End-of-Life Electric Vehicle Lithium-Ion Batteries: Physical Methods for the Recycling

P.S.S. Camargo*, J. V. Bender*, N. M. Gräff*, A. R. B. Franco*, H.M. Veit*,

Department of Materials Engineering, Federal University of Rio Grande do Sul (UFRGS), Av. Bento Gonçalves, 9500, CEP: 91509-900, Porto Alegre, RS, Brazil

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Presenting author email: priscila.silveira@ufrgs.br

Introduction

For the European Union (EU) it is reported that 74,900 t of **lithium-ion batteries (LIBs)** were placed on the EU market in 2019, of which 51% are industrial and automotive batteries.

On the one hand, there are **supply risks for lithium and cobalt.** On the other hand, LIBs are seen as excellent **secondary resources for the recovery of these critical raw materials**.

Besides, spent LIBs contain **hazardous metals such as nickel and manganese**, toxic and corrosive electrolytes, metal casting, and polymer binders that pose a serious threat to the environment and human health.

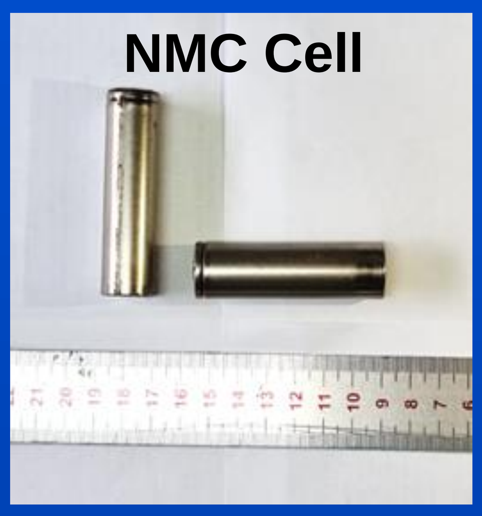
For this reason, EU member states should achieve a **minimum collection rate for LIBs of 70%,** a **recycling rate of 95% for nickel, copper, and cobalt**, as well as **70% for lithium by 2030. So**, more efforts should be made to **recover metals through recycling methods.**

Mechanical processes are often used with pretreatment to concentrate certain materials for later steps (such as pyrometallurgical and hydrometallurgical methods), increasing efficiency, reducing costs, and lowering environmental impact.

Therefore, the objective of this work was to test a mechanical grinding and screening treatment for lithium-ion batteries with different cathode materials.

Materials & Methods

Two different brands of cylindrical lithium-ion batteries, **a Lithium Nickel Manganese Cobalt Oxide (NMC) cell** and a **Lithium Iron Phosphate (LFP) cell** were subjected to chemical characterization as well as to the mechanical separation process by milling and sieving.



First, approximately 500 g of cells of each type were comminuted in a **knife mill**. The ground material was quarried twice, and 25 % (by mass) was identified as the ground whole Lithium Ion Battery (LIB).

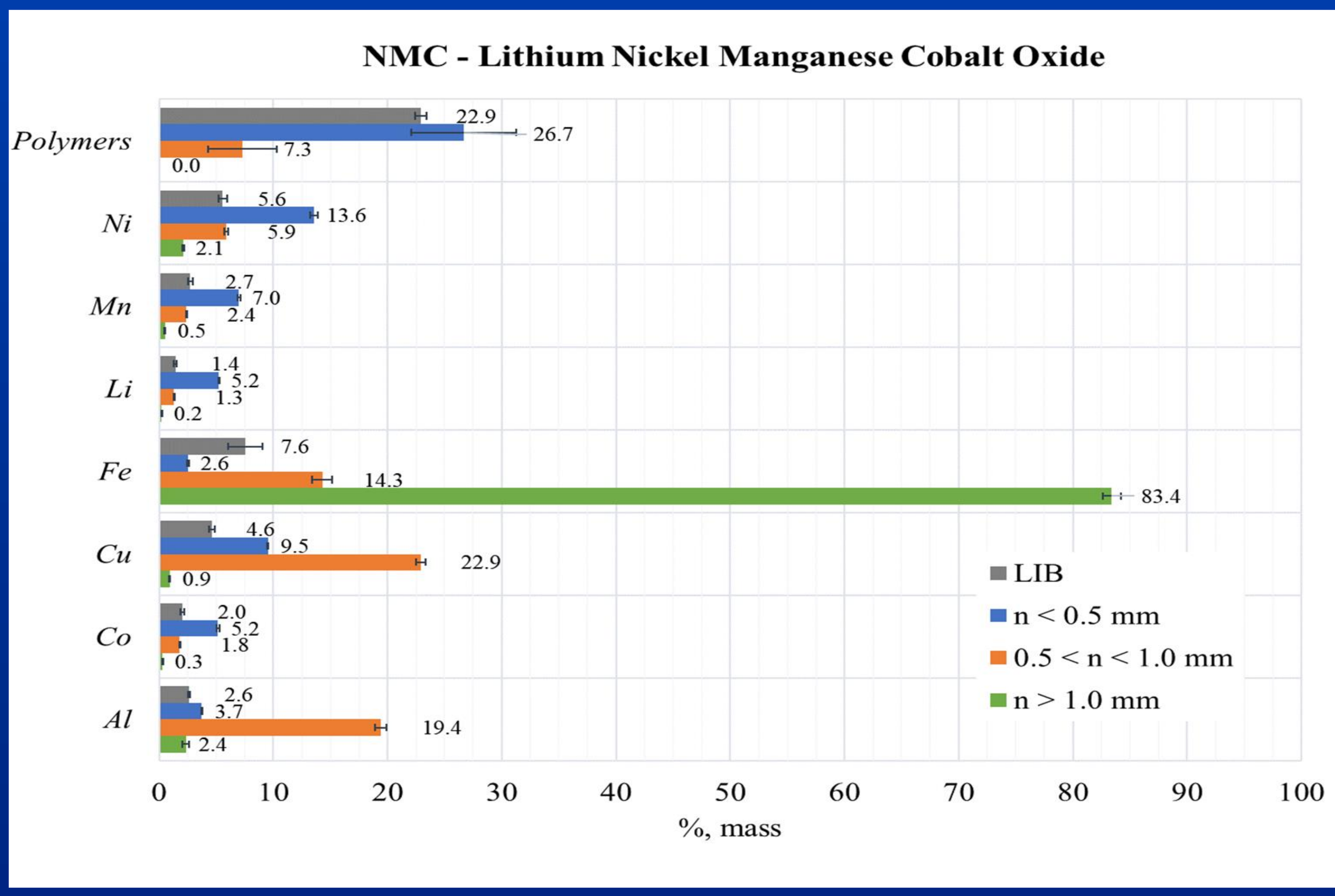
The remaining material (75% by mass) was placed on a sequence of bench sieves with a vibration system, resulting in 3 different fractions: the **Fine Fraction (FF: n<0.5 mm)**, the **Intermediate Fraction (IF: 0.5 < n < 1.0 mm),** and the **Coarse Fraction (CF: n > 1.0 mm).**

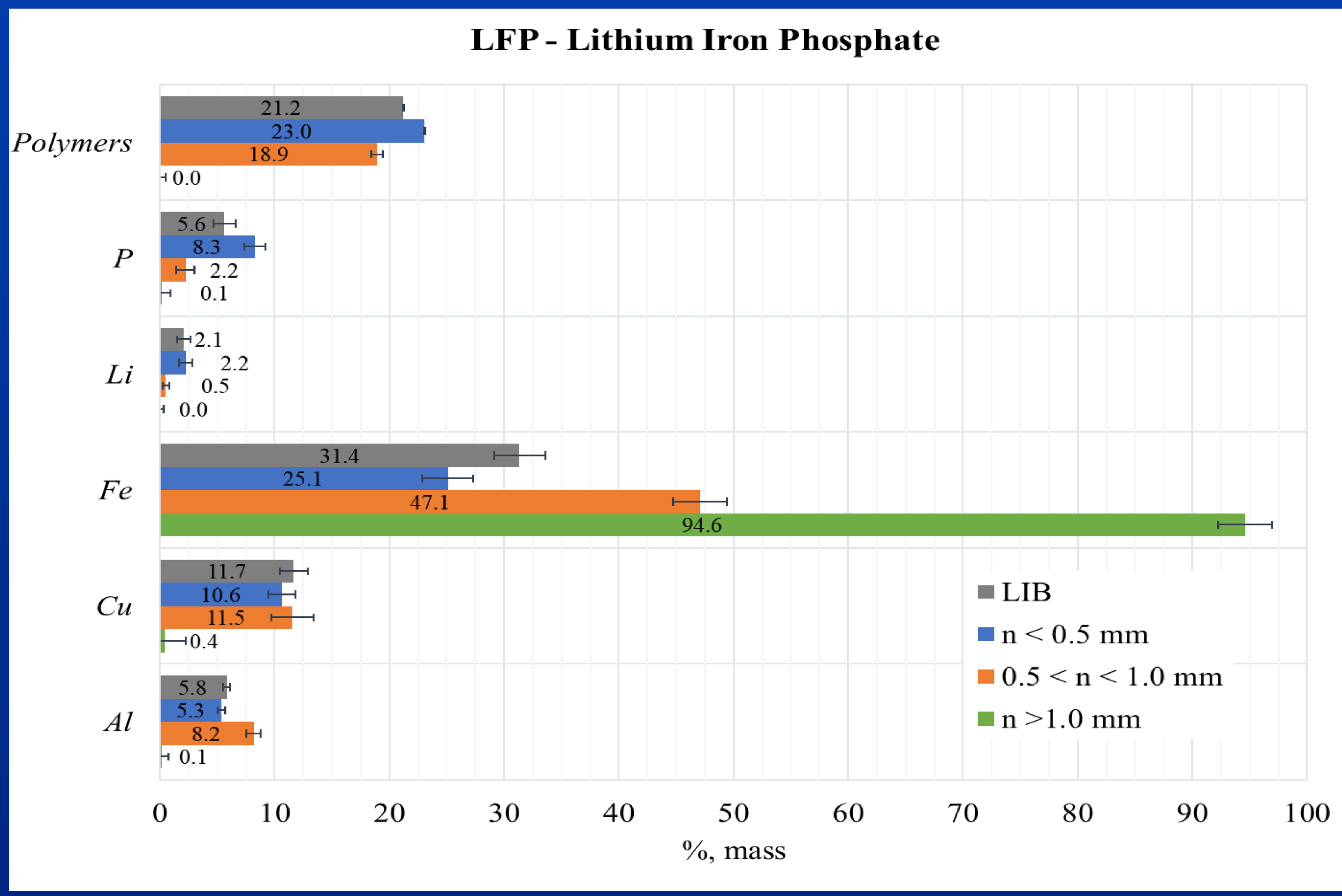
The mass of each fraction was measured to calculate the mass percentage in relation to the whole sample without sieving.

Six samples of approximately 5 g of each fraction (LIB, FF, IF, and CF), were submitted to 600 ºC for 1 hour to verify the **percentage of polymers present**, corresponding to the identified mass loss.

Subsequently, these samples were subjected to **acid leaching** with aqua regia (75% HCl and 25% HNO_3) for 2h, with heating (temperature 70-80ºC), and a solid-liquid ratio of 1/40. After filtration, the liquid fraction containing the solubilized metals was analyzed by **Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).**

Results & Discussion





It is observed that the applied treatment had better results for the NMC cell than for the LFP.

The proposed separation process allowed the **cathodic materials to become more concentrated in granulometry smaller than 0.5 mm (FF)** in both cell types.

The FF of the NMC cell had 3.6, 2.4, 2.6, and 2.5 times more respectively lithium, nickel, cobalt, and manganese than the LIB.

Copper from the anode support and aluminum from the cathode support tended to remain in the granulometry 0.5 < n < 1.0 mm (IF). **IF had 7.4 times more aluminum and 5.0 times more copper than LIB for the NMP cell.**

The fraction **n > 1.0 mm (CF) has more than 80% iron**, especially from the robust housing, in addition to having no polymers in its composition.

For cell NMC, CF has 11 times more iron. The polymers were concentrated in a particle size smaller than 1.0 mm.

Conclusions

The mechanical separation process by grinding and sieving indicated that **cathode materials tend to concentrate in the particle size smaller than 0.5 mm**, copper and **aluminum tend to be in 0.5 <n< 1.0 mm**, and **iron from the robust cell housing concentrates in n > 1.0 mm.** Mechanical treatment has shown more promise for NMC cells than LFP cells. Although the process needs improvement, the information obtained gives a north about the behavior of these materials.

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