

Vanadium Extraction

Roast-Leach Process

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Table of Contents

1	EXPERIMENTAL PROCEDURE.....	3
2	RESULTS AND DISCUSSION	5
2.1	VANADIUM EXTRACTED FROM TTR SAND	5
2.2	VANADIUM EXTRACTED FROM PC AND VRC SAND	5
2.3	DETERMINING THE OPTIMUM CONDITIONS FOR VANADIUM EXTRACTION	7
2.3.1	<i>Pre-treatment</i>	7
2.3.2	<i>Roasting</i>	7
2.3.3	<i>Leaching</i>	8
2.4	VANADIUM EXTRACTION UNDER OPTIMUM CONDITIONS.....	9

1 Experimental Procedure

The sand and sodium salt were homogeneously mixed in a ball mill for 60 minutes before the roasting process. The roasting process was performed in a furnace with a temperature control programmer to allow different roasting temperature and time. Once the roasting process had finished, the samples were cooled down to room temperature then ground. The roasted materials were leached, then separated via centrifuge and the residue was washed three times with distilled water. The composition of the sand after leaching was analysed by X-ray fluorescence (XRF). The leachate was also analysed by inductively coupled plasma mass spectrometry (ICP-MS). The overall process flow is shown in Figure 1.

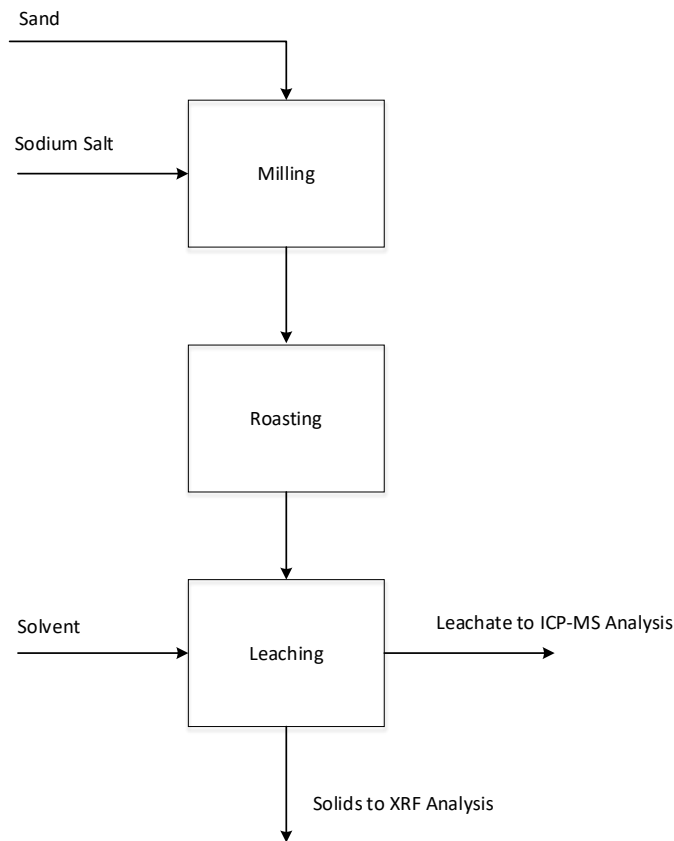


Figure 1: The process flow of the roast-leach process for vanadium extraction.

The vanadium extracted (η) was calculated using Equation 1.

$$\eta = \frac{m_1 f_1 - m_2 f_2}{m_1 f_1} \times 100\% \quad 1$$

m_1 and m_2 are the total masses of sand before and after leaching, respectively. f_1 and f_2 are the mass fractions of vanadium in sand before and after leaching, respectively.

2 Results and Discussion

2.1 Vanadium extracted from TTR Sand

The TTR sand was roasted with 5.00 g of sodium carbonate at 1000 °C for 2 hours then leached with distilled water for 1 hour. From Table 1, 43% of the vanadium was extracted from TTR sand. It is also evident that the Al and Si outlet are larger than the inlet, which was due to the uncertainties associated with the compositions.

Table 1: The mass of the different metals in TTR sand, leached solids and leachate.

Metal	XRF Analysis	XRF Analysis	ICP-MS Analysis
	TTR Sand (g)	Leached Solids (g)	Leachate (g)
Fe	11.93	10.74	0.00
Ti	0.96	0.96	0.00
P	0.01	0.01	0.02
Al	0.40	0.38	0.05
Si	0.19	0.48	0.00
Na	0.01	1.11	0.55
V	0.07	0.03	0.03
Total	20.17	21.91	0.66

2.2 Vanadium extracted from PC and VRC sand

For comparison, PC and VRC sand were roasted and leached at the same conditions mentioned above for TTR sand. From Table 2 and Table 3, 57% of the vanadium was extracted from PC sand and only 9% of the vanadium was extracted from VRC sand.

Table 2: The mass of the different metals in PC sand, leached solids from and leachate.

Metal	XRF Analysis	XRF Analysis	ICP-MS Analysis
	PC Sand (g)	Leached Solids (g)	Leachate (g)
Fe	11.69	11.32	0.00
Ti	0.95	0.91	0.00
P	0.01	0.00	0.01
Al	0.40	0.37	0.05
Si	0.24	0.29	0.00
Na	0.01	1.60	0.42
V	0.07	0.03	0.04
Total	20.02	22.43	0.49

Table 3: The mass of the different metals in VRC sand, leached solids from and leachate.

Metal	XRF Analysis	XRF Analysis	ICP-MS Analysis
	VRC Sand (g)	Leached Solids (g)	Leachate (g)
Fe	4.50	4.18	0.00
Ti	1.67	1.40	0.00
P	0.00	0.00	0.00
Al	0.17	0.14	0.00
Si	1.65	1.29	0.35
Na	0.02	1.66	0.20
V	1.54	1.17	0.14
Total	20.03	18.61	0.78

2.3 Determining the optimum conditions for vanadium extraction

2.3.1 Pre-treatment

The vanadium extracted increased from 55% to 65% if the sand was air roasted prior to roasting with sodium salt.

2.3.2 Roasting

The effect of sodium salt on the vanadium extraction was investigated using different sodium salts. From Figure 2, 55% of the vanadium was extracted after roasting with sodium carbonate. Similarly, 54% of the vanadium was extracted after roasting with 50 wt.% sodium chloride and 50 wt.% sodium carbonate.

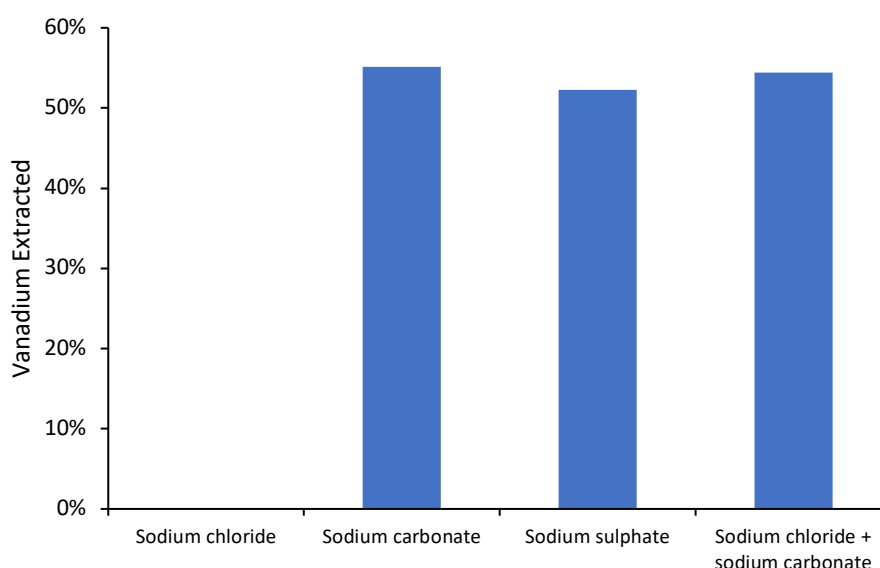


Figure 2: Effect of sodium salt on vanadium extraction.

The roasting conditions were also investigated as shown in Figure 3 and Figure 4. The vanadium extracted increased with temperature as expected, which reached a maximum of 55% vanadium extracted at 1000 °C. From Figure 4, the maximum vanadium extracted was 56% after 4 hours of roasting. However, since the vanadium extracted at 2 hours of roasting was only 1% less than 4 hours of roasting, the result at 3 hours of roasting could be inaccurate.

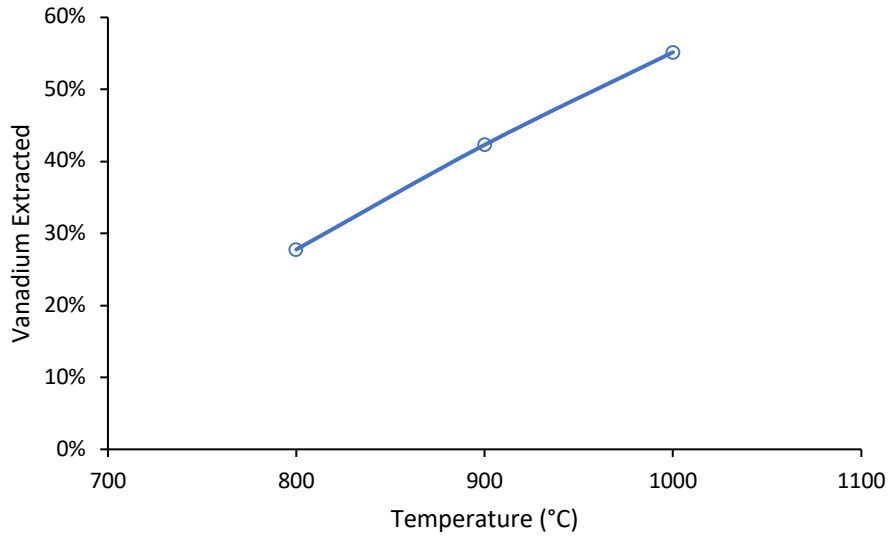


Figure 3: Effect of roasting temperature on vanadium extraction.

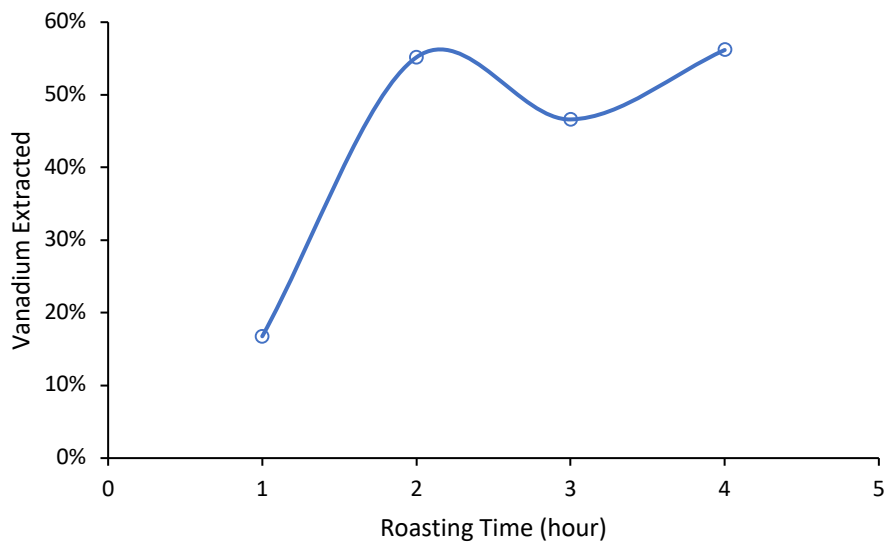


Figure 4: Effect of roasting time on vanadium extraction.

2.3.3 Leaching

The effect of the leaching time on the vanadium extracted only varied slightly, reaching a maximum of 57% at 2 hours as shown in Figure 5. However, the effect of the leaching solvent on the vanadium extracted varied a lot as shown in Figure 6. 65% of the vanadium was extracted after using acid as a leaching solvent.

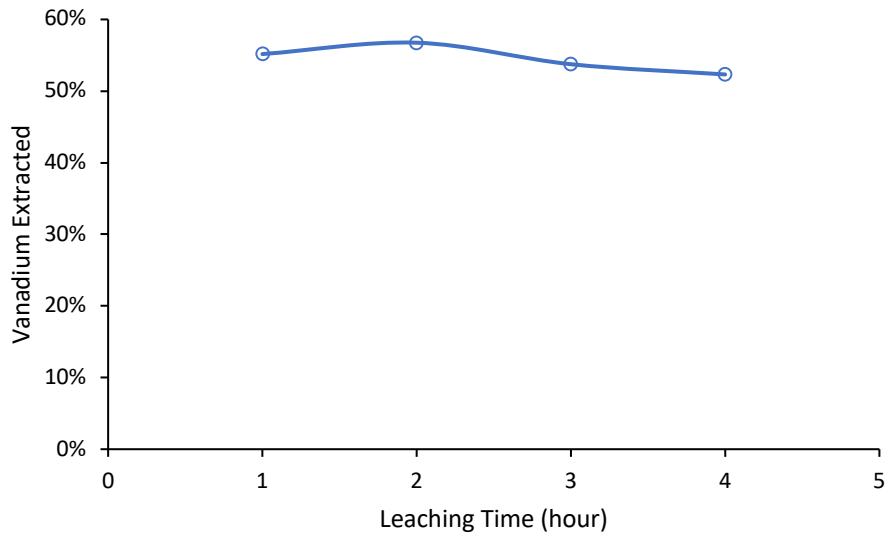


Figure 5: Effect of leaching time on vanadium extraction.

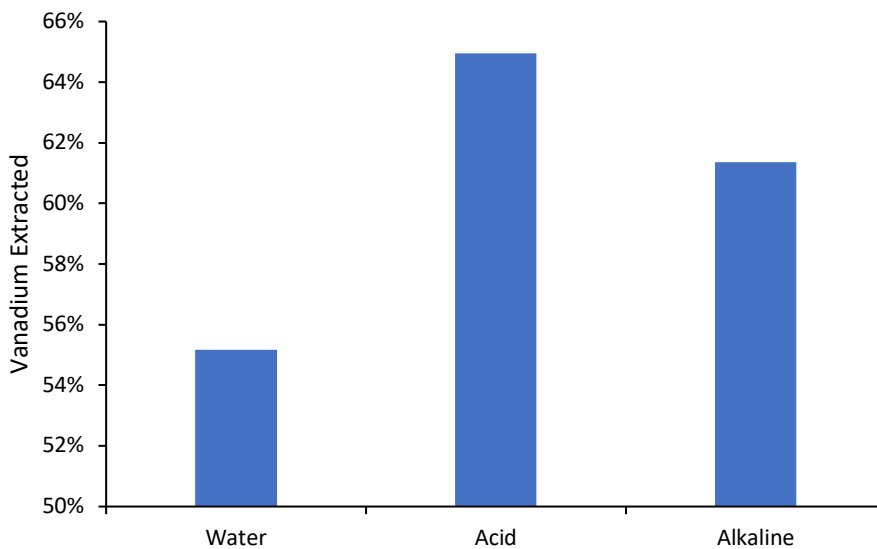


Figure 6: Effect of different leaching solvents on vanadium extraction.

2.4 Vanadium extraction under optimum conditions

From Section 2.3, the following optimum conditions were combined and carried out three times:

- Air roasting at 800 °C for 2 hours
- Roasting with sodium carbonate at 1000 °C for 2 hours
- Leaching with acid for 2 hours

From Table 4, the average vanadium extracted was 79%.

Table 4: The average mass of the different metals in PC sand, leached solids and leachate under optimum conditions.

Metal	XRF Analysis	XRF Analysis	ICP-MS Analysis
	PC Sand (g)	Leached Solids (g)	Leachate (g)
Fe	11.72	9.50	3.64
Ti	0.95	0.77	0.15
P	0.01	0.00	0.01
Al	0.40	0.15	0.24
Si	0.24	0.17	0.07
Na	0.01	0.50	1.35
V	0.07	0.02	0.05
Total	20.07	17.47	3.64