

How the Proper Management of Extractive Waste Can Support the Circular Economy [†]

Petros Maraboutis ^{*}, Niki-Iliana Poulimenou and Elena Nikolaou

Eco-Efficiency Technical & Engineering Ltd., G. Papandreou 60A Dasos Haidariou, 12462 Athens, Greece; n.poulimenou@ecoeficiency.gr (N.-I.P.); el.nikolaou@ecoeficiency.gr (E.N.)

^{*} Correspondence: p.maraboutis@ecoeficiency.gr; Tel.: +30-210-5325110

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Abstract: The Circular Economy begins at the start of a product's life cycle. Throughout the life of a product, both the design phase and the manufacturing processes have an influence on sourcing, resource consumption, and waste creation. Article 5.2 (a) and (b) of the Extractive Waste Directive (2006/21/EC) encompasses waste avoidance or reduction and its harmfulness, as well as encourages the recovery of extractive waste via recycling, reusing, or reclaiming, if this is ecologically in conformity with current environmental regulations and technically feasible. After many years of developing Extractive Waste Management Plans by the sector, substantial knowledge has been established across the entire EU that should enable the identification of best practices that merit more widespread implementation across the extractive sector. Two years ago, the European Commission authorized a study to shed light on the practices that strengthen the spirit of the Circular Economy in the field of mineral extraction and its resulting waste streams, applied technologies, and their environmental impacts. This study is focused on (a) the harmfulness of extractive waste generation and its prevention or reduction, (b) the recovery of extractive waste (by recycling, reusing, or reclaiming), as well as (c) the assurance of short- and long-term safe disposal of extractive waste. It is based on the exchange of information among the Member States and extractive industries associations, as well as contact with EU mining companies to determine the best practices used. The present article focuses on achieving a Circular Economy throughout the whole life cycle of an extractive operation and summarizes eight best practices promoting the Circular Economy followed by companies from the extractive sector.

Keywords: Circular Economy; extractive waste; best practices; waste management plan; Directive 2006/21/EC



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1. Introduction

The Directive 2006/21/EC on the management of waste from extractive industries (EWD) provides a clear legal framework tailored to this specific industry sector. The EWD provides guidance to avoid or limit any adverse effects on the environment and human health caused by management of extractive waste. The EWD also states procedures and measures with regards to the facilities that accommodate the extractive waste not only during the operational phase but also for the after-closure phase. The EWD requires Member States to ensure that the operator develop an Extractive Waste Management Plan (EWMP) for the avoidance of waste production by recycling or recovering and, as a last option, disposal of extractive waste, as part of their permit applications, taking into account the principle of sustainable development [1].

Operators have developed EWMPs as part of permission applications since the EWD went into effect on 1 May 2008, and relevant authorities in the various Member States have been responsible for approving and monitoring its implementation. Articles 5 (2a) and 5 (2b) of the EWD, in particular, set out the EWMP's objectives for preventing or reducing

waste creation or damage, as well as recovering extractive waste by recycling, reusing, or reclaiming, if this is ecologically appropriate. Thus, the EWD, namely, Article 5, expressed the Circular Economy approach as early as 2006. As a result of the many years of experience with EWMPs, in 2019 the Commission authorized a study [1] to aid the discovery of the best practices in EWMPs that contribute to a Circular Economy. The study's goal was to incorporate Circular Economy ideas into EWMPs and promote Circular Economy best practices (BPs) gathered from submitted EWMPs.

2. Waste Management and Circular Economy

Most extractive waste comes from two stages of production: mining (extraction) and mineral processing [2]. Extractive waste production can be avoided, according to the Swedish Guidance for the Handling of Extractive Waste [3], by optimizing mineral extraction and processing while taking into consideration the ore that is mined (developing new knowledge and technologies that address how to increase recycling of waste). By strengthening the role of the first two phases of the mining life cycle (exploration and design) optimization of the extraction and processing can be achieved. Furthermore, the extractive industry manages its operations to guarantee efficient resource utilization by minimizing extractive waste creation, and in most situations, excavated materials that are not ore may be used for in-site uses or as marketable commodities.

A wide range of EWMPs were collected and reviewed with respect to their coverage of the relevant requirements stipulated in Article 5 of the EWD. Specifically, the initial work was mainly focused on the evaluation of the EWMPs according to Articles 5 (2a) and 5 (2b) of the EWD to discover potential techniques for preventing and reducing extractive waste creation, as well as enforcing the recovery of extractive waste by recycling or reuse. This desk research process was enriched by country study visits to exchange information with competent authorities and extractive operators. Further study was carried out in France, Germany, Hungary, Greece, Spain, Sweden, and Finland through these visits. Overall, a total number of 75 factsheets were prepared, based on the collected EWMPs and through the country visits. These factsheets describe practices applied in the extractive sector that are used for the minimization, treatment, recovery, and disposal of extractive waste, taking into account the principles of the Circular Economy and sustainable development.

The data collection investigation and the country visits conducted by the working team revealed several applicable practices that demonstrated the extractive industry's ongoing pursuit of resource-maximizing strategies that may be included in mining and processing operations. The practices mostly relate to:

- Taking into account extractive waste generation and management throughout the design process.
- Filling excavation spaces with extractive material using various procedures and approaches (note: in some MS, excavated materials are considered waste, while in others, they are considered secondary raw material; the goal was to demonstrate strategies that improve the role of the Circular Economy, not to define what waste is or is not or what a by-product is).
- Using waste rock in various types of earthworks on site during active mining operations as landscape material or for outside sale as aggregate.
- Repurposing mined material that would otherwise be discarded in a variety of ways outside of the mine, such as in earthworks and the chemical industry.
- Recycling or reusing historical extractive waste.
- Recycling of wastewater.
- Segregating and reusing topsoil.

The assessed information for the Circular Economy candidate practices was shared with a diverse group of stakeholders, including competent authorities, academia, NGOs, the extractive industry, the Expert Group on Waste, the Raw Materials Supply Group, and the Technical Working Group for the Best Available Techniques Guidance Document on the management of waste from extractive industries, to receive feedback and solicit additional

practices. These experts were also invited to the workshop held in Brussels to discuss and decide which candidate best practices for the Circular Economy could be implemented by the sector.

The “distillation” of practices that may be characterized as “best” and be applicable to all the extractive sectors in Europe is a very difficult process. Each mine is unique, the kind, volume, and properties of extractive waste vary depending on the deposit, geology, and process technology used at the location. Because of the big differences and individual characteristics of each operational location, the criteria for design of an Extractive Waste Management Plan and the selection of the practices that strengthen the Circular Economy should be based on risk assessment. According to ISO 31000:2018 [4], risk assessment is a component of risk management, which is a structured, dynamic, and frequently iterative process for identifying how objectives may be impacted and analyzing risks in terms of consequences and probability before deciding whether additional treatment/management measures are required. As a result, risk-based considerations aid in the objective and scientific framing of environmental and social protection priorities. At the same time, the integration of risk information is useful in developing workable solutions for a country’s and company’s particular contexts. Extractive waste risk assessment is a time-consuming process that might result in a variety of failure situations. Specific site characteristics (such as geology and nearby land use) should always be taken into account. Furthermore, the risk-based considerations will also be presented in the Best Available Techniques Reference Document regarding the management of waste from the extractive industry (MWEI BREF) [5].

The selection of the best practices (BPs) related to the Circular Economy should be based on a systemic life-cycle approach. More specifically, the practices in the field of extractive waste recycling and recovery (potential use) can be applied to the first five basic phases of a mining life cycle (exploration, design, construction, extraction, and processing) and have direct implications for the generation and management of extractive wastes. Effective extractive material management begins with the design phase of a mine, since extractive waste generation can be reduced by optimizing mineral extraction and processing. Depending on the formation that is mined, an optimization of the mineral extraction and processing can be achieved by strengthening the role of the two first steps of the mining life cycle (exploration and design). Developing new strategies and technologies that address how to increase recycling of waste will further reduce the amount of such waste to be disposed.

3. Best Practices Collected from EWMPs Related to Circular Economy

3.1. Effective Exploration and Site Layout

The exploration efforts are fundamental for mining projects. A resource that has been investigated thoroughly facilitates the focus and the effectiveness of the extraction, in order to achieve the EWD’s Article 5.2 (a) and (b) objectives. The extraction may also be optimized with a comprehensive understanding of the mineral deposit, resulting in less extractive waste. Furthermore, preparing ahead of time enhances extraction efficiency while preventing resource sterilization.

As far as the site layout is concerned, the choice between underground and open-pit mining is a critical one during the planning process, and it is made with the Circular Economy in mind in terms of environmental, economic, and social advantages. By considering the technical, economic, and environmental possibilities for placing materials back into the excavation void after extraction, careful planning to reduce the need for materials handling and to allow progressive rehabilitation can help to prevent or reduce waste production and its harmfulness.

3.2. Effective Rock Breaking

A number of factors influence the mining technique that is used. While it is well established that CAPEX (Capital expenditures) and OPEX (operating expenses) in a certain

market context are key elements, today's market climate also requires consideration of resource efficiency and the reduction of extractive waste output. Drill time (energy efficiency), explosive consumption, and waste creation may all be reduced by optimizing the drilling and blasting process and selecting the appropriate extraction equipment. This approach also aids in the effective extraction of ore and the prevention of sterilizing unextracted mineral materials on site.

3.3. Efficient Haulage

A well-designed and maintained haulage network is the key to minimizing haulage hazards and costs and to increasing productivity. A poorly designed and constructed road infrastructure may need repeated maintenance (consumption of raw materials) and may lead to accidents. Each component of the road infrastructure should therefore be adequately addressed at the design stage [6].

3.4. Effective Ore Sorting and Selective Ore Processing

This method is based on the concept that "today's garbage is tomorrow's raw material". Market circumstances affect the material streams created in a mine and the subsequent processing.

3.5. Effective Usage of Excavated Materials

This practice is subdivided into (a) filling excavation voids with excavated material and (b) deriving construction minerals as a source of marketable commodities from extractive waste. These were the most frequently presented practices in the EWMPs that were evaluated. The application of placing extracted materials back into excavation voids was presented as a best practice in many EWMPs submitted to the European Commission because it contributes to the prevention and/or reduction of extractive waste generation, facilitates site remediation, and avoids using up new land for the collection, storage, and disposal of extractive waste. Simultaneously, rather than employing fresh building materials for rehabilitation, the extractive sector makes use of its own waste.

3.6. Effective Management of Topsoil

The use of topsoil is one of the practices specified in the majority of EWMPs. Putting topsoil back in place once the waste facility closes or utilizing topsoil elsewhere (for example, landscaping and re-vegetation sites) may help to reinforce the Circular Economy principles. Therefore, all topsoil removed during construction and mining preparation should be stored in separate places and under circumstances that do not compromise their operation. For the same reason, it is urged that they be reused as soon as possible. The soil heaps will vegetate by free succession during the operating period, which will protect them from erosion and dust production while also helping to maintain their fertility.

3.7. Disposal Planning and Management for Later Recovery

The activity of reprocessing historical extractive waste has a long history and is used for a variety of minerals, energy, metal ores, industrial and building waste. Low-value residues that are easily available in tailings or heaps can undergo recovery operations to produce fully qualified goods such as metals, aggregates, coal (energy products), and so on. Historical extractive waste can now be used as a resource owing to technological advancements, especially when combined with freshly found mineral deposits.

3.8. Effective Monitoring of the Implementation of the EWMPs and Their Review

The EWD emphasized the premise that good design will prevent the development of extractive waste, stimulate its recovery, and minimize short and long-term liabilities beginning with the design phase of a mining site. Indeed, the ultimate objective is to ensure that a closed facility may be abandoned without the need for ongoing monitoring. As a result, keeping frequent records of all the amounts and composition of extractive

trash created at a site will improve decision making about its fate and guarantee that it is managed optimally.

4. Conclusions

The EWD's "ambition" to reduce waste creation whenever possible and to stimulate the recovery of extractive waste by recycling, reusing, or reclaiming, where this is ecologically sound and economically applicable, is reflected in the EWMPs that are now available. Sometimes the ambitions formulated in the EWD, particularly those with respect to achieving more sustainability and a Circular Economy aspect, often go beyond what individual operations would want to achieve. The regulatory requirements and a given economic context are two factors that need to be balanced. Each operation has to be treated individually and best practices, whether from an operational or technical point of view, often cannot be applied uniformly. Thus, for instance, one operation may be able to market a certain fraction of the extracted material as by-product, while another operation extracting the same kind of mineral may not find a market and therefore would need to dispose of it as waste. It must also be noted that the disposal option's (environmental, geotechnical, and health) safety is a critical component that must constantly be evaluated in conjunction with environmental and Circular Economy considerations.

Every five years, the operator reviews and/or amends each Extractive Waste Management Plan, as needed, in case of significant changes to the waste facility's operation or the waste deposited. The objective of the EWMP is to summarize these findings with respect to the actual extractive waste management options to be implemented.

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References

1. Eco-Efficiency Consulting and Engineering Ltd.; WEFalck; Pöyry Finland Oy; CRS Ingeniería; Kertész, B. *Study Supporting the Elaboration of Guidance on Best Practices in the Extractive Waste Management Plans*; By Directorate-General for Environment under Service contract № 070201/2017/768854/ETU/ENV.B.3; Publications Office of the European Union: Luxembourg, 2019.
2. Lèbre, E.; Corder, G.D.; Golev, A. Sustainable practices in the management of mining waste: A focus on the mineral resource. *Miner. Eng.* **2016**, *107*, 34–42. [CrossRef]
3. The Swedish Environmental Protection Agency and the Swedish Geological Survey (SGU) FÖRSLAG TILL STRATEGI FÖR HANTERING AV GRUVAVFALL. Stockholm och Uppsala: Accounting for a Government Mission LETTER 2017-09-14 Cases: NV-03195-16 SGU: 311-888/2016. Available online: <https://www.naturvardsverket.se/upload/miljoarbete-i-samhallet/miljoarbete-i-sverige/regeringsuppdrag/2017/gruvavfall/strategi-forslag-hantering-gruvavfall-20170913.pdf> (accessed on 31 July 2021).
4. ISO. ISO 31000: 2018 Risk Management—Guidelines. 2018. 16p. Available online: <https://www.iso.org/standard/65694.html> (accessed on 12 July 2020).

5. Garbarino, E.; Orveillon, G.; Saveyn, H.G.M.; Barthe, P.; Eder, P. Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries in Accordance with Directive 2006/21/EC.-JRC Science for Policy Report, 2018 EUR 28963 EN 722p. Available online: <http://publications.jrc.ec.europa.eu/repository/handle/JRC109657> (accessed on 16 May 2020).
6. Thompson, R. Mine Haul Road Design and Management Best Practices for Safe and Cost-Efficient Truck Haulage. In Proceedings of the Society for Mining, Metallurgy and Exploration Annual Meeting & Exhibit, Phoenix, AZ, USA, 28 February–3 March 2010; Society for Mining, Metallurgy and Exploration (SME): Littleton, CO, USA, 2010; pp. 1–10.