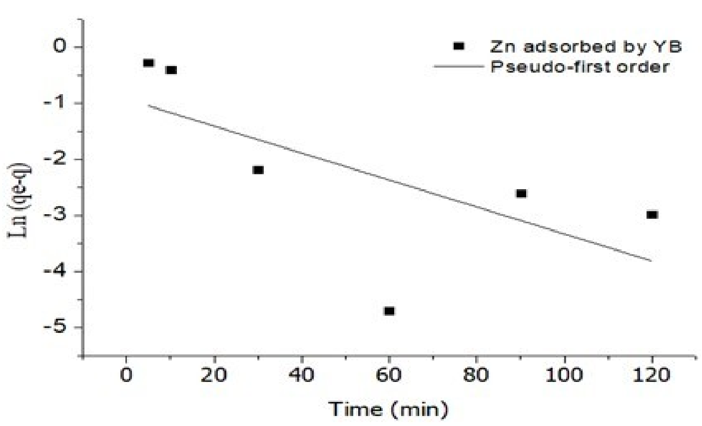
YB-MNP → **Nd magnet**

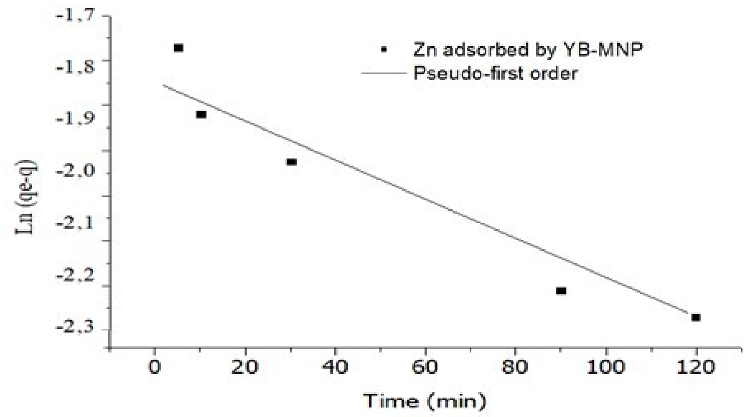


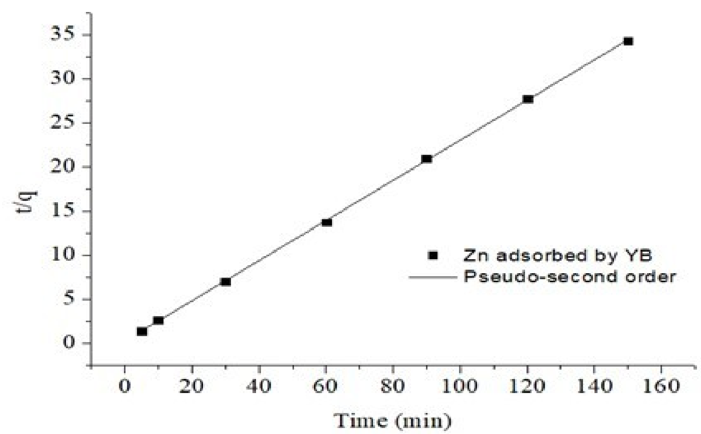
Zn determination by FAAS

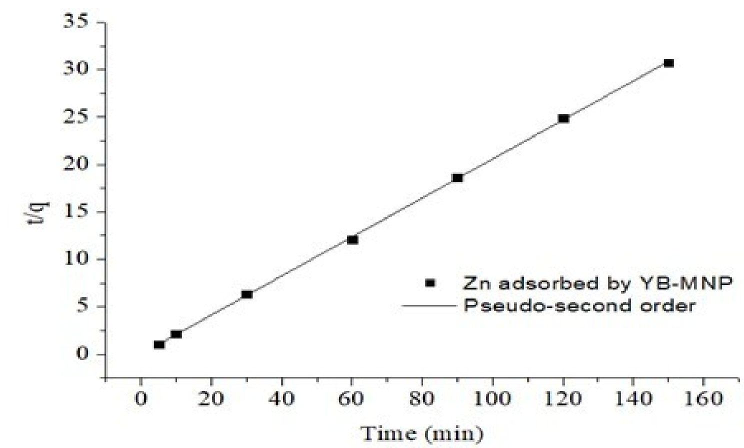
Kinetic studies











Kinect studies

	YB		YB-MNP	
Parameters	Pseudo 1st order	Pseudo 2nd order	Pseudo 1st order	Pseudo 2nd order
Qe	0.3967	4.3917	0.1743	4.8641
χ^2	1.9650	0.0270	0.0225	0.0306
r^2	0.2969	0.9998	0.6526	0.9997
K_1 or K_2*	0.0240	0.1788	0.0175	1.2268

* K_1, pseudo-first order; K_2, pseudo-second order.

Q_{exp} YB = 4.26

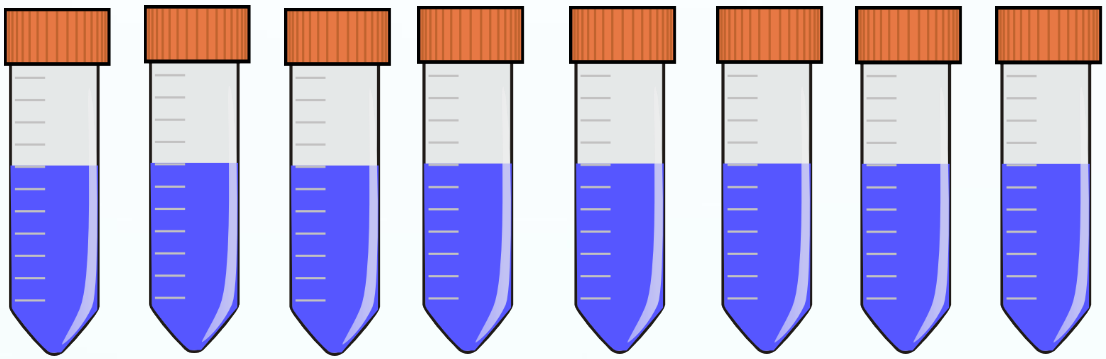
YB-MNP = 4.70

Chemical nature!!!

Sorption capacity tests

200 mg of YB, MNP or YB-MNP **10 mL of Zn(II) solutions**

Stirring at 185 rpm; pH 6.0; 5 and 30 min



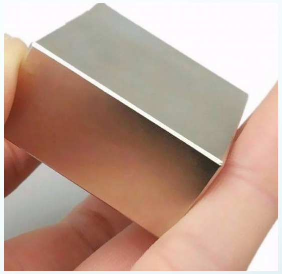
mg Zn/L 25 50 75 100 125 150 175 200

YB

centrifugation

YB-MNP

Nd magnet

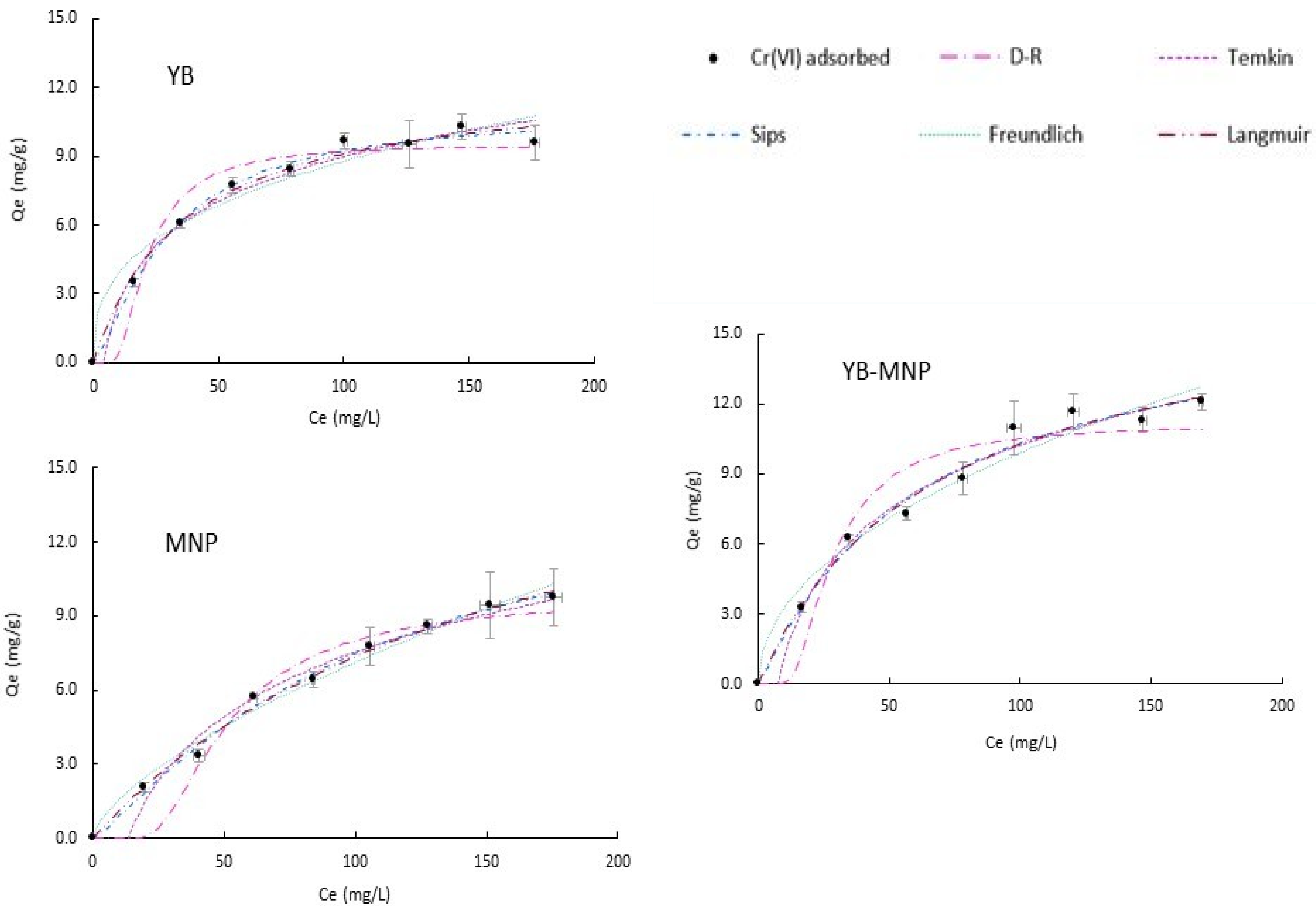


Zn determination by FAAS

Non-linear isotherm models employed to fit Zn(II) adsorption by YB, MNP, and YB-MNP.

Model	Non-linear equation
Langmuir	$q_e = \frac{Q_{max} bC}{1 + bC}$
Freundlich	$q_e = bC^n$
Temkin	$q_e = \frac{RT}{B} \ln (K_T C)$
Dubinin-Radushkevich (D-R)	$q_e = Q_{max} \exp (-B\mathcal{E}^2)$
SIPS	$q_e = \frac{Q_{max}(bC)^n}{1 + (bC)^n}$

Foo and Hammed, 2010; Saadi et al., 2015; Ayawei et al., 2017.


YB
YB-MNP
MNP
Cr(VI) adsorbed
D-R
Temkin
Sips
Freundlich
Langmuir
Qe (mg/g)
Ce (mg/L)
15.0
12.0
9.0
6.0
3.0
0.0
0
50
100
150
200

	YB	MNP	YB-MNP
SC_{exp} (mg/g)	10.31 ± 0.54 (SD)	9.76 ± 1.15 (SD)	12.08 ± 0.36 (SD)
Langmuir Isotherm Model			
Q_{max} (mg/g)	12.41 ± 0.52 (SE)	19.26 ± 1.74 (SE)	17.03 ± 1.24 (SE)
b (L/mg)	0.027 ± 3.9 × 10^{-3} (SE)	6.2 × 10^{-3} ± 9.6 × 10^{-4} (SE)	0.015 ± 2.7 × 10^{-4} (SE)
r^2	0.9874	0.99299	0.98339
χ^2	0.15119	0.08276	0.29107
Freundlich Isotherm Model			
K_f (L/mg)	1.71 ± 0.43 (SE)	0.35 ± 0.83 (SE)	1.09 ± 0.28 (SE)
n_f	2.81 ± 0.43 (SE)	1.52 ± 0.12 (SE)	2.08 ± 0.24 (SE)
r^2	0.95439	0.98428	0.96809
χ^2	0.54715	0.18555	0.55931
D-R Isotherm Model			
Q_{DR} (mg/g)	9.54 ± 0.34 (SE)	9.77 ± 0.62 (SE)	11.16 ± 0.66 (SE)
B_{DR} (mol^2/kJ)	5.88 × 10^{-5} ± 1.2 × 10^{-5} (SE)	3.26 × 10^{-4} ± 7.5 × 10^{-5} (SE)	9.89 × 10^{-5} ± 3.1 × 10^{-5} (SE)
E (kJ/mol)	92.21	39.16	71.10
r^2	0.95276	0.9294	0.90166
χ^2	0.56672	0.83335	1.72355
Sips Isotherm Model			
Q_{max} (mg/g)	10.95 ± 0.61 (SE)	15.03 ± 2.66 (SE)	16.06 ± 3.22 (SE)
K_s (L/mg)	0.034 ± 3.8 × 10^{-3} (SE)	9.88 × 10^{-3} ± 3.16 × 10^{-3} (SE)	0.017 ± 7.3 × 10^{-3} (SE)
n	1.36 ± 0.21 (SE)	1.20 ± 0.18 (SE)	1.08 ± 0.27 (SE)
r^2	0.99061	0.99321	0.98093
χ^2	0.11265	0.08012	0.33416
Temkin Isotherm Model			
b (J/mol)	33424 ± 2813 (SE)	24911 ± 1521 (SE)	23858 ± 1647 (SE)
K (L/mg)	0.25 ± 0.062 (SE)	0.074 ± 8.6 × 10^{-3} (SE)	0.14 ± 0.022 (SE)
T (K)	298.15	298.15	298.15
r^2	0.9791	0.98316	0.98203
χ^2	0.25076	0.19874	0.31502

Conclusions

- With characterization, it was possible to infer that, in fact, the impregnation of the nanoparticles to the yeast biomass occurred;
- The model that best fit the experimental data was Sips, considering that chemical and physical phenomena contribute to the sorption process;
- The magnetite, besides facilitating the removal of the biosorbent from the medium, increases the sorption capacity;
- Thus, it is perceived that the synthesized material is environmentally advantageous and functions as a good biosorbent for removal of Zn(II) in aqueous medium.

The biosorption group

ΕΥΧΑΡΙΣΤΩ

Thank you

Obrigada