Key Aspects of Aluminium Value Chain Sustainability in East – Southeast Europe for Red Mud Valorization

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Abstract

Nowadays, at the European scale, a fast-growing need for raw materials is observed. At the same time, the industrial processes implementing the whole raw materials value chain, developed several solutions, aiming at the sector's circular economy initiatives and sustainability reinforcement. In the case of the aluminium industry, there is an increasing need for aluminium products globally, indicating the increasing production trend for this material. Taking into account the principles of circular economy and sustainability that are currently adopted by the European industries, and the European low potential, for instance for rare earth elements, it is important to manage the wastes or by-products generated from the Bayer process. Various studies have been conducted for the valorization of red mud / bauxite residue with significant technological breakthroughs. Nevertheless, the successful valorization of this waste / by-product ought to take into consideration, apart from the technological advances, also the current economic / legislative / environmental / social and other frameworks. For this reason, the current study investigates the abovementioned conditions of four countries in East – Southeast Europe: Bosnia and Herzegovina, Greece, Hungary, and Montenegro. Following the review and analysis of countries' status-quo, the major strengths and obstacles to the sustainable utilization of this commodity are presented, using Strengths, Weaknesses, Opportunities, and Threats or else SWOT Analysis. According to the evaluation, all four countries present significant potential for red mud / bauxite residue valorization. For the two countries, Greece, and Bosnia and Herzegovina, which currently have active aluminium production, long-term valorization solutions appear to be more suitable, while for Montenegro and Hungary, short-term solutions focused on environmental relief could be more appropriate to deal with this emerging issue.

Keywords: Red mud, Bauxite residue, SWOT analysis, Sustainability, Environmental management.

1. Introduction

Red Mud or Bauxite Residue (RM / BR) is the major by-product, generated in the aluminium industry through the leaching of bauxite ores at the Bayer process step. RM disposal is considered a techno-economical problem for the aluminium industry, causing environmental harm. On a global scale, RM disposal is calculated at 2.7 billion tonnes, with an increase of 120 million tonnes per year [1]. Those factors influence the need to explore a better solution.

The increasing global aluminium demand indirectly affects RM generation. It is highlighted that to produce 1 tonne of aluminium, almost 2 tonnes of alumina are needed, generating 1 to 2.5 tonnes of RM / tonne of alumina [2-9]. According to World Mining Data, during the last decade, increasing trends were recorded for aluminium production worldwide (approx. 30 % from 2011 to 2015, and 9 % from 2015 to 2019) [2-7]. By the 2030's, RM production increases are expected, given that the growth of aluminium demand is forecasted to 40 % [11]. For the 2040's, RM production is possible to reach 8 billion tonnes, in line with International Aluminium Institute [12]. The aforementioned play an important role in affecting RM generation.

The effects of increasing RM quantities, in combination with the material's environmental impacts, highlight the need to address this issue. The most common practice of RM handling and management by the aluminium industries was lagoons until the 1980's, recently replaced with dry stacking [13]. Material's high pH values ranging from 10.5 – 12.5, the possible alkali seepage into underground water, the large-scale land uses, the dams' instability, and the alkaline airborne dust impact, enhance this view [14]. The Ajka disaster, which occurred at the aluminium refinery in Hungary in 2010, points out the requirement to implement a more suitable solution. As a result of the dam's collapse, the death of 10 people and chemical burns by the flood, etc. were caused, as well environmental impacts, such as land and water contamination in the adjacent areas [15-16]. As stated by Gelencsér et al. [17]:

"This catastrophic industrial accident has been unprecedented in the 120-year-long history of the Bayer process."

Considering the industrial accident and in an effort to prevent similar catastrophic consequences, the efficient treatment or even valorization of RM / BR is one of the focal points of aluminium industry research and development (R&D) activities. Nevertheless, the stakeholders' management to adopt technical solutions should also encounter other non-technical aspects such as the economic / legislative / environmental / social framework of each involved country. Within this frame, this paper attempts to map the status-quo of the countries in East-Southeast Europe: Bosnia and Herzegovina, Greece, Hungary, and Montenegro. Simultaneously, to ensure the optimal receptiveness for new technological solutions, SWOT tool was used for managing countries potential [18].

SWOT tools have examined the mining sector's sustainability in the Balkans. The Greek SWOT analysis by Nikolaou and Evangelinos dealt with the strengths and challenges faced by the country's Mining and Metal (M&M) industry when adopting environmental management practices [19]. SWOT/Gap analysis was also conducted to examine the mineral raw materials resource efficiency of six East-Southeastern countries within the Balkans for the growth of regions' economies [20]. Focusing on Bulgarian SWOT, it examined the general frame of the country's mining industry and its potential was addressed for additional valorization [21]. In the current study, RIS-RESTORE, funded by the EIT-Raw materials, is under the priority axis of RM valorization for the four countries. Results included the helpful and harmful factors from the internal and external environment. The total SWOT analysis is the cornerstone for the forthcoming roadmaps' creation in RIS-RESTORE, to develop new plans in the final stage (Figure 4).

2. Status-Quo

As a starting point, the geographic distribution of RM / BR sites for Bosnia and Herzegovina (Birac, and Dobro Selo), Montenegro (Podgorica), Hungary (Ajka, Almasfüzíto-AF I-VII, Neszmely-AF VIII, Mosonmagyarovar), and Greece (St. Athanasios) represented in Figure 1. The produced material's quantities are larger than 65 million tonnes, in alignment with the RIS-RESTORE. Moreover, the countries' current aluminium and alumina production were examined compared to the global players (Figure 2).

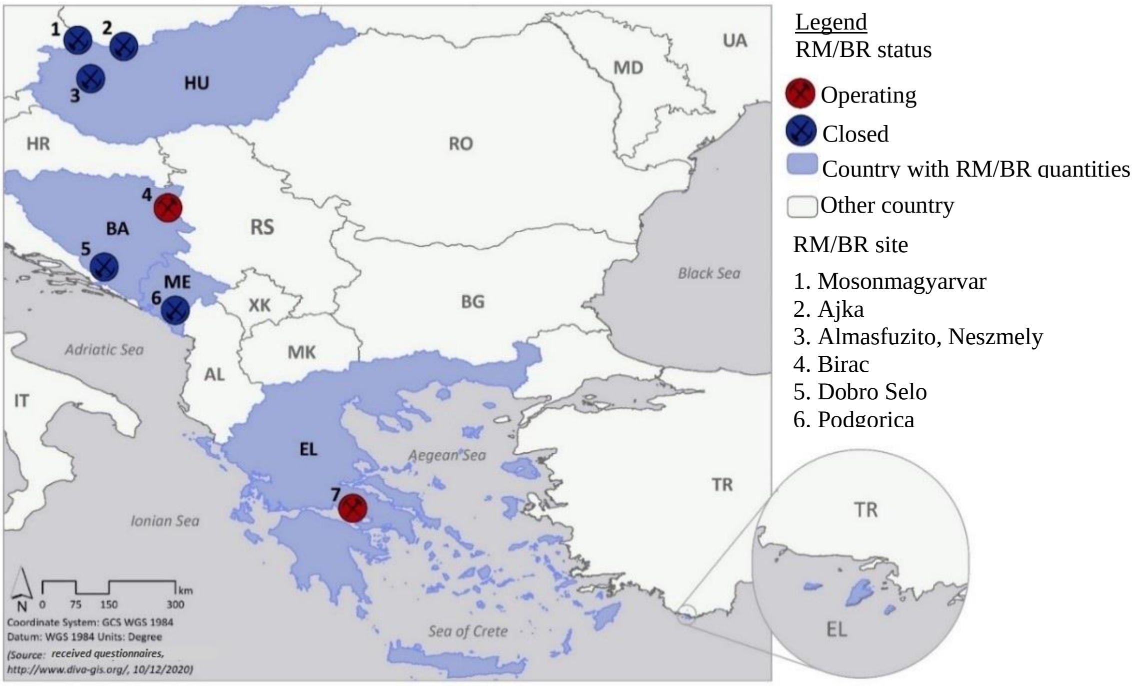

Figure 1. Geographic distribution of RM / BR sites.

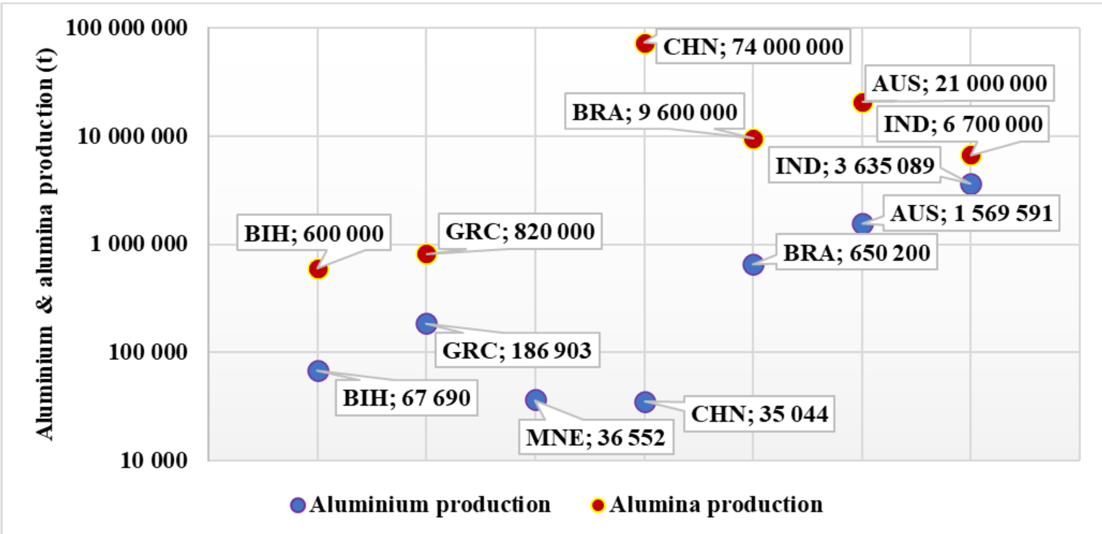

Figure 2. Aluminium and alumina production (t) for 2019 – 2020, East-Southeastern countries compared to the global market. [2-3, 22].

2.1 Greece

Greece is the major, among the other countries, with a vertically integrated Al-value chain incorporating individual stages of companies', i.e. production, manufacturing, etc. [23]. To this aspect, Mytilineos S.A. owns the largest vertically integrated alumina and aluminium production plant in Europe [17]. The aluminium sector contribution to the country's Gross Domestic Product (GDP) with 2.3 % in 2019, the existence of one of the ten sites for primary aluminium production units of Europe, as well as the sector steady classification at the 13th and 28th places for bauxite, and aluminium production, for the latest five years, proves the Al-value chain's significance for the national economy [2-6, 23-24]. Regarding BR reuse, the Greek industrial partner efforts were initialized in 1991, for the recovery of basic metals (e.g. iron for pig iron and wool production, rare earth elements (REEs), scandium, and vanadium extraction for compounds construction) or in the clinker and construction industry [25]. Company's efforts by participating to research programmes for the viable scandium extraction for Sc compounds and Sc-Al alloys' generation at pilot scale, is a potential solution for BR partial valorization [26-27]. At the same time, BR reuse as an additive in cement is a good practice. Given that, the production of cement plants in Greece and abroad achieved utilizing 15 % of the company's filtered BR, generated in 2018 [25].

2.2 Bosnia and Herzegovina

Bosnia and Herzegovina is involved in the Al-value chain, excepting the aluminium production [2, 22, 28]. Alumina d.o.o. Zvornik and Aluminij d.d. Mostar are the owners of the operational Birac and the closed Dobro Selo sites, accordingly [28-29]. Alumina d.o.o. Zvornik is significant for the country's economy, being the only company processing bauxites in the former Yugoslavia, with activities ranging from bauxite mining to alumina processing as well other products, such as aluminosilicates [22, 28, 29]. In 2009, Alumina d.o.o. Zvornik successfully faced problems originating from the electricity costs that affected directly Birac's operations [31]. Similarly, to the above, the large debt for electricity affected Aluminij d.d. Mostar causing its bankruptcy [32]. Focusing on Birac site, company's interest shifted to prioritizing the safety standards in dam management, and the sludge deposition methods on the site [28]. This fact, combined with the existence of both potential space and equipment for future RM processing at the bauxite processing plants, could potentially assist the Birac site further exploitation [28].

2.3 Montenegro

Nowadays, Montenegro covers partially the Al-value chain. The country's economy is based on aluminium exporting activities and the extracted bauxite exported to the alumina factory of Birac in Bosnia and Herzegovina, and from there, it is traded internationally [28, 34-36]. Moreover, the country mainly includes the private company UNIPROM KAP.A.D., the mining company Boksiti – part of the UNIPROM KAP.A.D. – and several factories, as well as the WEG Kolektor, with the major processes of bauxite extraction to aluminium production [28]. Following 1990s Balkan War, many changes were inflicted in Montenegrin value chain, such as the Kombinat Aluminijuma Podgorica's (KAP) fragmentation into parts, which owned the whole Al-value chain till then [28, 35]. Alumina production was conducted till the end of the 2000's, being replaced by the factory for aluminium billets and resulting in RM production exclusively at the two, independent basins of the Podgorica site, as well [28]. Since then, the RM site privatization processes led to the ownership by the WEG Kolektor, with the constant privatizations harming the situation [28].

2.4 Hungary

The Hungarian Al-value chain involves only the processing of secondary aluminium wastes, casting of aluminium wastes, etc., including low amounts of aluminium [28, 37-38]. Concerning primary aluminium production, the limitation of domestic sources of energy caused a modest productivity, despite the substantial bauxite and alumina production [39]. As regards RM generation, the Ajka disaster in 2010 caused the Hungarian alumina plant closure three years later [40]. Next to that, the liquidation of Magyar Aluminium Ltd. (MAL) by the Hungarian government was realized, with the company's alumina assets being acquired by the IC Profil in 2015 [28, 41]. Apart from the alumina plant in Ajka, two more alumina plants operated: one in Mosonmagyarovar (closed since 2002), and one in Almasfuzito (closed since 1997), leading to four RM sites: Mosonmagyarovar, Ajka, Almasfuzito, and Neszmely [28] (Figure 1).

3. Methodology

3.1 SWOT Analysis

SWOT is a well-known strategic planning technique, providing a good grouping device for investigating ideas about the future and the ability to exploit them [42]. It evaluates the current and future potential of a specific topic. This tool used to assess the Strengths, Weaknesses, Opportunities, and Threats to solve a problem. Strengths and Weaknesses (internal factors) are the characteristics adding an advantage or disadvantage, respectively, over the subject, while the Opportunities, and Threats (external factors) are those helpful or harmful features in the greater environment, accordingly [43]. For study's purpose, features of above were considered: advantages such as the simplicity in resolving differentiated problems, the multi-aspect character focusing on many domains, the connectivity and interoperability, providing a holistic view [18, 44]. On the contrary, disadvantages such as the authors' subjectivity, the simplicity (meaning that everyone is capable of implementing it), the difficulty to find out the impact from each element, the complexity and influence among elements, could produce misleading results [18, 43].

3.2 Critical Stages

The scheme summarizes the conducted steps for the SWOT analysis (Figure 3). Firstly, the collection of the necessary information realized, through the completion of dedicated questionnaires by the industrial and / or academic representatives per country of the RIS-RESTORE. Seven (7) key aspects were identified to implement SWOT, and the related questions were included in questionnaires (Figure 3). Despite the initial SWOT was performed per investigated country, the combination of the gathered information, and the identification of the similarities and differences among the areas lead to a final SWOT, as well the overall conclusions.

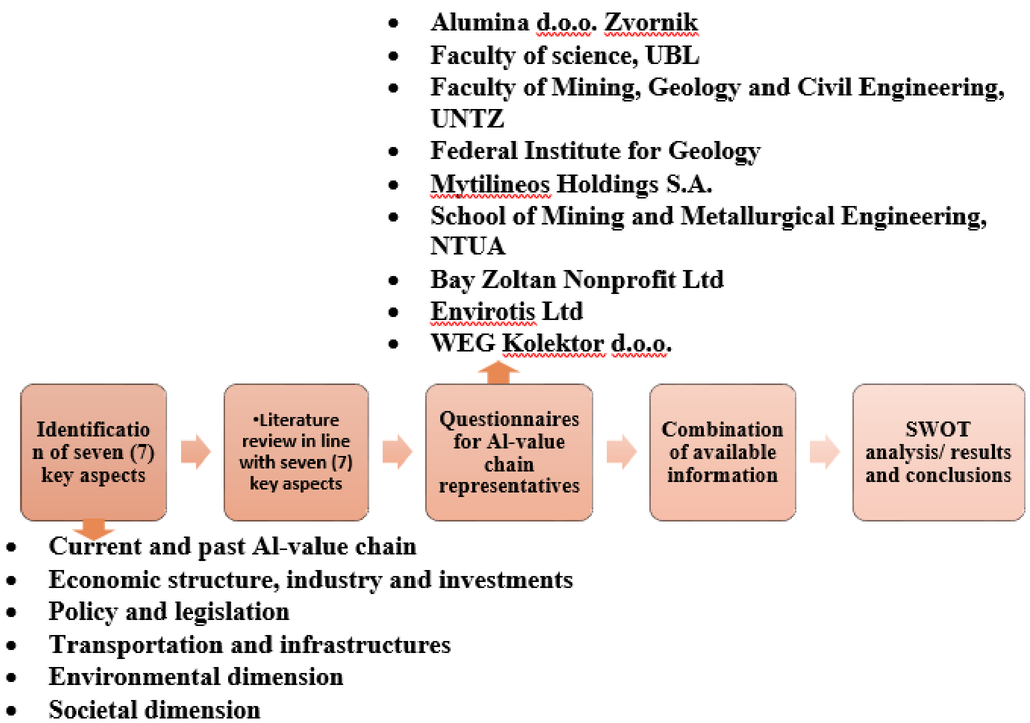

Figure 3. Methodological approach for RM or BR valorization.

4. Results

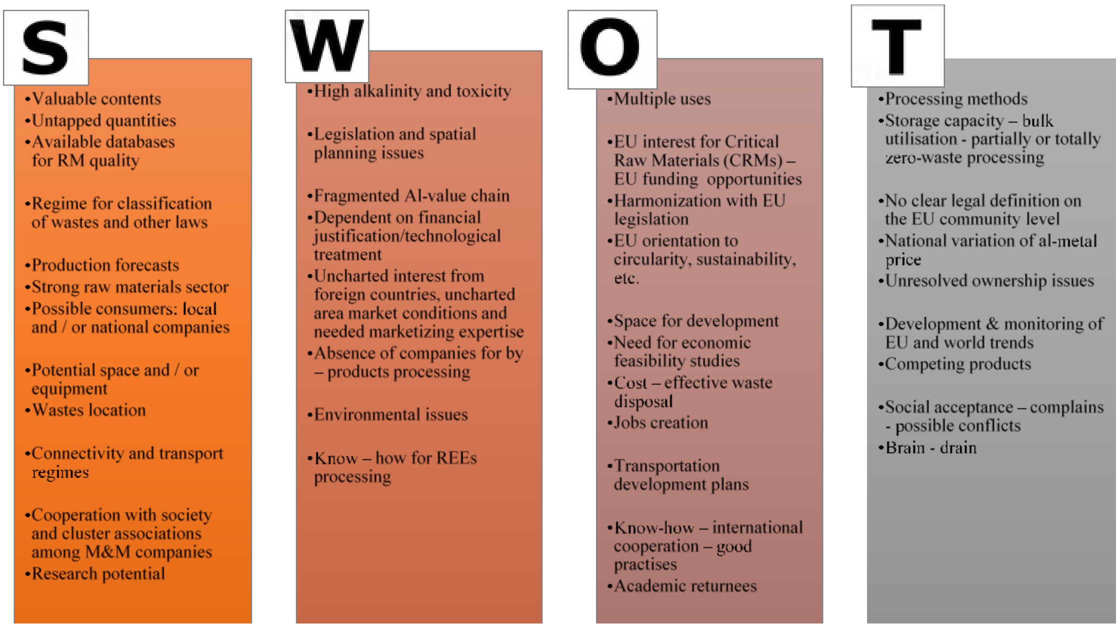

Figure 4. Basic points of SWOT analysis of the four countries in East-Southeast Europe.

The presented scheme briefly shows the major internal and external factors to map the future perspectives for RM / BR valorization (Figure 4). It must be noted that for Greece, RM is currently referred to as BR, due to the initial processing of the produced RM liquid through filtering, and the production of a solid residue. Furthermore, country's characteristics e.g. the vertical integration of Al-value chain, the already developed practice of material's re-usage in clinker, the good results as regards the scandium extraction. The seven parameters (current and past Al-value chain, economic structure, industry and investments, policy and legislation, transportation and infrastructure, environmental, and finally, societal dimension) were evaluated based on the collected data (Figure 3 & 4).

4.1 Internal Environment: Strengths and Weaknesses

As highlighted in RIS-RESTORE project, countries' untapped quantities, and the RM chemical composition appear promising for future reuse [45-47]. As aborementioned, RM can contain non-negligible amounts of iron, aluminium, and titanium, as well as REEs, vanadium, and scandium [27]. Present work for the majority of the sites (St. Athanasios, Dobro Selo, and Podgorica basins, Almasfuzito-AF I-VII, and Ajka) indicates the concentration of iron ranging from 23 – 45 %, aluminium varying from 19 – 24 %, titanium till the value of 10 %, scandium, and vanadium, indicating their potential value [47-48]. Available databases for RM quality from the recent projects (RIS-RESTORE [49], RemovAL [50]) highlight the current efforts and is possible to confirm the initial data / information for implementing a sustainable solution.

The favorable business environment for raw materials activities is examined as a strength for material's future use. Only for 2019, the sector participated in countries' economies approximately from 160 to 1900 MUSD, with the highest corresponding to Greece and the lowest to Montenegro [3]. Potential consumers have expressed their interest to invest in innovative business opportunities, contributing to a business-friendly environment [28, 50]. The expressed interest, and the already developed collaboration among the Greek Al-value chain, and other companies for material reuse (e.g., TITAN, AGET Heracles, Vassiliko Cement Works, [25]) create a supportive climate in the frame of industrial symbiosis [25].

RM can be a potential (or current) environmental threat, and its valorization will help countries to deal with environmental issues of concern. Existing remediation plans of the basins in Podgorica, financed by the World Bank in combination with the interest of RM's potential uses in construction by the University of Montenegro, and the Geological Institute, show the attempts to deal with this environmental issue [28, 51-52]. As for Hungary, recultivation of the lands is a temporary solution [28, 51]. For the last case, the coverage can be easily removed to minimize the amount of potential secondary raw materials (SRMs), given that a sustainable solution is found [46]. The above shows the efforts / interest for RM sites to create a favorable, entrepreneurship situation.

An additional aspect to assist RM valorization is associated with connectivity and transport. According to Mishra and Mohanty, mining activities of primary raw materials are affected by the infrastructure quality [53]. Under the same applies, SRMs activities could be also influenced. Key parameters describing the performance of a country in terms of transportation are Logistics Performance Indices (LPI), calculated in line with: customs / infrastructure / international shipments / logistics competence / tracking and tracing / timeliness. Countries' ranking is as follows: LPI: 31 (Hungary) > 42 (Greece) > 72 (Bosnia and Herzegovina) > 77 (Montenegro) out of the 160 countries being classified, representing a good level of infrastructures quality [54]. As an example, the Greek site's key position is helpful for trading, with the plant shipping almost 100 000 t of BR to four cement plants inside and outside the country in 2019 [55]. Simultaneously, the Bosnian company's connectivity by rail and road with the Adriatic and Danube ports for the Dobro Selo, as well as the Birac site location close to the border with Serbia, will enable trade and transportation [28].

As for the weaknesses, the first one originates from the inherent material properties. The main deterrent factor for safe disposal is high alkalinity due to the caustic soda, causing high pH values (10.5 – 12.5, [46]). Depending on RM origin, material toxicity is proven, due to As, Pb, Cu, Ni, V, Cr naturally occurring radionuclides (226Ra, 238U, 232Th, 40K), etc., which in several contents affect human health, soil, and water qualities [56-57]. As reported in RIS-RESTORE existent heavy metals, e.g., Cd, Cr, and As, ought to be examined in case of valorization [46, 58]. Alumina refineries make efforts to overcome the above by maximizing the recovery of caustic soda, reusing it during the Bayer process [33]. The cost of neutralization will be offset by a reduction in the need for long-term management of the residue deposits, at least to some degree [59]. Following neutralization, it is possible to discharge RM into the natural environment, and enable RM in steel and / or construction industries [33].

Continuing, the non-vertically integrated aluminium production resulted in the fragmentation of the value chain in most of the investigated counties (except Greece) [2, 23-24, 28, 37-38]. All investigated countries have industrial sites but only two of them (located in Greece, and Bosnia and Herzegovina) are actually active [28]. Vertical integration could assist in cost reduction among the different parts of the production processes (including reuse and recycling) [61]. However, the absence of industrial activity making use of by-products, signifies the lack of interest to invest to identify solutions [28]. Summing up, in the fragmented value chain, either there are no industries active in alumina production, therefore no interest in identifying a long-term technical solution, or the fragmented value chain inhibits the upcycling of valorised RM [28].

Moreover, the uncharted interest from foreign countries / areas for market conditions and marketizing expertise can also be considered as barriers [28]. RM exploitation, as any other material, is highly dependent on financial forecasting / planning, business planning and the applied technological treatment [28]. Therefore, if the mapping of potential market and the identification of prospective clients are not performed diligently, as currently in the case of produced RM in the four countries, then the motivation for implementing the high-tech, high-cost RM valorisation solutions is minimized [28].

Additionally, in all four countries there seem to exist certain legislative issues. The main gaps in legislation concerning the usage of SRMs, as recorded considering the Guidance on the classification of waste are the product labeling, as well the transport regime, and the strict requirements for waste transport [25]. On the contrary, the classification from waste to by-products and the simplified European (EU) Commission waste transport legislation could help to create a better business climate and stimulate entrepreneurship. In cases such as Bosnia and Herzegovina, the absence of strategy in spatial planning might also be a barrier to future product exploitation [28]. In parallel, the legislation in the country is complex due to the existence of two separate administrative state structures: Federation of Bosnia and Herzegovina and the Republic of Srpska, an issue resulting to separate laws for treating and regulating land use planning issues within their territorial competencies and creating conflicts, given that the two sites are located on different regimes [28, 61].

Continuing with the disadvantages, the environmental impacts due to RM ought to be mentioned. In the closed Dobro Selo, the increasing RM dust levels in the process of exploitation, transport, and processing / the leakage issues of red sludge on the permeable soils / the problem of processing red sludge, are considerable [28]. In Greece, the past practice was sea disposal, replaced by sludge dewatering and dry stacking them on land [62]. The latter process contributed significantly to the overall cost of alumina production, also resulting in surface and underground water pollution [62]. The environmental concerns and implemented practices caused, in varying degrees, significant friction between the industries and the local society (e.g. reactions after the Ajka accident) [10, 63]. This neutral to negative relationship among industries and societies can become a significant inhibiting parameter for the deployment of new industrial activity, including the valorisation aspect [28].

A technical solution can be viable only if it can generate greater profits than the cost of deployment. For RM valorisation a high added value technical solution that could assist the sustainability of RM valorisation could be the extraction of REEs. Hence, the limited know-how for REE processing, which generally recoreded in Europe, can be considered disadvantageous for the next steps [64]. On the other hand, it is reported that for lower technological and profit solutions such as iron extraction, there are companies to be involved with ironworks, e.g. ArcelorMittal Zenica, Jelsingrad Foundry in Banja Luka of Bosnia and Herzegovina [65]. Those are willing to produce high-alloy steels, containing rare or critical metals [65]. As a result, the low know-how for REEs processing is considered a drawback, suggesting that these elements need to be export-oriented despite the existing paradigms [66].

4.2 External Environment: Opportunities and Threats

The variety of RM potential exploitation solutions, and the raising interest in critical raw materials (CRMs) by Europe, are considered emerging opportunities for establishing viable exploitation routes [66]. In detail, all counties have developed novel methods for treating RM. Among the solutions is the extraction of iron, titanium recovery with sulfuric acid, and REEs extraction, including Sc, Y, Ti, and Ga [13, 67-68]. Considering the iron extraction, RMs are possible to be reused as a low-grade resource of iron, while BR reuse as an additive in the clinker is a good practice [25, 69]. The viable scandium extraction at a pilot scale is a potential solution for BR partial valorization [25]. In the last years, one of the techniques being developed at a pilot scale is the REEs / Sc extraction for scandium compounds and scandium, aluminium alloys' generation. China's major role in REEs exports and Europe's ambition of boosting its productivity are indicative of technique's significance [26, 70].

Waste disposal is assumed as cost-effective by EU standards, and national policies [71]. This fact represents an opportunity, given that it obligates countries to invest in RM valorization techniques, providing incentives to investments [71]. Europe aims at circular economy, proposing wastes management in an environmentally-friendly way and exploiting the valuable elements, despite solutions might be non-sustainable in the linear economy model [72-73]. From this point of view, pre-feasibility studies are required, aiming to identify the most promising idea(s) and discard the unattractive options. The space for development is considered an opportunity, given that there is no competition for this product [28]. Finally, the countries that will develop the best available techniques, will add value to their value chains [28].

Candidate and / or potential candidate countries' legislation will be incorporated into European directives, being under the same regime, and facing the same bottlenecks [74]. The EU perspective on actions related to sustainability, circular economy, and waste management will indirectly assist valorization activities. As explained in the Guidance on classification of wastes, RM from alumina production classified as non-hazardous, originating from naturally occurring material [75]. The categorization of wastes in general according to the statistical waste nomenclature is helpful in setting the frame for future exploitation of SRMs in general, and RM in particular.

Infrastructure development plans are an opportunity, affecting indirectly the closing loop on aluminium. For instance, the Bosnian infrastructure plans including the construction of VC corridor (highway planned to run through Bosnia and Herzegovina) and the development of the highway, providing the connection with countries such as Serbia, and Croatia, is supportive to the transport regime of the Dobro Selo landfill [76].

Simultaneously, the development of research programmes on the EU scale is another positive feature. Projects such as SCALE focus on the extraction of CRMs from BRs to produce Sc compounds and Sc-Al alloys from EU metallurgical by-products, highlighting that BR is considered a by-product resource-efficient [27]. Projects are opportunities to support / exchange the required technical experience to make progress with the re-evaluation of historical mining sites / the recovery of RM / BR from historical extractive wastes. Through research and projects, know-how, and good practices, will result in industrial development concerning SRMs such as red sludge, supported by international cooperation. As for the capacity building, BR valorization requires technical know-how. Efforts were recorded by the Greek company via participation in projects addressing the issue of capacity development.

As regards the threats, the processing methods in combination with the needed storage capacity can threaten the development of this market. Residues' processing characterized as complicated, demanding space and / or equipment [28]. Partial waste processing is not suggested causing challenges to manage the space and / or equipment [28]. As a result, the recommended practise ought to be zero or near zero waste processes [28].

Global economic effects due to the Covid-19 pandemic, in combination with the emerging situation of the Russian-Ukrainian war, affect countries' economic stability and Al-metal prices [77-79]. Simultaneously, the national variation of Al-metal price indirectly affects RM / BR quantities to be disposed / reused [80]. Competing products and their low purchase prices, as for the case of pig iron with the iron ore exploitation being cheap, are threats to RMs' future valorization [80]. Developed business plans ought to cover the mentioned parameter for industrial growth.

The unclear legal definition about SRMs at EU community level is opposed to materials' exploitation [56, 81]. For example, in Greece, the missing discrimination between the terms of

RM / BR in the EC waste classification can be considered a significant threat to future valorization, since the regime for transportation and use is unclear [25].

Social acceptance (or rather lack of acceptance) is also deemed a potential threat for the Al-value chain, indirectly affecting the valorization of by-products. The Ajka accident had social costs, with several people injured, and others being dead, while several of them expressed their worries / scare / anger about this difficult situation, as aforementioned [10, 63]. In Bosnia and Herzegovina, civic associations e.g. the Eco-Forum Zenica, and Non-Governmental Associations, are currently active and express complaints about mining [82]. At the same time, it was observed a need to country-level data and insights for the Social License to Operate (83).

Finally, RM exploitation requires skilled and specialized scientists and engineers. That workforce will be able to tackle the barriers and develop environmentally friendly recovery to close the loops. Brain-Drain phenomenon recorded in all Eastern EU countries, is a risk for future activities, causing migration and lack of the needed workforce: the youngest, and the high-skilled people. In the majority of countries, the increasing rates of unemployment, the unfavorable, current economic situation, and the lack of policy focus on promoting excellence and on providing opportunities for advancement, discourage the Brain-Gain [84].

5. Conclusions and Discussion

The alternative management of the red mud residue based on exploitation / valorization can potentially contribute to the development of the aluminium industry in the countries of East - Southeastern Europe, with several valorization solutions having potentially an economic interest. In this aspect, non-technical issues are expected to play a fundamental role. Under SWOT analysis, a set of conclusions can be drawn:

Apart from material technical characteristics, the method of processing and the material classification quantities-to-be-valorized refer to historical or currently produced tailings should also be focused on materials quantities-to-be-valorized based on historical or currently produced tailings. The proposed distinction significantly affects the business model / plan for the valorization per case. Countries such as Greece and Bosnia and Herzegovina with active and constant alumina production industries, resulting to constant RM / BR production should be directed to long-term solutions / models. On the other hand, for Hungary and Montenegro, with fragmented Al-value chain, in which alumina production is no longer operative, a short-term valorization model would be more fitting aiming to efficient, environmental management.
Considering the obtainable quantitative / qualitative information, the examined East-Southeast EU countries include RM / BR potential. At the same time, factors such as material's alkalinity / toxicity / processing methods and sites storage capacity ought to be reviewed, granting the available, exploitation solutions to be used. As for the economic environment, the global, currently developed economic situation affect Al-metal prices. The advantageous business frame, including the potential consumers, could be the answer to the present space for development in the global market for this product. On the contrary, the low values regarding RM / BR competing products are an area to be considered by the potential consumers of local and / or national companies, with prefeasibility studies being the key to material's forthcoming exploitation.

As for legacy, the outlined gaps such as the absence of a clear legal definition for BRs, are drawbacks in the current classification of waste. EU perspective, which among the others also emphasizes countries' CRMs potential, can be helpful for valorization. As for the interest for environmental issues by the authorities, it could balance the previous wrong practices during disposal methods. Infrastructures development and capacity building perspectives should respond to the materials' valorization challenges.

In conclusion, the specification of the non-technical features for material valorization has a significance on the required, sustainable management strategies. Roadmaps creation is going to promote decision-making process, taking into consideration the referred non-technical characteristics, as well.

Acknowledgments

This research was implemented frame of RIS-RESTORE in the project (Project Number: 19269), funded by EIT RawMaterials, initiated, and funded by the European Institute of Innovation and Technology (EIT). The authors would like to thank for their support, and contribution in the evaluation of the aluminium RM sector, the team of the University of Zagreb, coordinator of the Project, and the Task Partners from the Alumina d.o.o. Zvornik, the University of Banja Luka, the University of Tuzla, the Federal Institute for Geology, the Mytilineos Holdings S.A., the Bay Zoltan Nonprofit Ltd., the Envirotis Ltd., and the WEG Kolektor d.o.o. This work was reviewed from Michalis Samouhos and Chrysa Politi from the Laboratory of Metallurgy of the National Technical University of Athens and the authors would like to thank them. The included map has been carried out with the usage of ArcGIS 10.5.1.

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