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STUDY ON THE BATTERY CHEMICAL ELEMENTS RECYCLING POSSIBILITIES

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Abstract

The recycling of car batteries has become a crucial issue in the current context of the transition to electric vehicles. The authors summarise the most critical chemical elements mining and use trends in battery production. Additionally, the issue of the distribution of cobalt, a key material in battery manufacturing, raises ethical and environmental concerns, particularly regarding mining practices in the Democratic Republic of Congo. While traditional lead-acid battery recycling methods are well understood and applied, the appearance of lithium-ion batteries poses new challenges. Indeed, the recycling of lithium batteries presents technical and economic difficulties due to the complexity of the processes and the associated costs. The authors present battery recycling options. Therefore, sustainable recycling practices must be highlighted to ensure the preservation of the environment and promote a circular economy. This research underscores the urgent need for sustainable recycling practices in the context of battery production and use trends.

Keywords*:* *battery, electric car, recycling, cobalt, lithium-ion, lead.*

Introduction

In the past decades, the carbon footprint of the industrial area and personal life has increased significantly [1]. Between the carbon emission source, transportation is a relevant area [2]. The European Union aims to cut net carbon dioxide emissions from the 1990 year level to 55% below by 2030 [3]. The members of the EU want to achieve this goal by using renewable energy sources. The energy is derived from natural sources and can be replenished at a higher rate than consumed energy, called renewable energy. Clean energy from renewable sources can be a suitable way to decrease carbon dioxide emissions.

It can find research results that discuss decreased carbon dioxide emissions by alternative fuels or electric vehicles [4]. All electric engines use battery energy since vehicles are zero-emission because they don't produce poisonous pollution and don't damage nature and the environment [5]. The battery technology increases intensively. It can find several kinds of accumulators [6]. The materials used in the accumulator are lead-acid, Li-Co, Ni-Cd, Ni-MH, Li-ion, Li-Polymer, etc. [6]. The most common are the lead-acid and the Li-Co accumulators. Lead-acid battery manufacturing is almost standard, and the recycling of the used materials is available

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[7]. The manufacturing and recycling of other batteries are under research [8-12]. Nowadays, batteries include lithium, cobalt, manganese, iron and phosphate.

The reduction of carbon emissions can be further increased with electric cars if carbon emissions are also reduced during battery manufacturing. The rare and unique metals such as lithium and cobalt used in battery manufacturing cannot be found in small quantities. They are mined in Europe, so they are transported from far away by ships with high carbon emissions [8]. The lack of suitable materials causes serious supply disruptions in car manufacturing and transport. In the last year, a significant problem was the global chip shortage, which caused a major crisis for the automotive industry. The available materials for battery manufacturing in Europe must be ensured to prevent a crisis in the battery market. Hungary has significant battery manufacturing capacity for electric car production. Also, an important issue of sustainability is the recycling of used or reduced-performance batteries. The typical recycling types for the recovery of Li-ion battery active materials are the direct, pyrometallurgical and hydrometallurgical recycling methods.

The generated global e-waste in 2022 was 62 billion kg (half of the waste materials are metals), and the projection and future scenarios for 2030 will be 82 billion kg of the generated e-waste [13]. The recycling rate and the global e-waste collection in our age can't keep pace with this growing digital transformation, while resources are becoming increasingly scarce at the same time. In Europe, there is no standard or regulation for the recycling requirements of Li-ion batteries yet.

Nowadays, at least 100 kWh of power is required to cover the wanted distances, which can be achieved with a battery of 800 - 1325 kg. The solution for sustainable digital transformation is recycling e-waste materials [8]. In this research, the authors introduced some of the available battery recycling processes to highlight the importance and possibility of this solution and reinforce the importance of research in this area [14-18].

Materials of the Batteries

The necessary components of a Li-ion cell include a cathode, anode, electrolyte, and separator. The Li-ion cells' names are defined on the base of the cathode material. The most applied materials for the cathode are lithium manganese oxide (LMO), lithium iron phosphate (LFP), lithium cobalt oxide (LCO) and lithium nickel manganese cobalt oxide (NMC) [8]. The batteries contain graphite or graphene as an anode material. For the battery packaging, several materials like battery tabs, prismatic cans, aluminium laminate film, lids, and cases are used. It also contains an electrolyte (lithium hexafluorophosphate) and battery-grade lithium. In lithium-ion batteries, a high-viscosity binder solution was developed for this battery application. It also includes anode foils (copper), cathode foils (aluminium) and some scarce elements such as Mn, Co, and Ni [19].

Lithium as a Primary Material for the Batteries

Lithium is an essential raw material in electric vehicle battery manufacturing. In Portugal, Europe has only one lithium mine, and imports cover most of its needs. About 87% of the unrefined lithium available to the EU comes from Australia, and the rest comes from Portugal. Australia, Chile, and China have significant lithium mining industries [20]. Lithium mining is highly damaging to the environment, so many countries, even if they can find lithium, do not support its mining. Fig. 1. shows the ranking of lithium mining in the world in 2022. The ranking of lithium mining can change because it was discovered in 2023 at a big lithium site in Nevada, US. The global lithium production was more than 180,000 tons in 2023 [21, 22]. China's lithium mining is insignificant, accounting for 14 % of the world's lithium reserves, but 50 % of the world's lithium processing was done in China.

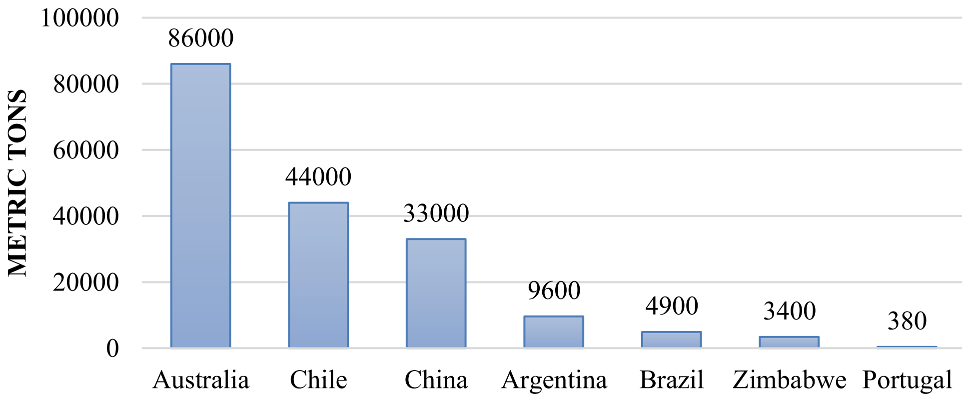

Fig. 1. Lithium mining by country in 2023 (Statista) [20]

Cobalt, the Component of the Battery

The cobalt issue is crucial in the current context of the battery industry [23]. Cobalt is essential in manufacturing lithium-ion batteries, which are widely used in electric cars and electronic devices. According to the Cobalt Institute, cobalt is Earth's 32nd most common element, meaning it isn't scarce [24]. Between the cobalt mining regions, the Democratic Republic of the Congo is the largest producer. The dominant cobalt producer of the world's is the Democratic Republic of Congo (DRC), accounting for roughly 74 % of global production [23, 24]. On the cobalt market, this country has dominated as the top metal producer for some time and is likely to remain determinative for the following years. Fig. 2. shows the ranking of cobalt mining in the world in 2023. The global cobalt production was 219 600 tons in 2023 [24]. Cobalt mining is associated with environmental problems such as water and soil pollution and deforestation.

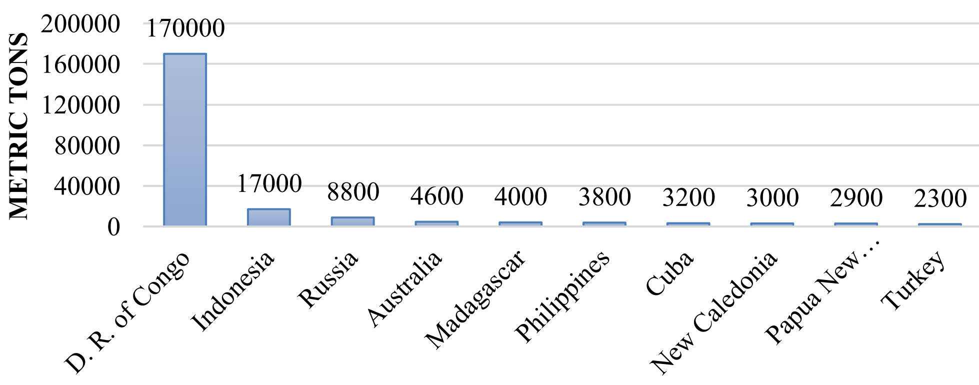

Fig. 2. Cobalt Mining by country in 2023 (Statista) [23]

Copper is the Component of the Battery

Copper is a well-known metal in electronic device production. Copper has good physical and mechanical properties, such as good electronic and thermal conductivity, high toughness, and good corrosion resistance. These properties are the reason for its broad applicability. Copper is an old material in the life of humanity. Copper mining and processing have grown significantly in the last decade [25]. The global copper mining production reached 18,617 million tons in 2023 [26]. The biggest copper producer is Chile, which produces 27% of the world's production. Fig. 3. shows the ranking of copper mining in the world in 2023.

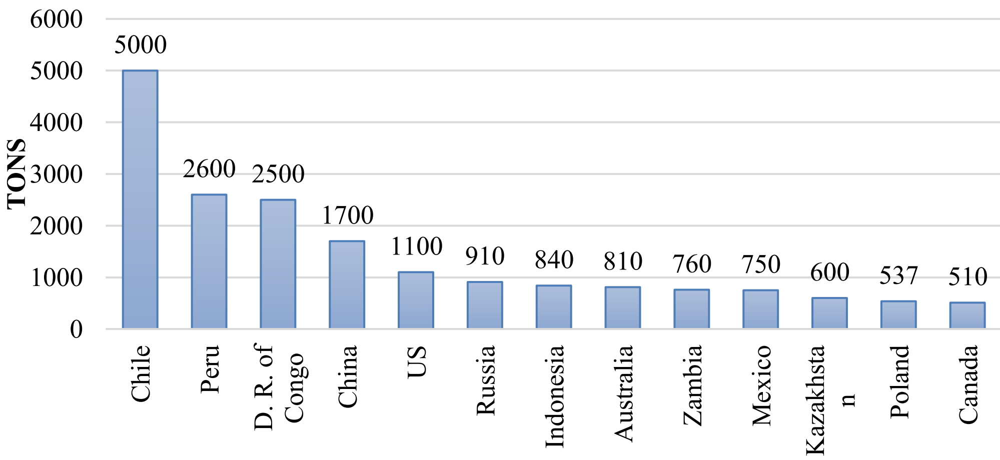

Fig. 3. Copper mining by country in 2023 (Statista) [26]

Nickel is the Component of the Battery

Nickel is a malleable and ductile metal with good conductivity of electricity and heat. Indonesia, Indonesia, Philippines, Russia, New Caledonia, and Australia produced the largest nickel ore in 2023 [27]. Global nickel mining production as of 2023 was 337,23 million tons [27]. Fig. 4. shows the ranking of nickel mining in the world in 2023.

Battery Recycling, Recycling of traditional battery

Traditional battery recycling, such as lead-acid batteries, relies on well-established processes to recover and reuse components from used batteries. These methods typically involve collecting used batteries, disassembling them to separate components such as lead, plastic and acid, and then processing these materials to reintegrate them into new products [28]. Traditional battery recycling provides significant environmental benefits by reducing toxic waste and conserving natural resources while contributing to the sustainability of the battery industry.

The manufacturing of the lead-acid battery uses several materials. Fig. 5 shows the flowchart of the battery recycling process. In the battery process, the major components are lead, which can be metallic, oxide, sulphate and sulphuric acid.

For the reduction of SO_2 emissions, the separated paste needs to be treated with an alkali solution such as NaOH or Na_2CO_3 to react with the $PbSO_4$. The reaction chemical process in the following reactions (1),(2) [29]:

$$PbSO_4 + 2NaOH \rightarrow Pb(OH)_2 + Na_2SO_4 \quad (1)$$

$$PbSO_4 + Na_2CO_3 \rightarrow PbCO_3 + Na_2SO_4 \quad (2)$$

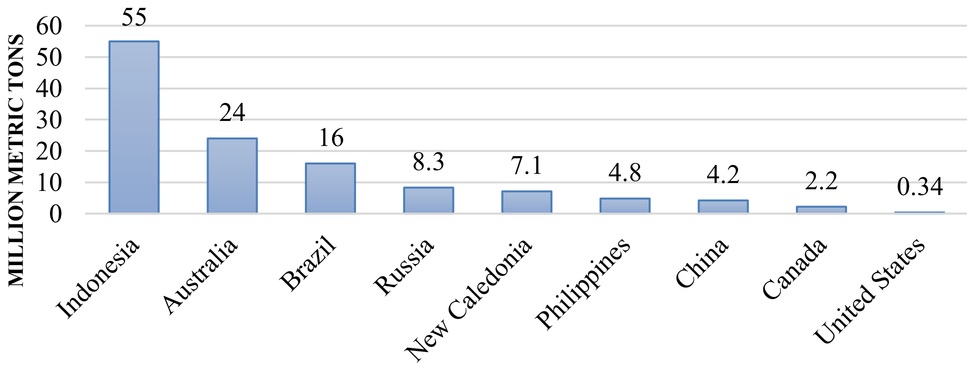

Fig. 4. Nickel mining by country in 2023 (Statista) [27]

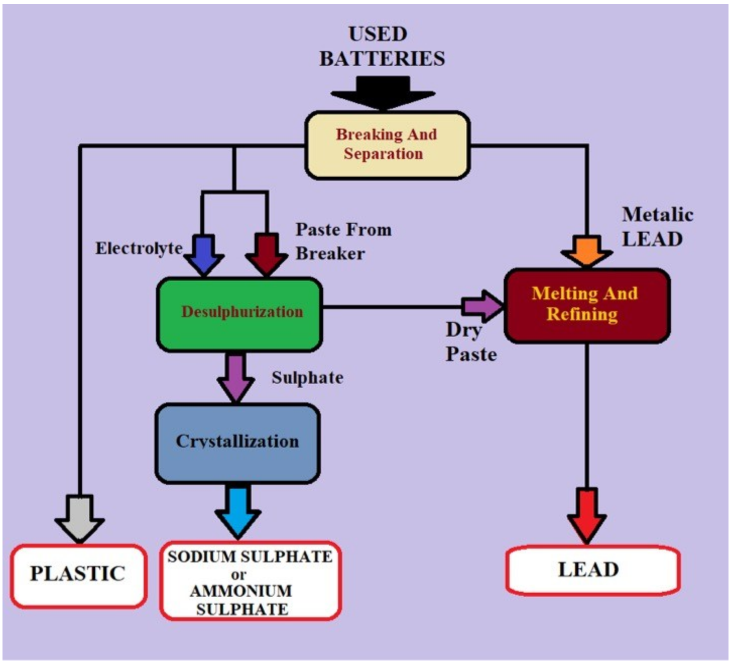

Fig. 5. Flow chart of the Lead-Acid battery recycling

The lead and the polypropylene are recyclable materials. The recycling process needs to separate, value, and stabilize these products from others.

The collection and storage of lead batteries and the recycling and neutralization of hazardous components are solved. Even though the use of lead in several areas of the industry (food industry, vehicle industry, etc.) is forbidden, the world's annual lead mining is significant. Mining lead ore (galena PbS) causes significant environmental damage, which recycling can reduce to a small extent.

Recycling of Lithium-ion battery

Lithium-ion battery recycling represents a major advancement in the automotive industry, providing more sustainable and environmentally friendly solutions. With the rise of this technology, it has become crucial to develop efficient methods to recover and reuse the valuable materials contained in these batteries.

Lithium-ion batteries are complex and contain several special metals, such as lithium, cobalt, and nickel, which require sophisticated recycling processes to be efficiently recovered. Currently, it is challenging to adapt recycling technologies for all kinds of lithium-ion batteries, making the process more complex and expensive. Additionally, the collection, transportation and processing of used batteries could be better nowadays. Currently, the diversity of electrical car batteries in terms of chemical composition and structure is very high. Prof. Ghica and his colleagues at the National University of Science and Technology Bucharest developed a recycling technology that can be introduced into industrial practice [14, 15, 17].

The recycling process includes the following steps (Fig. 6.):

1. Manual dismantling of the battery.
2. Discharging the battery in a salt solution for one hour.
3. Manually dismantle and remove the cathode materials from the aluminium foil (ultrasonic cleaning made in an acidic solution, lactic acid).
4. The ultrasonic cleaning was made at 20 - 80ºC temperature during 1-60 min.
5. Analyzing the filtrate solution.

The introduced process is helpful for recovering aluminium foil, copper foil, and the filtrate solution. The filtrate solution includes the main compounds are lithium-based layered oxides – $LiCoO_2$ or $LiNiO_2$ (during the charging process, nickel dioxide is formed), establishing the solid solution ($LiCoxNi_1$-xO_2) in which cobalt ions are substituted for nickel ions. It can find other research results for metal recovery from spent Li-ion batteries [16-18]. The different separation processes focus on recycling metal materials from batteries. Unfortunately, the processes include manual components. During manual separation, the worker's health needs to be cared for because some of the battery's components are poisoned. This is probably the reason for the low recycling quantity of the batteries.

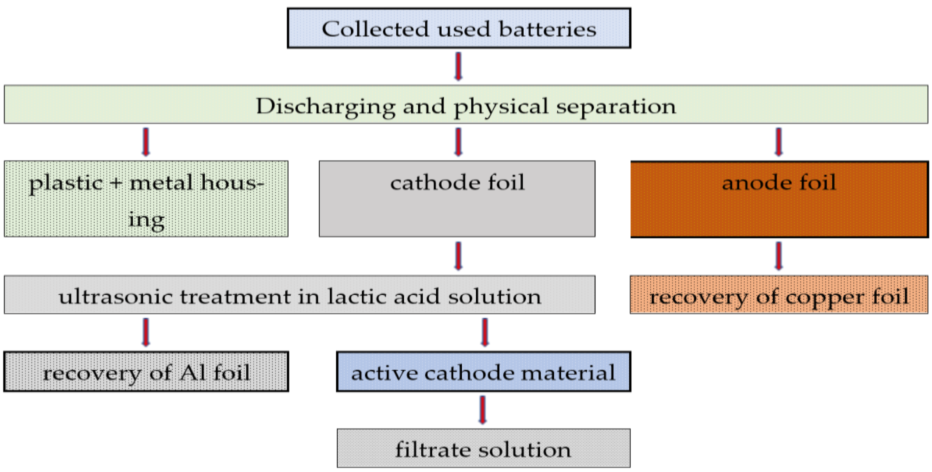

Fig. 6. Flow chart of the separation process of the cathode material

It can find other solutions in the published battery recycling methods, such as the solutions shown by Li J. et al. and Xin Y. et al. [30, 31].

Conclusions

It can be concluded that Li-ion batteries nowadays are the most common e-energy source. The manufacturing of the batteries is increasing rapidly. The availability of metals required for battery production is limited. The country with the largest cobalt mining industry is the Democratic Republic of Congo. This single country provides 80% of the cobalt used in the world's battery production. It can be seen as a strong dependence on mining the battery's basic metals. The number of Li-ion batteries that reach the end of life is high. The recycling of waste batteries is a key manufacturing process in the sustainable cycle of batteries.

Based on this study, in accordance with the e-waste monitoring study [32], we can conclude that battery recycling is a key point in sustainable e-mobility.

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