CIRCULAR ECONOMY IN THE EXTRACTIVE SECTOR

R. BELLOPEDE*, L. ZICHELLA*, O. BAIETTO*, P. MARINI*

**DIATI Department, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy*

Abstract

The mining and the quarry sector shares the need to enhance the by-products as one of the most effective tools to limit waste production. This has the aim of minimizing the environmental cost of raw materials upstream production chains and to support research and technological innovation, providing opportunities for growth, competitiveness and creation of added value for important sectors.

The exploitation of mines, quarries and the related treatment plants produces large quantities of "tailings". The by-product can be reused for different purposes within the construction supply chain (construction of road embankments, concrete, pre-mixed products, fillers etc.) thanks to their shape, size, physical and petrographic characteristics. For this reason it is essential to enhance the use of by-products of the extractive industry according to the last European regulation and implementing the National ones.

In particular, the main crucial points in extractive industry to be faced and improved applying the Circular Economy approach are:

- mining/quarry tailings.
- sawing sludge from ornamental stone industry.
- waste water from aggregate processing.

The "circular approach" in the extractive industry is possible considering by-products in zero-waste supply chains as valuable secondary raw materials since the very beginning of every operation planning. A change in this vision is needed to sustain, also by means of proper indicator, an even more efficient circular economy.

Keywords: stone sludge, extractive tailings, by-products, circular indicators.

Introduction

The concept of Circular Economy aims to redefine growth by focusing on positive benefits at the society level. It is based on three fundamental principles: designing waste and pollution, keeping products and materials in use and regenerating natural systems (https://www.ellenmacarthurfoundation.org/circular-economy/concept) (MacArthur, E. 2013).

European Commission (2019) developed a guidance document on best practices in the extractive waste management plans according to Circular Economy Action Plan (2019). The guidance document focuses on the prevention or reduction of extractive waste production and its harmfulness and the recovery of extractive waste by means of recycling, reusing or reclaiming such waste. The circular economy action plan established concrete and ambitious actions, with measures covering the whole life cycle: from production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste. Joint

Research Centre (JRC, 2019) produced a report on recovery of critical and other raw materials from mining waste and landfills, answering to the goals of Circular economy Action plan.

Mining and quarry waste is one of the largest waste streams in the EU reaching about 30% of whole waste generated . Mining waste comes from extracting and processing mineral resources. It includes materials such as waste rock and tailings (after the extraction of the valuable mineral). Quarry waste comes from extraction, cutting and finishing of ornamental stone and includes quarry tailings and sawing sludge. The aggregate processing instead produce waste water and silt deriving from their washing process. All these waste can be reused, either within the production chain or re-purposed elsewhere.

Waste rock, for example, is often used as backfill, as landscaping material or as aggregate in road construction, while for example, sludge rich in iron content coming from acid rock drainage treatment –can be sold commercially for use in pigments. Other by-products of the mining and quarry sector can be re-used for making construction materials (such as bricks or cement), resins, glass and glazes, in agroforestry, or as part of the wastewater treatment process (Almeida J. et al. 2020; Sharma U. et al. 2014; Zichella et al. 2020) .

Materials and Methods

The European Commission, in accordance with COM (2018) 29 final, has proposed a selected set of indicators (figure 1) to measure progress towards production-consumption systems in the perspective of the new circular economy (EC) approach.

Figure 1. Set of indicators provided by European Commission; Source: COM (2018) 29 final.

Production and Consumption

- EU self-sufficiency for raw materials (EU figures only)
- Generation of municipal waste per capita
- Generation of waste excluding major mineral wastes per GDP unit
- Generation of waste excluding major mineral wastes per domestic material consumption

Waste Management

- Recycling rate of municipal waste
- Recycling rate of all waste excluding major mineral waste
- Recycling rate of packaging waste by type of packaging
  - Plastic
  - Wood
- Recycling rate of e-waste (low data coverage)
- Recycling of bio-waste (composted/digested municipal waste (in mass unit) over the total population (in number)
- Recovery rate of construction and demolition mineral waste (data for 2010 only)

Secondary raw materials

- Contribution of recycled materials to raw materials demand- End-of-life recycling input rates (data for 2016 only)
- Circular material use rate (data for 2010 only)
- Trade in recyclable raw materials (Imports from EU, import from non-EU, export...)

Competitiveness and innovation

- Private investments, jobs and gross value added related to circular economy sectors
- Patents related to recycling and secondary raw materials

The indicators that will be considered in the following study both at European that at national and regional level will be:

- Waste generation: Total waste generated by mining and quarrying (NACE B in the statistical classification of economic activities in European Committee (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_economic_activities_in_the_European_Commu nity_(NACE)). NACE B activities includes the waste produced by waste treatment activities (sorting, composting, incineration), considering only the non-hazardous waste.

- Recycling rate for the waste management. The waste recycling rate directly monitors the amount of material fed back into the economy, thereby capturing the value of materials as far as possible and reducing losses. The indicator, expressed in percent (%), is the ratio between recycled waste and total waste produced, in weight. Recycled waste is the waste treated sent to recovery operation other than energy recovery and backfilling (for simplification referred to as recycling).

- Contribution of recycled materials to raw materials demand – End of Life recycling input rates for secondary raw materials (EOL_RIR). The indicator measures, the quantity of secondary raw materials used in a manufacturing process. The EOL-RIR does not take into account scrap that originates from manufacturing processes ("new scrap"). The EOL-RIR is determined by several factors as the demand for raw materials, which is increasing for almost all materials and the amount of materials that are available to be recycled. As some materials are embedded in long-life capital goods, they will only be available for recycling in the future.

After an analysis of the data at a European level, a focus on national case study has been made.

Results and Discussion

Mining and quarry waste generation

During the reference period 2006-2014, waste from mining activities increased by 15% reaching a total amount of 590'370'000 (t) in Europe for the year 2018 (Data provided by European Commission CIRCTER final report 2019). Regions of Northern Eastern Europe (Romanian, Bulgaria and Sweden), produced highest quantities of waste resulting from mining and quarrying extraction reflecting local economies highly specialized in mining activities. In 2018 (EUROSTAT website), the situation has not changed. Figure 2 shows a graph with the production quantities in tons of non-hazardous waste derived from mining for the year 2018.

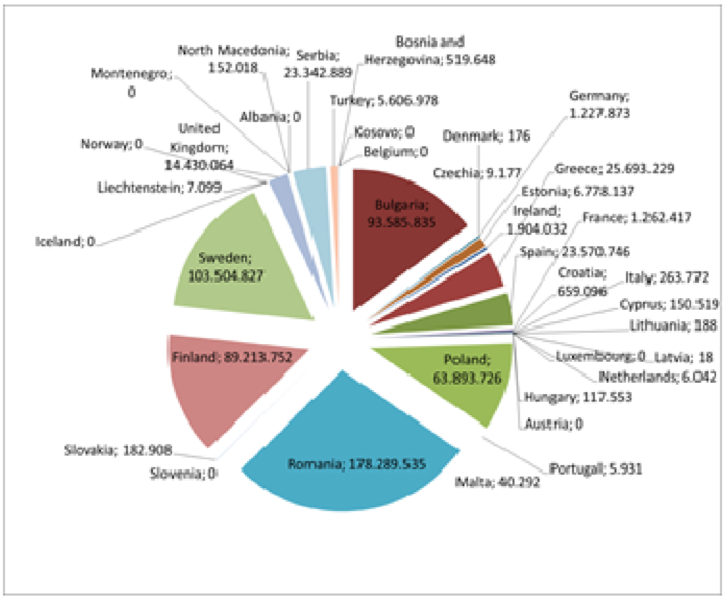

Figure 2. Non hazardous waste generation in mining and quarrying sector for year 2018. Source: Data available on EUROSTAT website

The highest production of non-hazardous waste from extractive sector came from Romania (179’289’535 t) and in Italy only 263’772 t of mining and quarry waste were produced.

The Italian mining and quarry waste generated from Eurostat does not represent the real value obtained analysing the national extractive data. However, analysing data from EUROSTAT on waste treatment and recycling in Italy is possible to observe that only the 15% is landfill disposed. At regional level , table 1 show data of waste generation, recovery and disposal operation (in tons) for quarrying activities in Piedmont. The amount of waste generation, only in Piedmont, in one year is higher than the amount considered from Eurostat analysis. The recovery operation quantities are higher than disposal operation. The disposal operation quantities decrease from 2012 to 2017.

Table 1. Waste generation, recovery and disposal operation tons from quarrying activities (extraction and processing) in Piedmont for the range years 2012-2017. (Source data: ARPA Piedmont data base for extractive sector plan at regional level)

	Piedmont quarrying extraction and processing [t]					
	2012	**2013**	**2014**	**2015**	**2016**	**2017**
waste generation	166.177,2	161.080,3	147.321,2	198.759,8	131.262,5	163.666,4
recovery operation	68.331,4	71.515,8	81.661,1	65.446,9	59.414,9	34.494,8
disposal operation	7.031,2	9.631,2	6.218,5	3.331,2	324,6	684,4

Mining and quarry recycling rate

At European level the Recycling rate of waste from mining and construction are not officially available (Eurostat website) due strong fluctuations related to the different kind of minerals and limited data quality and comparability. At a European level it is difficult to have disaggregated values for different sectors and materials. An analysis based on sectoral and material breakdown is necessary, at National and Regional level. Luciano A. et al. (2018) assert that this analysis is useful for showing material flows between different sectors long and beyond the life cycle of construction products.

At local level in table 3 is represented a focus on recovery operation value (tons) in Piedmont for extraction and processing of ornamental stone (Italian CER CODE: 010102; 010408; 010409; 010410; 010413, which are part of the materials included in the NACE B classification) useful to calculate the recycling rate.

Code and description of recovery operation, interested for quarrying and mining sector in Italy, are represented in table 2.

Table 2. Recovery Operation code and related description, according to Directive 2008/98/EC. * Operation that are not considered recovery to a final product.

Recovery Operation Code	Description
R5	Recycling / reclamation of other inorganic materials
R10	Land treatment resulting in benefit to agriculture or ecological improvement
R11	Use of wastes obtained from any of the operations numbered R1 to R10)
R12*	Exchange of wastes for submission to any of the operations numbered R1 to R11
R13*	Storage of wastes pending any of the operations numbered R1 to R12 (excluding temporary storage, pending collection, on the site where it is produced)

According to Eurostat definition of recycling rate the formulas used for the evaluation are the following:

Recycling rate = (recycled waste/ total waste produced)*100

Piedmont Recycled Rate = ((R5+R10+R11)/Rtot)*100

Table 3. Piedmont recovery operation value (in tons) for CER code: 010102; 010408; 010409; 010410; 010413. (Source data: ARPA Piedmont data base for extractive sector plan at regional level)

year	R5(t)	R10(t)	R11(t)	R12 (t)	R13(t)	Rtot (t)	Recycling rate
2012	16.058	36.362	0	0	18.954	71.374	73.4%
2013	44.199	3.648	0	17	26.248	74.112	64.5%
2014	45.234	4.650	0	14	34.825	84.723	58.8%
2015	45.860	6.100	430	0	16.302	68.692	76.2%
2016	34.015	559	0	0	26.811	61.385	56.3%
2017	22.008	12.512	0	0	2.817	37.337	92.4%

Mining and quarry EOL- RIR

On the basis on the data available on web site of statistical data of European Commission on materials useful for industry, some EOL-RIR macro inidcators can be calculated and analysed (table 4).
It is possible to note :
-for metal coming from mining activities the index is very variable (i.e. Aluminiun, Cobalt, Copper);
-limestone, related to quarry, has a EOL-RIR major than aggregates extraction.

Table 4. EOL_RIR value for different materials for year 2016. Data source: EUROSTAT website modified

Material	EOL_RIR rate (%)
Aggregates - crushed rock, other sands (not silica), pebbles, gravel, bitumen additives	8
Aluminium	12.4
Cobalt	0
Copper	55
Lead	75
Zinc	30.8
Tantalum	1
Limestone	58

Conclusions

This work confirms, as pointed out by Kulczycka J. Et al (2020), that the information and data available on the mining sector are scarce and sometimes inconsistent with the realities of each member country.

Classification of mining and quarrying waste at European level on waste production and management (Eurostat) refer to generic code B. Publications and reports on waste from the extractive sector rely on Eurostat data, which calculate waste from this sector based on the total mass produced or production calculated as kg/ per capita, discriminating between hazardous and not-hazardous waste.

The assessment of proper waste management, in accordance with the concept of circular economy, even through indices such as the recycling rate or the EOL_RIR, may not be reliable if you start from incomplete data. It is necessary that every company has a performance sustainability report with indices related to waste recycling. Indicators per country should then be constructed from the data of individual companies.. In this regard we can refer to the recent "responsible mining index" https://2020.responsibleminingindex.org/en” as a good practice of the mining sector, which lacks, however, the assessment of the recycling rate of waste. This "circular" reporting system of economic and environmental sustainability could also be designed for others extractive sectors as ornamental stones and aggregates quarries, focusing more and more on the use of proer indicator of recycling and reuse of waste.

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