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OVERVIEW ON THE MINING ENVIRONMENTAL IMPACT OF ELECTRIC VEHICLES BATTERIES PRODUCTION

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Abstract: *The Electric Vehicles (EVs) have evolved to become an important transport mean with an electric battery that contribute to the fuel gas emissions elimination, despite this colossal advantage, the double-edged effect has been observed. The dominant EVs Batteries in the market are the Lithium-ion batteries (LIB) that made of combined set of elements which differ in weight from each LIB type to another. Different LIB types are NCA, LMO, NMC, LCO, and LFP, the common elements that are utilized in all LIB battery's types are Cobalt, Copper, Lithium, Manganese, Nickel, and Graphite. The current study explores the approximate tonnes of rock that should be mined in order to extract the required amount of minerals for a typical LIB production. The study shows that production of single NCA, LMO, NMC, LCO, and LFP battery types require an average mining of 55-369 tonnes, 18-120 tonnes, 91- 607 tonnes, 115-773 tonnes, 12-83 tonnes respectively. The estimated tonnes of mined rocks needed to cover the LIBs production in 2023 were 7484 megatonnes, considering the number of EVs sold in this year along with LIBs used for these vehicles manufacturing. The mining of these minerals has a negative impact on the environment, this study delineates the social and environmental impact of recent extensive mining activities that have been implemented in the last few years to cover the growing market demand of the Electric Batteries minerals, including an overview of the mining effect on the water and air pollution, increased greenhouse gas emissions and associated human right abuses.*
Keywords: *Electric Vehicles batteries, Lithium-ion batteries, Ore grade, Average mining for LIBs production, LIBs production in 2023, Environmental mining impact*

1. Introduction

Throughout the last few decades, transport industry has found to have the largest impact on environment by causing air pollution with more than 25% of the world's greenhouse gas emission as a result of fossil energy used in this sector [1]. Road transport is the reason for more than 70% of these emissions [2], [3]. To overcome the negative impact of road transport, a noticeable growth in the electric vehicles (EV) market has started to cope up with the Net Zero Emissions scenario (NZE) by 2050 [4]. Statistics are reflecting an immense growth in the EV sales in the last ten years [5], from 0.2 million cars sold in 2014 to 16.6 million cars sold in 2024 and is expected to reach 17 million by the end of 2024, the remarkable rise in sales has been spotted in the last four years with an addition 14.4 million cars sold compared to the 2.2 million cars that are sold in 2019 [6] (Figure 1). The growing demand of the EVs batteries to power the newly EVs has been reflected on providing the required material (raw minerals) that are used for the batteries manufacturing, the cells in the EVs batteries are roughly composed of 185 Kg of minerals per battery [7] with an estimated number of 27 million EVs that are expected to be on the road by 2027 [8], extracting a sufficient quantity of minerals to operate these EVs with its all types (BEV, HEV, and PHEV) will be a matter of urgency.

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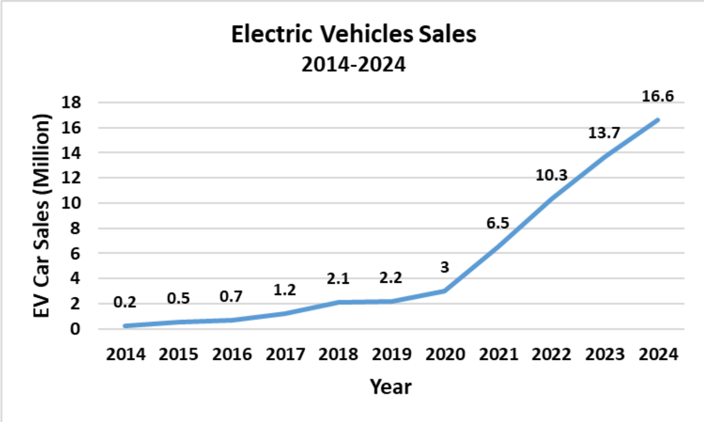

Fig.1. Electric Vehicles Sales - 2014-2024, modified after (Electric Vehicles – IEA) [6]

The expanding in EV production has encouraged the electric batteries industry with its different types, numerous battery types have been proposed to the market such as 1) Battery Electric Vehicle (BEV) which uses only battery to provide electricity and power the vehicle, 2) Hybrid Electric Vehicle (HEV) that gather both the Internal Combustion Engine (ICE) and the battery in its drivetrain and 3) Plug-in Hybrid Electric Vehicle (PHEV) that is typically like the HEV but can be charged through charger [9], each with its own merits and demerits. The BEV is considered as the most common type nowadays due to its own benefits, including simplicity in manufacturing, lower cost in power expenses and car maintenance, zero emissions of the harmful Co2 and No2 gases and efficiency [10].

There are several types of BEV batteries: Lead-acid battery, Nickel Cadmium battery (Ni-Cd), Nickel metal hydride battery (NIMH), and Lithium-ion battery (LIB) [11]. Lead-acid battery is the earliest rechargeable battery in the market that was invented in 1859. The composition of this battery depends on lead plates combined with Sulfuric acid deposits, this composition guarantees specific energy to this battery which is quite low compared to the rest of the batteries [10]. Nickel Cadmium battery is a battery that uses Nickel oxide hydroxide as a cathode and the metallic cadmium as anode with Potassium hydroxide electrolyte, the energy of Ni-Cd battery is higher than the lead acid [12], [13]. Nickel metal hydride is similar to the Ni-Cd battery except for a slight change in the negative electrodes of the battery, the metallic alloys are used to store hydrogen instead of the cadmium at the anode [14]. In the last, the most common and usable battery is the Lithium-ion battery (LIB).

The Lithium-Ion Battery (LIB) is the most dominant type – rechargeable battery – used in EVs market [15], the LIB industry has started in 1991 when SONY Company developed the first LIB to be used in mobile phones [16], since then this industry has expanded to include the Electric Vehicles (EV) manufacturing nowadays. LIB incorporates different combined set of elements that differ from each battery type to another, e.g.: Lithium Nickel Manganese Cobalt Oxide battery (NMC), Lithium Nickel Cobalt Aluminium Oxide battery (NCA), Lithium Cobalt Oxide battery (LCO), Lithium Manganese Oxide battery (LMO), Lithium Iron Phosphate (LFP) and Lithium Titanium Oxide (LTO) [17], [10]. The common elements that are utilized in all battery's types are Lithium, Nickel, Cobalt, Manganese and Graphite [18].

The current study aims to clarify the EVs industry negative impact, especially LIB batteries production, on both the environment and society despite its all advantages. The study includes an overview of the recent extensive mining activities and its effect on the water and air pollution, increased greenhouse gas emissions and associated human right abuses. The ore grade concept will be used to estimate the average number of tonnes that should be mined in order to extract the required amount of minerals for production of a typical LIB EV battery.

2. Review on LIB EV

This section is discussing briefly the LIB including features, composition and advantages since it's the dominant rechargeable battery in the market now and in the future. The LIB uses lithium as a key element in all the battery types considering its light weight compared to the rest of the metallic materials [17]. The distinctive composition of this battery allows the reversible electrochemical process through the Lithium salt as an electrolyte [19]. The evolve of the LIB in the market has come out with many advantages to the EVs industry such as the lightweight of the battery, the low internal resistance, the larger travel distance and the higher specific energy than the other batteries- three times higher in energy compared to the lead acid battery [12].

The dominant LIB types commercially used in the market are 1) Lithium Nickel Manganese Cobalt Oxide **(NMC),** 2) Lithium Nickel Cobalt Aluminium Oxide **(NCA),** 3) Lithium Manganese Oxide **(LMO),** 4) Lithium Titanium Oxide **(LTO),** 5) Lithium Cobalt Oxide **(LCO),** and 6) Lithium Iron Phosphate **(LFP).** The composition of each battery defines its power, capacity, performance and lifespan. The anode in all LIB types is made of Graphite, the cathode basically incorporates Lithium as a main component along with different other components, e.g. Manganese, Nickel, Cobalt…etc. [20]. The percentage of metals that form both the cathode and anode in each LIB type was reported in many studies [21] (Figure 2).

- **Nickel Manganese Cobalt Oxide (NMC)**

The cathode in this battery is a mixture of Cobalt, Nickel and Manganese, NMC battery is called a 1-1-1 configuration due to the equal quantity of Nickel, Manganese and Cobalt. Different configurations have shown significant success in the market as well such as NMC811 (80% Mg-10% Ni-10% Co), NMC532 and NMC622, the specific capacity for this battery is from 150 to 220Wh/kg and usually involved in the E-bikes, medical devices, EVs industry [10].

- **Lithium Nickel Cobalt Aluminum Oxide (NCA)**

This battery is an advanced configuration to the Lithium Nickel Oxide battery by adding the Aluminum that guarantees greater stability to the chemistry of the battery. The combination of the Lithium Nickel Cobalt Aluminum Oxide in the cathode in addition to the graphite in the anode has formed this battery. The NCA has specific energy reaches up to 260 Wh/Kg. The common applications for the NCA battery are the medical devices, electric powertrain [17].

- **Lithium Manganese Oxide (LMO)**

The essential material for this battery is the Lithium Manganese Oxide in the cathode and the graphite in the anode, this configuration has led to a quite low specific energy ranges from 100 to 150 Wh/Kg as a consequence, the mixture of lithium nickel manganese cobalt oxide has been added to improve the battery capacity and life span. This type of battery is involved in the power tools and electric powertrains manufacturing [10], [17].

- **Lithium Titanate Oxide (LTO)**

The particular composition of this battery using the lithium titanate oxide as an anode material alongside with either NMC or LMO in the cathode to achieve optimum thermal stability of the battery during charging, moreover, the capacity of this battery is between 50–80Wh/Kg and used in UPS, solar-powered street lighting and electric powertrain [10], [17].

- **Lithium Cobalt Oxide (LCO)**

The components of this battery are Lithium cobalt oxide cathode and graphite in the anode, this battery considered as the choice for applications that don't require much load such as Mobile phones, tablets, laptops, cameras due to its limitations to provide good thermal stability, capacity and high performance compared to the other types, in addition to the high cost of this battery because of the cobalt mineral overprice. The capacity of the LCO equals to 200Wh/Kg [17].

- **Lithium Iron Phosphate (LFP)**

This battery employs the Lithium Iron Phosphate as a cathode and graphite as an anode, its specific energy varies between 90–120Wh/Kg, LFP contributes to the Portable and stationary that needs high load currents [17].

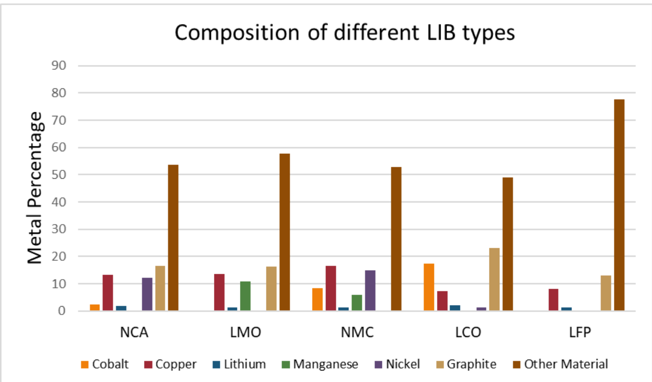

Fig.2. Metal percentage of LIB different types, modified after (Winslow et al., 2017) [21]

3. Methodology

The recent analysis determines the amount of earth that should be moved prior to subsurface mineral extraction using published data of ore grade of the dominant minerals forming LIB, considering the different composition of each LIB type. The calculations take into consideration the average ore grade from published data for Cobalt, Copper, Lithium, Manganese, Nickel and Graphite, as they are the elements involved in the major types of LIBs, to estimate the immense number of tonnes should be mined to produce a LIB battery. As shown in Figure 2, other material forms approximately 50% or more of a LIB, however there are variable and several materials concerned here that differ from one LIB type to another.

The analysis utilizes the average lithium-ion battery weight and the approximate percentages of the dominant minerals that constitute the battery to calculate the average minerals weight in kilogram. Furthermore, the required tonnage that must be mined to extract these minerals for an individual battery manufacturing was estimated by combining the average ore grade along with the calculated weight of minerals. Ore accessibility varies significantly based on the mineral type and location therefore, the rock that should be displaced to reach the ore was estimated assuming the overburden ratio as a range from 3 to 20 tonnes [22].

4. Results and Discussion

The LIB EV has an average weight of 453.6 Kg [22], involving approximate percentages of minerals that differ from each LIB type to another. Table 1 shows the weight of the dominant elements forming the NCA, LMO, NMC, LCO and LFP batteries in both percentage [21] and Kilogram. Moreover, according to the collected published data, the average ore grade was estimated for the LIB dominant minerals (Table 2).

Table 1. The weight of the minerals [%, KG] involved in each battery type manufacturing, modified after (Winslow et al., 2017)

BATTERY NAME	**NCA** WEIGHT		**LMO** WEIGHT		**NMC** WEIGHT		**LCO** WEIGHT		**LFP** WEIGHT	
METAL	**(%)**	**KG**	**(%)**	**KG**	**(%)**	**KG**	**(%)**	**KG**	**(%)**	**KG**
COBALT	2.3	10.43	0	0.00	8.45	38.33	17.3	78.47	0	0.00
COPPER	13.3	60.33	13.5	61.24	16.6	75.30	7.3	33.11	8.2	37.20
LITHIUM	1.9	8.62	1.4	6.35	1.28	5.81	2	9.07	1.2	5.44
MANGANESE	0	0.00	10.7	48.54	5.86	26.58	0	0.00	0	0.00
NICKEL	12.1	54.89	0	0.00	14.84	67.31	1.2	5.44	0	0.00
GRAPHITE	16.5	74.84	16.3	73.94	0	0.00	23.1	104.78	13	58.97
OTHER MATERIAL	53.6	243.13	57.7	261.73	52.87	239.82	48.9	221.81	77.6	351.99

Table 2. Average ore grade for the LIB dominant minerals

ORE GRADE	**COBALT** (%)	**COPPER** (%)	**LITHIUM** (%)	**MANGANESE** (%)	**NICKEL** (%)	**GRAPHITE** (%)
	0.245 [23]	0.6 [22]	0.46[30]	10 [35]	1 [40]	4.45 [45]
	0.1 [22]	3 [24]	0.05[31]	20 [36]	0.2 [41]	10 [22]
	0.5 [24]	2.65 [27]	0.22[32]	15 [37]	0.8 [42]	6.5 [46]
	0.05 [25]	0.33 [28]	0.25[33]	20 [38]	0.5 [43]	2.5 [47]
	0.22 [26]	5 [29]	0.7[34]	20 [39]	1 [44]	7 [48]
AVERAGE	0.22	2.32	0.336	17	0.7	6.09

The extended calculations in Table 3 were achieved utilizing the weight (Kg) of the dominant minerals in Table 1 along with the average ore grades that are available in Table 2 to estimate the quantity of minerals (tonne) that should be mined for a LIB battery manufacturing. The overburden that should be moved for accessing each tonne of ore was estimated as well (3 to 20 tonnes) [22].

Table 3. Amount of rock mined for ore accessing considering the overburden of each battery type

AMOUNT OF MINED ROCK (TONNE)	**NCA BATTERY**	**LMO BATTERY**	**NMC BATTERY**	**LCO BATTERY**	**LFP BATTERY**
COBALT	4.26	0.00	15.64	32.03	0.00
COPPER	2.60	2.64	3.25	1.43	1.61
LITHIUM	2.57	1.89	1.73	2.70	1.62
MANGANESE	0.00	0.29	0.16	0.00	0.00
NICKEL	7.84	0.00	9.62	0.78	0.00
GRAPHITE	1.23	1.21	0.00	1.72	0.97
SUM	18.50	6.03	30.40	38.66	4.19
TONNES OF ORE AND OVERBURDEN CONSIDERING THE ESTIMATED VALUE 3-20 TONNES					
FROM (3 TONNES)	55.49	18.10	91.19	115.97	12.58
TO (20 TONNES)	369.96	120.67	607.93	773.15	83.89

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The previous calculations estimate the enormous weight of rock that should be excavated and moved to extract the key minerals of LIB. Delineating mining required for supplying these essential minerals, the calculations were performed for each mineral individually. Cobalt which is necessary for NCA, NMC and LCO batteries, requires approximately 85165, 312891, 640594 Kg rocks to be mined for NCA, NMC and LCO batteries production respectively (Figure 3a). Copper that is essential mineral in all LIB types needs nearly 52097, 52880, 65023, 28594, 32120 Kg rocks to be mined for NCA, LMO, NMC, LCO, LFP production respectively (Figure 3b). Lithium as a fundamental component incorporates all LIB types requires 51300, 37800, 34560, 54000, 32400 Kg rocks to be mined for NCA, LMO, NMC, LCO, LFP respectively (Figure 3c). Manganese is included in both LMO and NMC batteries production that needs rocks mining of 5710, 3127 Kg respectively (Figure 3d). Nickel is required for NCA, NMC and LCO batteries production that needs mining of 156816, 192326, 15552 Kg of rocks respectively (Figure 3e). Furthermore, the graphite required for NCA, LMO, LCO, LFP batteries requires rocks mining of 24579, 24281, 34411, 19365 Kg respectively (Figure 3f). All these calculations don’t consider all chemicals and materials utilized to process the various ores which may represent a massive amount of rock as well if it’s going to be considered in the calculations.

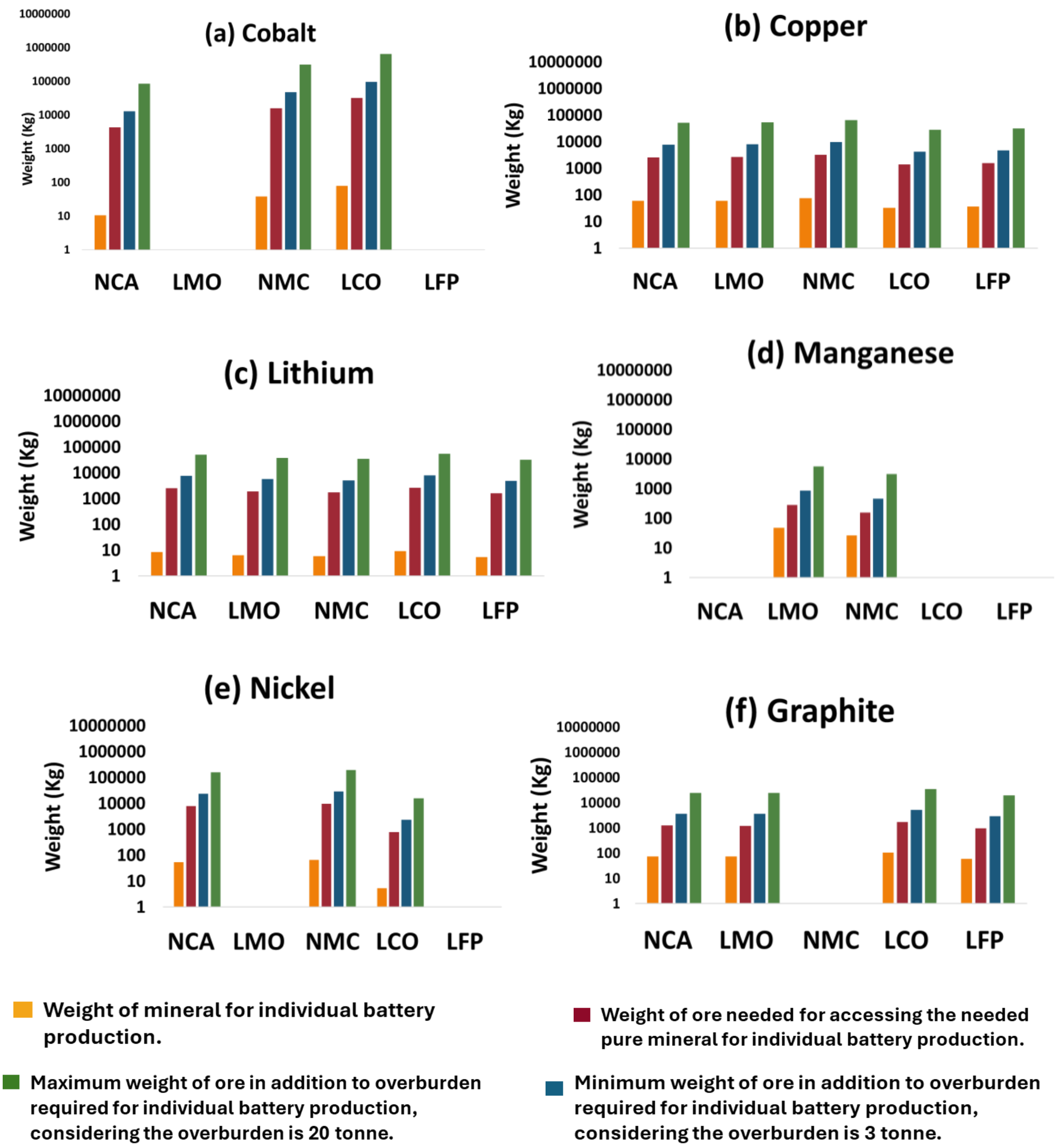

Fig.3. Key minerals weight in LIB, needed ore tonnage and overburden weight

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The amount of rock that should be mined for each LIB type production was graphed aiming to reflect how many tonnes of ore needed, in addition to considering the overburden for each battery given a value of (3-20 tonnes) [22]. The production of a single NCA, LMO, NMC, LCO, LFP requires approximately 18, 6, 30, 38, 4 tonnes of ore respectively, meanwhile the total rock that should to be mined for these batteries are 369, 120, 607, 773, 83 respectively, considering the overburden 20 tonnes (Figure 4).

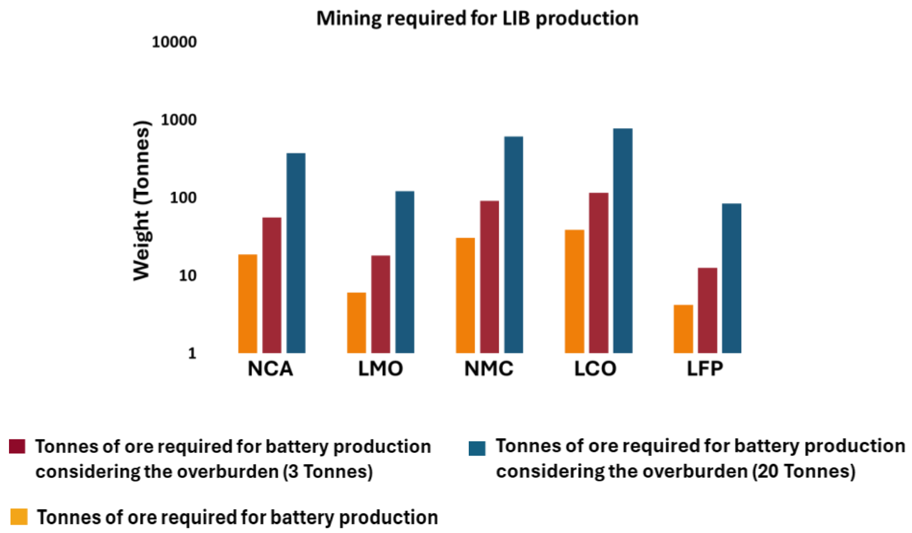

Fig. 4. Mined rocks required for LIB production

The number of EVs sales in 2023 was 13.7 million cars [6], 90% of these cars were using LIBs [49] which reflect that 12.33 million LIBs were used for EVs manufacturing in this year. Considering that the dominant LIB type is NMC [50] which requires approximately 607 tonnes of mined rock for a single battery production, a total number of 7484 megatonnes approximately was mined to cover the market demand of LIBs in 2023. Considering the previous analysis with respect to the EV growing market, an extensive mining practices should be accomplished to provide the LIB critical minerals, these practices are linked with a significant negative impact on environment that influence water, land, air, ecology and society. The usual practices for mineral extraction such as quarrying and dumping considered as contributors to environmental degradation, since these operations cause distraction of hydrological system, lower the ground water table and led to surface and ground water pollution due to the flow of mine water from overburden dumps. The impact of mining on air pollution can be attributed to many aspects such as blasting, drilling and transporting of material that usually led to emissions of pollutant gases: sulfur dioxide (SO2), Carbon dioxide (CO2) and Nitrogen oxides (NOX). The auto-emissions as a result of vehicles and machines burning fuels used in mining area, can all be considered as main reasons for air pollution especially that most of the mining activities are operated by fossil fuels considering that mining alone accounts for approximately 4-7% of the global greenhouse gas emissions [51]. The impact of mining on land is crucial as well since it causes significant change on land topography due to extensive drilling activities which in turn causes soil erosion and degradation, moreover the presence of mining polluted water affects the soil as well. Mining effects on ecology in many factors as well since it aids the deforestation which is necessary to situate mines in forest areas, besides the noise pollution occurs that usually caused by blasting and machine operations that have a harmful effect on animals and birds in the regions. The impact of mining on society includes dislocation of people to make way for mining activities, also noise and dust caused by these operations affect the health of people located at the mining surrounding area, many diseases infect the inhabitants including lung infections, heart ailments and cancer. The working of young individuals in mines that violates the child labor law in addition to abusing human rights in several mines all can be highlighted as a negative impact on society.

5. Conclusion

Despite the advantages of the electric vehicles being on roads with a remarkable increase yearly, the disadvantages that accompany electric batteries manufacturing considered. Battery Electric Vehicles are the most type used due to its configuration that uses only battery in the vehicle which in turn lower the harmful gas emissions. The LIB is the dominant battery type used in EV nowadays, this battery has different configurations based on the key minerals involved in each type, such as NMC, NCA, LMO, LTO, LCO, and LFP. The key

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minerals involved in all LIB types are Cobalt, Copper, Lithium, Manganese, Nickel and Graphite. The extraction process of these minerals requires massive quantity of mined rock, the mineral percentage used in each LIB type were collected from published data and converted into kilograms considering that the average LIB weight is 453.6 Kg. Moreover, the average ore grade for LIB key minerals were collected from published data, where average ore grades are estimated as 0.22%, 2.32%, 0.336%, 17%, 0.7%, 6.09% for cobalt, Copper, Lithium, Manganese, Nickel and Graphite respectively. The ore grades along with the weight of key minerals needed for LIB production, were used to estimate the quantity of ore needed to obtain the pure key minerals for LIB production. Furthermore, considering the overburden that usually differs in weight and volume based on location and mineral type, a range of overburden from 3 to 20 tonnes were assumed allowing to estimate the minimum and maximum weight of rock must be moved to obtain the key minerals.

The current study shows that production of single NCA, LMO, NMC, LCO, and LFP battery types require an average mining of 55-369 tonnes, 18-120 tonnes, 91- 607 tonnes, 115-773 tonnes, 12-83 tonnes respectively. Considering the LIBs number used for EVs manufacturing in 2023, the tonnes of mined rocks needed to cover the annual production of LIBs in 2023 were estimated approximately as 7484 megatonnes. The estimated massive amount of rock that should be moved for LIB production reflects the extensive mining operations that must be accomplished to cope up with the EV growing market. These operations effect on a large scale on environment and society, causing water pollution, hydrological regime disruption and ground water table lowering. Mining operations including drilling, blasting and material transport effect on air quality through releasing harmful gases which effect locally and on global climate, deforestation and soil erosion are other issues occurred due to these operations. Additionally, mining activities have a negative impact on society as it leads to residents' displacement, severe health issues, abusing human rights through several violations occur in mines. Future work should consider widely the number of different LIB types production to estimate the required tonnes of rocks needed for each type. Moreover, the environmental impact associated with each mineral mined specifically given that the different mineral processing needed for each kind of mineral.

References

[1] **Alanazi F.**, 2023
Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation. Applied Sciences, 13(10), 6016. https://doi.org/10.3390/app13106016

[2] **Global EV**
Outlook 2022 Analysis—IEA. Available online: https://www.iea.org/reports/global-ev-outlook-2022 (accessed on 15 April 2023).

[3] **Shahzad M., Shafiq M.T., Douglas D., Kassem M.**, 2022
Digital Twins in Built Environments: An Investigation of the Characteristics, Applications and Challenges. Buildings 2022, 12, 120 [Google Scholar]

[4] **IEA**
A renewed pathway to net zero emissions – Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach – Analysis. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach/a-renewed-pathway-to-net-zero-emissions

[5] **Manas A., Patel R., Sufiyan M.** (2020)
Global Perspective on Electric Vehicle. International Journal of Engineering Research and. V9. 10.17577/ IJERTV9IS010005

[6] **IEA**
Electric vehicles - IEA. (n.d.). https://www.iea.org/energy-system/transport/electric-vehicles

[7] **Bhutada G.**, 2022
The key minerals in an EV battery. Visual Capitalist. https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/

[8] **International Copper Association**, 2017
E-mobility: Copper is at the heart of the electric vehicle revolution. https://internationalcopper.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf

[9] **Faraz A., Ambikapathy A., Thangavel S., Logavani K., Prasad G.A.**, 2020
Battery Electric Vehicles (BEVs). In Green energy and technology (pp. 137–160). https://doi.org/10.1007/978-981-15-9251-5_8

[10] **Darbari N.A., Sawant N.S.**, 2024
Electric vehicle batteries and its effect on the global market. Global Journal of Engineering and Technology Advances, 20(1), 010–017. https://doi.org/10.30574/gjeta.2024.20.1.0117

[11] **Mohammadi F., Saif M.**, 2023
A comprehensive overview of electric vehicle batteries market. e- Prime - Advances in Electrical Engineering Electronics and Energy, 3, 100127. https://doi.org/10.1016/j.prime.2023.100127

[12] **Muslimin S., Nawawi Z., Suprapto B.Y., Dewi T.**, 2022
Comparison of batteries used in electrical vehicles. Atlantis Highlights in Engineering/Atlantis Highlights in Engineering. https://doi.org/10.2991/ahe.k.220205.074

[13] **Compare Battery Electrolyte**
Lithium vs. Lead-Acid vs. NiCd. (n.d.). Ufine Battery [Official]. https://www.ufinebattery.com/blog/electolyte-comparison-lead-nickel-cadmium-and-lithium/

[14] **Chian T., Wei W., Ze E., Ren L., Ping Y., Bakar A., Noor Z., Fauzan Ir., Mohd F., Sivakumar S.**, 2019
A Review on Recent Progress of Batteries for Electric Vehicles. International Journal of Applied Engineering Research. 14. 4441-4461.

[15] **Tracy B.S.**, 2022
Critical Minerals in Electric Vehicle Batteries. Congressional Research Service

[16] **Nishi Y.**, 2001
Lithium ion secondary batteries; past 10 years and the future. Journal of Power Sources, 100(1–2), 101–106. https://doi.org/10.1016/s0378-7753(01)00887-4

[17] **ZTA**, 2020
Types of Lithium-ion batteries. https://zta.nu/wp-content/uploads/2020/03/Paper-2.2-Li-Ion-Battery-Types.pdf

[18] **Scott S., Ireland R.**, 2020
Lithium-Ion battery materials for electric vehicles and their global value chains. Office of Industries, US International Trade Commission

[19] **Saskia M.K., Kartini E.**, 2019
Current state of lithium-ion battery components and their development. In IOP Conference Series: Materials Science and Engineering (Vol. 553, No. 1, p. 012058). IOP Publishing.

[20] **Sankaran G., Venkatesan S.**, 2022
IOP Conf. Ser.: Earth Environ. Sci. 1042 01201

[21] **Winslow K.M., Laux S.J., Townsend T.G.**, 2018
A review on the growing concern and potential management strategies of waste lithium-ion batteries. Resources, Conservation and Recycling, 129, 263-277.

[22] **Mills M.P.**, 2020
Mines and «Green» energy: a reality check. URL: https://media4. manhattaninstitute. org/sites/default/files/mines-minerals-green-energy-reality-checkMM. pdf

[23] **Barnard F.L., Lambert R.J., Noble A.C.**, 2007
NI 43-101 Technical Report Nkamouna and Mada Cobalt Projects, Cameroon (pp. 1–28). https://www.sec.gov/Archives/edgar/data/1398005/000102189007000084/geovicform10ex1017.htm

[24] **Shengo M.L., Kime M., Mambwe M.P., Nyembo T K.**, 2021
A review of the beneficiation of copper-cobalt-bearing minerals in the Democratic Republic of Congo. Journal of Sustainable Mining, 18(4). https://doi.org/10.46873/2300-3960.1109

[25] **Gautneb H., Knežević J., Gloaguen E., Melleton J., Gourcerol B., Törmänen T.**, 2019
Occurrences of energy critical elements; Lithium–Cobalt and Graphite in Europe, a preliminary overview. In SGA 2019-15th Biennial Meeting of the Society for Geology Applied to Mineral Deposits.

[26] **Hitzman M.W., Bookstrom A.A., Slack J.F., Zientek M.L.**, 2017
Cobalt—Styles of deposits and the search for primary deposits (No. 2017-1155). US Geological Survey.

[27] **Wikipedia**, 2024
Polkowice-Sieroszowice mine. Wikipedia. https://en.m.wikipedia.org/wiki/Polkowice-Sieroszowice_mine?utm

[28] **USGS**, 2021
Majdanpek Porphyry copper (Cu-Au) deposit in Bor, Serbia. USGS. Retrieved 3 April 2021.

[29] **Basov V.**, 2017
The World's Top 10 Highest-Grade Copper Mines. Mining.com

[30] **Fanka A., Tadthai J.**, 2023
Petrology and geochemistry of Li-bearing pegmatites and related granitic rocks in southern Thailand: implications for petrogenesis and lithium potential in Thailand. Frontiers in Earth Science, 11, https://doi.org/10.3389/feart.2023.1221485

[31] **Chile S.Q.M.**, 2022
SEC Technical Report Sumary - Operation Report, Salar de Atacama, Chile (Issue April, pp. 1–268)

[32] **Jamasmie C.**, 2025
Lithium Americas raises Thacker Pass reserves, names new CFO. mining.com. https://www.mining.com/lithium-americas-raises-thacker-pass-reserves-names-new-cfo/

[33] *****
Mineral Resource Estimate | British Lithium. https://imerysbritishlithium.com/lithium-exploration/mineral-resource-estimate/?utm

[34] **Yeo B.**, 2025
School of Rock: How to read lithium results. Stockhead. https://stockhead.com.au/resources/school-of-rock-how-to-read-lithium-results/?utm

[35] **Dunn B.M., Pringle I., Filipov M.**, 2022
NI 43-101 North Star Manganese Inc Technical Report, Emily Manganese Project, Minnesota, USA. https://electricmetals.com/site/assets/files/4937/final_-_december_5-_2022_-_ni43-101_resource_report_120.pdf

[36] **Muliyah P., Aminatun D., Nasution S.S., Hastomo T., Wahyuni S.S., Sitepu T.** 2020
Scheme of Mining, MOIL Limited, India. Journal GEEJ, 7(2).

[37] **Bryah Resources Limited**, 2023
Bryah Basin Manganese Mineral Resource, Australia. https://www.omholdingsltd.com/wp-content/uploads/2023/08/2023.08.24-ASX-Bryah-Bryah-Basin-Manganese-Mineral-Resource-Increases-to-3.07-Million-Tonnes-at-20.2-Mn.-Production-Study-to-Commence.pdf

[38] **The Diggings**, 2025
Mine ID 6267. Retrieved January 28, 2025, from https://thediggings.com/mines/6267

[39] **MOIL**
Workshop on Threshold value. https://ibm.gov.in/writereaddata/files/11162017145236MOIL.pdf

[40] **Glass R.**, 2024
FY24 - Mineral resources and ore reserves statement & 2024 exploration results I (Issue AUGUST)

[41] **Purchase J., Debreil J.A., Mackey P., Dodd D., Meyer S.**, 2023
NI 43-101 Technical Report Selkirk Nickel Project, North East District, Republic of Botswana

[42] *****, 2023
Glencore Resources & Reserves

[43] **Gauld C., Gardner N.A., Hossack A., Puro G.**, 2022
Technical Report Summary Sudbury Property, Sudbury Basin, Canada

[44] **Royal Nickel Corporation**, 2016
NI 43-101 Technical Report Preliminary Economic Assessment The Beta Hunt Mine (Vol. 5)

[45] **Bussieres Y., Yassa A.R.**, 2023
NI 43-101 Technical Report for the 2023 Mineral Resource Estimate for the Mousseau West Graphite Deposit, Canada

vol. 31, issue 2 / 2025
pp. 105-114

[46] *******, 2025
The Molo graphite deposit, Wayback Machine, https://web.archive.org/web/20121104232331/http://energizerresources.com/projects/the-molo-graphite-deposit-.html (Accessed: 28 January 2025)

[47] *******, 2013
Understanding High-Grade Lump Graphite, https://www.streetwisereports.com/article/2013/11/18/understanding-high-grade-lump-graphite.html

[48] **Schulz K.J. (Ed.)**, 2017
Critical mineral resources of the United States: economic and environmental geology and prospects for future supply. Geological Survey

[49] **IEA**
Status of battery demand and supply – Batteries and Secure Energy Transitions – Analysis - (n.d.) https://www.iea.org/reports/batteries-and-secure-energy-transitions/status-of-battery-demand-and-supply

[50] **IEA**
Trends in batteries – Global EV Outlook 2023 – Analysis - (n.d.). IEA. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries

[51] **Khobragade K.**, 2020
Impact of Mining Activity on environment: An Overview. International Journal of Scientific and Research Publications, 10(05), 784–791. https://doi.org/10.29322/ijsrp.10.05.2020.p10191