PHOSPHATE REMOVAL FROM AQUEOUS SOLUTIONS USING MXENE MATERIAL

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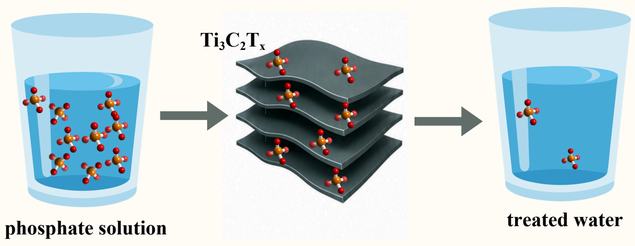
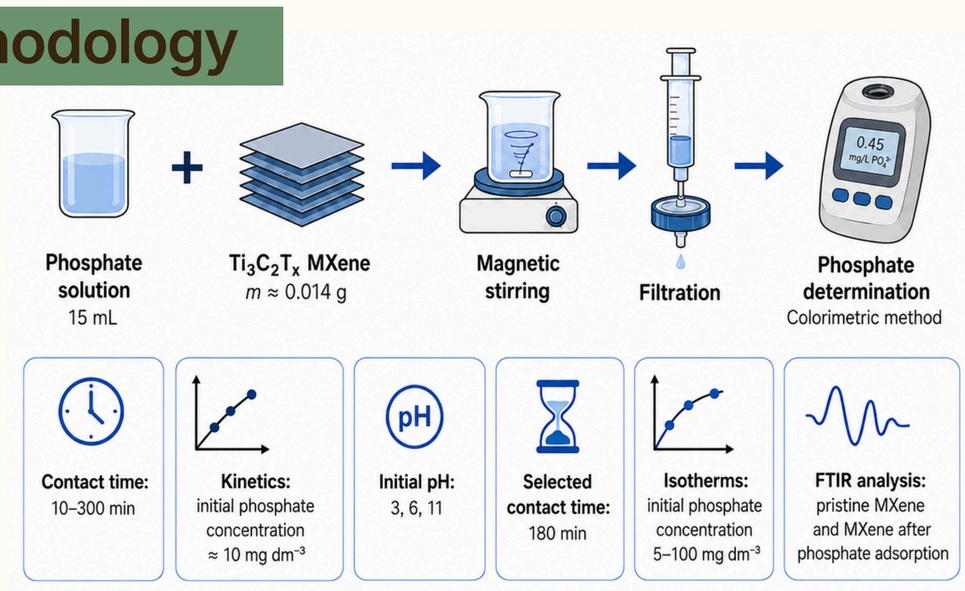
Introduction

MXenes are two-dimensional transition-metal carbides, nitrides and carbonitrides with a layered structure, hydrophilicity and tunable surface chemistry. $Ti_3C_2T_x$ is one of the most extensively studied MXenes, contains surface terminations such as –O, –OH and –F that may participate in interactions with dissolved ions. Phosphate enrichment in aquatic systems contributes to eutrophication and water quality deterioration, creating a need for efficient phosphate removal technologies.

The aim of this work was to evaluate the potential of commercial multilayer $Ti_3C_2T_x$ MXene for phosphate removal from aqueous solutions.



Methodology



Results and discussion

Effect of contact time

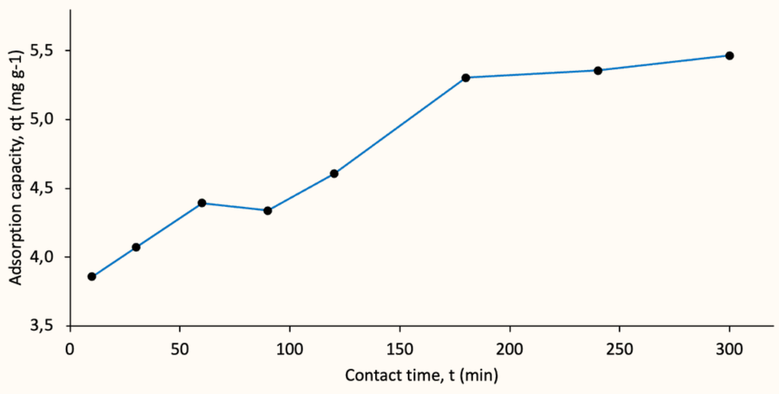


Figure 1. Effect of contact time on phosphate adsorption onto $Ti_3C_2T_x$ MXene.

Phosphate uptake was rapid during the first 60 min and increased only slightly after 180 min. Adsorption capacity reached 5.30 mg g^{-1} at 180 min and 5.46 mg g^{-1} at 300 min.

→ 180 min was selected as the practical contact time

Adsorption kinetics

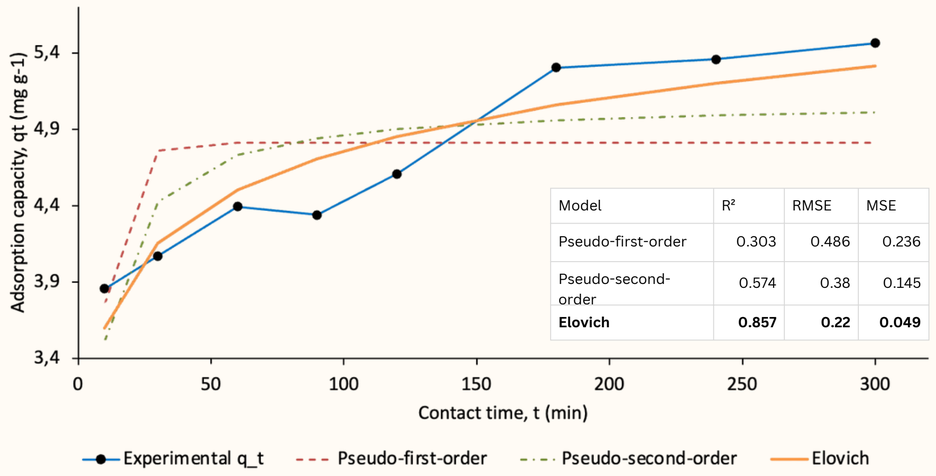


Figure 2. Kinetic modelling of phosphate adsorption onto $Ti_3C_2T_x$ MXene.

Among the tested models, the Elovich model showed the best fit (R^2=0.857; RMSE = 0.220), following the gradual slowdown of phosphate uptake.

→ Elovich best described the adsorption kinetics

Effect of pH

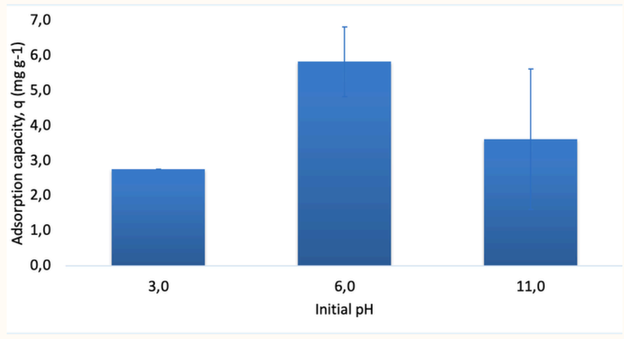


Figure 3. Effect of initial pH on phosphate adsorption capacity of $Ti_3C_2T_x$ MXene.

Phosphate adsorption was highest at pH 6, reaching 5.83 mg g^{-1} and 54% removal. Lower adsorption was observed at pH 3 and 11.

→ pH 6 was the most favorable tested condition

Effect of Initial Phosphate Concentration and Isotherms

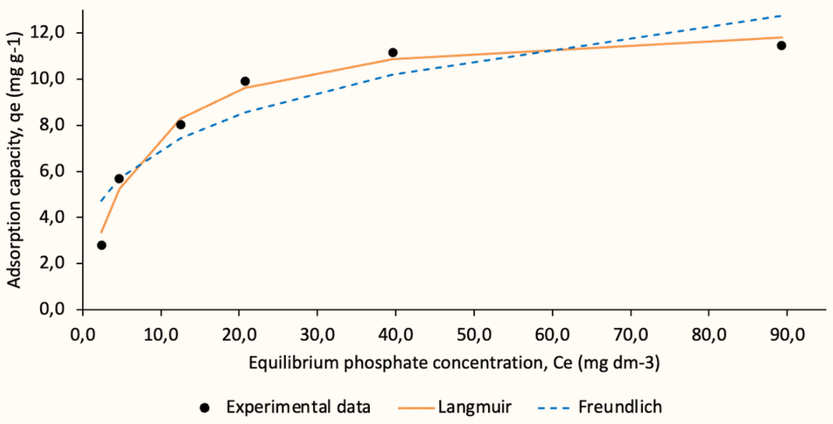


Figure 4. Experimental adsorption isotherm data fitted with Langmuir and Freundlich models for phosphate adsorption onto $Ti_3C_2T_x$ MXene.

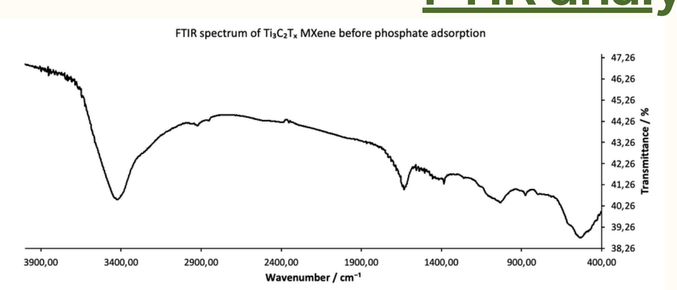
Freundlich		Langmuir	
R2	0.853	***R2***	0.985
RMSE	1.193	***RMSE***	0.379
MSE	1.424	***MSE***	0.144

Adsorption capacity increased from 2.81 to 11.55 mg g^{-1} as the initial phosphate concentration increased from 5 to 100 mg dm^{-3}.

The Langmuir model showed a better fit to the experimental data than the Freundlich model (R^2=0.985) with an estimated q_{max} of 12.69 mg g^{-1}

→ Langmuir best described the adsorption isotherm

FTIR analysis



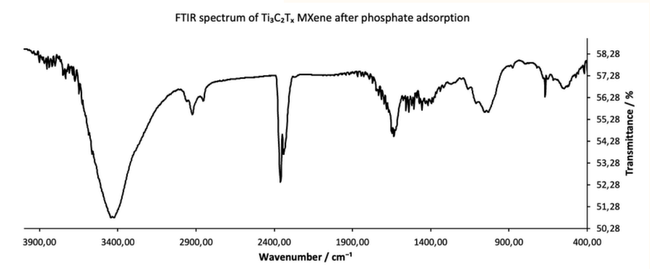


Figure 5. FTIR spectra of $Ti_3C_2T_x$ MXene before and after phosphate adsorption.

After phosphate adsorption, spectral changes were observed around 3400, 1100–1000 and ~550 cm^{-1}, corresponding to O–H, P–O/C–F and Ti–O vibration regions.

FTIR changes are consistent with interactions between phosphate species and $Ti_3C_2T_x$ surface groups.