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Title: Ion exchange of heavy metals using a modified zeolite filter integrated into a prototype autonomous water purifier (AWP) on a community scale

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1. Introduction

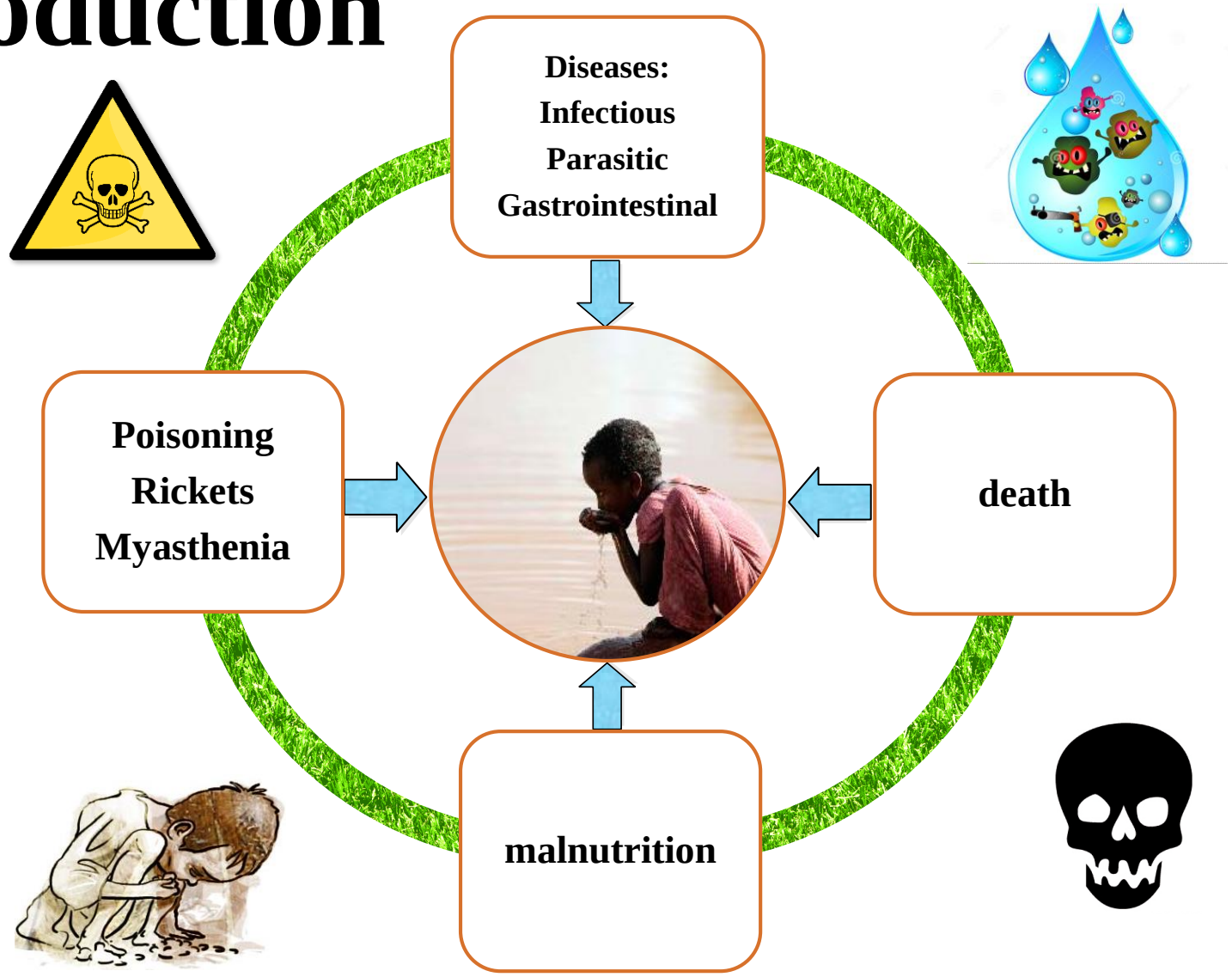


Figure 1.1 Main consequences of consumption of contaminated water.

Organización Mundial de la Salud (OMS)/UNICEF (2006).

2. Methodology

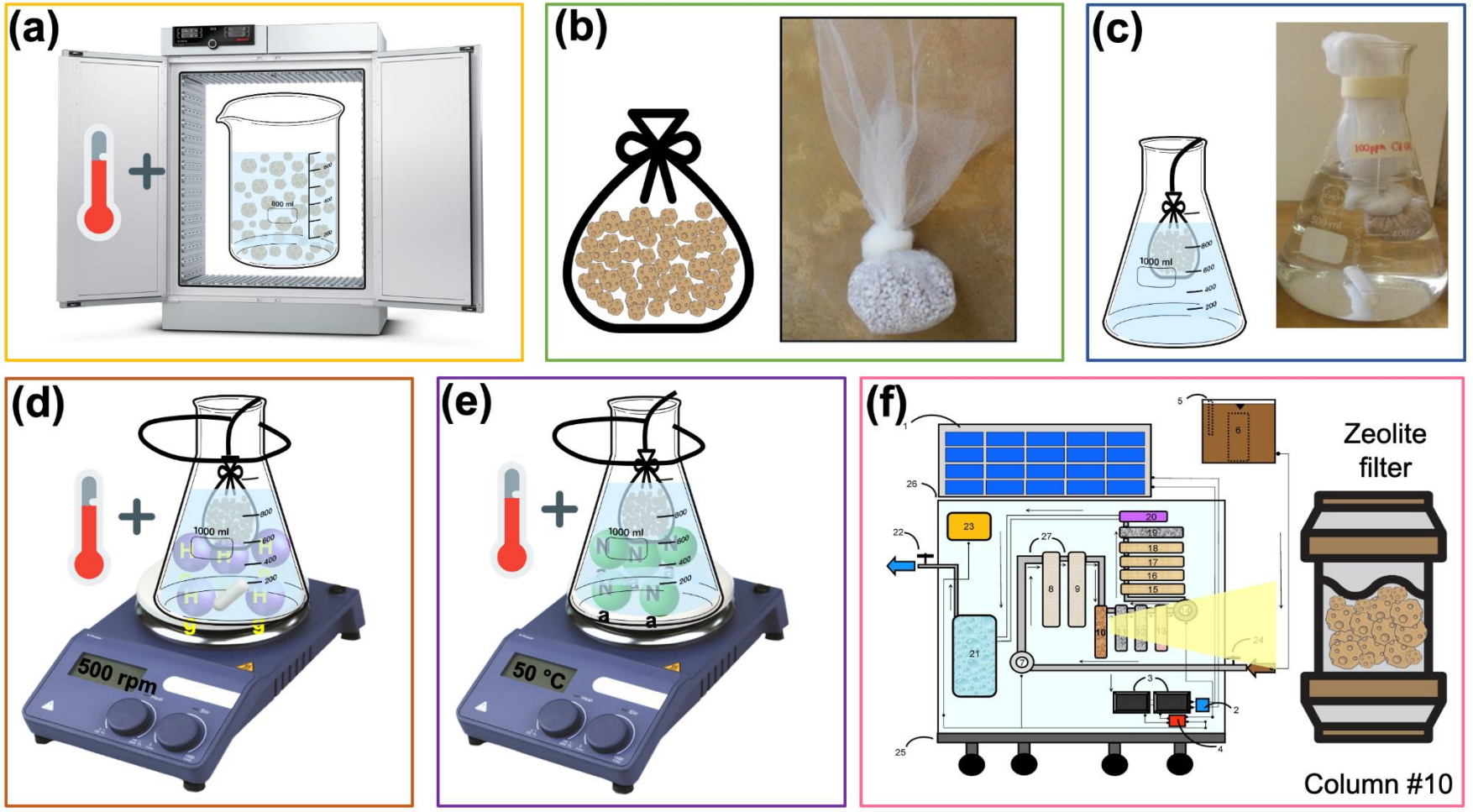
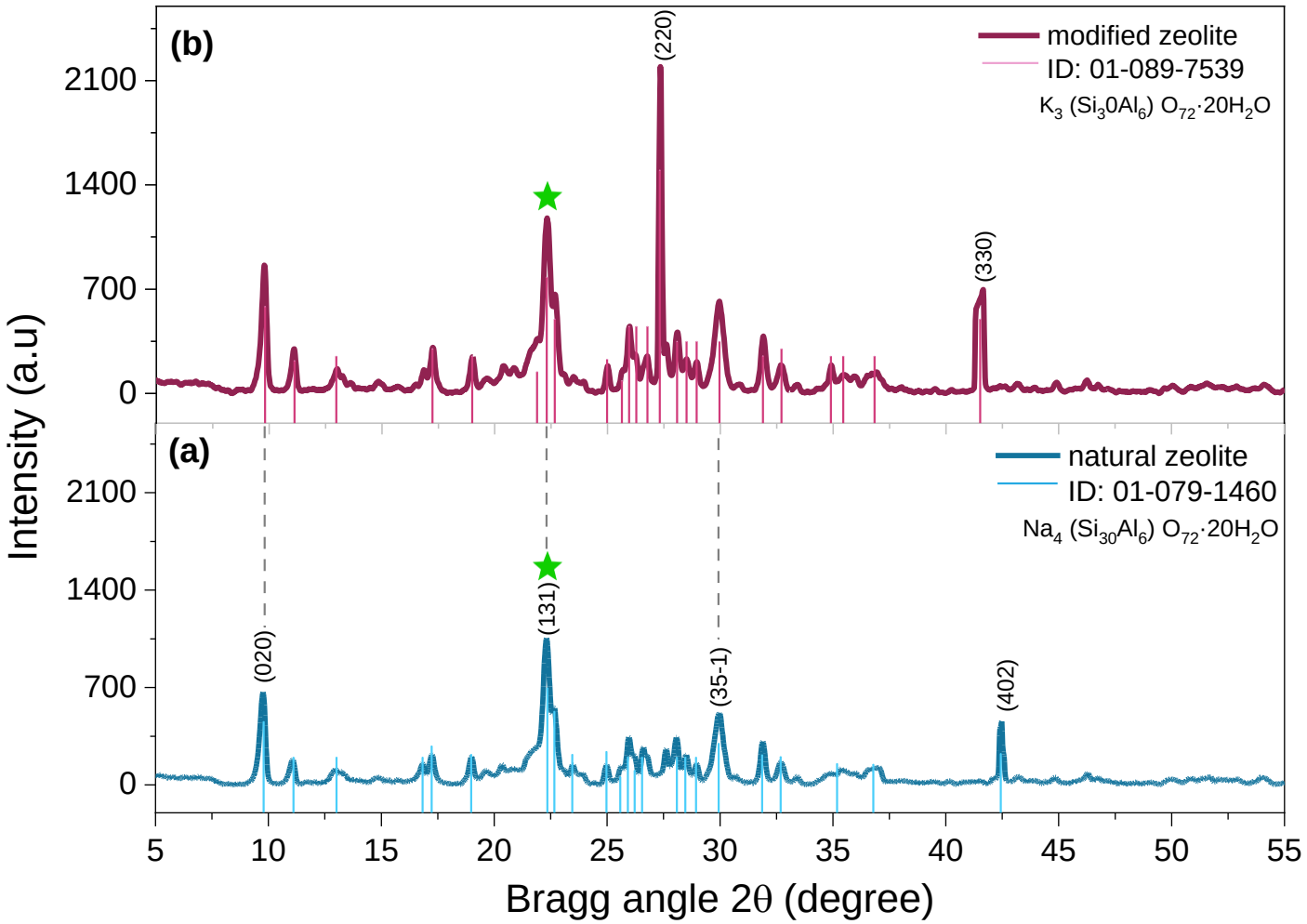


Figure 1.2 Scheme of the natural and modified zeolite adsorption and ion exchange methodology: a) conditioning of natural zeolite, b) preparation of exchangeable metal ion solutions, c) ion exchange isotherms, d) ion exchange kinetics, e) modification of the zeolite by cation exchange (effect of pH) and, f) validation of zeolite as a filter in the Autonomous Water Purifier (AWP) prototype.

3. Results

3.1 Structural analysis



Graph 1. X-ray diffractograms of (a) natural zeolite with the clinoptilolite-K pattern and (b) for modified zeolite with the clinoptilolite-Na pattern. *Source of consultation: Elaborated by authors in Software Origin*

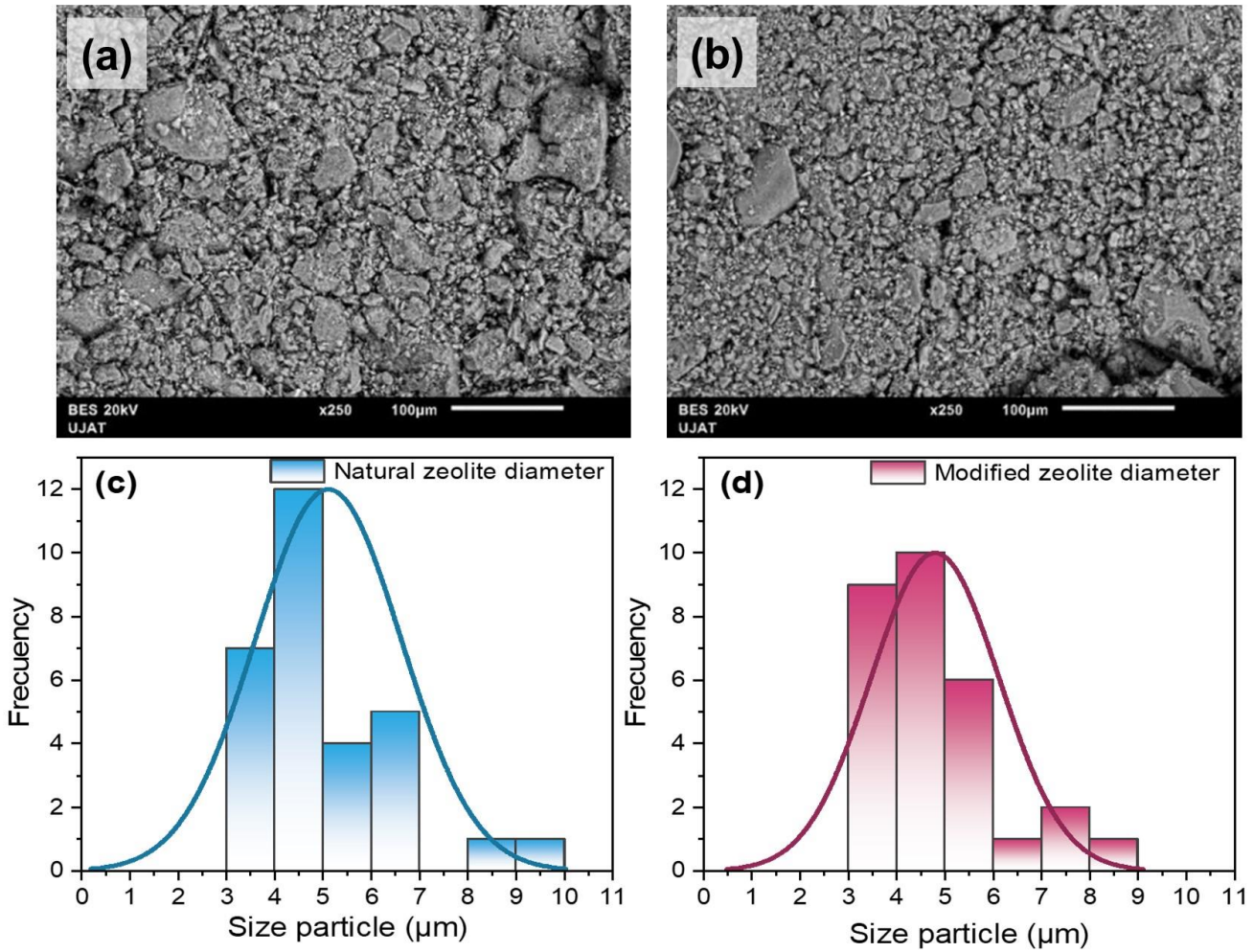
Debye-Scherrer equation:

$$D = \frac{K\lambda}{\beta\cos\theta}$$

Monocliny symmetry:

$$\frac{1}{d^2} = \frac{1}{\operatorname{sen}^2\beta}\left(\frac{h^2}{a^2} + \frac{k^2\operatorname{sen}^2\beta}{b^2} + \frac{l^2}{c^2} - \frac{2hl\cos\beta}{ac}\right)$$

3.2 Morphology analysis



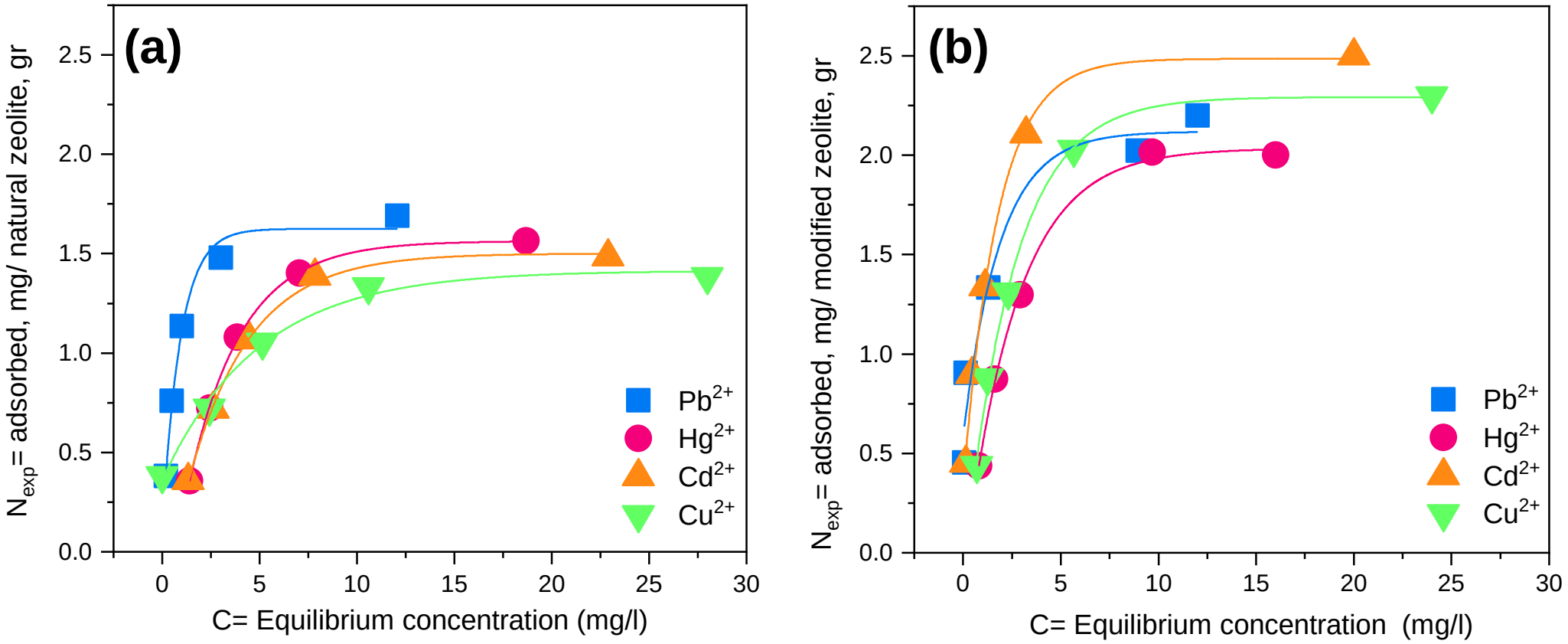
Graph 2. SEM images of samples of (a) natural zeolite and (b) modified zeolite; (c and d) particle size distribution of natural zeolite and modified zeolite respectively. *Source of consultation: Elaboration by authors in Software Origin; SEM images acquired from Jeol JSM-5300*

3.3 Chemical composition analysis

Table 1 Elemental composition of natural and modified zeolite, in percent by weight (wt%).

Zeolite samples	Molar ratio Si/Al	SiO_2 (%w)	Al_2O_3 (%w)	Na_2O (%w)	MgO (%w)	K_2O (%w)	CaO (%w)	Fe_2O_3 (%w)
Natural	4.63	68.877	14.862	1.840	0.990	7.806	3.384	2.237
Modified	4.30	64.668	15.026	10.970	0.798	5.402	0.365	2.767

3.4 Evaluation of heavy metals on zeolites



Graph 3 Ion exchange isotherm of Pb2+, Hg2+, Cd2+ and Cu2+ on (a) natural zeolite and (b) modified zeolite. *Source of consultation: Elaboration by authors in Software Origin; data obtained from the ICP-OES team.*

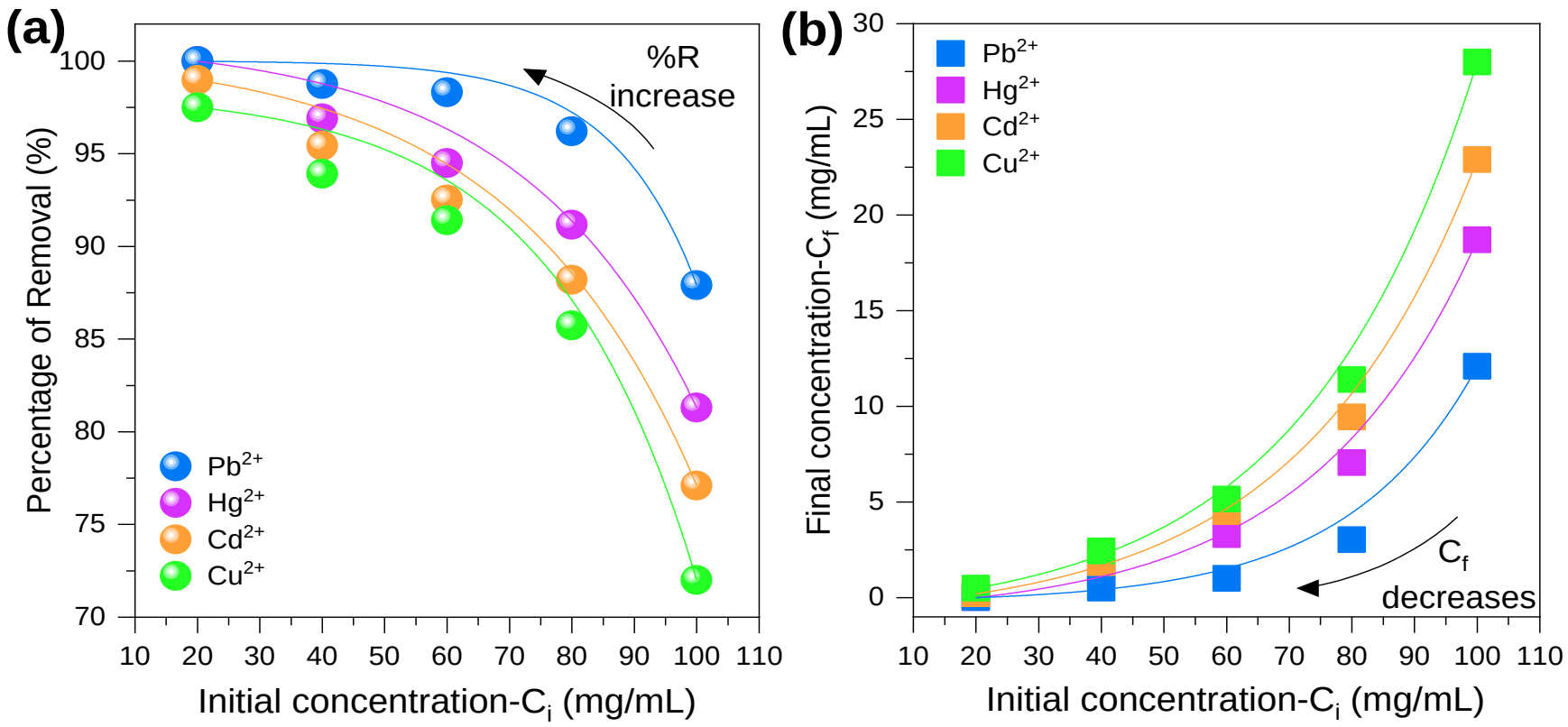
Table 2 Values of the Langmuir isotherm constant..

Ion	Zeolite	Langmuir		
		N_{max} (mg/gr)	K (L/mg)	%D
Pb^{2+}	Natural	1.785	1.523	3.33
Hg^{2+}		1.769	0.258	8.96
Cd^{2+}		1.753	0.276	10.73
Cu^{2+}		1.446	0.767	9.11
Cd^{2+}	Modified	2.610	1.259	11.20
Cu^{2+}		2.559	0.372	9.80
Pb^{2+}		2.349	2.242	27.81
Hg^{2+}		2.227	1.789	8.54

Table 3 Mass balance of adsorbed and exchanged ions during ion exchange.

Initial concentration (mg/l)	Zeolite	Ions adsorbed on the zeolite (mg)				Ions exchanged in zeolite (mg)			
		Pb^{+2}	Hg^{+2}	Cd^{+2}	Cu^{+2}	Pb^{+2}	Hg^{+2}	Cd^{+2}	Cu^{+2}
100	Natural	31.5	25.3	24.4	21.5	46.4	45.9	45.5	37.5
100	Modified	35.3	31.8	39.3	37.8	51.6	48.4	57.4	56.2

3.4.1 Application of zeolite filter in the Autonomous Water Purifier prototype (AWP)



Graph 4 (a) Percentage of removal (circles) and (b) final concentration (squares) of Pb2+, Hg2+, Cd2+ and Cu2+ in the zeolite ion exchange column as a function of the initial concentration. Source of consultation: Elaboration by authors in Software Origin; data obtained from the ICP-OES team.

5. Conclusions

1. Using the XRD technique, the clinoptilolite-K type crystalline phase was identified for the natural resin and clinoptilolite-Na for the modified resin with a crystal size range of 32.7 to 39.1 nm.

2. The SEM technique made it possible to compare the morphology of the resin samples using microstructural micrographs. Irregular particle shapes and distributions are observed for natural resin, compared to the modified one, which has regular particle shapes and distribution.

3. From the XRF technique it was possible to know the chemical composition and the ion exchange capacity that is a function of the Si/Al ratio. The decrease in this ratio is observed in the modified resin with respect to the natural resin, showing that the modified resin has a better ion exchange capacity.

4. The recorded data represented by the Langmuir isotherm of ion exchange on the minerals revealed that the metal ions Hg^{2+} and Cu^{2+} were exchanged very slightly. On the other hand, the metal ions of Pb^{2+} and Cd^{2+} were exchanged on the resins in greater quantity than the other ions.

5. This project contributes to providing solutions to improve the quality of life and health of society.

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