Technospheric Mining Towards a Circular Economy

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Human activities, such as product manufacturing, mining, and ore extraction, chemical and metallurgical processing, road and building construction, municipal and household activities, and agriculture among others, have relocated and accumulated metal and material resources from geological origins to the technosphere. The technosphere is defined broadly as a material stockpile that has been established by human activities and technological processes (Johansson et al., 2013). Iron, for example, is mined and extracted from iron oxide ores from the Earth's crust, by high temperature metallurgical processes and is used to produce steel, other metal alloys, and chemical products. Iron is now present in many things we use everyday, i.e., buildings, bridges, cutting tools, bicycle, and a multitude of other materials and equipment. These materials containing iron, either active or inactive stocks, are part of the technosphere and are considered technospheric stocks or secondary sources of iron.

There are numerous other metals and material stocks of finite resources accumulated in the technosphere. But the most important technospheric stocks and the main targets of current technological and policy initiatives are the wastes and waste repositories. Industrial, municipal, metallurgical, and mining wastes pose health and environmental hazards if not managed properly. These wastes present serious storage or space problem (for disposal) and take a huge chunk of operational costs for government and companies for management and treatment. However, wastes and waste repositories from different sources are highly relevant due to the presence of valuable elements, especially the technology metals, which are considered critical and strategic based on studies by the European Commission (2011 and 2014) and the United States Department of Energy (Simandl et al., 2015). These elements include the rare earth elements (REEs), precious metals, cobalt (Co), the refractory metals particularly niobium (Nb) and tantalum (Ta), indium (In), germanium (Ge) and others. Recovering these elements from wastes and waste repositories is vital for the move towards a circular economy and sustainable development.

The extraction and recovery of metals and mineral resources from technospheric stocks, predominantly wastes and waste repositories, is called technospheric mining, in contrast to conventional mining, which targets primary ores of geologic origin. This increasingly important and significantly relevant new concept, which is geared towards waste valorisation, was introduced in the papers published by Johansson et al. (2013) and Krook and Baas (2013) and covers various areas, including urban mining, slag, tailings, waste and landfill mining, as presented in Figure 1.

The recovery of precious metals, such gold (Au), silver (Ag), platinum (Pt), and palladium (Pd) from waste electronics and electrical equipment (WEEE) is generally classified under urban mining. Slag mining is dedicated to the extraction of valuable elements from slag, a by-product or waste material generated by high temperature metallurgical processing or pyrometallurgical processing of ores or mineral concentrates. Processing of copper and nickel sulphide minerals, iron ore, tin minerals particularly cassiterite (SnO2), produces slag materials, which contain valuable elements. Slag may contain critical and strategic elements, such as cobalt, REEs, Ta, and Nb. Landfill mining refers to the recovery of valuable materials from landfill sites, which mostly house municipal solid wastes and other industrial rejects. Mining and mineral processing operations also generate significant amounts of wastes that can serve as valuable technospheric stocks. Wastes from these operations would include mine overburdens, mine, and beneficiation tailings. Some tailings from historical operations when extraction and processing technologies were not yet sophisticated, may contain valuable metals of concentrations higher than primary ore sources. In the Philippines, a very good example is the gold mine tailings, which can be reprocessed using new technologies to recover residual gold. Recovery of valuable elements or materials from other waste streams, such as coal fly ash (may contain REEs), steelmaking dusts, and dredged sediments, can be categorized under waste mining.

Aside from valuable elements, wastes and waste repositories can also be used as secondary sources of other materials with varied applications. For instance, coal fly ash has been known to contain

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aluminosilicate components, which makes it useful as an additive in cement manufacturing or the synthesis of zeolitic materials. Mine waste tailings which are rich in iron minerals can be used for iron extraction and synthesis of magnetite or other iron oxides for pigment and environmental applications. Some mine wastes are used to produce bricks for buildings and road construction purposes. Mine wastes and some industrial residues containing clays, carbonates, phosphates, and iron oxides are utilized in soil amendment/amelioration applications.

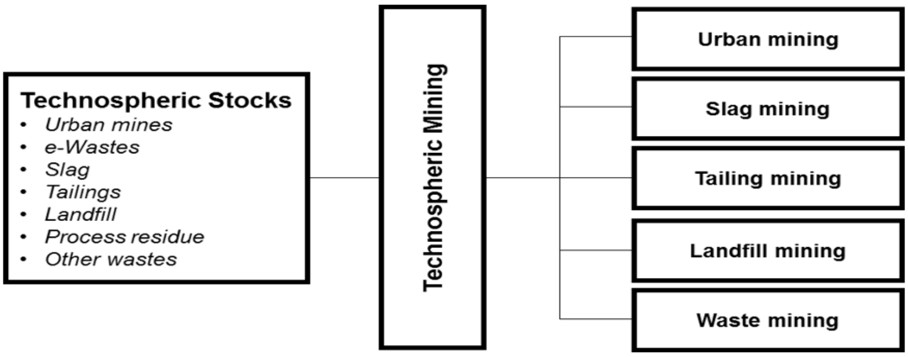

Figure 1. General concept of technospheric mining (adapted from N. Johansson et al., 2013).

Technospheric mining can be considered as the mining of the future. It will transform the essence of mining as it will shift the focus of resource recovery from the lithosphere to the technosphere. As the grade and quality of ores or minerals, we mine from Earth's crust decrease, and as the technology required for conventional mining becomes more challenging, it is apparent that mining will adapt accordingly to the exploitation of previously extracted minerals or materials now accumulated in the technosphere. Wastes and waste repositories are abundant in the present world but the nature and the engineering used to generate them vary significantly between countries and waste types (Sapsford et al., 2017). These would have significant impacts on their repurposing and utilization for resource recovery. Some wastes may require decontamination before they can be converted to useful products or prior to valuable metal extraction. Some are regulated by legislations for waste management practices and these could vary between countries as well. The technologies required for technospheric mining also vary depending on waste types and the target material for recovery. There are existing technologies that are readily transferrable to technospheric mining, such as technologies applied for mineral processing and extractive metallurgy, but these require proper assessment on amenability and suitability. The technology readiness levels (TRLs), applied by scientists, engineers, and policy makers to evaluate the maturity of a particular process or technology, are also variable ranging from laboratory scale to commercialization levels. The development of technology tailored for a specific waste or waste repository is highly important. But of course, technospheric mining is not only about technology and scientific innovations. As with the general concept of a circular economy, the involvement of the different sectors of the society is imperative.

Figure 2. Mine wastes are technospheric stocks and can be utilized for metal or mineral resource recovery as part of technospheric mining (photo: https://research.curtin.edu.au/industry-partners/invest/resources/mine-waste-management/)

REFERENCES

Johansson, N., Krook, J., Eklund, M., & Berglund, B.(2013). An integrated review of concepts and initiatives for mining the technosphere: towards a new taxonomy. Journal of Cleaner Production, 55, 35-44

Krook, J., Bas, L. (2013). Getting serious about mining the technosphere: a review of recent landfill and urban mining research. Journal of Cleaner Production, 55, 1-9

Sapsford, D., Cleall, P., Harbottle, M. (2017). In situ recovery from waste repositories: exploring the potential for mobilization and capture of metals from anthropogenic ores, Journal of Sustainable Metallurgy, 3, 375-392

Simandl, G. J., Akam, C., & Paradis, S. (2015). Which materials are 'critical' and ‘strategic’? Industrial Minerals, 57-59