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## List of Publications

### Published Articles

- Jha, R., Rao, M. D., Meshram, A., Verma, H. R., & Singh, K. K. (2020). **Potential of polymer inclusion membrane process for selective recovery of metal values from waste printed circuit boards: A review.** *Journal of Cleaner Production*, 265, 121621. <https://doi.org/10.1016/j.jclepro.2020.121621>
- Jha, R., Agrawal, M., & Singh, K. K. (2023). **Synthesis and Characterisation of PVC-based non- plasticised polymer inclusion membranes for selective metal extraction.** *Canadian Metallurgical Quarterly*, 1–11. <https://doi.org/10.1080/00084433.2023.2175302>
- Jha, R., Sharma, R., Agrawal, M., Dhanunjaya Rao, M., & Singh, K. K. (2023). **Exploring the pretreatment routes of waste printed circuit boards for enhanced metal recovery.** *Materials Today: Proceedings*, July. <https://doi.org/10.1016/j.matpr.2023.08.006>
- Jha, R., Mishra, G., Agrawal, M., Dhanunjaya Rao, M., Meshram, A., & Singh, K. K. (2022). **Opportunities for an en-route to polymer inclusion membrane approach from conventional hydrometallurgical recycling of WPCBs: a mini-review.** In *Canadian Metallurgical Quarterly* (Vol. 0, Issue 0, pp. 1–15). <https://doi.org/10.1080/00084433.2022.2126576>
- Jha, R., Agrawal, M., Jena, A., Mishra, G., Verma, H. R., Meshram, A., & Singh, K. K. (2024). **A review on existing pre-treatment techniques of waste printed circuit boards.** In *Canadian Metallurgical Quarterly* (pp. 1–17). <https://doi.org/10.1080/00084433.2024.2310348>
- Jha, R., et al., Exploration of polymer inclusion membrane for nickel recovery from waste printed circuit boards, *Process Safety and Environmental Protection* <https://doi.org/10.1016/j.psep.2024.07.051>

### Under Review

- Jha, R., et al., Copper leaching from ultrasonically treated milled waste printed circuit boards: Investigation of parameters optimization and kinetics, *Environmental science and pollution research (ESPR-D-24-05380)*
- Jha, R., et al., Nickel leaching from obsolete mobile printed circuit boards: Parameters optimization and kinetics, *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, (240400999)

## References

- Abdul-Halim, N.S., Whitten, P.G., Nghiem, L.D., 2013. Characterising poly (vinyl chloride)/Aliquat 336 polymer inclusion membranes: Evidence of phase separation and its role in metal extraction. *Sep. Purif. Technol.* 119, 14–18. <https://doi.org/10.1016/j.seppur.2013.08.038>
- Adhapure, N.N., Dhakephalkar, P.K., Dhakephalkar, A.P., 2014. Use of large pieces of printed circuit boards for bioleaching to avoid ‘ precipitate contamination problem ’ and to simplify overall metal recovery. *MethodsX* 1, 181–186. <https://doi.org/10.1016/j.mex.2014.08.011>
- Agaya, S.K., Aeno, T.M., To, K.I., De, M.G.E., Attrall, R.W.C., Olev, S.D.K., 2017. Improvement of Chromium ( VI ) Extraction from Acidic Solutions Using a Poly ( vinyl chloride ) -based Polymer Inclusion Membrane with Aliquat 336 as the Carrier 33, 643–646.
- Almeida, Cattrall, R.W., Kolev, S.D., 2012. Recent trends in extraction and transport of metal ions using polymer inclusion membranes (PIMs). *J. Memb. Sci.* 415–416, 9–23. <https://doi.org/10.1016/j.memsci.2012.06.006>
- Almeida, M.I.G.S., Cattrall, R.W., Kolev, S.D., 2017. Polymer inclusion membranes (PIMs) in chemical analysis - A review. *Anal. Chim. Acta* 987, 1–14. <https://doi.org/10.1016/j.aca.2017.07.032>
- Amosova, S. V, Gavrilova, G.M., Cherkashina, V.G., Albanov, A.I., 2004. Unexpected reaction of thio-semicarbazide with 3,6-BIS(Vinyl-sulfonyl)-1,2,4,5-tetrafluorobenzene. *Chem. Heterocycl. Compd.* 40, 1228–1229.
- Argiropoulos, G., Cattrall, R., Hamilton, I., Kolev, S.D., Rohani, P., 1998. The study of a membrane for extracting gold (III) from hydrochloric acid solutions. *J. Memb. Sci.* 138, 279–285. [https://doi.org/10.1016/S0376-7388\(97\)00235-4](https://doi.org/10.1016/S0376-7388(97)00235-4)
- Arous, O., Amara, M., Trari, M., Bouguelia, A., Kerdjoudj, H., 2017. Cadmium ( II ) and lead ( II ) transport in a polymer inclusion membrane using tributyl phosphate as mobile carrier and CuFeO<sub>2</sub> as a polarized photo electrode Cadmium ( II ) and lead ( II ) transport in a polymer inclusion membrane using tributyl phosphate. <https://doi.org/10.1016/j.jhazmat.2010.04.057>
- Arous, O., Kerdjoudj, H., Seta, P., 2004. Comparison of carrier-facilitated silver ( i ) and copper ( ii ) ions transport mechanisms in a supported liquid membrane and in a plasticized cellulose triacetate membrane 241, 177–185. <https://doi.org/10.1016/j.memsci.2004.04.024>
- Assunção, A., Vieira, B., Lourenço, J.P., Costa, M.C., 2016. Recovery of gold(0) nanoparticles from aqueous solutions using effluents from a bioremediation process. *RSC Adv.* 6, 112784–112794. <https://doi.org/10.1039/c6ra24503j>
- Baba, Y., Kubota, F., Goto, M., Cattrall, R.W., Kolev, S.D., 2016. Separation of cobalt(II) from manganese(II) using a polymer inclusion membrane with N-[N,N-di(2-ethylhexyl)aminocarbonylmethyl]glycine (D2EHAG) as the extractant/carrier. *J. Chem. Technol. Biotechnol.* 91, 1320–1326. <https://doi.org/10.1002/jctb.4725>

- Baczyńska, M., Regel-rosocka, M., Coll, M.T., Sastre, A.M., Wiśniewski, M., 2016. TRANSPORT OF Zn(II), Fe(II), Fe(III) ACROSS polymer inclusion membranes (pim) and Flat sheet supported liquid membranes(slm) containing phosphonium ionic liquids as metal ions carriers 6395. <https://doi.org/10.1080/01496395.2016.1174265>
- Baczynska, M., Rzelewska, M., Regel-rosocka, M., 2015. Transport of iron ions from chloride solutions using cellulose triacetate matrix inclusion membranes with an ionic liquid carrier ‡. <https://doi.org/10.1515/chempap-2015-0198>
- Bahrami, S., Reza, M., Najvak, P., Dolatyari, L., 2020. Separation and Purification Technology PVDF-HFP based polymer inclusion membranes containing Cyphos® IL 101 and Aliquat® 336 for the removal of Cr ( VI ) from sulfate solutions. *Sep. Purif. Technol.* 250, 117251. <https://doi.org/10.1016/j.seppur.2020.117251>
- Bakker, E., Bühlmann, P., Pretsch, E., 1997. Carrier-Based Ion-Selective Electrodes and Bulk Optodes. 1. General Characteristics. *Chem. Rev.* 97, 3083–3132. <https://doi.org/10.1021/cr940394a>
- Baldé, A.C.P., Kuehr, R., Yamamoto, T., Mcdonald, R., Angelo, E.D., Althaf, S., Bel, G., Deubzer, O., Fernandez-cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Deepali, S., Luda, V., Lobuntsova, Y., Nnorom, I., Pralat, N., Wagner, M., Baldé, C.P., Kuehr, R., Yamamoto, T., Mcdonald, R., Angelo, E.D., Honda, S., Iattoni, G., Khetriwal, D.S., Luda, V., 2024. The global e-waste monitor 2024.
- Barnwal, A., Dhawan, N., 2020. Recycling of discarded mobile printed circuit boards for extraction of gold and copper. *Sustain. Mater. Technol.* 25, e00164. <https://doi.org/10.1016/j.susmat.2020.e00164>
- Barnwal, A., Mir, S., Dhawan, N., 2020. Processing of Discarded Printed Circuit Board Fines via Flotation. *J. Sustain. Metall.* 6, 631–642. <https://doi.org/10.1007/s40831-020-00304-4>
- Bayou, N., Arous, O., Amara, M., Kerdjoudj, H., 2010. Comptes Rendus Chimie Elaboration and characterisation of a plasticized cellulose triacetate membrane containing trioctylphosphine oxyde ( TOPO ): Application to the transport of uranium and molybdenum ions. *Comptes rendus - Chim.* 13, 1370–1376. <https://doi.org/10.1016/j.crci.2010.04.015>
- Behnamfard, A., Salarirad, M.M., Veglio, F., 2013. Process development for recovery of copper and precious metals from waste printed circuit boards with emphasize on palladium and gold leaching and precipitation. *Waste Manag.* 33, 2354–2363. <https://doi.org/10.1016/j.wasman.2013.07.017>
- Benosmane, N., Hamdi, S.M., Hamdi, M., Boutemour, B., 2009. Selective transport of metal ions across polymer inclusion membranes (PIMs) containing calix[4]resorcinarenes. *Sep. Purif. Technol.* 65, 211–219. <https://doi.org/10.1016/j.seppur.2008.10.039>
- Birloaga, I., De Michelis, I., Ferella, F., Buzatu, M., Vegliò, F., 2013. Study on the influence of various factors in the hydrometallurgical processing of waste printed circuit boards for copper and gold recovery. *Waste Manag.* 33, 935–941. <https://doi.org/10.1016/j.wasman.2013.01.003>
- Birloaga, I., Vegliò, F., 2016. Study of multi-step hydrometallurgical methods to extract the valuable content of gold, silver and copper from waste printed circuit boards. *J. Environ. Chem. Eng.* 4, 20–29. <https://doi.org/10.1016/j.jece.2015.11.021>

- Bonggotgetsakul, Y.Y.N., Cattrall, R.W., Kolev, S.D., 2016. Recovery of gold from aqua regia digested electronic scrap using a poly(vinylidene fluoride-co-hexafluoropropene) (PVDF-HFP) based polymer inclusion membrane (PIM) containing Cyphos® IL 104. *J. Memb. Sci.* 514, 274–281. <https://doi.org/10.1016/j.memsci.2016.05.002>
- Carson, I., MacRuary, K.J., Doidge, E.D., Ellis, R.J., Grant, R.A., Gordon, R.J., Love, J.B., Morrison, C.A., Nichol, G.S., Tasker, P.A., Wilson, A.M., 2015. Anion Receptor Design: Exploiting Outer-Sphere Coordination Chemistry to Obtain High Selectivity for Chloridometalates over Chloride. *Inorg. Chem.* 54, 8685–8692. <https://doi.org/10.1021/acs.inorgchem.5b01317>
- Cayumil, R., Ikram-ul-haq, M., Khanna, R., Saini, R., Mukherjee, P.S., Mishra, B.K., Sahajwalla, V., 2018. High temperature investigations on optimising the recovery of copper from waste printed circuit boards. *Waste Manag.* 73, 556–565. <https://doi.org/10.1016/j.wasman.2017.01.001>
- Cayumil, R., Khanna, R., Ikram-Ul-Haq, M., Rajarao, R., Hill, A., Sahajwalla, V., 2014. Generation of copper rich metallic phases from waste printed circuit boards. *Waste Manag.* 34, 1783–1792. <https://doi.org/10.1016/j.wasman.2014.05.004>
- Chauhan, S., Patel, T., 2014. A Review on Solvent Extraction of Nickel. *Int. J. Eng. Res. Technol.* 3, 1315–1322.
- Chen, J., Nie, X.A., Jiang, J.C., Zhou, Y.H., 2018. Thermal degradation and plasticizing mechanism of poly(vinyl chloride) plasticized with a novel cardanol derived plasticizer. *IOP Conf. Ser. Mater. Sci. Eng.* 292, 0–8. <https://doi.org/10.1088/1757-899X/292/1/012008>
- Chen, W., Shu, Y., Li, Y., Chen, Y., Wei, J., 2021. Co-pyrolysis of waste printed circuit boards with iron compounds for Br-fixing and material recovery. *Environ. Sci. Pollut. Res.* 28, 64642–64651. <https://doi.org/10.1007/s11356-021-15506-w>
- Chen, Y., Li, J., Duan, H., Wang, Z., 2011. Thermal cracking of waste printed wiring boards for mechanical recycling by using residual steam preprocessing. *Front. Environ. Sci. Eng. China* 5, 167–174. <https://doi.org/10.1007/s11783-011-0308-4>
- Chen, Y., Liang, S., Xiao, K., Hu, J., Hou, H., 2021. A cost-effective strategy for metal recovery from waste printed circuit boards via crushing pretreatment combined with pyrolysis : Effects of particle size and pyrolysis temperature. *J. Clean. Prod.* 280, 124505. <https://doi.org/10.1016/j.jclepro.2020.124505>
- Chen, Y., Liu, J., Zhang, M., Feng, B., Wang, L., Wei, J., Fu, W., Tan, X., 2022. Effects of waste printed circuit board powder on strength, durability and microstructure of cement-based materials. *J. Build. Eng.* 61, 105255. <https://doi.org/10.1016/j.job.2022.105255>
- Chien, Y., Wang, H.P., Lin, K., Yang, Y.W., 2000. OXIDATION OF PRINTED CIRCUIT BOARD WASTES IN SUPERCRITICAL WATER 34, 4279–4283.
- Croft, C.F., Almeida, M.I.G.S., Cattrall, R.W., Kolev, S.D., 2018. Separation of lanthanum(III), gadolinium(III) and ytterbium(III) from sulfuric acid solutions by using a polymer inclusion membrane. *J. Memb. Sci.* 545, 259–265. <https://doi.org/10.1016/j.memsci.2017.09.085>
- Cui, H., Anderson, C., 2020. Hydrometallurgical treatment of waste printed circuit boards: Bromine leaching. *Metals (Basel)*. 10, 1–18. <https://doi.org/10.3390/met10040462>

- Cui, J., Zhang, L., 2008. Metallurgical recovery of metals from electronic waste : A review 158, 228–256. <https://doi.org/10.1016/j.jhazmat.2008.02.001>
- Deep, A., Kumar, P., Carvalho, J.M.R., 2010. Recovery of copper from zinc leaching liquor using ACORGA M5640. *Sep. Purif. Technol.* 76, 21–25. <https://doi.org/10.1016/j.seppur.2010.09.015>
- Deveci, H., Yazici, E.Y., Bas, A.D., 2016. Cementation of silver from synthetic leach solutions of waste of printed circuit boards (WPCB). *IMPC 2016 - 28th Int. Miner. Process. Congr.* 2016-Septe.
- Dhanunjaya, M., Singh, K.K., Morrison, C.A., Love, J.B., 2022. Selective recovery of nickel from obsolete mobile phone PCBs. *Hydrometallurgy* 210, 105843. <https://doi.org/10.1016/j.hydromet.2022.105843>
- Ding, Z.Y., Li, L., Wade, D., Gloyna, E.F., 1998. Supercritical Water Oxidation of NH<sub>3</sub> over a MnO<sub>2</sub> / CeO<sub>2</sub> Catalyt. *Ind. Eng. Chem. Res.* 5885, 1707–1716.
- Djokić, S.S., 1996. Cementation of Copper on Aluminum in Alkaline Solutions. *J. Electrochem. Soc.* 143, 1300. <https://doi.org/10.1149/1.1836634>
- Doidge, E.D., Carson, I., Tasker, P.A., Ellis, R.J., Morrison, C.A., Love, J.B., 2016. A Simple Primary Amide for the Selective Recovery of Gold from Secondary Resources. *Angew. Chemie - Int. Ed.* 55, 12436–12439. <https://doi.org/10.1002/anie.201606113>
- Dutta, D., Panda, R., Kumari, A., Goel, S., Kumar, M., 2018. Sustainable recycling process for metals recovery from used printed circuit boards ( PCBs ). *Sustain. Mater. Technol.* 17, e00066. <https://doi.org/10.1016/j.susmat.2018.e00066>
- Encinas-Romero, M.A., Tiburcio-Munive, G., M., Y.-M., 2015. A Kinetic Study of Gold Leaching in CuBr<sub>2</sub>-NaBr system. *J. Multidiscip. Eng. Sci. Technol.* 2, 2118–2121.
- Eng, J.A.C., Cui, H., Anderson, C.G., 2016. Literature Review of Hydrometallurgical Recycling of Printed Circuit Boards (PCBs). *J. Adv. Chem. Eng.* 6, 1–11. <https://doi.org/10.4172/2090-4568.1000142>
- Fatehi, M., Mohebbi, A., Moradi, A., 2018. Understanding the structural, dynamic and thermodynamic properties of 5-Nonylsalicylaldehyde: Molecular dynamics and experimental studies. *J. Mol. Liq.* 271, 290–300. <https://doi.org/10.1016/j.molliq.2018.08.159>
- Ficeriová, J., Baláž, P., Gock, E., 2011. Leaching of gold, silver and accompanying metals from circuit boards (PCBs) waste. *Acta Montan. Slovaca* 16, 128–131.
- Figueira, M.M., Volesky, B., Ciminelli, V.S.T., Roddick, A., 2000. BIOSORPTION OF METALS IN BROWN SEAWEED 34, 196–204.
- Fleming, C.A., 1992. Hydrometallurgy of precious metals recovery. *Hydrometallurgy* 30, 127–162. [https://doi.org/10.1016/0304-386X\(92\)90081-A](https://doi.org/10.1016/0304-386X(92)90081-A)
- Fontàs, C., Tayeb, R., Tingry, S., Hidalgo, M., Seta, P., 2005. Transport of platinum(IV) through supported liquid membrane (SLM) and polymeric plasticized membrane (PPM). *J. Memb. Sci.* 263, 96–102. <https://doi.org/10.1016/j.memsci.2005.04.008>
- Gherasim, Cristina Veronica I., Bourceanu, G., Olariu, R.I., Arsene, C., 2011. Removal of lead(II) from aqueous solutions by a polyvinyl-chloride inclusion membrane without

- added plasticizer. *J. Memb. Sci.* 377, 167–174. <https://doi.org/10.1016/j.memsci.2011.04.042>
- Gherasim, Cristina Veronica I, Cristea, M., Grigoras, C.-V., Bourceanu, G., 2011. New Polymer Inclusion Membrane. Preparation and Characterization. *Dig. J. Nanomater. Biostructures* 6, 1499–1508.
- Ghosh, B., Ghosh, M.K., Parhi, P., Mukherjee, P.S., Mishra, B.K., 2015. Waste Printed Circuit Boards recycling: An extensive assessment of current status. *J. Clean. Prod.* 94, 5–19. <https://doi.org/10.1016/j.jclepro.2015.02.024>
- Goldman, L., Franke, E., Kindel, D., Blaney, D., Richfield, D., 1963. Ion specific polymer membrane. *Nature* 197, 912–914. <https://doi.org/10.1038/197452a0>
- Gomes, C.P., Almeida, M.F., Loureiro, J.M., 2001. Gold recovery with ion exchange used resins. *Sep. Purif. Technol.* 24, 35–57. [https://doi.org/10.1016/S1383-5866\(00\)00211-2](https://doi.org/10.1016/S1383-5866(00)00211-2)
- Guo, L., Liu, Y., Zhang, C., Chen, J., 2011. Preparation of PVDF-based polymer inclusion membrane using ionic liquid plasticizer and Cyphos IL 104 carrier for Cr ( VI ) transport. *J. Memb. Sci.* 372, 314–321. <https://doi.org/10.1016/j.memsci.2011.02.014>
- Gurung, M., Adhikari, B.B., Kawakita, H., Ohto, K., Inoue, K., Alam, S., 2013. Recovery of gold and silver from spent mobile phones by means of acidothiourea leaching followed by adsorption using biosorbent prepared from persimmon tannin. *Hydrometallurgy* 133, 84–93. <https://doi.org/10.1016/j.hydromet.2012.12.003>
- Gyves, J. De, Rodr, E., Miguel, D.S., Julio, C., 2008. Structural effects on metal ion migration across polymer inclusion membranes : Dependence of transport profiles on nature of active plasticizer 307, 105–116. <https://doi.org/10.1016/j.memsci.2007.09.012>
- Haghighi-Yazdi, M., Lee-Sullivan, P., 2015. FTIR analysis of a polycarbonate blend after hydrothermal aging. *J. Appl. Polym. Sci.* 132, 2–7. <https://doi.org/10.1002/app.41316>
- Han, J., Duan, C., Lu, Q., Jiang, H., Fan, X., Wen, P., Ju, Y., 2019. Improvement of the crushing effect of waste printed circuit boards by co-heating swelling with organic solvent. *J. Clean. Prod.* 214, 70–78. <https://doi.org/10.1016/j.jclepro.2018.12.288>
- Harjanto, S., Pratama, F.W., Lazuardiyani, A., Taris, M., Salam, M.Y., 2019. Additional of NaCl on Chloride Leaching of Gold Ore from Indonesian Artisanal Mining. *IOP Conf. Ser. Mater. Sci. Eng.* 515. <https://doi.org/10.1088/1757-899X/515/1/012032>
- Havlik, T., 2008. *Hydrometallurgy Principles and applications*, Hydrometallurgy. <https://doi.org/10.1533/9781845694616>
- Havlik, T., Orac, D., Petranikova, M., Miskufova, A., Kukurugya, F., Takacova, Z., 2010. Leaching of copper and tin from used printed circuit boards after thermal treatment 183, 866–873. <https://doi.org/10.1016/j.jhazmat.2010.07.107>
- Hoque, B., Kolev, S.D., Cattrall, R.W., Gopakumar, T.G., Almeida, M.I.G.S., 2021. A cross-linked polymer inclusion membrane for enhanced gold recovery from electronic waste. *Waste Manag.* 124, 54–62. <https://doi.org/10.1016/j.wasman.2021.01.009>
- Hsu, E., Barmak, K., West, A.C., Park, A.H.A., 2019. Advancements in the treatment and processing of electronic waste with sustainability: A review of metal extraction and recovery technologies. *Green Chem.* 21, 919–936. <https://doi.org/10.1039/c8gc03688h>

- Huang, Y., Pan, M., Lo, S., 2020. Hydrometallurgical metal recovery from waste printed circuit boards pretreated by microwave pyrolysis. *Resour. Conserv. Recycl.* 163, 105090. <https://doi.org/10.1016/j.resconrec.2020.105090>
- Huang, Y., Wang, H.P., Li, C., Chien, Y., 2000. Minimization of cobalt nuclide emissions in supercritical water oxidation of spent resin 40, 1999–2001.
- Iannicelli-Zubiani, E.M., Giani, M.I., Recanati, F., Dotelli, G., Puricelli, S., Cristiani, C., 2017. Environmental impacts of a hydrometallurgical process for electronic waste treatment: A life cycle assessment case study. *J. Clean. Prod.* 140, 1204–1216. <https://doi.org/10.1016/j.jclepro.2016.10.040>
- Ippolito, N.M., Birloaga, I., Ferella, F., Centofanti, M., Vegliò, F., 2021. Preliminary study on gold recovery from high grade e-waste by thiourea leaching and electrowinning. *Minerals* 11, 1–16. <https://doi.org/10.3390/min11030235>
- Işildar, A., Rene, E.R., van Hullebusch, E.D., Lens, P.N.L., 2017. Electronic waste as a secondary source of critical metals: Management and recovery technologies. *Resour. Conserv. Recycl.* <https://doi.org/10.1016/j.resconrec.2017.07.031>
- Izatt, R.M., Izatt, S.R., Bruening, R.L., Izatt, N.E., Moyer, B.A., 2014. Challenges to achievement of metal sustainability in our high-tech society. *Chem. Soc. Rev.* 43, 2451–2475. <https://doi.org/10.1039/c3cs60440c>
- Jadhao, P.R., Ahmad, E., Pant, K.K., Nigam, K.D.P., 2020. Environmentally friendly approach for the recovery of metallic fraction from waste printed circuit boards using pyrolysis and ultrasonication. *Waste Manag.* 118, 150–160. <https://doi.org/10.1016/j.wasman.2020.08.028>
- Jadhav, U., Hocheng, H., 2015. Hydrometallurgical Recovery of Metals from Large Printed Circuit Board Pieces. *Sci. Rep.* 5, 1–10. <https://doi.org/10.1038/srep14574>
- Jha, M.K., Lee, J.C., Kumari, A., Choubey, P.K., Kumar, V., Jeong, J., 2011. Pressure leaching of metals from waste printed circuit boards using sulfuric acid. *Jom* 63, 29–32. <https://doi.org/10.1007/s11837-011-0133-z>
- Jha, R., Rao, M.D., Meshram, A., Verma, H.R., Singh, K.K., 2020. Potential of polymer inclusion membrane process for selective recovery of metal values from waste printed circuit boards: A review. *J. Clean. Prod.* 265, 121621. <https://doi.org/10.1016/j.jclepro.2020.121621>
- Jha, R., Sharma, R., Agrawal, M., Dhanunjaya Rao, M., Singh, K.K., 2023. Exploring the pretreatment routes of waste printed circuit boards for enhanced metal recovery. *Mater. Today Proc.* <https://doi.org/10.1016/j.matpr.2023.08.006>
- Jinglei Yu, Williams, E., Meiting Ju, 2009. Review and prospects of recycling methods for waste printed circuit boards. 2009 IEEE Int. Symp. Sustain. Syst. Technol. 1–5. <https://doi.org/10.1109/ISSST.2009.5156727>
- John, A.M., Cattrall, R.W., Kolev, S.D., 2012. Transport and separation of uranium(VI) by a polymer inclusion membrane based on di-(2-ethylhexyl) phosphoric acid. *J. Memb. Sci.* 409–410, 242–250. <https://doi.org/10.1016/j.memsci.2012.03.061>
- Kamberovi, Ž., 2018. Hydrometallurgical Process for Selective Metals Recovery from Waste-Printed Circuit Boards. *Metals (Basel)*. <https://doi.org/10.3390/met8060441>

- Kang, K.D., Ilankoon, I.M.S.K., Dushyantha, N., Chong, M.N., 2021. Assessment of pre-treatment techniques for coarse printed circuit boards (PCBs) recycling. *Minerals* 11, 1–18. <https://doi.org/10.3390/min11101134>
- Kavitha, N., Palanivelu, K., 2012a. Recovery of copper(II) through polymer inclusion membrane with di (2-ethylhexyl) phosphoric acid as carrier from e-waste. *J. Memb. Sci.* 415–416, 663–669. <https://doi.org/10.1016/j.memsci.2012.05.047>
- Kavitha, N., Palanivelu, K., 2012b. Recovery of copper(II) through polymer inclusion membrane with di (2-ethylhexyl) phosphoric acid as carrier from e-waste. *J. Memb. Sci.* 415–416, 663–669. <https://doi.org/10.1016/j.memsci.2012.05.047>
- Kebiche-Senhadji, O., Tingry, S., Seta, P., Benamor, M., 2010. Selective extraction of Cr(VI) over metallic species by polymer inclusion membrane (PIM) using anion (Aliquat 336) as carrier. *Desalination* 258, 59–65. <https://doi.org/10.1016/j.desal.2010.03.047>
- Kim, E., Kim, M., Lee, J., Pandey, B.D., 2011. Selective recovery of gold from waste mobile phone PCBs by hydrometallurgical process. *J. Hazard. Mater.* 198, 206–215. <https://doi.org/10.1016/j.jhazmat.2011.10.034>
- Kolev, S.D., Baba, Y., Cattrall, R.W., Tasaki, T., Pereira, N., Perera, J.M., Stevens, G.W., 2009. Talanta Solid phase extraction of zinc ( II ) using a PVC-based polymer inclusion membrane with di ( 2-ethylhexyl ) phosphoric acid ( D2EHPA ) as the carrier 78, 795–799. <https://doi.org/10.1016/j.talanta.2008.12.047>
- Kozłowski, C.A., Kozłowska, J., 2009. PNP-16-crown-6 derivatives as ion carriers for Zn(II), Cd(II) and Pb(II) transport across polymer inclusion membranes. *J. Memb. Sci.* 326, 215–221. <https://doi.org/10.1016/j.memsci.2008.10.002>
- Kozłowski, C.A., Walkowiak, W., Pellowski, W., Koziol, J., 2002. Competitive transport of toxic metal ions by polymer inclusion membranes. *J. Radioanal. Nucl. Chem.* 253, 389–394. <https://doi.org/10.1023/A:1020461217949>
- Kubota, F., Kono, R., Yoshida, W., Sharaf, M., Kolev, S.D., Goto, M., 2018a. Recovery of gold ions from discarded mobile phone leachate by solvent extraction and polymer inclusion membrane (PIM) based separation using an amic acid extractant. *Sep. Purif. Technol.* <https://doi.org/10.1016/j.seppur.2018.04.031>
- Kubota, F., Kono, R., Yoshida, W., Sharaf, M., Kolev, S.D., Goto, M., 2018b. Separation and Purification Technology Recovery of gold ions from discarded mobile phone leachate by solvent extraction and polymer inclusion membrane ( PIM ) based separation using an amic acid extractant. *Sep. Purif. Technol.* 0–1. <https://doi.org/10.1016/j.seppur.2018.04.031>
- Kumar, M., Lee, J.C., Kim, M.S., Jeong, J., Yoo, K., 2014. Leaching of metals from waste printed circuit boards (WPCBs) using sulfuric and nitric acids. *Environ. Eng. Manag. J.* 13, 2601–2607.
- Kumar, R., Pandey, A.K., Sharma, M.K., Panicker, L. V, Sodaye, S., Suresh, G., Ramagiri, S. V, Bellare, J.R., Goswami, A., 2011. Diffusional Transport of Ions in Plasticized Anion-Exchange Membranes 5856–5867.
- Kumari, A., Kumar, M., Prasad, R., 2016. Hydrometallurgy Recovery of metals from pyrolysed PCBs by hydrometallurgical techniques. *Hydrometallurgy* 165, 97–105. <https://doi.org/10.1016/j.hydromet.2015.10.020>

- Lahtinen, E., Kivijärvi, L., Tatikonda, R., Väisänen, A., Rissanen, K., Haukka, M., 2017. Selective Recovery of Gold from Electronic Waste Using 3D-Printed Scavenger. *ACS Omega* 2, 7299–7304. <https://doi.org/10.1021/acsomega.7b01215>
- Lee, C.H., Tang, L.W., Popuri, S.R., 2011. A study on the recycling of scrap integrated circuits by leaching. *Waste Manag. Res.* 29, 677–685. <https://doi.org/10.1177/0734242X10380995>
- Li, C., Li, H., Yang, X., Wang, S., Zhang, L., 2015. Gold leaching from a refractory gold concentrate by the method of liquid chlorination. *Rare Met. Technol.* 71–77. [https://doi.org/10.1007/978-3-319-48188-3\\_9](https://doi.org/10.1007/978-3-319-48188-3_9)
- Li, H., Eksteen, J., Oraby, E., 2018. Hydrometallurgical recovery of metals from waste printed circuit boards (WPCBs): Current status and perspectives – A review. *Resour. Conserv. Recycl.* 139, 122–139. <https://doi.org/10.1016/j.resconrec.2018.08.007>
- Li, H., Wang, X., Cao, L., Zhang, X., Yang, C., 2015. Gold-recovery PVDF membrane functionalized with thiosemicarbazide. *Chem. Eng. J.* 280, 399–408. <https://doi.org/10.1016/j.cej.2015.06.021>
- Li, J., Duan, H., Yu, K., Liu, L., Wang, S., 2010. Characteristic of low-temperature pyrolysis of printed circuit boards subjected to various atmosphere. *Resources, Conserv. Recycl.* 54, 810–815. <https://doi.org/10.1016/j.resconrec.2009.12.011>
- Li, J., Shrivastava, P., Gao, Z., Zhang, H., 2004. Printed Circuit Board Recycling : A State-of-the-Art Survey. <https://doi.org/10.1109/TEPM.2004.830501>
- Liu, F., Wan, B., Wang, F., Chen, W., 2019. Effect of thermal shock process on the microstructure and peel resistance of single-sided copper clad laminates used in waste printed circuit boards. *J. Air Waste Manag. Assoc.* 69, 1490–1502. <https://doi.org/10.1080/10962247.2019.1674751>
- Liu, W., Hu, D., Liu, H., Ma, W., 2021. A new reutilization strategy of waste printed circuit board nonmetal powders for constructing superhydrophobic coatings. *Polym. Eng. Sci.* 61, 2193–2199. <https://doi.org/10.1002/pen.25747>
- Loganath, R., Meenambal, T., 2018. A novel method for the removal of epoxy coating from waste printed circuit board. <https://doi.org/10.1177/0734242X18782392>
- Long, L., Sun, S., Zhong, S., Dai, W., Liu, J., Song, W., 2010. Using vacuum pyrolysis and mechanical processing for recycling waste printed circuit boards. *J. Hazard. Mater.* 177, 626–632. <https://doi.org/10.1016/j.jhazmat.2009.12.078>
- Lozano, L.J., Godínez, C., Ríos, A.P.D.L., Hernández-fernández, F.J., 2011. Recent advances in supported ionic liquid membrane technology. *J. Memb. Sci.* 376, 1–14. <https://doi.org/10.1016/j.memsci.2011.03.036>
- Luda, M.P., 2011. Recycling of Printed Circuit Boards. *Integr. Waste Manag. - Vol. II* 285–299. <https://doi.org/10.5772/17220>
- Mack, C., Wilhelmi, B., Duncan, J.R., Burgess, J.E., 2007. Biosorption of precious metals. *Biotechnol. Adv.* 25, 264–271. <https://doi.org/10.1016/j.biotechadv.2007.01.003>
- Małgorzata Ulewicz, W.W., 2006. Removal Of Zn ( II ), Cd ( II ) And Pb ( II ) Using Polymer Inclusion Membrane Transport With Proton Ionizable Db-16-C-5 Crown. *Physicochem. Probl. Miner. Process.* 40, 185–194.

- Martino, C.J., Savage, P.E., 1997. Thermal Decomposition of Substituted Phenols in Supercritical Water 1385–1390.
- Melashvili, M., Fleming, C., Dymov, I., Manimaran, M., O'Day, J., 2014. Study of gold leaching with bromine and bromide and the influence of sulphide minerals on this reaction. *Conf. Metall. Proc.*
- Menad, N.E., 2016. Physical Separation Processes in Waste Electrical and Electronic Equipment Recycling, WEEE Recycling: Research, Development, and Policies. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-803363-0.00003-1>
- Meng, X., Wang, C., Zhou, P., Xin, X., Wang, L., 2017. Transport and selectivity of indium through polymer inclusion membrane in hydrochloric acid medium. *Front. Environ. Sci. Eng.* 11. <https://doi.org/10.1007/s11783-017-0950-6>
- Mirgorod, Y.A., Borshch, N.A., Borodina, V.G., Yurkov, G.Y., Timakov, D.I., 2014. Preparation of gold nanoparticles from the metal scrap. *Theor. Found. Chem. Eng.* 48, 487–492. <https://doi.org/10.1134/S004057951404006X>
- Moyo, T., Chirume, B.H., Petersen, J., 2020. Assessing alternative pre-treatment methods to promote metal recovery in the leaching of printed circuit boards. *Resour. Conserv. Recycl.* 152, 104545. <https://doi.org/10.1016/j.resconrec.2019.104545>
- Mubarok, M.Z., Yunita, F.E., 2015. Solvent Extraction of Nickel and Cobalt from Ammonia-Ammonium Carbonate Solution by Using LIX 84-ICNS 15–27.
- Narita, H., Tanaka, M., Morisaku, K., Abe, T., 2006. Extraction of gold(III) in hydrochloric acid solution using monoamide compounds. *Hydrometallurgy* 81, 153–158. <https://doi.org/10.1016/j.hydromet.2005.10.008>
- Neto, I.F.F., Soares, H.M.V.M., 2021. Simple and near-zero-waste processing for recycling gold at a high purity level from waste printed circuit boards. *Waste Manag.* 135, 90–97. <https://doi.org/10.1016/j.wasman.2021.08.025>
- Nghiem, L.D., Mornane, P., Potter, I.D., Perera, J.M., Cattrall, R.W., Kolev, S.D., 2006. Extraction and transport of metal ions and small organic compounds using polymer inclusion membranes (PIMs). *J. Memb. Sci.* 281, 7–41. <https://doi.org/10.1016/j.memsci.2006.03.035>
- Nie, C. chen, Zhang, H., Qi, X. feng, Shang, H. yu, Li, T. yu, Xue, P., Wang, J. xiang, Zhu, X. nan, 2021. Environment-friendly flotation technology of waste printed circuit boards assisted by pyrolysis pretreatment. *Process Saf. Environ. Prot.* 152, 58–65. <https://doi.org/10.1016/j.psep.2021.05.040>
- Ning, C., Lin, C.S.K., Hui, D.C.W., McKay, G., 2017. Waste Printed Circuit Board (PCB) Recycling Techniques. *Top. Curr. Chem.* 375, 1–36. <https://doi.org/10.1007/s41061-017-0118-7>
- Ocampo, A.L., Aguilar, J.C., Rodríguez de San Miguel, E., Monroy, M., Roquero, P., de Gyves, J., 2009. Novel proton-conducting polymer inclusion membranes. *J. Memb. Sci.* 326, 382–387. <https://doi.org/10.1016/j.memsci.2008.10.010>
- Ogunniyi, I.O., Vermaak, M.K.G., 2009. Investigation of froth flotation for beneficiation of printed circuit board comminution fines. *Miner. Eng.* 22, 378–385. <https://doi.org/10.1016/j.mineng.2008.10.007>

- Ortuño, N., Conesa, J.A., Moltó, J., Font, R., 2014. Pollutant emissions during pyrolysis and combustion of waste printed circuit boards , before and after metal removal. *Sci. Total Environ.* 499, 27–35. <https://doi.org/10.1016/j.scitotenv.2014.08.039>
- Park, Y.J., Fray, D.J., 2009. Recovery of high purity precious metals from printed circuit boards 164, 1152–1158. <https://doi.org/10.1016/j.jhazmat.2008.09.043>
- Petter, P.M.H., Veit, H.M., Bernardes, A.M., 2015. Leaching of gold and silver from printed circuit board of mobile phones. *Rem Rev. Esc. Minas* 68, 61–68. <https://doi.org/10.1590/0370-44672015680152>
- Polat, C., Eyupoglu, V., Sara, O.N., 2016. The novel approach to Cd(II) extraction by polymer inclusion membrane using TIOA as carrier. *AIP Conf. Proc.* 1726. <https://doi.org/10.1063/1.4945936>
- Pospiech, B., 2015a. Hydrometallurgy Studies on extraction and permeation of cadmium ( II ) using Cyphos IL 104 as selective extractant and ion carrier. *Hydrometallurgy* 154, 88–94. <https://doi.org/10.1016/j.hydromet.2015.04.007>
- Pospiech, B., 2015b. Application of Phosphonium Ionic Liquids as Ion Carriers in Polymer Inclusion Membranes (PIMs) for Separation of Cadmium(II) and Copper(II) from Aqueous Solutions. *J. Solution Chem.* 44, 2431–2447. <https://doi.org/10.1007/s10953-015-0413-2>
- Pośpiech, B., Walkowiak, W., 2007. Separation of copper(II), cobalt(II) and nickel(II) from chloride solutions by polymer inclusion membranes. *Sep. Purif. Technol.* 57, 461–465. <https://doi.org/10.1016/j.seppur.2006.07.005>
- Qiu, X., Hu, H., Hu, F., Tang, J., Yang, C., Zhou, Y., Lin, X., Hu, J., 2019. Simultaneous recovery of copper(II) from two different feed solutions based on a three-compartment module with selective polymer inclusion membranes. *Hydrometallurgy* 188, 64–72. <https://doi.org/10.1016/j.hydromet.2019.06.007>
- Quinet, P., Proost, J., Lierde, A. Van, 2005. Recovery of precious metals from electronic scrap by hydrometallurgical processing routes 22, 17–22.
- Radzimska-lenarcik, E., Ulewicz, M., 2012. Selective Transport of Cu ( II ) across a Polymer Inclusion Membrane with 1- Alkylimidazole from Nitrate Solutions Separation Science and Technology Selective Transport of Cu ( II ) across a Polymer Inclusion Membrane with 1-Alkylimidazole from Nitrate So. <https://doi.org/10.1080/01496395.2011.646378>
- Randhawa, N.S., Gharami, K., Kumar, M., 2016. Hydrometallurgy Leaching kinetics of spent nickel – cadmium battery in sulphuric acid. *Hydrometallurgy* 165, 191–198. <https://doi.org/10.1016/j.hydromet.2015.09.011>
- Rao, M.D., Shahin, C., Jha, R., 2021a. Materials Today : Proceedings Optimization of leaching of copper to enhance the recovery of gold from liberated metallic layers of WPCBs. *Mater. Today Proc.* 1–4. <https://doi.org/10.1016/j.matpr.2021.01.052>
- Rao, M.D., Singh, K.K., Morrison, C.A., Love, J.B., 2021b. Recycling copper and gold from e-waste by a two-stage leaching and solvent extraction process. *Sep. Purif. Technol.* 263, 118400. <https://doi.org/10.1016/j.seppur.2021.118400>
- Rao, M.D., Singh, K.K., Morrison, C.A., Love, J.B., 2021c. Optimization of process parameters for the selective leaching of copper, nickel and isolation of gold from

- obsolete mobile phone PCBs. *Clean. Eng. Technol.* 4, 100180.  
<https://doi.org/10.1016/j.clet.2021.100180>
- Rao, M.D., Singh, K.K., Morrison, C.A., Love, J.B., 2020. Challenges and opportunities in the recovery of gold from electronic waste. *RSC Adv.* 10, 4300–4309.  
<https://doi.org/10.1039/c9ra07607g>
- Rautela, R., Arya, S., Vishwakarma, S., Lee, J., Kim, K.H., Kumar, S., 2021. E-waste management and its effects on the environment and human health. *Sci. Total Environ.* 773, 145623. <https://doi.org/10.1016/j.scitotenv.2021.145623>
- Ravi, B., Duraisamy, P., Marimuthu, T., 2021a. A novel approach to epoxy coating removal from Waste Printed Circuit Boards by solvent stripping using NaOH under autoclaving condition A novel approach to epoxy coating removal from Waste Printed Circuit Boards by solvent stripping using NaOH under autoc. *Clean. Mater.* 1, 100015.  
<https://doi.org/10.1016/j.clema.2021.100015>
- Ravi, B., Duraisamy, P., Marimuthu, T., 2021b. A novel approach to epoxy coating removal from Waste Printed Circuit Boards by solvent stripping using NaOH under autoclaving condition. *Clean. Mater.* 1, 100015. <https://doi.org/10.1016/j.clema.2021.100015>
- Razi, M.K., Khosravi, M., Mamoori, R.S., Mohammadi, M., 2010. Preparation of nano gold powder from acid leaching tail solution. *Int. J. nano Dimens.* 1, 47–55.
- Reena, G., Sangita, Verinder, K., 2011. Ft-ir studies of e-plastic obtained from obsolete computers. *J. Chem. Pharm. Res.* 3, 660–667.
- Rodrigues, M.L.M., Leão, V.A., Gomes, O., Lambert, F., Bastin, D., 2015. Copper extraction from coarsely ground printed circuit boards using moderate thermophilic bacteria in a rotating-drum reactor. *Waste Manag.* 41, 148–158.  
<https://doi.org/10.1016/j.wasman.2015.04.001>
- Ruan, J., Xu, Z., 2016. Constructing environment-friendly return road of metals from e-waste : Combination of physical separation technologies. *Renew. Sustain. Energy Rev.* 54, 745–760. <https://doi.org/10.1016/j.rser.2015.10.114>
- Saito, N., Hieda, J., Takai, O., 2009. Synthesis process of gold nanoparticles in solution plasma. *Thin Solid Films* 518, 912–917. <https://doi.org/10.1016/j.tsf.2009.07.156>
- Sellami, F., Kebiche-Senhadji, O., Marais, S., Couvrat, N., Fatyeyeva, K., 2019. Polymer inclusion membranes based on CTA/PBAT blend containing Aliquat 336 as extractant for removal of Cr(VI): Efficiency, stability and selectivity. *React. Funct. Polym.* 139, 120–132. <https://doi.org/10.1016/j.reactfunctpolym.2019.03.014>
- Sethurajan, M., van Hullebusch, E.D., Fontana, D., Akcil, A., Deveci, H., Batinic, B., Leal, J.P., Gasche, T.A., Ali Kucuker, M., Kuchta, K., Neto, I.F.F., Soares, H.M.V.M., Chmielarz, A., 2019. Recent advances on hydrometallurgical recovery of critical and precious elements from end of life electronic wastes - a review. *Crit. Rev. Environ. Sci. Technol.* 49, 212–275. <https://doi.org/10.1080/10643389.2018.1540760>
- Shahira, N., Zulkefeli, W., Weng, S.K., Syazana, N., Halim, A., 2018. Removal of Heavy Metals by Polymer Inclusion Membranes 84–92.
- Silvas, F.P.C., Jiménez Correa, M.M., Caldas, M.P.K., de Moraes, V.T., Espinosa, D.C.R., Tenório, J.A.S., 2015. Printed circuit board recycling: Physical processing and copper extraction by selective leaching. *Waste Manag.* 46, 503–510.

- <https://doi.org/10.1016/j.wasman.2015.08.030>
- Smid, C.-S.D.G. and V., n.d. Separation of Copper, Nickel, Tin and Lead By Ion Exchange from Plating Rinsewater. *Plat. Surf. Finish.* 360, 74–79.
- Sodha, A.B., Tipre, D.R., Dave, S.R., 2019. Optimization and kinetics of copper cementation from bio - leachate generated during the waste printed circuit board ( E - waste ) processing. *Environ. Sustain.* <https://doi.org/10.1007/s42398-019-00084-y>
- Sridhar, V., Verma, J.K., Shenoy, N.S., 2010. Separation of nickel from copper in ammoniacal / ammonium carbonate solution using ACORGA M5640 by selective stripping. *Miner. Eng.* 23, 454–456. <https://doi.org/10.1016/j.mineng.2009.12.001>
- Suah, F.B.M., Ahmad, M., 2017. Preparation and characterization of polymer inclusion membrane based optode for determination of Al<sup>3+</sup>ion. *Anal. Chim. Acta* 951, 133–139. <https://doi.org/10.1016/j.aca.2016.11.040>
- Suah, F.B.M., Ahmad, M., Heng, L.Y., 2015. A novel polymer inclusion membranes based optode for sensitive determination of Al<sup>3+</sup> ions. *Spectrochim. Acta - Part A Mol. Biomol. Spectrosc.* 144, 81–87. <https://doi.org/10.1016/j.saa.2015.02.068>
- Suah, F.B.M., Ahmad, M., Heng, L.Y., 2014. Highly sensitive fluorescence optode for aluminium(III) based on non-plasticized polymer inclusion membrane. *Sensors Actuators, B Chem.* 201, 490–495. <https://doi.org/10.1016/j.snb.2014.04.081>
- Sugiura, M., 1981. Coupled-Ion Transport through a Solvent Polymeric Membrane 81, 2–6.
- Sugiura, M., Kikkawa, M., Urita, S., 1989. Carrier-mediated transport of rare earth ions through cellulose triacetate membranes. *J. Memb. Sci.* 42, 47–55. [https://doi.org/10.1016/S0376-7388\(00\)82364-9](https://doi.org/10.1016/S0376-7388(00)82364-9)
- Szalatkiewicz Jakub, 2014. Metals Content in Printed Circuit Board Waste. *Polish J. Environ. Stud.* 23, 2365–2369.
- Tasaki, T., Oshima, T., Baba, Y., 2007. Extraction Equilibrium and Membrane Transport of Copper ( II ) with New N -6- ( t -Dodecylamido ) -2-Pyridinecarboxylic Acid in Polymer Inclusion Membrane 5715–5722.
- Taylor, P., Li, J., Duan, H., Yu, K., Wang, S., 2012. Interfacial and Mechanical Property Analysis of Waste Printed Circuit Boards Subject to Thermal Interfacial and Mechanical Property Analysis of Waste Printed Circuit Boards Subject to Thermal Shock. *J. Air Waste Manag.* 37–41. <https://doi.org/10.3155/1047-3289.60.2.229>
- Turkington, J.R., Cocalia, V., Kendall, K., Morrison, C.A., Richardson, P., Sassi, T., Tasker, P.A., Bailey, P.J., Sole, K.C., 2012. Outer-sphere coordination chemistry: Amido-ammonium ligands as highly selective tetrachloridozinc(II)ate extractants. *Inorg. Chem.* 51, 12805–12819. <https://doi.org/10.1021/ic301691d>
- Ulewicz, M., Lesinska, U., Bochenska, M., Walkowiak, W., 2007. Facilitated transport of Zn ( II ), Cd ( II ) and Pb ( II ) ions through polymer inclusion membranes with calix [ 4 ] - crown-6 derivatives. <https://doi.org/10.1016/j.seppur.2006.09.018>
- UNEP, 2007. E-waste Volume I: Inventory Assessment Manual. United Nations Environ. Program. 127.
- Veit, H.M., de Pereira, C.C., Bernardes, A.M., 2002. Using mechanical processing in

- recycling printed wiring boards. *Jom* 54, 45–47. <https://doi.org/10.1007/BF02701850>
- Verma, H.R., Singh, K.K., Basha, S.M., 2018. Effect of Milling Parameters on the Concentration of Copper Content of Hammer-Milled Waste PCBs: A Case Study. *J. Sustain. Metall.* 4, 187–193. <https://doi.org/10.1007/s40831-018-0179-z>
- Verma, H.R., Singh, K.K., Mankhand, T.R., 2017a. Delamination mechanism study of large size waste printed circuit boards by using dimethylacetamide. *Waste Manag.* 65, 139–146. <https://doi.org/10.1016/j.wasman.2017.04.013>
- Verma, H.R., Singh, K.K., Mankhand, T.R., 2017b. Liberation of metal clads of waste printed circuit boards by removal of halogenated epoxy resin substrate using dimethylacetamide. *Waste Manag.* 60, 652–659. <https://doi.org/10.1016/j.wasman.2016.12.031>
- Verma, H.R., Singh, K.K., Mankhand, T.R., 2016. Dissolution and separation of brominated epoxy resin of waste printed circuit boards by using di-methyl formamide. *J. Clean. Prod.* 139, 586–596. <https://doi.org/10.1016/j.jclepro.2016.08.084>
- Wang, D., Hu, J., Liu, D., Chen, Q., Li, J., 2017. Selective transport and simultaneous separation of Cu(II), Zn(II) and Mg(II) using a dual polymer inclusion membrane system. *J. Memb. Sci.* 524, 205–213. <https://doi.org/10.1016/j.memsci.2016.11.027>
- Wang, D., Liu, F., Zhang, X., Wu, M., Wang, F., Liu, J., Wang, J., Liu, Q., Zeng, H., 2021. A Janus facilitated transport membrane with asymmetric surface wettability and dense/porous structure: Enabling high stability and separation efficiency. *J. Memb. Sci.* 626, 119183. <https://doi.org/10.1016/j.memsci.2021.119183>
- Wang, X.U.N., Jiao, F.E.N., Qin, W., Li, Z., Wang, N.A., Liu, W.E.I., Yang, C., 2020. Combination of Pyrolysis and Physical Separation to Recover Copper and Tin from Waste Printed Circuit Boards. *JOM* 72, 3179–3185. <https://doi.org/10.1007/s11837-020-04135-2>
- Wang, Z., Sun, Y., Tang, N., Miao, C., Wang, Y., Tang, L., Wang, S., Yang, X., 2019. Simultaneous extraction and recovery of gold(I) from alkaline solutions using an environmentally benign polymer inclusion membrane with ionic liquid as the carrier. *Sep. Purif. Technol.* 222, 136–144. <https://doi.org/10.1016/j.seppur.2019.04.030>
- Wath, S.B., Katariya, M.N., Singh, S.K., Kanade, G.S., Vaidya, A.N., 2015. Separation of WPCBs by dissolution of brominated epoxy resins using DMSO and NMP : A comparative study. *Chem. Eng. J.* 280, 391–398. <https://doi.org/10.1016/j.cej.2015.06.007>
- Wilson, A.M., Bailey, P.J., Tasker, P.A., Turkington, J.R., Grant, R.A., Love, J.B., 2014. Solvent extraction: The coordination chemistry behind extractive metallurgy. *Chem. Soc. Rev.* 43, 123–134. <https://doi.org/10.1039/c3cs60275c>
- Witt, K., Radzaminska-lenarcik, E., Kosciuszko, A., 2018. The Influence of the Morphology and Mechanical Properties of Polymer Inclusion Membranes ( PIMs ) on Zinc Ion Separation from Aqueous Solutions. *MDPI* 10, 134. <https://doi.org/10.3390/polym10020134>
- Xing, M., Zhang, F., 2013. Degradation of brominated epoxy resin and metal recovery from waste printed circuit boards through batch sub / supercritical water treatments. *Chem. Eng. J.* 219, 131–136. <https://doi.org/10.1016/j.cej.2012.12.066>

- Xiu, F., Qi, Y., Zhang, F., 2013. Recovery of metals from waste printed circuit boards by supercritical water pre-treatment combined with acid leaching process. *WASTE Manag.* 1–7. <https://doi.org/10.1016/j.wasman.2013.01.023>
- Xiu, F., Zhang, F., 2009. Recovery of copper and lead from waste printed circuit boards by supercritical water oxidation combined with electrokinetic process 165, 1002–1007. <https://doi.org/10.1016/j.jhazmat.2008.10.088>
- Xiu, F.R., Qi, Y., Zhang, F.S., 2015. Leaching of Au, Ag, and Pd from waste printed circuit boards of mobile phone by iodide lixiviant after supercritical water pre-treatment. *Waste Manag.* 41, 134–141. <https://doi.org/10.1016/j.wasman.2015.02.020>
- Xiu, F.R., Zhang, F.S., 2012. Size-controlled preparation of Cu<sub>2</sub>O nanoparticles from waste printed circuit boards by supercritical water combined with electrokinetic process. *J. Hazard. Mater.* 233–234, 200–206. <https://doi.org/10.1016/j.jhazmat.2012.07.019>
- Xue, Y., Zhou, S., Brown, R.C., Kelkar, A., Bai, X., 2015. Fast pyrolysis of biomass and waste plastic in a fluidized bed reactor. *Fuel* 156, 40–46. <https://doi.org/10.1016/j.fuel.2015.04.033>
- Yaftian, M.R., Almeida, M.I.G.S., Cattrall, R.W., Kolev, S.D., 2018. Selective extraction of vanadium(V) from sulfate solutions into a polymer inclusion membrane composed of poly(vinylidene fluoride-co-hexafluoropropylene) and Cyphos®IL 101. *J. Memb. Sci.* 545, 57–65. <https://doi.org/10.1016/j.memsci.2017.09.058>
- Yan, G., Guo, J., Zhu, G., Zhang, Z., Zhao, P., Xiangnan, Z., Zhang, B., 2020. Liberation enhancement and copper enrichment improvement for waste printed circuit boards by heating pretreatment. *Waste Manag.* 106, 145–154. <https://doi.org/10.1016/j.wasman.2020.03.023>
- Yildirim, E., Onwudili, J.A., Williams, P.T., 2015. Chemical Recycling of Printed Circuit Board Waste by Depolymerization in Sub- and Supercritical Solvents. *Waste and Biomass Valorization* 6, 959–965. <https://doi.org/10.1007/s12649-015-9426-8>
- Yildiz, Y., Manzak, A., Aydin, B., Tutkun, O., 2014. Preparation and application of polymer inclusion membranes (PIMs) including Alamine 336 for the extraction of metals from an aqueous solution. *Mater. Tehnol.* 48, 791–796.
- Yin, J., Deng, B., 2015. Polymer-matrix nanocomposite membranes for water treatment. *J. Memb. Sci.* 479, 256–275. <https://doi.org/10.1016/j.memsci.2014.11.019>
- Yoo, J.M., Jeong, J., Yoo, K., Lee, J. chun, Kim, W., 2009. Enrichment of the metallic components from waste printed circuit boards by a mechanical separation process using a stamp mill. *Waste Manag.* 29, 1132–1137. <https://doi.org/10.1016/j.wasman.2008.06.035>
- Zaheri, P., Ghassabzadeh, H., 2017. Preparation of polymer inclusion membrane including mixture of D2EHPA and Cyanex272 for the extraction of Eu from nitrate media. *Chem. Pap.* <https://doi.org/10.1007/s11696-017-0155-2>
- Zhang, S., Forsberg, E., 1997. Mechanical separation-oriented characterization of electronic scrap. *Resour. Conserv. Recycl.* 21, 247–269. [https://doi.org/10.1016/S0921-3449\(97\)00039-6](https://doi.org/10.1016/S0921-3449(97)00039-6)
- Zhang, T., Mao, X., Qu, J., Liu, Y., Ali, A., Ao, W., 2021. Microwave-assisted catalytic pyrolysis of waste printed circuit boards, and migration and distribution of bromine. *J.*

- Hazard. Mater. 402, 123749. <https://doi.org/10.1016/j.jhazmat.2020.123749>
- Zhou, C., Pan, Y., Lu, M., Yang, C., 2016. Liberation characteristics after cryogenic modification and air table separation of discarded printed circuit boards. *J. Hazard. Mater.* 311, 203–209. <https://doi.org/10.1016/j.jhazmat.2016.03.008>
- Zhu, P., Chen, Y., Wang, L.Y., Qian, G.R., Zhou, M., Zhou, J., 2013a. A novel approach to separation of waste printed circuit boards using dimethyl sulfoxide. *Int. J. Environ. Sci. Technol.* 10, 175–180. <https://doi.org/10.1007/s13762-012-0124-9>
- Zhu, P., Chen, Y., Wang, L.Y., Zhou, M., Zhou, J., 2013. The separation of waste printed circuit board by dissolving bromine epoxy resin using organic solvent. *Waste Manag.* 33, 484–488. <https://doi.org/10.1016/j.wasman.2012.10.003>
- Zhu, P., Chen, Y., Wang, L.Y., Zhou, M., Zhou, J., 2013b. The separation of waste printed circuit board by dissolving bromine epoxy resin using organic solvent. *Waste Manag.* 33, 484–488. <https://doi.org/10.1016/j.wasman.2012.10.003>
- Zong Gao, Jianzhi Li, Zhang, H.C., 2002. Printed circuit board recycling: a state-of-art survey. *Conf. Rec. 2002 IEEE Int. Symp. Electron. Environ. (Cat. No.02CH37273)* 234–241. <https://doi.org/10.1109/ISEE.2002.1003272>