# A facile and environment-friendly method for leaching of Ni, Cd and Co from the spent Ni-Cd batteries over polyvinyl chloride (PVC) in subcritical water

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## INTRODUCTION

Ni-Cd batteries are widely used as a rechargeable power sources in portable devices, such as camera, remote controls, and laptops (Tanong K., Tran L.H. et al., 2017). However, due to the arrival of new batteries, for example, Ni-MH and Li-ion into the market, a huge number of spent Ni-Cd batteries are being disposed into the landfill instead of recycling. Meanwhile, Ni-Cd batteries contain valuable (such as Ni, Co) and hazardous (Cd) metals. Apart from these, the electrolyte used in the Ni-Cd batteries decomposes to several harmful substances and causes human health threat (Karnchanawong S., Limpiteeprakan P. et al., 2009). Although a wide variety of researches have been focused on the recycling of Ni-Cd batteries, use of harsh reaction conditions and harmful reagents limit their application in industrial sectors. Therefore, developing an environment-friendly method for the recovery of valuable and hazardous metals from the spent Ni-Cd batteries still remains a big challenge. To resolve the current problem, in this research, an efficient and environmentally benign technique for the recovery of Nickel (Ni), Cadmium (Cd) and Cobalt (C) from the spent Ni-Cd batteries have been developed using subcritical water assisted by PVC as an HCl source.

## MATERIALS AND METHODS

### Pretreatment of the spent Ni-Cd battery:

All Ni-Cd batteries were discharged with 20 wt. % of NaCl solution for 2 h and mechanically dismantled with hand tools. After dehydrating at 50°C for 2 days, the positive and negative electrodes powders were separated from the steel support plates and then the particle size of the powder was reduced by grinding.

### Leaching of Cd, Co and Ni from the spent Ni-Cd batteries in subcritical water

The leaching experiments were carried out in a 150 mL high-pressure hydrothermal reactor. For the leaching experiments, Ni-Cd battery powder and PVC were dissolved in 60 mL of deionized water into the reactor. Experiment temperature was ranging from (150 to 350) °C with the time varied from (30 to 150) min. After completing the desired conditions, the reaction mixture was cooled to room temperature in an ice bath and the solid residue was separated from the liquid by filtration.

## RESULTS AND DISCUSSION

### Leaching of Cd, Ni and Co

Figure 1 (a, b, c and d) show the optimization of different process parameters, while Figure 2 (a and b) display the elemental composition of Ni, Co and Cd before and after the leaching experiments. From Figs. 1

and 2, it was found that more than 88% of Cd, 72% of Ni and 99% of Co were recovered under the following conditions: temperature of 300°C, PVC/Ni-Cd ratio of 3:1, time of 120 min and a solid/liquid ratio of 15:1 (g/L), respectively.

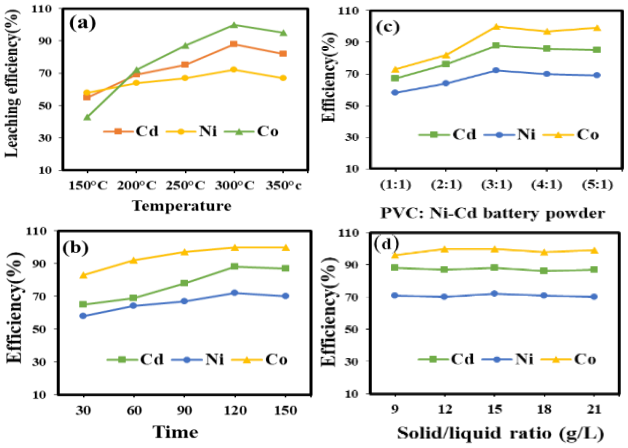


**Figure 1. Effect of a) temperature b) PVC/Ni-Cd ratio c) time and d) solid/liquid ratio on the leaching efficiency of Cd, Ni and Co.**

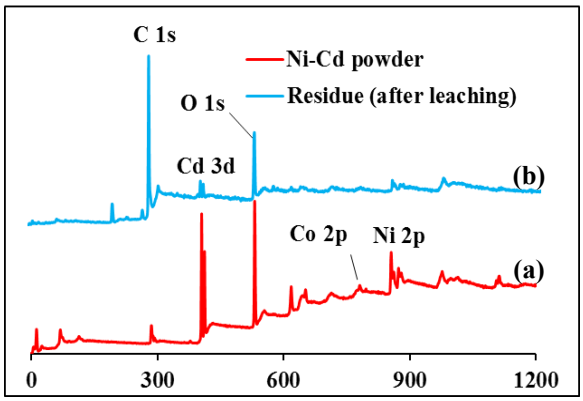


**Figure 2. XPS spectra of a) Ni-Cd powder and b) Residue (after leaching)**

## Environmental and economic effect

In comparison to other processes, such as hydrometallurgy process, which uses harsh reaction conditions and strong inorganic acids (e.g. $HNO_3$, HCl, $H_2SO_4$) as well as a reducing agent (such as $H_2O_2$) that are harmful and bring secondary environmental pollution. PVC-assisted subcritical water extraction of valuable and hazardous metals from the spent Ni-Cd battery makes the leaching operation environment-friendly and economical via avoiding the use of corrosive and harmful reagents, and shortening the reaction time.

## CONCLUSION

PVC assisted subcritical water extraction process was investigated for the leaching of precious and harmful metals (Ni, Co, and Cd) from the spent Ni-Cd batteries. PVC acted as an HCl source generated via PVC dechlorination that helps to accelerate the leaching of Ni, Co and Cd metals. Result showed that more than 88% of Cd, 72% Ni and 99% Co were recovered under the following conditions: 300°C, 120 min, PVC/Ni-Cd mass ratio of 3:1, and a solid/liquid ratio of 15:1(g/L), respectively. The proposed process recommends that subcritical water extraction using PVC is green and sustainable treatment of the spent Ni-Cd battery.

## ACKNOWLEDGEMENT

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