Zeolite – Ammonium interaction: physical-chemistry of adsorption process

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Zeolites are crystalline microporous tectosilicates, either natural or synthetic. Natural zeolites were formed as a result of the interaction of volcanic rocks and volcanic ash with alkaline groundwater. Due to the formation process, there are more than 50 types of natural zeolites, the most common being clinoptilolite, which belongs to the heulandite family and has the simplified ideal formula of $(Na,K,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36}{\cdot}12(H_2O)$. Geological settings and conditions during zeolite formation and geological weathering influence several parameters such as mineralogy, rock porosity/permeability and reaction rate, all of which affect their operational capabilities, hence their use in technical applications. Indeed, zeolites, due to their properties, can be used in several operations, including gas separation, adsorption, ion exchange and catalysis. In recent years, they have been playing an important role in the recovery and removal of nutrients from treated wastewater due to their ion exchange property. Their ability to adsorb cations (such as ammonium ions) comes from the substitution of Si^{4+} by Al^{3+}, which increases the negative charge of the mineral lattice. The resulting negative charge is balanced by exchangeable cations such as Na^+, K^+ and Ca^{2+}. The recovery of nutrients (nitrogen and phosphorus) from wastewater is necessary, as their presence in wastewater accelerates the eutrophication of receiving water bodies, creating a potentially toxic environment for fish and other aquatic life. In addition, nutrient recovery from wastewater allows solving problems i.e. the poor access to fertilizers in developing countries and the looming high cost of fertilizers; in fact, the recovered fraction of nutrients can be reused as fertilizer in agriculture promoting a circular economy approach. Furthermore, the use of natural adsorbent materials, such as zeolites, to recover nutrients from wastewater overcomes the problem associated with existing technologies. Which are often expensive and difficult to apply, limiting their use in economically poor countries due to lack of infrastructure and maintenance costs. However, the removal of ammonium by ion exchange on zeolites is influenced by the origin of the zeolites used. Previous studies on clinoptilolites with different lithological matrix have shown how the ability to adsorb NH_4^+ varies in clinoptilolites of different origin. For example, a Canadian clinoptilolite was capable of adsorbing about 20 mg NH_4^+ g^{-1}, while a Chinese clinoptilolite did not exceed 5 mg NH_4^+ g^{-1}. The original matrix may also have an influence on the treatment when natural zeolites are treated to increase the adsorption capacity. Based on the above considerations, the objectives of the PhD project, carried out within the Wider Uptake project (Horizon2020 EU project), are: i) to compare the ammonium adsorption rate on two clinoptilolites of different origin (Slovakia and Cuba), ii) to evaluate the effect that the matrix had on the treatment carried out to improve the adsorption capacity