Recovery of vanadium from alkaline wastes leachates

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Introduction

Alkaline wastes from carbon-intensive industries such as steel and aluminium production are major global by-product fluxes. Leachates from such residues have high pH, high chemical oxygen demand, salinity, and also elevated concentration of oxyanions metals and metalloids (e.g. As, Co, Cr, Mo, V). Challenging pollutants such as Vanadium (V) are released during leaching and often found in pentavalent form (the most toxic and a possible human carcinogen [1]). While it is contaminant of concern, V is also highlighted in recent strategic reviews of mineral security as being of critical importance to green technologies (with other elements such as La, Li, Co, V, Te, Ga, Se) [2]. **This work presents findings of a new research project: "R3AW: Resource Recovery and Remediation of Alkaline Wastes" which aims to developing sustainable treatment methods for alkaline leachates by recovering critical elements soluble at high pH.** More specifically, we report here the results of the testing of a commercial ion exchange resin for the recovery of V from alkaline wastes leachates.


Steel slag

Alkaline leachates

Materials and Methods

The steel slag leachate was produced in the lab with a steel slag sample from Yarborough, Scunthorpe, and deionised water. A NaOH solution of V_2O_5 was used as a surrogate of red mud leachate. Batch tests were performed to determine the extent of vanadium removal at room temperature with a basic anion exchange resin (Table 1). The effect of pH was investigated at pH 7.5, 9.5 and 11.5 with an initial V concentration of 0.1, 1 and 10 mg L^{-1} in the steel slag leachate and the NaOH solution. Vanadium concentrations were measured at 1, 2, 3, 4, 5, 10, 15, 20, 25 and 30 min.

Column experiments with the synthetic slag leachate were carried out in a Plexiglas column ɸ 1.8 × 35 cm at 15 ± 2 °C. The resin pre-treated with NaOH and hydrated was wet-packed into the column (25 mL). The experiments performed with a constant downstream flow rate of 6 mL min^{-1}. Samples were periodically collected from the column effluent and analysed to determine vanadium concentrations. The column elution was made with NaOH 2M.

Table 1. Characteristics of Amberlite®IRA-400 [3].

Properties	
Polymer matrix	Polystyrene divinylbenzene copolymer
Functional group	$-N^+R_3$ (quaternary ammonium)
Physical form	Pale yellow translucent beads
Ionic form	Cl^-
Exchange capacity	2.6–3 eq kg^{-1} (dry mass)
Effective size	0.3–0.9 mm
Operating temperature	80°C (maximum)
pH range	0–14

Ion exchange resins
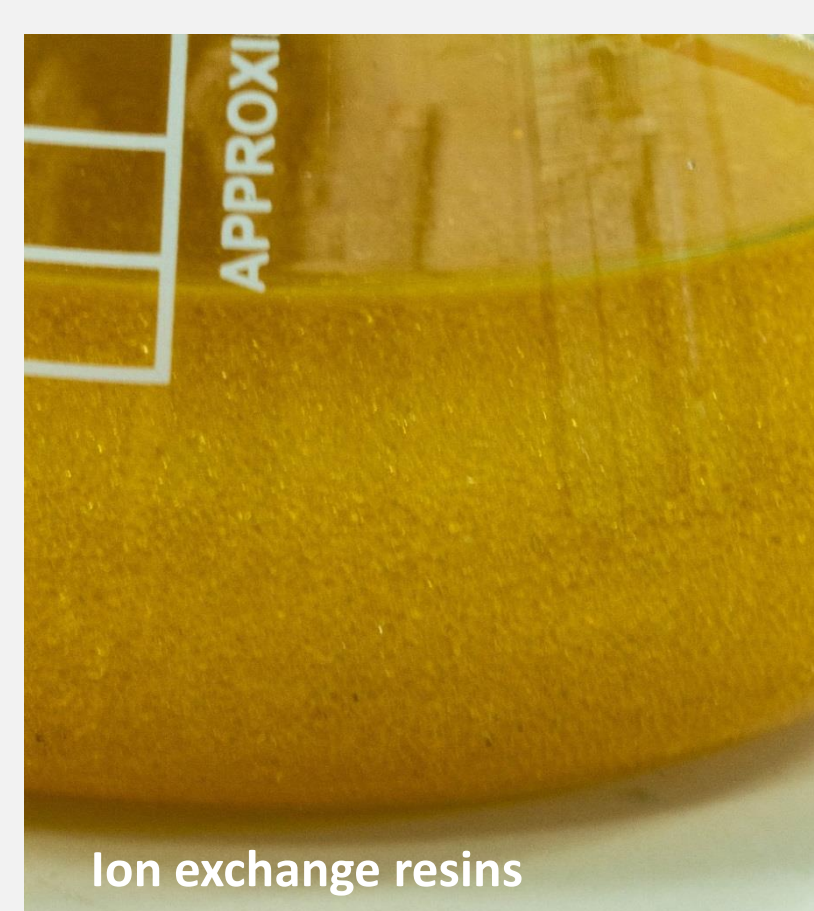
Results and Discussion

The experimental runs measuring the effect of contact time on the batch adsorption of V at the tested pH and initial V concentration of 10 mg L^{-1} are shown in Fig. 1. Within 20 minutes of contact time, the resins removed >99% V at a pH of 11.5. Higher removal rates were found with higher V concentrations and higher pH, both in the steel slag and the NaOH solution.
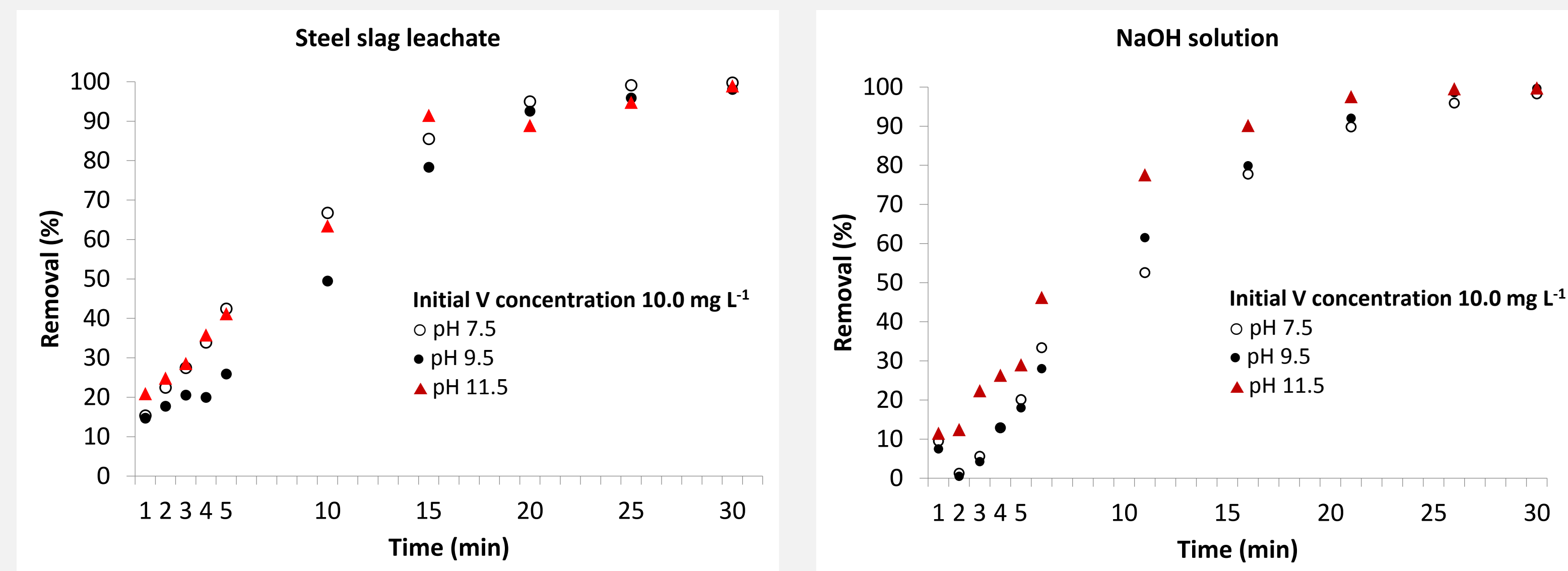

Figure 1. Effect of pH in the removal of V with the ion exchange resins in the steel slag leachate and the NaOH solution.
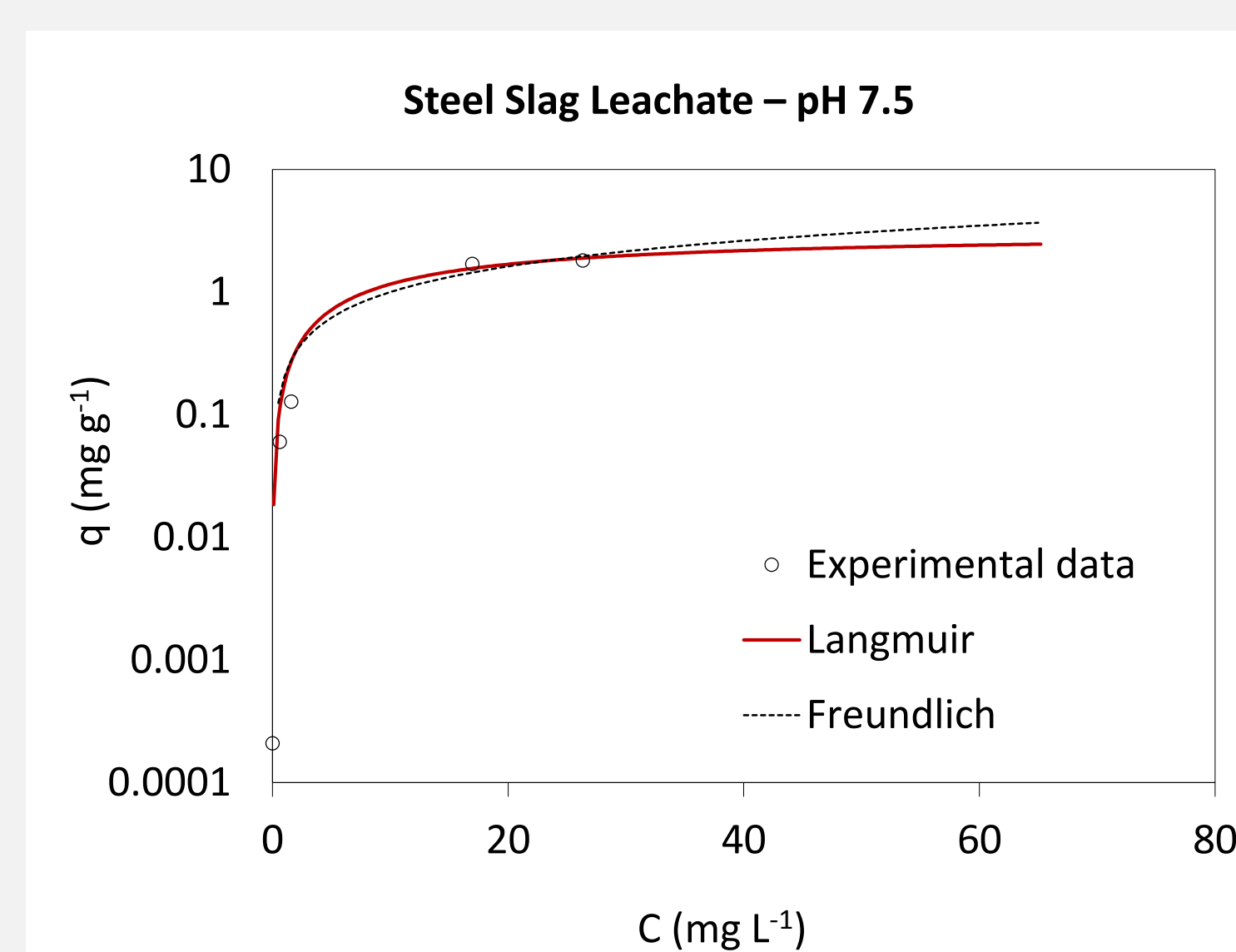

Figure 2. Adsorption isotherms for steel slag leachate at pH 7.5.

Table 2. Langmuir and Freundlich isotherm constants and coefficient of determination (R^2) for adsorption of V.

	pH	Langmuir isotherm			Freundlich isotherm		
		q_{max} (mg g^{-1})	b (L mg^{-1})	R^2	K_f	n	R^2
eel slag eachate	7.5	3.081	0.060	0.986	0.201	1.437	0.966
	9.5	24.370	0.004	0.999	0.111	1.067	0.999
	11.5	49.054	0.002	0.998	0.099	1.037	0.998
NaOH	7.5	29.404	0.003	0.999	0.111	1.069	0.999
	9.5	12.522	0.008	0.996	0.116	1.144	0.995
	11.5	26.991	0.004	0.999	0.116	1.082	0.999

The kinetics of V adsorption was studied from the time versus percentage removal curves (Fig. 1) using the 1st-order and the pseudo first order kinetic models. For both the steel slag leachate and the NaOH solution, the 1st-order model had a better fit, except for the 0.1 mg L^{-1} V, where the pseudo first order kinetic model fits better.

The Langmuir and Freundlich adsorption models were also fitted to the data (Fig. 2), which enabled to calculate the maximum adsorption capacity, q_{max} (Table 2). The highest adsorption capacity was found for steel slag leachate at pH 11.5 and for the NaOH solution at pH 7.5.

The first results of the column experiments showed that the breakthrough was not reached after 600 bed volumes, which show that the resin can be used effectively with steel slag leachate. The elution curve (Figure 3) shows that 75% of the vanadium could be recovered from the ion exchange resin.
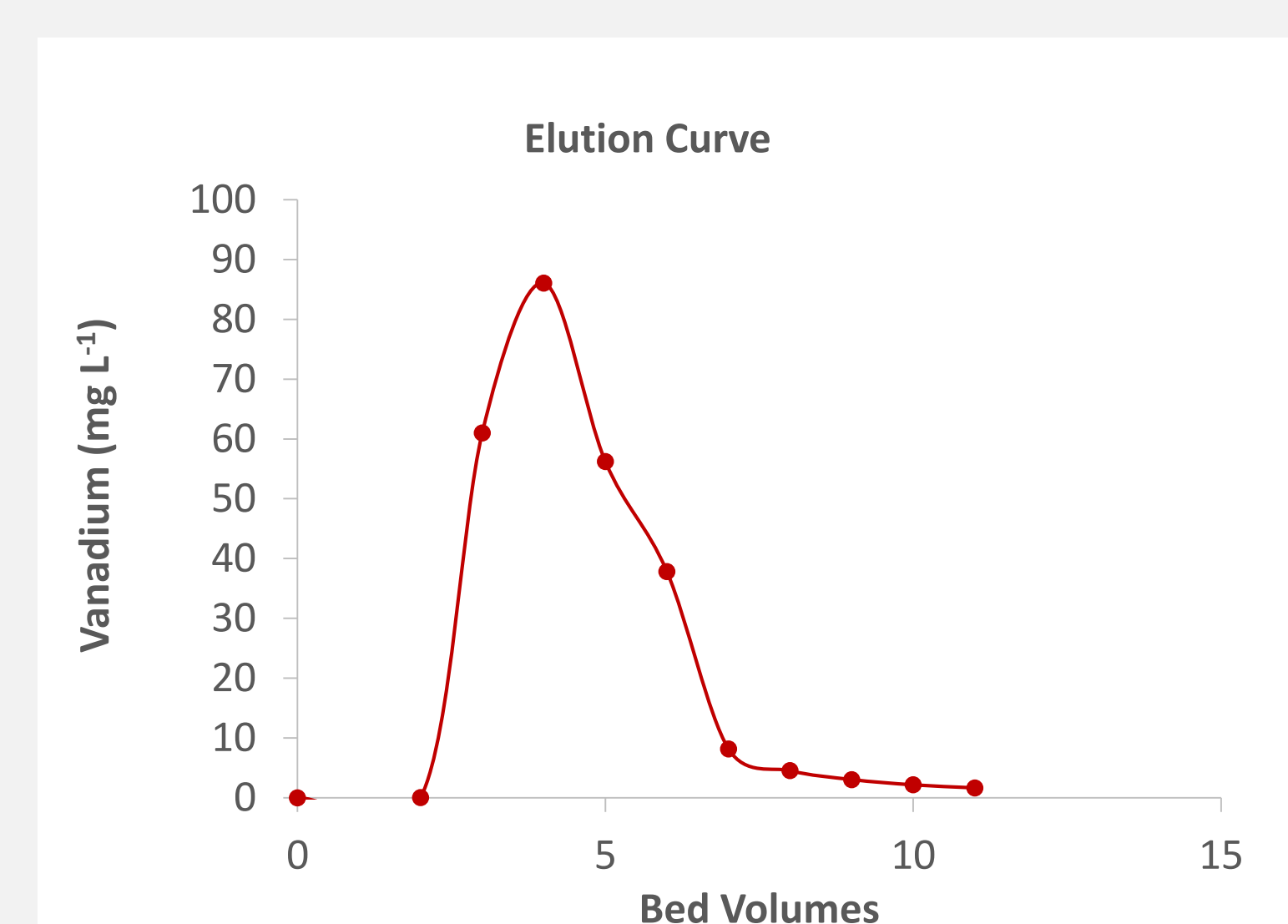

Figure 3. Elution curve of V from the ion exchange resins with 2M NaOH.

Conclusions

- The results demonstrate for the first time the extended alkaline pH range over which anion exchange resins can be used for metal removal and recovery from waste leachates.
- These results are promising for both the treatment of hazardous alkaline leachates and the recovery of metals of critical importance.
- Ongoing experiments are scaling-up the resin columns for pilot scale deployment, as well as assessing the impact of competing ions, such as Al and Si.

References

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