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Editorial

Urban mining: Concepts, terminology, challenges

It is becoming fashionable to "close the loop", "secure resources" and "join the circular economy." Processes such as recycling, resource recovery, urban and landfill mining, waste minimisation and material recovery and concepts such as the circular economy, eco-design, ecological footprinting and zero waste are terms that are being increasingly used by politicians, industrialists and businesses. This signifies that society is starting to catch up with the waste and resource management community in recognising that the resources which are contained in wastes should be recovered and utilised as much as possible. There are multiple reasons for this significant moment, including: concern about increasing global consumption of non-renewable resources, progressive shortages of primary raw materials, reduction of space available for final disposal of wastes, the need for quantity and volume reduction of wastes generated, the need for control of environmental contamination caused by emissions from waste treatment, changing social attitudes towards waste management, etc.

However, not everyone agrees on terminology. Differences in the terminologies used are not merely lexical but refer to the different philosophies and approaches taken in resource recovery from waste, because different viewpoints and weightings are taken and given by different stakeholders to the various technical, economic, political, environmental, social and ethical issues. For the goal of a generally agreed rational resource recovery strategy to be achieved, agreement on terminology is essential.

Excluding terms that are not strongly linked to technical and economic aspects, an attempt is made with Fig. 1 to represent the differences between key definitions.

Landfill Mining represents the activities involved in extracting and processing wastes which have been previously stocked in particular kinds of deposits (municipal landfills, mine tailings, etc.).

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 (Baccini and Brunner, 2012; Lederer et al., 2014). The stocked materials may represent a significant source of resources, with concentrations of elements often comparable to or exceeding natural stocks.

As for natural ores, extraction and processing of anthropogenic stocks is necessary and the generation of an economic benefit is essential. For these reasons, urban mining originally focussed on electrical and electronic wastes (WEEE) which contain relatively high concentrations of expensive metals and rare earth elements.

Resource Recovery includes the energy that can be generated by treating and managing wastes as well as materials recycling.

Materials Recycling aims to transform selected wastes into materials that can be used in the manufacture of new products. Packaging waste (plastics, paper, cans, glass), putrescibles, bottom ash, sewage, exhausted oils, scrap tyres, WEEE (or e-waste), end-of life vehicles etc., are waste flows commonly considered as falling within material recycling strategies. The recovered materials after processing (not necessarily implying an extraction process) are reintroduced in production cycles. Whilst from an etymological point of view, it is clear that urban mining should refer to the exploitation of anthropogenic stocks, today the term is widely used for describing almost any sort of material recycling.

In order to clarify terminology, a definition distinguishing between stock and flow resources, either anthropogenic or natural, may be necessary (Lederer et al., 2014). Annual stocks of materials held in geological deposits, groundwater reservoirs, household and industrial buildings, infrastructure and scrap products may not vary much over time. However, annual flows of materials may change considerably from year to year, depending upon the prevailing economic situation, fashion, technical innovations, etc. Nevertheless, from both anthropogenic stock and flow resources, secondary raw materials are produced (see Fig. 2).

Fig. 1. Graphical representation of the sequential differences in the terms that refer to recovery, recycling and extraction of resources from waste.

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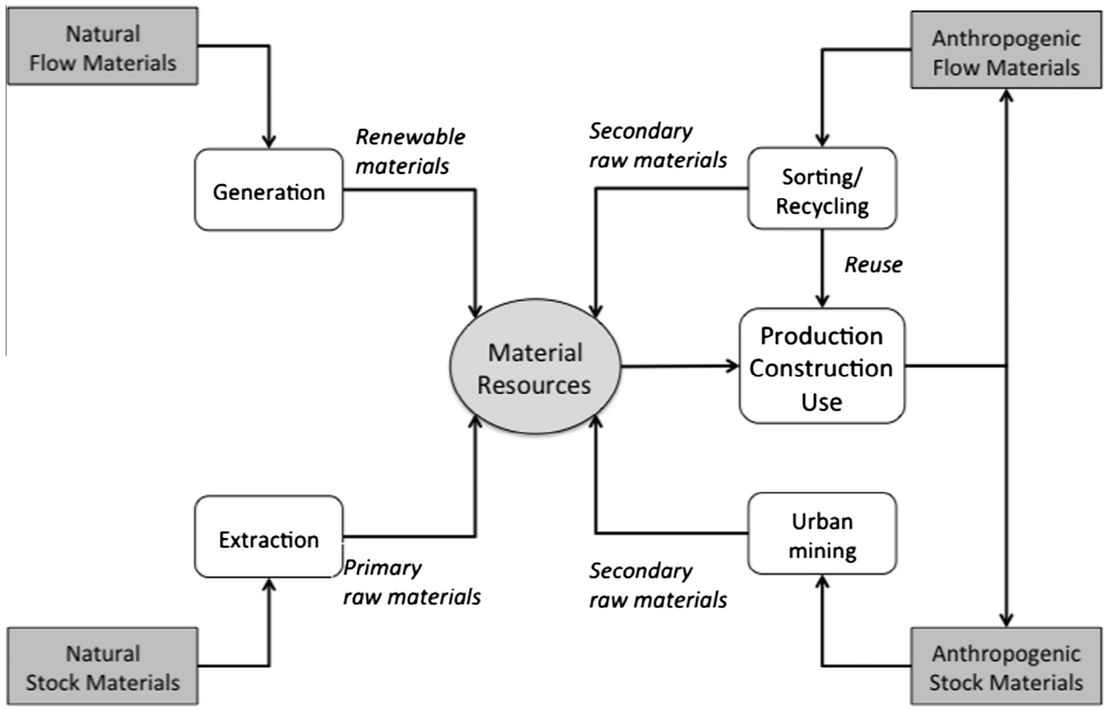

Fig. 2. Scheme for describing the material flows among different kind of sources of material resources, differentiating origin (Natural vs. Anthropogenic) and generation dynamics (Stock vs. Flow).

Given that the storage time of a material cannot really be accurately estimated, the difference between a "stock" and a "flow" resource is very difficult to establish. In addition, processing may not differ at all between a stock and a flow resource (e.g. WEEE vs. bottom ash).

If we use a wider concept of a "mine", considering it as a large "pot" of resources that could be exploited for the benefit of people, then materials recycling and urban mining become synonyms. The extraction and processing of materials during urban mining is strongly based on economic feasibility. However, in some current material recycling strategies, political and social issues may drive recycling practices, sometimes inappropriately, either by following ideologies or by excluding technical options on the basis of negative public opinions. As an example, in the context of material recycling, incineration technologies are sometimes regarded driving the loss of material resources, whilst in an urban mining context they are often a standard mechanism for enhancing the concentration and extraction of given elements (e.g. metal recovery from combustion residues, phosphorous recovery from sewage ash).

Waste Minimisation refers to strategies that aim to prevent waste at source through upstream interventions and includes waste prevention. In terms of production, such strategies often focus on optimizing resource and energy use and lowering toxicity in order to significantly reduce the quantitities, volumes and hazards of waste, either as stock or flow source. In terms of consumption, such strategies aim to stimulate environmentally conscious consumption patterns and consumer responsibility to reduce overall waste generation or prevent waste via avoidance, reduction at source, reuse, etc.

The *Circular Economy* is based on business models which reject the linear "take-make-waste" approach. It aims to: (i) maintain products in use for a longer time by reusing and repairing them, reducing waste generation, and (ii) use more secondary raw materials in production cycles, creating new growth and job opportunities.

In Europe, this concept is still far from being adopted at a legislative level (Bartl, 2015). There are concerns that the circular economy approach may result in "political" interventions that may inappropriately demonise other available technical options which could be virtuously integrated with materials recycling. For example, either incineration or landfilling may play a role in either concentrating elements to be extracted or in providing a final sink for closing the loop of the materials cycle (Cossu, 2012). Additionally, issues such as the control of diffusive emissions generated along the steps of a circular economy (Cossu, 2013, 2014) and the risk of recycling some potentially toxic substances that are contained in products to be recycled (flame retardant, bisphenol, etc.) need to be carefully considered when setting national strategies based on a circular economy.

Urban Mining is an intriguing and pragmatically-based concept which must be strongly structured within a Circular Economy strategy which, for this reason, needs to be further discussed in order to better define within the Technical and Scientific community, terminology, targets, technologies, challenges and opportunities. Keeping this in mind, the IWWG promoted the constitution of a specific Task Group on Urban and Landfill Mining, which had a kick-off meeting during the recently held Sardina Symposium (October 2015).

In addition, since 2012 the IWWG jointly with the Lombardia Region Government, organises, with the scientific support of several international universities, a biennial event, the Symposium on Urban Mining (SUM), which is entirely devoted to these issues.

From the Proceedings of the last SUM (held in Bergamo, Italy, May 2014), a selection of the most interesting papers have been made. After the traditional peer-review process they have been organised, jointly with other submitted contributions to Waste Management, in this Special Issue. Articles dealing with concepts and strategies have been grouped. New concepts such as the DUM (Distinctive Urban Mines) are proposed, case studies dealing with collection of information and collaboration between authorities, research institutions and industry are presented and the role in Urban Mining of the informal sector in emerging economies is illustrated.

Then opportunities offered for recovery of materials from different waste streams are discussed by several Authors. Food waste is one of the streams which is currently receiving strong attention. Extraction of nutrients, production of monomers for bioplastics production and production of animal feed are among the many other possible options. Different kind of separation processes for plastics separation are illustrated. With regards to paper recycling, an overview of the potentially critical substances which have been identified in paper products highlights the need for careful control of the emissions of these substances during the recycling processes. Treatment and disposal of scrap tyres offer a wide range of recycling opportunities. Similarly C&D waste represents a typical anthropogenic stock that presents a huge variety of opportunities (new concrete, aggregates, clay bricks, ceramics). WEEE is the backbone stream in urban mining as they concern critical raw materials of industrial interest. An overview of the recovery potential of rare elements and pretreatment steps of mobile phones is presented. Several contributions, ordered by individual scrap components (PCB, LCD, CRT, batteries) describe the results of investigations into the recovery of precious metals (gold, silver), rare elements (indium, neodymium) and other metals-metalloids. Finally, some contributions discuss national case studies where non-technical issues such as the legislative framework and public perceptions are discussed.

Important evidence is provided for sewage sludge, which is considered the most important source of phosphorous for the future, considering that supplies from natural stock may end, according to some estimates, within a couple of decades.

Examples of urban mining applied to different industrial waste (spent adsorbents, phosphogypsum waste, spent catalysts and ashes) are given.

The Special Issue closes by illustrating the recycling opportunities offerred by landfill mining (LFM). These opportunities are additional to the other advantages which may be offerred by LFM in term of remediation of critical environmental situation, land reuse, better management of land availability for waste disposal, etc.

We hope that this Special Issue on Urban Mining will advance technical knowledge and contribute ideas with respect to the clarification of terminologies that are more widely agreed and utilised.

Now enjoy surfing on the waves of the many interesting articles!

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