Chapter 7

Conclusions and scope for the future work

7. Conclusions and scope for the future work

7.1 Major conclusions of the present work

In order to transform the tonnes of electronic waste into a valuable resource while also protecting the environment, recycling stands as the sole viable choice. The primary focus of this thesis was the extraction of high value-added materials, particularly nanoparticles, from discarded printed circuit boards. In view of this, we presented a facile process for the recovery of valuable metals such as copper and zinc from discarded computer motherboard PCBs through a hydrometallurgical route. Initially, a chemical pre-treatment process was employed to liberate metallic fractions from non-metallic layers of downsized PCBs. A nitric acid leaching process was proposed to provide a bulk separation of copper-rich solution using liberated metal clads. Use of nitric acid under optimized conditions (3 M HNO_3, 30°C, 2 h, 50 g/L pulp density, 500 rpm agitation speed) results in the nearly complete leaching of copper (99.9%) and zinc (99.3%) by leaving tin-rich residue. Leaching is conducted at a relatively low temperature (30°C), which leads to a significant reduction in the emission of toxic gases, thus making this technique more environmentally friendly.

Subsequently, CuO NPs were synthesized from reclaimed copper via a facile precipitation route to obtain a value-added nanoproduct, without the use of any chemical precursor as starting material for copper source. Furthermore, the recovered value-added material is explored as a potential photocatalyst for the degradation of textile dyes in the presence of visible light. The photocatalytic performance of the CuO NPs was verified by Congo Red and Methylene Blue degradation under visible light irradiation. CuO NPs with irregular spherical morphology and average particle size of 18.709±5.662 nm (sample N1) exhibited better photocatalytic activity than other CuO nanoparticles synthesized via the precipitation route but under different process conditions (i.e., samples N2, N3, and N4). This N1 nanoparticle showed 96.79% Congo Red degradation in 180 min and 98.09% Methylene Blue degradation in 200 min under visible light irradiation.

$Cu(OH)_2$/CuO hybrid nanostructure and CuO microparticles were effectively fabricated by a facile solution technique at low temperature using strip solution obtained from discarded mobile phone PCBs as the copper source. $Cu(OH)_2$/CuO nanoflakes exhibited 97.28% Rhodamine Blue degradation in 100 min under a visible light source.

Thus a process has been developed for the separation of copper from obsolete computer motherboard PCBs and recovery of copper oxide nanoparticles. We believe that recycling and recovering valuable materials from PCBs through this recovery method will play a crucial role in the concept of utilizing one waste material to eliminate another waste during wastewater treatment. Hence, the idea of resource recovery is achieved here by using e-waste as an input material to create a valuable product as a new output. The aim is to help realize a circular economy's objective for huge quantities of e-waste generated annually, hence reusing and recycling waste, maximizing sustainable use of resources, and minimizing waste, which would benefit both the economy and the environment.

7.2 Scope for the future work

The work presented in the thesis has potential for expansion in several directions. Some of these possibilities include:

- Other methods of synthesis such as hydrothermal route for the recovery of other added-value products can be investigated.
- Other potential applications of recovered copper oxide nanoparticles can be studied.
- The recovery of precious metal and tin-based nanoparticles from the residue obtained after leaching can be explored.
- Material recovery from memory slots and mixture of other electronic waste can be explored.
- Integration of the developed approach into circular economy system can be studied.
- Research on utilization of discarded non-metallic part of the PCBs is required to further reduce the environmental burden.