U-MATE INTERNATIONAL, INC.

PROCESS POTENTIAL STUDY

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Effect of pH on Heavy Metal Concentration

AIM:

It is well known that many metallic elements are soluble in an acidic environment. However, a highly alkaline environment cannot guarantee the complete removal of these same heavy metals. This study examines the changes in heavy metal concentration as caustic is added to a wastewater sample that was initially very high in acid. The purpose is to:

1. Find a pH level that can assist in removing most heavy metals.

2. Discover whether pH adjustments alone can remove certain problem elements.

3. Recognize those situations where other methods are required to reduce heavy metal concentrations to acceptable levels.

SCOPE:

A sample of processed wastewater was spiked with thirteen different metallic elements and then acidified to a pH of 1. A 50 ml portion was reserved for analysis. The remainder of the sample was treated with concentrated sodium hydroxide solution until the pH reading increased by two additional units. Another 50 ml sample was reserved for analysis. This process was repeated until the final mixture reached a pH of 13.

These aliquots were centrifuged and the clarified liquid portions were analyzed for the thirteen key elements and iron. The resulting graphs depict the behavior of any of the key elements over a pH range of 1 to 13. All of the elements tested were most soluble in a highly acidic environment (pH 1). As the pH level increased, the heavy metal concentrations tended to decrease.

DATA:

	pH 1	pH 3	pH 5	pH 7
Antimony	0.159	0.136	0.067	0.006
Arsenic	0.442	0.380	0.236	0.083
Cadmium	0.250	0.230	0.185	0.024
Chromium	0.342	0.314	0.131	0.025
Cobalt	0.501	0.471	0.446	0.334
Copper	0.100	0.098	0.086	0.017
Lead	0.279	0.255	0.077	0.039
Nickel	3.76	3.56	3.32	2.77
Silver	0.052	0.018	ND	ND
Tin	0.425	0.251	0.145	0.032
Titanium	0.230	0.157	0.068	0.004
Vanadium	0.344	0.317	0.182	0.036
Zinc	1.56	1.43	1.32	0.510
Iron	31.2	28.0	20.1	ND

	pH 9	pH 11	pH 12	pH 13
Antimony	0.028	0.014	0.019	ND
Arsenic	0.101	0.070	0.108	0.094
Cadmium	0.011	0.004	ND	ND
Chromium	0.021	0.011	0.010	0.010
Cobalt	0.300	0.208	0.258	0.249
Copper	0.039	0.039	0.023	0.023
Lead	0.038	0.028	0.005	0.025
Nickel	2.66	1.34	0.889	0.773
Silver	ND	ND	ND	ND
Tin	0.068	0.106	0.160	0.182
Titanium	0.012	ND	ND	ND
Vanadium	0.073	0.132	0.154	0.121
Zinc	0.370	ND	ND	0.004
Iron	0.586	ND	3.11	2.20

ND = Not Detected

DISCUSSION:

Graphs were generated, for each element, which depict the concentration of that element as a function of the pH. Three main patterns emerged from these diagrams:

Type 1 (Typical): The elements in this group exhibited a pH - solubility curve that declines rapidly to an initial low point, as the pH level increases. Thereafter, the concentration levels off and remains low. The elements in this group include:

Element	Acid Breakpoint
Silver	pH 5
Cadmium	pH 7
Chromium	pH 7
Lead	pH 7
Titanium	pH 7
Zinc	pH 11
Nickel	pH 13

Type 2 (Mixed): These elements also have a pH – solubility curve that declines rapidly to the breakpoint. After that the concentration appears to fluctuate, but remains generally low. There are no consistent trends after the breakpoint.

Element	Acid Breakpoint
Antimony	pH 7
Arsenic	pH 7
Copper	pH 7
Cobalt	pH 11

Type 3 (Amphoteric): the elements in this group exhibit significant solubility in strongly alkaline conditions. Their pH – solubility curves are generally V-shaped or U-shaped.

Element	Acid Breakpoint	Alkaline Breakpoint
Tin	pH 7	pH 7
Vanadium	pH 7	pH 7
Iron	pH 7	pH 11

CONCLUSIONS:

- In principle, the Type 1 metals can be removed efficiently if the pH is raised significantly above the acid breakpoint. For example: a pH of 9 will successfully remove **silver, cadmium, chromium, lead** and **titanium.**

- At alkaline pH's Type 2 metals give inconsistent results. This means that an alkaline pH can remove most, but not all of the available **antimony, arsenic** and **copper.**

- The acid breakpoints on **zinc, nickel** and **cobalt** are too high to be of any practical use in the process. In order to effectively reduce the concentrations of these metals, the pH would have to be raised well above the discharge limit of 11.5.

- Of the Type 3 metals, **tin** and **vanadium** have a V-shaped pH – solubility curve. This means that the discharge material must be held at a pH of 7 to successfully remove these two metals. Any deviation from a pH of 7 results in the return of **vanadium** and **tin** to solution.

- **Zinc, nickel, cobalt, tin** and **vanadium** cannot be adequately and reliably reduced by pH adjustment alone.

- **Iron** can be effectively removed by adjusting the pH between 9 and 11.