

# The Recovery of Gold Ions from Mine Effluents Using High Capacity Nanoporous Adsorbents.

Adel El-Hsaeri

School of Engineering, Laurentian University  
Sudbury, Ontario, Canada P3E 2C6

Louis Mercier

Department of Chemistry and Biochemistry, Laurentian University  
Sudbury, Ontario, Canada P3E 2C6

## **Abstract**

The development and application of high capacity heavy metal ion adsorbents with uniform nanoscale porosity (denoted MP-HMS) to extract precious metals from mine effluent is described. The adsorbents are selective towards platinum group metal (PGM) ions such as those of gold, platinum and palladium. The adsorption capacities of these materials are also among the highest reported (up to 50% of their weight). Another promising attribute of these materials is their favourable adsorption kinetics. The efficacy of these new materials for the recovery of PGMs from mining effluent is evaluated and their prospect for application in the mining industry discussed.

## **Introduction**

Although native gold is fairly common, it is rarely in the form of a pure metal. Invariably, gold is alloyed with other metals, most notably silver, and copper, but also with bismuth, mercury, iron, palladium and rhodium. Various methods are used to extract the gold from its ores, which includes gravity concentration, flotation, amalgamation and cyanidation (1,2,3). Gravity concentration and flotation are used mostly as pre-concentration processes. Actual recovery is done by amalgamation and/or cyanidation. Cyanidation is a method of extracting gold or silver based on the solubility of these metal-cyanide complexes that form in solution. The gold is then recovered from the solution either by zinc reduction or by carbon adsorption.

Here we present the application of a new high capacity and high selectivity adsorbent, denoted MP-HMS, to recover gold from leach solutions. Although several adsorptive materials can be used to capture metals ions from solution (i.e, activated charcoal (1), zeolites (2,3), and clays (4,5)), most of these suffer inherent disadvantages such as low loading capacities and weak binding interactions with the metal

ions. These limitations thus make such materials unsuitable for gold recovery applications.

In the past few years, the discovery of a new type of silica-based molecular sieve materials with ordered pore channels in the diameter range of 1-10 nm has attracted wide attention for many industrial and environmental applications (9). The preparation of highly effective heavy metal ion adsorbents by the incorporation of thiol moieties into the pore channels of mesoporous silica molecular sieves has been the subject of many research investigations (10-12). These functionalized adsorbent, denoted MP-HMS, were shown to exhibit high affinity towards the binding of chalcophilic ions such as Hg(II), and had unprecedentedly high loading capacities for these metals (up to 500 mg/g). Because PGM ions are expected to have similar chalcophilic properties as those of Hg(II), this report examines the use of MP-HMS as a plausible replacement activated carbon in the gold recovery process.

## **Methods**

*Adsorbent synthesis and characterization.* MP-HMS was prepared and structurally characterized in accordance with previously published methods (13).

*Gold Adsorption Studies.* Au(III) ion adsorption studies were performed by batch adsorption method. Thus, 10 mg samples of MP-HMS were suspended in 50 mL Au(NO<sub>3</sub>)<sub>3</sub> solution with varying concentrations (0-100 ppm) and the mixture stirred at room temperature for 24 hours. The suspensions were then filtered and the Au concentration in the filtrate solutions measured by ICP-MS (Inco Ltd.). Similar adsorption studies were also performed on solutions containing a mixture of Au, Fe, Cu and Ni ions in order to assess the selectivity of the adsorbents). Finally, the uptake rate of MP-HMS was also obtained by stirring Au solutions for fixed time periods (30 s to 5 minutes), followed by rapid filtration and ICP-MS analysis.

### **Results and Discussion**

The characterization of the adsorbents conformed with what would be expected for a functional nanoporous adsorbent (13), exhibiting ordered framework structure, uniform nanoscale porosity (diameter of about 3 nm), high mercaptan group loading (1.5 mmol g<sup>-1</sup>).

The Au(III) uptake isotherms of MP-HMS (Figure 1) showed the material to be extremely effective in adsorbing gold ions from low level solutions. The isotherm exhibits typical Type I uptake behaviour, adsorbing the majority of the gold ions in solution until saturation is reached. The distribution coefficients of the materials were also exceptionally high, ranging from 10<sup>6</sup> to 10<sup>8</sup> in the concentration range studied. The high adsorption saturation level of these materials (at 318 mg/g, or 31.8% of the adsorbent weight) is also a noteworthy feature of these materials.

MP-HMS also exhibits almost exclusive selectivity for the adsorption of Au(III) ions from mixed metal ion adsorption studies (Figure 2). The adsorbents thus appear to have negligible affinity for the more ubiquitous upper row transition metals such as Fe, Cu and Ni.

MP-HMS demonstrated very favourable adsorption kinetics (Figure 3), reaching equilibrium (saturation) in less than 1 minute of exposure. The rapid access of the Au ions to the

binding sites makes MP-HMS potentially useful under rapid flow conditions used in filtration and fixed/fluidized bed reactors.

The optimal adsorption properties of MP-HMS towards Au and other PGM ions (i.e., high loading capacity, exclusive binding selectivity and rapid kinetics) make these materials most promising for a multitude of mining applications in which PGM ion separation is of interest. Such applications may include the recovery of these ions from waste streams, providing simultaneous cost recovery and the mitigation of hazardous heavy metal ions in the environment.

### **Acknowledgements.**

We would like to thank Dr. John Bozic and Dr. Zbig Waszczylo (INCO Ltd.) for their analytical services and useful discussions regarding this work. We also gratefully acknowledge Materials and Manufacturing Ontario (MMO) for financial support.

## References

1. Lorenzen, L.; Van Deventer, J.S.J, 1993. *The identification of refractoriness in gold ores by the selective destruction of minerals. Minerals Engineering, Vol. 6, Nos. 8-10, pp 1013-1023.*
2. Lorenzen, L., 1995. *Some guidelines to the design of diagnostic leaching experiments. Minerals Engineering, Vol.299, pp.247-2256.*
3. Yalcin, T. *Mineral Separation II Text.* 2001.
4. Faust, S. D.; Ali, O. M. *Chemistry of Water Treatment*; Butterworth: Boston, 1983.
5. Huang, C. P.; Hao, O. J. *Environ. Technol. Lett.* **1989**, *10*, 863-874.
6. Zamzow, M. J.; Eichbaum, B. R.; Sandgren, K. R.; Shanks, D. E. *Sep. Sci. Technol.* **1990**, *25*, 1555-1569.
7. Sikalidis, C. A.; Alexiades, C.; Misaelides, P. *Toxicol. Environ. Chem.* **1989**, *20-21*, 175-180.
8. Keizer, P.; Bruggenwert, M. G. M. *NATO ASI Ser. E* **1991**, *190*, 177-203.
9. Beck, J. S.; Vartuli, J. C.; Roth, W. J.; Leonowicz, M. E.; Kresge, C. T.; Schmitt, K. D.; Chu, C. T.-W.; Olson, D. H.; Sheppard, E. W.; McCullen, S. B.; Higgins, J. B.; Schlenker, J. L. *J. Am. Chem. Soc.* **1992**, *114*, 10834-10843.
10. Mercier, L.; Pinnavaia, T.J. *Adv. Mater.* **1997**, *9*, 500-503.
11. Mercier, L.; Pinnavaia, T.J. *Micropor. Mesopor. Mater.* **1998**, *20*, 101-107.
12. Mercier, L.; Pinnavaia, T.J. *Chem. Mater.* **2000**, *12*, 188-196.

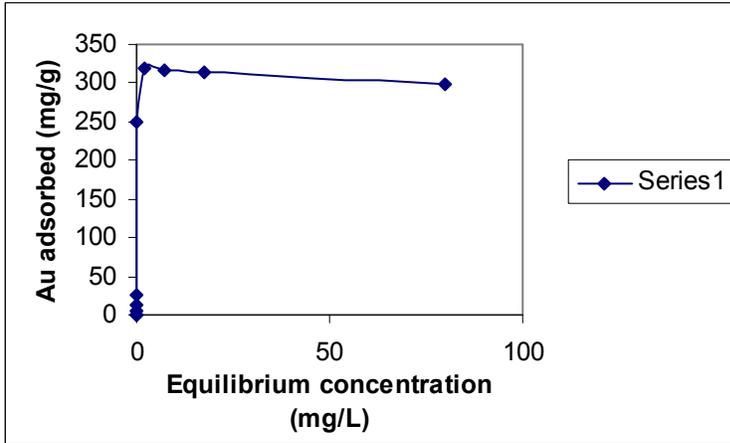


Figure 1. Au(III) adsorption isotherm of MP-HMS.

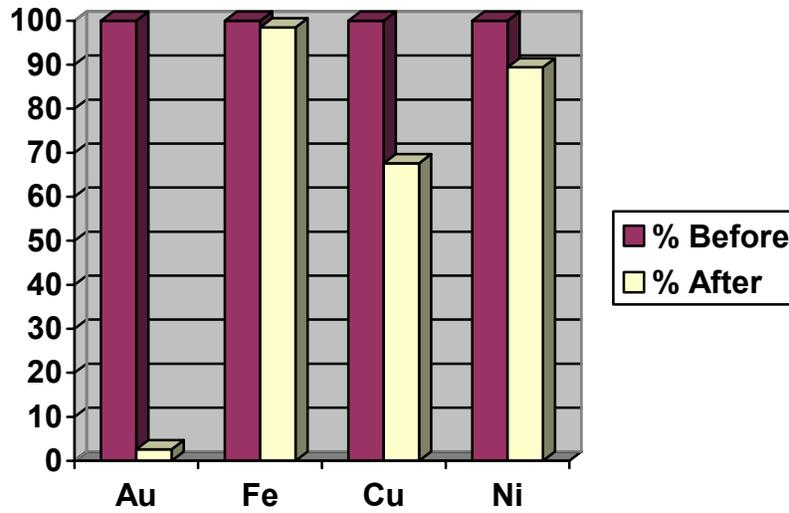
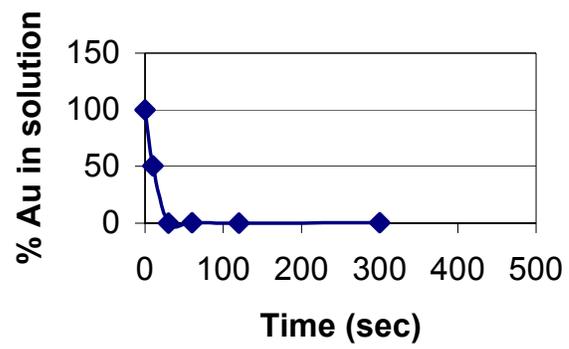


Figure 2. Selectivity of MP-HMS.



**Figure 3.** Au(III) uptake rate by MP-HMS.