On the Possibility of Microbiological Leaching of Molybdenum

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Abstract. The paper presents studies of the use of the biological leaching method for the processing of molybdenum-containing alloys (production waste). As a result, we can obtain economically viable and environmentally safe technology for the processing of molybdenum-containing wastes.

1. Introduction
In connection with the development of industry, the need for molybdenum is constantly increasing [1]. Today, in addition to molybdenum mining in the areas of deposits, molybdenum is extracted from spent alloys that accumulate in the production. According to the latest forecasts, molybdenum is the final resource, and the peak of production at constant consumption is expected to occur in 2060. The simulation results show that molybdenum is a finite resource, and can be exhausted if the degree of processing is not significantly improved [2]. Existing methods of processing molybdenum-containing alloys are expensive, energy-consuming and have a detrimental effect on the environment [3]. Therefore, the purpose of this study is to develop a new biotechnological method for processing molybdenum-containing wastes, which is economically and environmentally justified. Such technology will become not only a source of additional molybdenum, but will also make it possible to dispose of molybdenum-containing products.

2. Applicability of biotechnologies in the processing of molybdenum-containing alloys
The fundamental possibility of biotechnological processing of spent molybdenum-containing alloys has been verified. Presumably, the use of microbiological leaching will reduce the cost of processing and increase the environmental safety of recycling, since the participation of microorganisms occurs in the natural cycle of the cycle of substances, without affecting the ecosystem and without causing the emergence of new polluting agents.

The process is based on the interaction of molybdenum-containing waste with a biological solution in the presence of iron compounds and the association of microorganisms of sulfide-reducing bacteria such as Thiobacillus ferrooxidans and ferroplazmoids that oxidize iron.

Molybdenum crucibles (molybdenum content of 99.9%) and MV-50 alloy (molybdenum content of up to 50%) were used as samples for research (figure 1).
Figure 1. Molybdenum-containing waste: a - alloy grade MV-50, b - molybdenum crucible.

The experiment on the biological leaching of molybdenum from waste was carried out according to Scheme 2 (figure 2) developed by the authors.

Figure 2. Scheme of microbiological leaching experiment.

Stage 1. For intensification of microbiological leaching processes the authors propose to use the barrel tumbling machine. Intensification of microbiological leaching processes takes place due to processes of constant renewal of dispersing solution (Thiobacillus ferrooxidans with ferric concentration 10.0 g/l, pH = 1.8) at the interface of phases. At the same time, the collision of the waste to each other updates the phase interface.

For this propose spent molybdenum alloys weighing 134 g (I) were placed in a reactor (tumbling drum) with continuous mechanical stirring, the rotation speed of the reactor was 24 revolutions per minute. The temperature in the reactor, throughout the experiment, was maintained 22-25 °C in the reactor, the processes of molybdenum leaching by bio-solution occurred (II), in according to equations 1, 3. As a solution for biological leaching, 1 liter of Fe\(^{3+}\) solution was used, obtained by biological reduction of Fe\(^{2+}\) by a specially selected association of mesophilic microorganisms of the thiobacillus ferrooxidans.

Stage 2. The leaching process was controlled by indirect pH parameters and change in mass of molybdenum-containing wastes.

For this propose sample was taken daily from the reactor to measure the pH of the solution, which was maintained in the range of 1.5-2.5, and the change in the weight of the loaded fragments was also measured (III). If the pH deviated from the set values, the pH of the solution was adjusted by adding sulfuric acid until the required pH was established. After 2-fold adjustment of the pH, the solution was
sent for evaporation to the evaporator. As a result of the process, part of the molybdenum was extracted from the bio-solution in the form of molybdenum blue. Molybdenum passed into solution by the reactions (1, 2):

\[
Mo + 2H_2SO_4 = (MoO_2)SO_4 + SO_2 + H_2 \quad (1)
\]

\[
3Mo + Fe_{2+}(SO_4)_3 = 3(MoO_2)SO_4 + 2Fe \quad (2)
\]

The reason for the cessation of dissolution of the molybdenum-containing alloy (waste weight change) is the reduction of iron (3+) into iron (2+) by the reaction 3:

\[
Fe^{3+} + e \rightarrow Fe^{2+} \quad (3)
\]

After termination of dissolution of the molybdenum-containing alloy (change in weight of waste), a new portion of 0.5 liter solution containing an association of mesophilic microorganisms such as thiobacillus ferrooxidans was added to the reactor with a concentration of trivalent iron of 10.0 g/l, pH = 1.8. The process was carried out for 6 days, which showed a stable transition of molybdenum into the solution.

The resulting molybdenum salt product was evaporated to obtain a concentrate (IV). As a result of the process, molybdenum passes from the alloy to the solution in the form of molybdenum salts (molybdenum blue) with impurities of iron and sulfur (figure 3).

The diagram (figure 4) shows the results of the microbiological leaching experiment, which shows changes in the mass of the released molybdenum blue during the experiment. Analysis of the pattern shows a linear relationship on the transition of molybdenum to solution.

![Figure 3. Received molybdenum blue: a – appearance (obtained molybdenum blue), b – molybdenum blue under a microscope.](image-url)
Studies on the resulting product were carried out on a scanning electron microscope PHENOM proX (Scientific and Educational Center "Advanced technologies and materials", Sevastopol State University, Russian Federation). The resulting product has the following elemental composition (Table 1) it can be seen from the presented spectogram that the test substance is a sulphur contaminated compound (possibly molybdenum blue) (figure 5).

Table 1. Elemental composition of the obtained substance, alloy Mo 99.99%.

| Element Symbol | Atomic Conc. | Weight Conc. |
|---------------|--------------|--------------|
| O             | 75.22        | 57.10        |
| S             | 16.39        | 24.93        |
| Mo            | 3.31         | 15.07        |
| C             | 5.08         | 2.90         |
3. Conclusion

The results of experiments on the biotechnological processing of molybdenum waste showed the fundamental possibility of using biological leaching for recycling molybdenum waste. The obtained product is complex compounds, contains up to 15% molybdenum, presumably in the form of molybdenum blue. Considering the use of simple and inexpensive equipment, presumably this experiment can serve as the basis for the development of a new technology for the recycling of molybdenum waste.

The products obtained as a result of biological leaching (molybdenum blue) can be used as a catalyst in the chemical industry, corrosion inhibitors, high-performance lubricants, polymer production, manufacture of high-temperature furnaces, dyes, glazes, antibacterial substances, as additives to nickel, titanium, iron, steel alloys [4–7].

References

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