III International Scientific Conference "**Sustainable and efficient use of energy, water and natural resources – SEWAN-2021**"

Title: Recovery of silver from electronic scrap (methods, features and prospects)

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Research Objective

- A huge number of new electronic devices
- Increase in the amount of electronic waste containing
- Toxic heavy metals (Hg, Pb)
- Valuable metals such as gold, silver, platinum,
- Non-ferrous metals (Cu, Al, Co, Ni), etc.
- Surface and groundwater around landfills containing e-waste is particularly heavily contaminated
- The failure to stop and reverse the contamination can lead to serious negative consequences for the environment.

Currently: lack of an environmentally friendly technology for recycling e-waste, to obtain products of appropriate quality

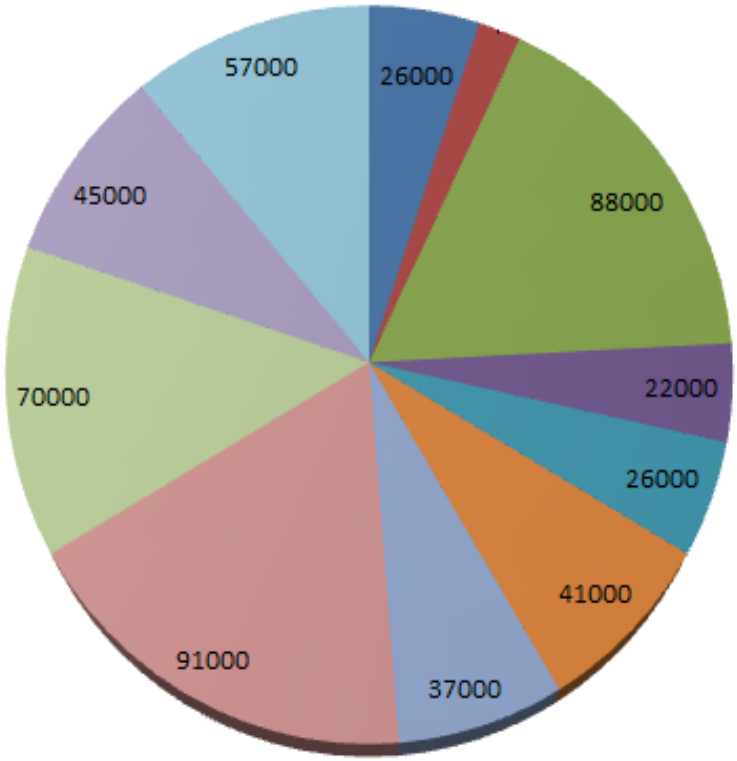
Imperative to create a new environmentally-friendly technology for extracting valuable components from electronic scrap.

Background

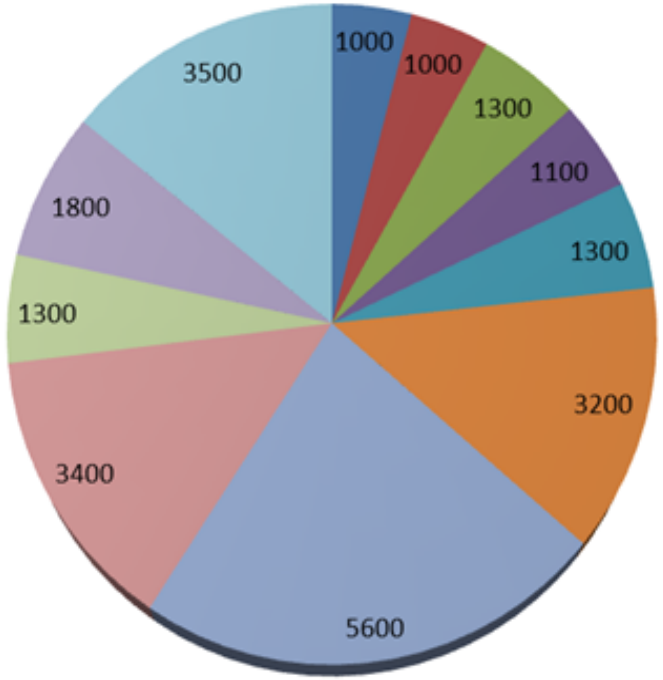
According to the US Geological Survey, the known world silver reserves at the end of 2020 are 500,000 tons, silver production in 2019 was 26,000 tons, and in 2020 - 25,000 tons (Figure 1). If the same growth rate continues in the future, world silver reserves may be depleted within 15 years.

In 2020, silver was used in electrical engineering and electronics - 28%; jewelry and silver items - 26%; coins and medals - 19%; photography - 3%; and others - 24% (figure 2) . Taking into account the fact that the development of the electronic industry also increases the consumption of silver, as electronic products containing up to 28% of all produced silver fail, it becomes extremely important to return it to the production cycle through processing.

Silver at the End of 2020

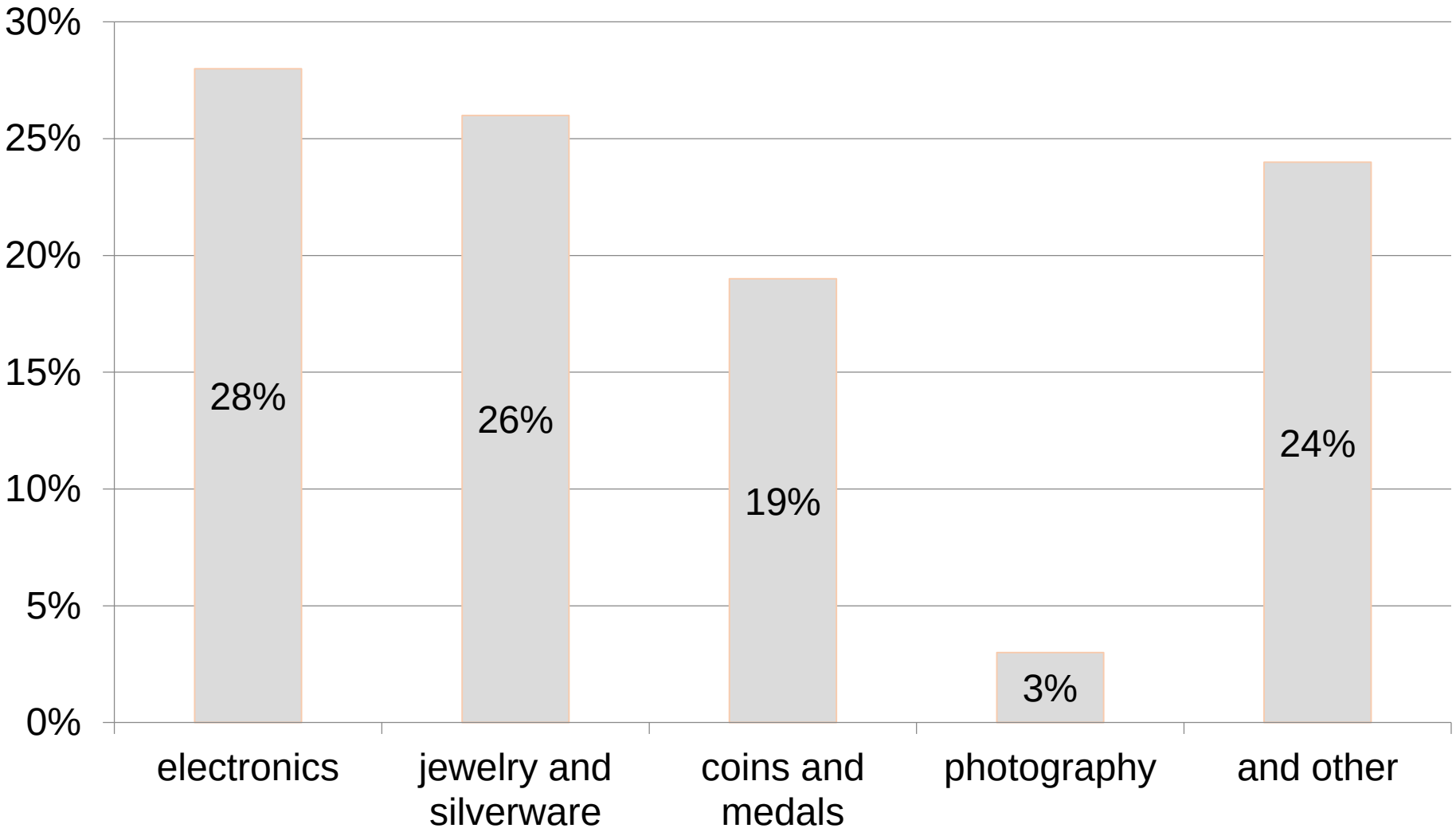


(a) Silver reserves

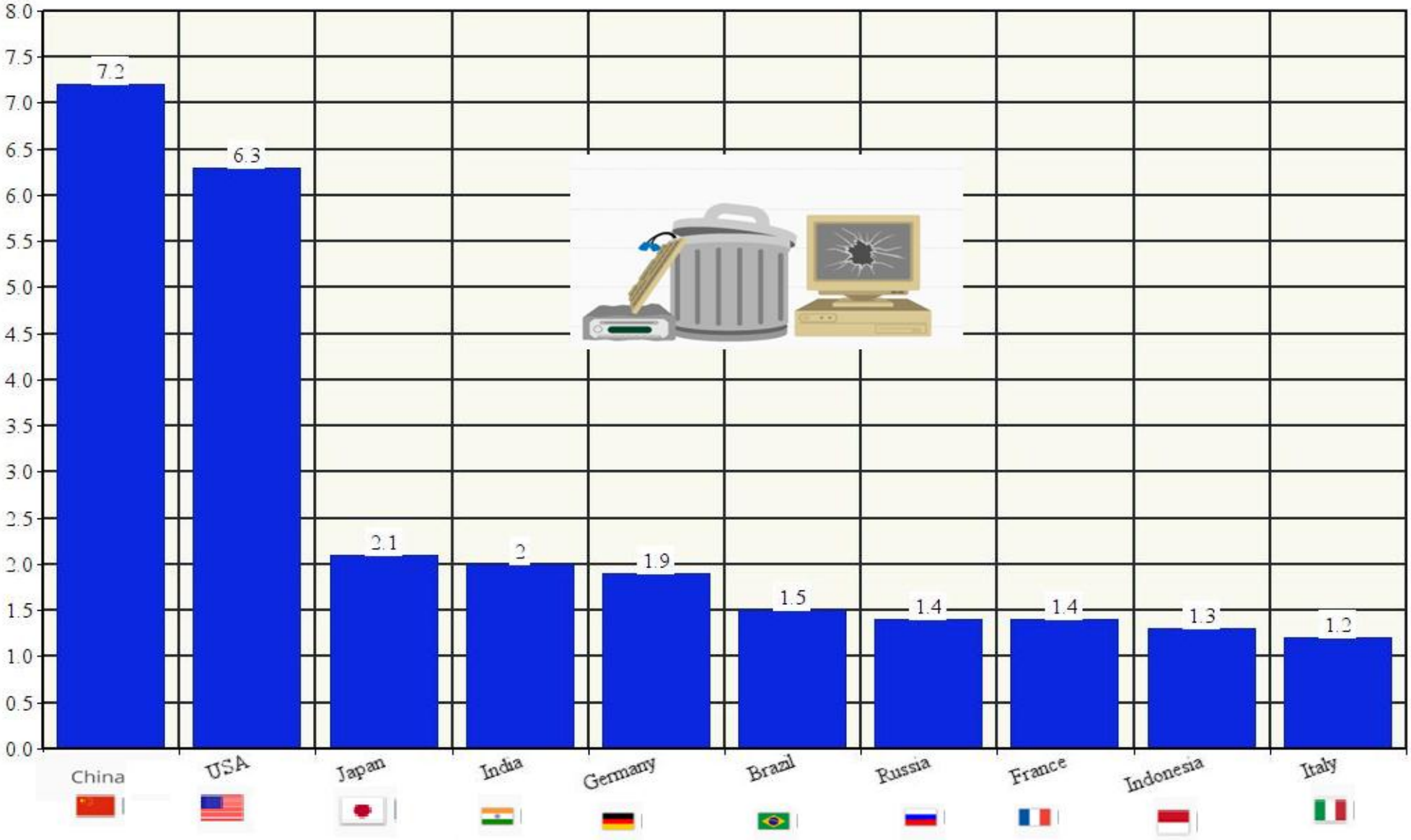


(b) Silver mine prodaction

Silver Consumption by Industry (2020)



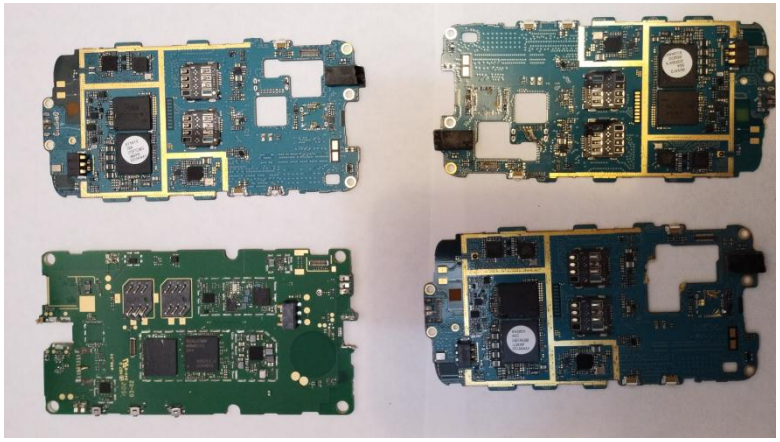
Gobal E-Waste Production (2016)



Experimental Part

A type of electronic scrap, the number of which is growing rapidly - gadgets, computers and smartphones. These types of e-waste are especially valuable due to the high content of precious metals in printed circuit boards and electronic components (gold, silver, platinum, etc.). It is proposed to use a combined processing scheme - for the extraction of metals from electronic scrap, in parallel with preliminary mechanical processing, apply pyrometallurgical and hydrometallurgical methods. After crushing the printed circuit board, the metals were separated from the non-metals using physical methods. Metals are copper, tin, lead, zinc and precious metals. To separate the silver, we melt the material and at the first stage we obtain a metal concentrate. Noble metals remain in the slag. Then we use hydrometallurgical operations: the slag is dissolved and sent to electrolysis.

Printed circuit boards (PCBs)



(a) after disassembly

(b) in a vessel

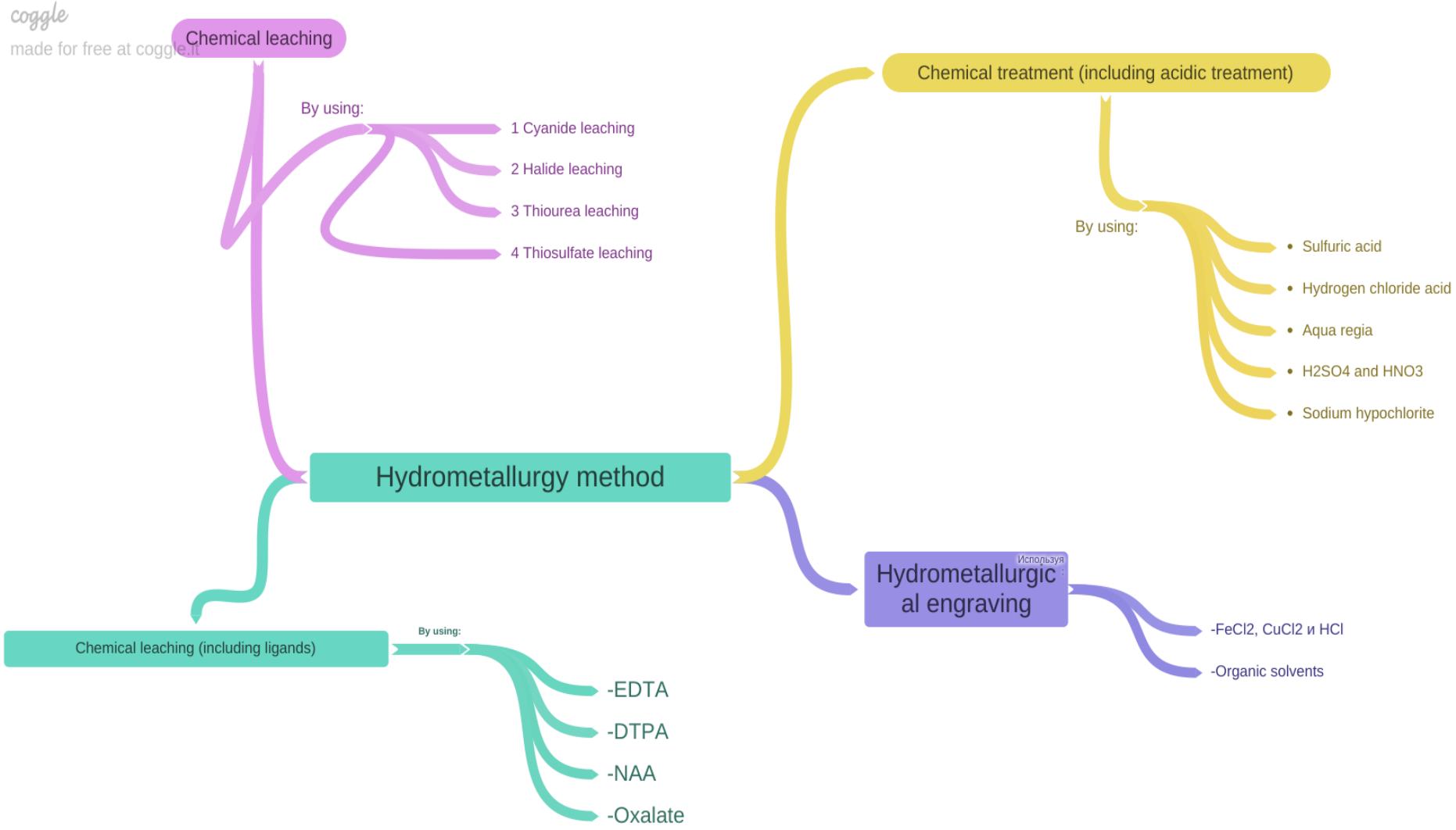
Used electronic PCBs contain a huge quantity of such precious metals as Ag, Au, Pd.

Average concentrations of metals in mixed PCB samples (weight, %)

Cu	Al	Sn	Ni	Zn	Pb	Fe	Ag	Au
26.4	3.9	3.2	2.3	1.2	1.7	4.2	0.2	0.35

Hydrometallurgy

Hydrometallurgical methods can be used for processing silver-containing electronic waste. Nitric acid is used as a reagent. Weaker acids cannot be used.



Leaching

Printed circuit boards (PCB)

Figure 6: Leaching of solder: **a** detached gold sputtering on the surface of PLS, **b** gold, silver sputtering and electronic components

Extraction of Silver

Extraction of silver from WPBs. Silver is found in some circuit boards in the form of silver plated copper contacts. Therefore, the removal of silver from copper contacts is one of the stages in the processing of printed circuit boards. Silver is not affected by hydrochloric acid. Despite this, this noble metal has good solubility in oxygenated nitric acid.

$$3Ag_{(s)} + HNO_{3\ (aq)} + 3HCl_{\ (aq)} = 3AgCl_{(s)} + 3H_2O_{(aq)} + NO_{(g)}$$

Conclusions

Considering all the above properties of silver, when dissolving the solder (tin-lead alloy), nitric acid is used with an extraction time of 2 hours with heating (temperature 60 ° C). At the same time, a certain amount of copper (0.02-0.07 g / l) can be found in the solution. Then, the separated silver-plated contacts were thoroughly washed with distilled water and sent for further processing to remove silver from them. To extract silver, nitric acid was used, and with its help silver contacts were dissolved, reducing it to silver chloride, that is, as a result of the precipitation of silver with hydrochloric acid, AgCl precipitates, after which the precipitate is filtered from the solution, and silver chloride was dissolved in an aqueous solution of ammonia ... At the end of the experiment, silver was precipitated by carburizing copper (a copper radiator was used to cool the laptop). Thus, in the course of the analysis, it was established that the processing of electronic waste for the purpose of extracting silver is one of the promising directions in increasing the material base of silver production. At the same time, hydrometallurgical methods using an aqueous solution of nitric acid are most effective from the point of view of the completeness of the extraction of silver and the environmental friendliness of the process.

Thank you for your attention!

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