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STATUS AND PROSPECTS OF METALLURGICAL PROCESSING OF ELECTRONIC WASTE IN KAZAKHSTAN

This article provides an overview of the current state of the problem of processing electronic waste in order to extract metals and other valuable components. Electronic waste is a source of potential danger to the environment, but at the same time a valuable raw material containing non-ferrous and ferrous metals. The content of some non-ferrous metals in electronic waste may exceed their content in mineral raw materials by several times. So, the content of printed circuit boards (PCBs) can reach up to 30 % of the weight of printed circuit boards, and tin up to 2–4 %. In addition, a ton of used smartphones can contain up to 30 grams of gold. It is also known that during the processing of secondary raw materials, the costs of obtaining metals are many times lower compared to the processing of mineral raw materials. Despite this, worldwide the percentage of recycling of electronic waste does not exceed 10 %. This fact requires a revision of traditional a PCBs to the processing of electronic waste and the formation of new, less costly and more environmentally friendly methods based on a review and analysis of existing a PCBs. To this end, the article considers examples of modern methods tested in laboratory conditions and already existing commercial technological solutions in the field of processing. Based on the review of world experience, conclusions were drawn about the current state of the world and the prospects for recycling electronic waste in Kazakhstan.

Keywords: electronic waste, recycling, hydrometallurgy, pyrometallurgy.

Introduction

The continuously growing consumption of electronic household a PCBs and gadgets until 2020 has led to an increase in the generation of electronic waste at the global level. Thus, studies conducted in 2017 assumed an annual growth rate of electronic waste generation of 3–4 % [1]. However, by 2019, the estimated growth in the generation of electronic waste has increased to 5–6 % [2]. In total, by the end of 2019, about 53.6 million tons of e-waste had been generated. The distribution of electronic waste by type in 2019 is shown in Figure 1. The COVID-19 pandemic has slightly reduced the pace of production of electronic equipment. However, such segments of the market as the production and sale of smartphones were practically not affected by the crisis. In 2016, the production of smartphones amounted to 3.7 million units. In 2021 – 6.26 million units. In 2022, the projected number of smartphone production is 6.56 million units, and by 2027, 7.69 million units.

The composition of electronic waste includes various materials: non-ferrous and ferrous metals, and non-metals. Many of the materials are toxic. Therefore, of particular concern is the fact that worldwide, only 10 % of the waste generated is recycled [2]. Most of the waste that ends up in landfills harms the environment. As a result, a significant amount of metals falls out of circulation, creating economic risks associated with a shortage of materials necessary for the production of electronics.

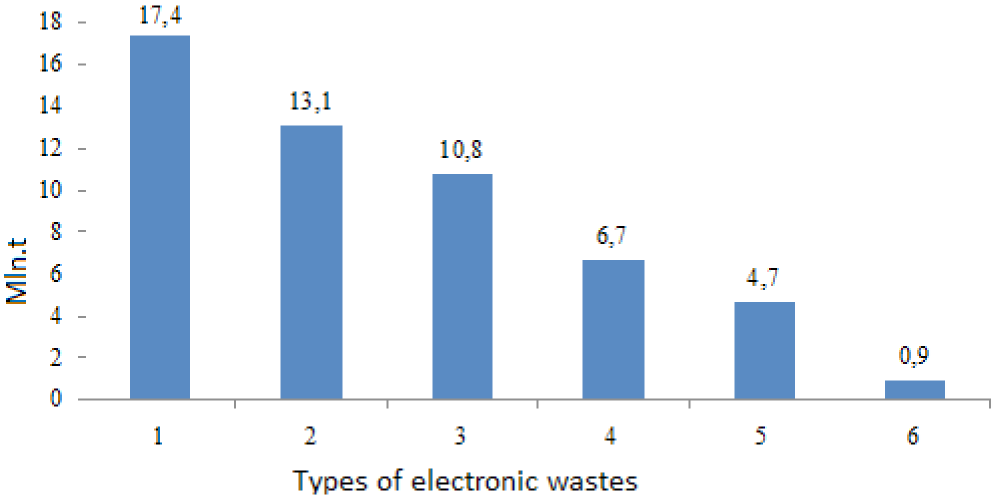

Figure 1 – Distribution of electronic waste by type

1 – small equipment, 2 – large equipment,
3 – heat exchangers, 4 – screens and monitors,
5 – IT equipment, 6 – lamps [2]

Research methodology and methods

The low percentage of electronic waste recycling is associated with the difficulty of separating closely integrated materials and the impossibility of a PCBs traditional recycling schemes to them [3]. The amount of electronic scrap generated in Kazakhstan reaches 136 thousand tons per year. And only a small part of this amount is recycled. So in 2018, only 4561 tons were processed [4]. Of particular value for recycling are electronic waste, represented by electronic gadgets, computer and other IT equipment containing a large amount of noble and precious metals. Precious metals are used in the manufacture of contacts, and parts of electronic components of gadgets and computers. So, one ton of printed circuit boards of used smartphones can contain up to 350 g of gold [5]. In addition, 30 % percent of the weight of printed circuit boards is co PCBs. The average composition of PCBs of computer equipment and gadgets is presented in Table 1 [6].

Table 1 – Average concentration of metals in PCB (wt.%)

Cu	Fe	Al	Sn	Ni	Zn	Pb	Ag
31,2	2,4	4,12	2,1	0,2	2,3	0,73	0,01

It should be noted that electronic waste exceeds mineral raw materials in terms of the content of valuable elements. This circumstance makes the recycling of electronic waste attractive from an economic point of view. Below are examples of modern methods tested in laboratory conditions and already existing commercial technological solutions in the field of processing. An analysis of the a PCBs technological solutions in this area will allow us to identify the best methods from the point of view of environmental friendliness and economics.

Results and discussion

A typical processing scheme for a computer system unit is shown in Figure 2, where at the first stage the case is separated from the printed circuit board, and then the electronic components are separated from the printed circuit board. The same recycling principle a PCBs to smartphones. The case, as a rule, contains ferrous metals and plastic. For the processing of printed circuit boards after their pre-treatment, pyro and hydrometallurgical methods are used.

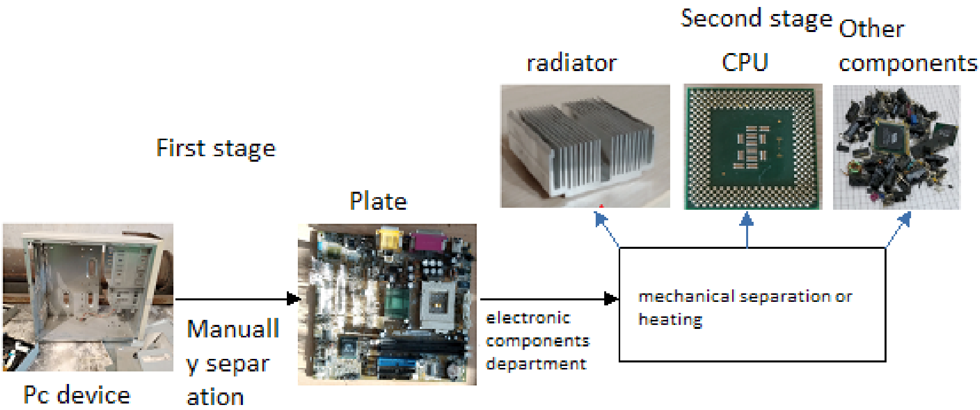

Figure 2 – Scheme of processing computer system blocks

Today, pyrometallurgy has evolved into a simple, promising and efficient e-waste recycling method, mainly used to extract non-ferrous metals such as co PCBs and precious metals [7]. Despite its widespread use, pyrometallurgical methods have a number of disadvantages. Disadvantages include an inability to recover iron, aluminium, organics and glass components, high energy consumption, release of toxic by-products such as dioxins and halogen compounds, and its primary use for processing only high quality printed circuit boards containing high concentrations of gold. The essence of recycling lies in the melting of the crushed mass of printed circuit boards. The resulting material is drained in the form of a cone to separate the heaviest metals. Modern commercial technologies offered on the free market by some companies are based on this principle. A typical processing scheme is shown in Figure 3.

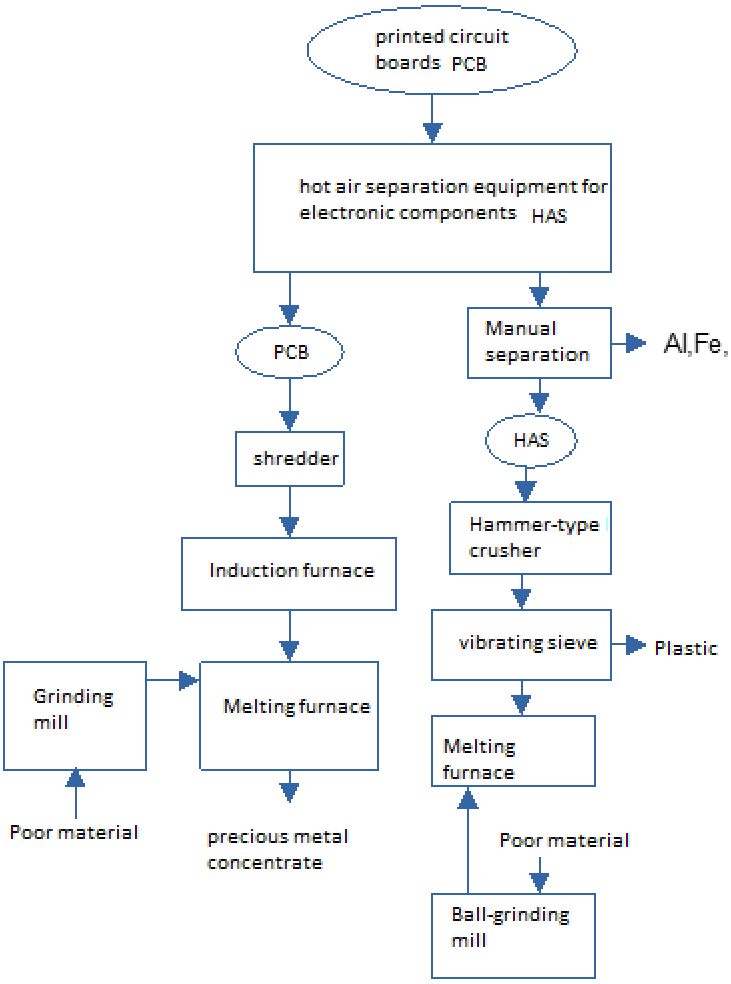

Figure 3 – A typical scheme for the processing of electronic equipment, offered on the market [8]

In a number of works, alternative pyrometallurgical methods of processing have been considered. The authors carried out high-temperature processing of printed circuit boards at a temperature of 900 °C to obtain metal microparticles [9]. The release characteristics of gold and silver were studied by heat treatment of incinerated waste PCB in a chlorine gas flow at a temperature of 1000 °C [10].

Hydrometallurgical methods involve the use of various acids to bring valuable components into solution. Printed circuit boards are usually shredded to a size of ≤ 0.1mm. Various acids are used as reagents. The extracted metals from the solution are precipitated by cementation, electrolysis, and other methods. Comparison and characteristics of some hydrometallurgical methods are shown in Table 2.

Table 2 – Main characteristics of hydrometallurgical methods for processing PCB

	[11]	[12]	[13]	[14]	[15]
Pre-treatment	No	No	No	No	C_4H_9NO;T/Zh=3/10; 50 °C;16 h
Reagents	HCl, 2 mol/l	HCl, 2 mol/l	25 % HNO_3;75 % HCl	H_2SO_4, $CuSO_4$ 1 mol/l	HNO_3
T/Zh;h; °C	10/1; 4; 75	10/1; 4; 75	20/1; 6; 80	10/1; 3; 65	35/1; 3; 60
Mixing speed.	500	500	550	500	Ultrasound
Precipitation	Cementation	Cementation	Electrolysis 1.5 A; 1 hour	H_2O_2	NaOH additive for Cu precipitation, filter for traPCBing Sn and Pb
Regeneration reagents	No	No	No	Yes	No

Hydrometallurgical methods compare favorably with pyrometallurgical methods by lower energy costs. The main problem of hydrometallurgical methods is the lack of reagent regeneration. Therefore, the question of storage and disposal of toxic waste solutions will arise. Against this background, the method using H_2SO_4, $CuSO_4$ as reagents looks the most promising, since it includes the regeneration of the reagent.

Conclusions

Thus, based on the foregoing, we can conclude that the optimal scheme for processing electronic waste should include, at the first stage, physical methods for separating black. Non-ferrous metals and non-metals. Ferrous metals are recycled using traditional methods. Recycling of the non-metal part should include separation of plastic, glass and other items for separate recycling. The extraction of non-ferrous and precious metals must be carried out by hydrometallurgical methods with the indispensable regeneration of reagents. This will eliminate the problem of storage and disposal of toxic waste solutions. A promising waste recycling scheme is shown in Figure 4.

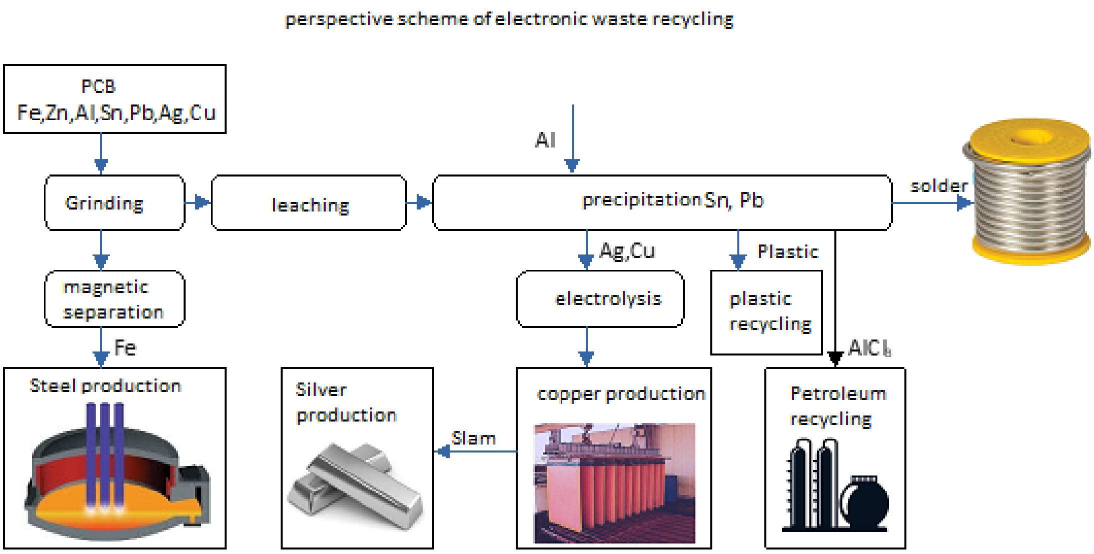

Figure 4 – Perspective processing schemee-waste

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫНДАҒЫ ЭЛЕКТРОНДЫҚ ҚАЛДЫҚТАРДЫ ҚАЙТА ӨҢДЕУ ЖАҒДАЙЫ ЖӘНЕ БОЛАШАҒЫ

Бұл мақалада металдар мен басқа да құнды компоненттерді алу үшін электронды қалдықтарды өңдеу мәселесінің ағымдағы жай-күйіне шолу жасалады. Электрондық қалдықтар әлеуетті экологиялық қауіптің көзі болып табылады, бірақ сонымен бірге құрамында түсті және қара металдар бар бағалы шикізат. Электрондық қалдықтардағы кейбір түсті металдардың мөлшері олардың минералдық шикізаттағы мөлшерінен бірнеше есе жоғары болуы мүмкін. Сонымен, баспа платаларының (PP) мазмұны баспа платаларының салмағы бойынша 30 % дейін, ал қалайы 2–4 % дейін жетуі *мүмкін. Сонымен қатар, бір тонна пайдаланылған смартфонның құрамында 30 грамға дейін алтын болуы мүмкін. Сондай-ақ, қайталама шикізатты өңдеу кезінде металдарды алуға кететін шығындар минералды шикізатты өңдеуге қарағанда бірнеше есе төмен болатыны белгілі. Осыған қарамастан, дүние жүзінде электронды қалдықтарды қайта өңдеу пайызы 10 %-дан аспайды. Бұл факт электрондық қалдықтарды өңдеудің дәстүрлі әдістерін қайта қарауды және қолданыстағы әдістерді қарастыру мен талдау негізінде жаңа, аз шығынды және экологиялық таза әдістерді қалыптастыруды талап етеді. Осы мақсатта мақалада зертханалық жағдайларда сыналған заманауи әдістердің мысалдары және өңдеу саласындағы бұрыннан бар коммерциялық технологиялық шешімдер қарастырылады. Әлемдік тәжірибені шолу негізінде әлемнің қазіргі жағдайы және Қазақстандағы электрондық қалдықтарды кәдеге жарату перспективалары туралы қорытындылар жасалды.*

Кілтті сөздер: электронды қалдықтар, қайта өңдеу, гидрометаллургия, пирометаллургия.

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СОСТОЯНИЕ И ПЕРСПЕКТИВЫ ПЕРЕРАБОТКИ ЭЛЕКТРОННЫХ ОТХОДОВ В РЕСПУБЛИКЕ КАЗАХСТАН

В данной статье представлен обзор современного состояния проблемы переработки электронных отходов с целью извлечения металлов и других ценных компонентов. Электронные отходы представляют собой источник потенциальной опасности для окружающей среды, но в то же время ценное сырье, содержащее цветные и черные металлы. Содержание некоторых цветных металлов в электронных отходах может в несколько раз превышать их содержание в минеральном сырье. Так, содержание печатных плат (ПП) может достигать до 30 % от массы печатных плат, а олова до 2–4 %. Кроме того, тонна бывших в употреблении смартфонов может содержать до 30 граммов золота. Известно также, что при переработке вторичного сырья затраты на получение металлов во много раз ниже по сравнению с переработкой минерального сырья. Несмотря на это, во всем мире процент утилизации электронных отходов не превышает 10 %. Этот факт требует пересмотра традиционных ПХД в сторону переработки электронных отходов и формирования новых, менее затратных и более экологически чистых методов на основе обзора и анализа существующих ПХД. С этой целью в статье рассмотрены примеры современных методов, апробированных в лабораторных условиях, и уже существующие коммерческие технологические решения в области переработки. На основе обзора мирового опыта сделаны выводы о современном состоянии мира и перспективах утилизации электронных отходов в Казахстане.

Ключевые слова: электронные отходы, рециклинг, гидрометаллургия, пирометаллургия.

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