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A Review of Urban Mining in the Past, Present and Future

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Abstract

As the world's population is growing exponentially, more and more resources are needed to meet the demand. The earth does not have an infinite amount of resources and natural reserves are on a trend towards depletion. In fact, about half of the world's copper and other metal stocks have been mined. A solution that would help to slow the mining of virgin materials is urban mining. This is the concept of extracting valuable materials from existing infrastructure, landfills, and the dissipation of them into the environment. This would allow an increased demand for metals to be met without having to mine additional virgin materials. There are many different types and processes that can be used to collect materials, especially metals. These types include secondary mining, landfill mining, hibernation mining, dissipation mining, and in-use mining. Although there are challenges associated with urban mining, there are many benefits to continue to expand. Future research will help to improve these processes.

Keywords: Population; Resources; Natural reserves; Mining; Environment

Introduction

The current era of humanity is marked with a booming population coupled with its far-reaching effects on the physical environment. Atop the daunting list of growing environmental concerns are the issues of energy production and consumption, industry, food production, and resource use as well as the interplays between these matters. Each of these connected challenges requires separate and innovative strategies to arrest and ultimately reverse their environmental impacts.

In the field of resource use and waste management, a growing remedy is a practice termed urban mining. Urban Mining extends landfill mining to the process of reclaiming compounds and elements from any kind of anthropogenic stocks, including buildings, infrastructure, industries, products (in and out of use), environmental media receiving anthropogenic emissions, etc. [1,2]. Urban Mining has been defined as the process of reclaiming compounds and elements from any kind of anthropogenic stocks, including buildings, infrastructure, industries, products (in and out of use), environmental media receiving anthropogenic emissions, etc. [1,2]. Another definition of urban mining is the recovery of materials within the technosphere to be used in the production of new products, where the technosphere is defined as all products, buildings, and infrastructure [3].

Currently the scope of urban mining activity is opportunistic and short-termed, but further innovations can drive it towards ubiquity [4,5] described the role of urban mining in material life cycle as a raw product recovery to be used in production as shown in Figure 1.

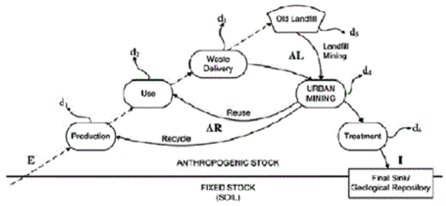

Figure 1: Role of urban mining in materials life cycle [5,6].

Currently the scope of urban mining activity is opportunistic and short-termed, but further innovations can drive it towards ubiquity [4]. A large benefit obtained from urban mining is reducing the need to mine virgin materials-chiefly, but not limited to, metals. The stock of copper in the technosphere is equal to that still residing in geologic stores, suggesting that half of the global copper stock has been extracted [7]. The state of the global iron reserve is the same as that of copper: half of the total reserve has already been mined [3]. This suggests the potential for large-scale resource recovery is immense if we as a society can develop efficient methods of recovering these metals, particularly in industrial urban regions [8]. It also suggests that consumption of virgin stores of these metals at the current rate will deplete the respective geological stores, spelling catastrophe for society as we know it; copper is used ubiquitously in electronics and iron is essential for buildings and infrastructure.

The value of urban mining is further observed as competition for resources continues to increase, which drives their respective prices upwards via supply and demand economics and declines the natural global reserves [9]. This competition is already at play and will likely exacerbate in the coming centuries under current or increasing consumption trends [9]. It can easily be speculated that competition for essential scarce resources may lead to international conflicts, not

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dissimilar to the sundry 20^{th} and 21^{st} century wars fought over petroleum resources.

In addition to reducing the demand for mining virgin materials and resource competition, urban mining delivers the benefit of reducing the flow of material into landfills. Landfills present a significant environmental challenge, as they are sources of toxic material leakage and carbon emissions. On an annual basis, landfills emit 0.03 Gtons of carbon, which equates to approximately 40% of that emitted by the energy sector [10]. By reducing the level of mining of virgin materials, the environmental impact of mining can be mitigated. On an economic basis, mining of copper, nickel, lead and zinc generates 1,470 Gton of CO_2 per million dollars of metal [11]. It additionally generates 77,000 short tons of hazardous waste and consumes 63,600,000 gallons of water per million dollars of metal [11]. Urban mining can be used to lessen some of these environmental impacts. The objectives of the study was to review urban mining practices throughout the world and evaluate the feasibility of urban mining in industrialized countries.

Methods and Materials

To investigate the scope of urban mining and the different types and processes that define it, the University of Wisconsin-Madison libraries database and Google Scholar was used to complete a literature review. Articles and books that had the full text online were used in order to gather the most information. Topics that were thought to be useful included elucidations of the current status of urban mining, the different types of urban mining, and what the status of urban mining may be in the future. These subjects were searched for while reviewing the articles. Keywords were searched such as "urban mining" along with specifics such as "e-waste" and "power grid cables". If the abstract of an article that was returned from the search contained information that seemed useful, the rest of the article was read. If the abstract seemed like it contained information that was not useful or information that had previously been read and used, the rest of the article would not be read and the next article of the search would be previewed. After gathering enough useful information, the information was tied together and the conclusions written.

Results

There are many benefits to implementing urban mining regularly. During the age of the Anthropocene, much of the world's natural resources have been diminished while the demand for them continues to grow. For metals such as iron and copper, it has been estimated that the "current accumulation in the technosphere is comparable to or even exceeds the remaining amount in known geological ores" [3]. Using urban mining as a way to collect more resources and may help to curb the mining of virgin materials, allowing the capacity of scarce resources to grow. Figure 2 shows the distribution of metals in the technosphere. Note that the largest amount of metals are already in use, but there is still a substantial amount that that can be harvested from inactive sources.

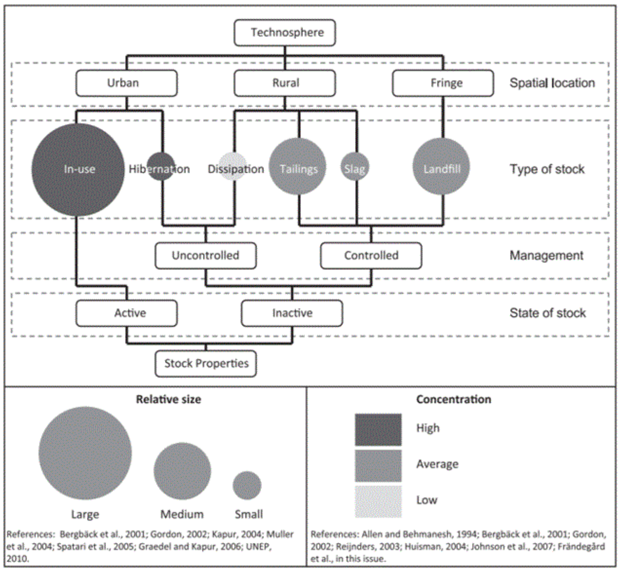

Figure 2: Flowchart showing presence of metals in the technosphere [3].

Of the several different types of urban mining, three types will be discussed in this paper. The three types were chosen to represent different points in a metals lifecycle: the extraction of material during the mining process, its use in infrastructure, and its disposal.

The first type of urban mining is secondary mining, which is the extraction of materials that are left over from mining of virgin materials [3]. After virgin ore is crushed and large metals are collected, the remaining material forms a very fine mud or powder. These leftovers are known as "mine tailings," and can be hazardous if disposed of incorrectly. The toxic chemicals in mine tailings may include cyanide, which is used in gold, arsenic, or mercury mining and can occur naturally in rock, or sulfide compounds that can convert to sulfuric acid if exposed to air and water [12]. Traditional mines have used wet storage methods that dispose of tailings as a wet mud diluted with water, which is then held in pits lined with clay or a synthetic liner. Storage of mine tailings can also be hazardous, as the water-tailing mixture could be falsely acclimated by local wildlife that would mistakenly drink the tailing-water, or the liner could leak or the dam could burst. Such is the case of Bento Rodirigues, Brazil, where the dam of a tailings pond burst and contaminated 88,000 km2 of area, covering a whole village in a few feet of metallic mud. In order to cut down on tailings waste and reduce the amount of contaminants present, a form of urban mining known as thermochemical treatment can be applied to extract heavy metals out of tailings.

Figure 3 is a diagram of the thermochemical treatment process, which takes platinum-group metals (PGMs) and mixes them with ammonium sulfate. This process is then thermochemically treated at over 550°C to induce mineral transformation. The leachate is then filtered and the filtrates are collected and acidified below pH 2. The metals from the filtrate are then are then extracted. This treatment process is still in the experimental stages, but recycling processes such as this one will cut down on the demand for mining virgin materials by utilizing mining byproducts [13].

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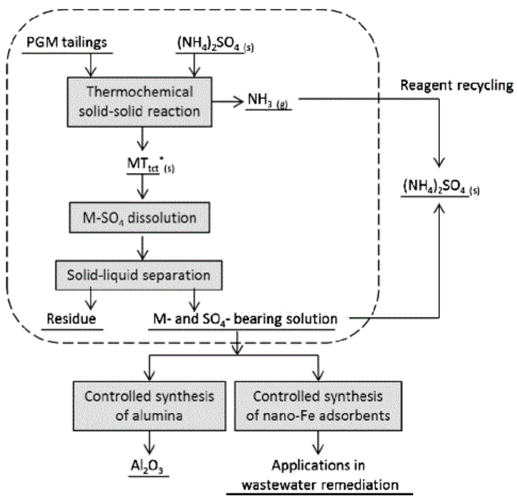

Figure 3: Thermochemical treatment using ammonium sulfate as an extracting agent.

A second type of urban mining is mining hibernation stocks. This is the extraction of metals that are not currently in use but have yet to be discarded to a waste management facility [8]. Many large cities have denser concentrations of collected metals where the industrial sections are located. Abandoned factories, unused railroads, and even old power grids contain metals, such as copper, iron, and aluminum, which can act as a viable source if repurposed and used on other projects. A study that was performed in Linkoping, Sweden, collected data with GIS on the amount of unused aluminum in the city. The results of the city are summarized in Figure 4. The largest concentration of metals was in the city center and old industrial sector.

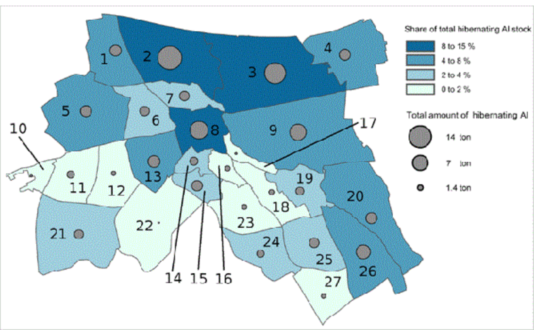

Figure 4: Location of Aluminum in the city of Linkoping [8].

Aside from aluminum, Linkoping's concentration of copper in hibernation stocks is growing as well. Copper cables, a subsurface infrastructure that provides telecommunications and power lines and makes up a majority of the copper source, are becoming outdated due to the more preferred fiber-optic cables. But due to the high costs of city excavation work in Sweden, traditional methods of extracting unused copper cables for the purpose of urban mining is not economically feasible [14]. Technologies such as Kabel-X, a trenchless cable replacement method, make it feasible to extract copper piping while simultaneously installing fiber-optic cables. Kabel-X starts by injecting fluid into the old copper cables. The fluid acts as a lubricant. Once a fiber-optic cable is attached to the existing copper, the copper cable is pulled through while at the same time installing the fiber-optic. Emerging technologies like Kabel-X is encouraging the urban recycling of copper by making upgrading power and telecommunications cables faster and easier.

The third type of urban mining that will be discussed is landfill mining. Landfill mining is the collection of waste found in landfills, which is then gasified and turned into a basalt-type rock, referred to technically as plasma rock. This plasma rock can replace cement, which was an industry that turned out 307 million metric tons of carbon dioxide in 1994. Forming plasma rock from waste not only creates a vitrified cement-substitute, but the plasma gasification process also produces energy in the form of a hydrogen-rich syngas (Waste Management World).

Narrowing the focus of landfill mining on recovering metals, this process of mining can be seen as a prosperous way of retrieving materials in a decade-old landfill. Landfill mining for metals works with conglomerate-type landfills, such as older landfill sites or landfills in countries without adequate metal recycling facilities. Recovery can consist of simply rummaging through piles of municipal solid waste (MSW) with a backhoe, or even recovery of metals through a landfill byproduct known as leachate. Run-off or excess moisture in landfills percolates through waste columns and dissolves heavy metals in the reduced condition, generating leachte. This leachate may be pumped out to be treated or reinjected into the landfill to increase moisture content. Then, metals dissolved in leachate can then be magnetically extracted and collected [15]. This collection of a small amount of metals from waste leachate completes the cycle of reusing all of the metals in different stages of the technosphere. Utilizing urban mining in large-scale facilities or even at home could decrease the demand for virgin metals as well as repurpose old material.

Conclusion

Urban mining is composed of myriad different techniques of recovering scrap material from the technosphere to repurpose and reallocate precious metals to a new, secondary life in active products. This can be accomplished through secondary mining, hibernation mining, and/or landfill mining. Secondary mining entails reprocessing tailings from decades-old metal ore mining operations with modern technology that sports improved effectiveness to recover the previously missed ore. Hibernation mining is recovering metals that are no longer in use but have not been collected in a waste management facility. Abandoned infrastructure and utilities materials are a prime source for urban mining. Lastly, landfill mining exhibits retrieval of metals from landfill collections. The current state of urban mining is small-scale, meaning it is executed on a case-by-case basis rather than by a central, dedicated organization or company. Urban mining is an intriguing and pragmatically-based concept which must be strongly structured within a Circular Economy strategy where products are used for a longer time and more secondary raw materials in production, while creating new growth and jobs [16]. The economics of urban mining is controlled by raw product price, level of technology, labor cost, land availability, degree of recycling, financial resources, waste management principles, government subsidies, waste collection and disposal cost, etc. Urban mining appears to be promising as natural metal reserves dwindles and is a sustainable societal target to work towards in the coming decades.

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