End-of-life liquid crystal displays as a source of critical raw materials
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BACKGROUND AND AIMS
In 2014 the European Union has identified 20 critical raw materials for Europe for their economic importance and high supply risk, including In, mainly used for the production of liquid crystal displays (LCD). Currently, this metal is extracted as by-product mainly in Zn mines and China is the largest producer [1, 2]. Modern LCD show an In concentration from 100 to 400 ppm, comparable with that in ores [3, 4]. Their short lifespan of about 3-8 years is causing the production of significant amount of waste that have to be managed [5]. In this context, we developed an efficient process for the recovery of In from end-of-life LCD. The treatment was characterized by a simple design and a low environmental load. Therefore, the development of efficient recycling processes for end-of-life LCD could combine the decrease of waste to treat with the reduction of dependency from other countries for the primary resources supply.

MATERIALS AND METHODS
We developed a process (Fig. 1) in which a first washing with water allowed the physical removal of liquid crystals. At the end of this operation, the LCD amount was treated in a 2 M H2SO4 solution at 80°C for 10 min. This leaching was carried out using a S/L of 20%. According to the cross-current configuration, we used the solution from a first step to treat a second amount of waste [6]. For the final In recovery, leaching solution was heated up to 55-60°C and NaOH was added up to pH 3. When this condition was reached, pure Zn powder was added at a concentration of 5 g/L and the cementation proceeded for 10 min [7]. A life cycle assessment was carried out to quantify the benefit due to cross-current design.

RESULTS
A reaction time of 10 min was sufficient for a complete In extraction. The cross-current configuration of leaching permitted the increase of metal concentration in the solution without a significant reduction of the efficiency after 2 steps (Fig. 2). A further advantage of the approach was the overall decrease of raw materials request. The next operation, including pH adjustment and cementation by Zn powder, allowed to obtain a complete In recovery thanks to the low potential of Zn that promoted the reduction of indium ion to the metal form. The results can be translated in an advantage also from an environmental point of view. The 3 environmental impact categories (acidification, global warming and resources depletion) show a benefit, particularly comparing the single step and the 2 step configuration (Fig. 3). This advantage can be quantified in the range of 30-40% for all the categories. It can also be observed that the leaching operation has the highest contribution, mainly due to the use of H2SO4. On the other hand, the cementation impact is evident in the category of resources depletion, due to the request of Zn.

CONCLUSIONS
An In recovery process from end-of-life LCD was performed including a first acid leaching, followed by a cementation by zinc powder with a final overall indium extraction efficiency higher than 90%. The LCA applied to the cross-current configuration showed an environmental benefit up to 40%, if compared with a single step process. The results prove the beneficial effect of the application of urban mining approach for the recovery of valuable elements from end-of-life LCD.

Fig. 1. Process for indium recovery from end-of-life LCD

Fig. 2. Efficiency and metal concentration during the cross-current leaching steps (operating conditions: 2M sulfuric acid 80°C, 10 min for each step)

Fig. 3. Effect of the number of cross-leaching steps on the environmental impact

References