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ELECTROCHEMICAL PRODUCTION OF LEAD FROM AQUEOUS SOLUTIONS OF LEAD SALTS

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Abstract
The escalating global demand for lead, primarily driven by applications such as lead-acid batteries, necessitates a critical examination of lead production methods. This overview explores the traditional pyrometallurgical and emerging hydrometallurgical and electrolytic refining approaches, emphasizing their environmental impact, operational efficiency, and sustainability. Kazakhstan, with substantial lead reserves, serves as a focal point, illustrating its prominent position in the international lead production landscape. The conventional sintering and blast furnace smelting method offer established technology but pose environmental threats, including air and water pollution. The innovative ISA smelting method showcases advantages in productivity and energy efficiency but requires careful consideration of specialized skills and financial implications. Hydrometallurgical processes, including electrolytic refining, present cleaner alternatives, with benefits such as resource extraction from diverse feed stocks and reduced environmental impact. However, challenges like complex concentrate preparation and slower processing times are acknowledged. A detailed literature review delves into various electrolytes for lead production, assessing their efficiency, challenges, and environmental implications. The discussion underscores the significance of automation, resource recovery, and heightened safety in electrolytic refining. The research concludes by acknowledging the potential of hydrometallurgy and electrolysis in greening lead production, provided ongoing research addresses challenges, ensuring a sustainable and efficient future for this essential metal.
Keywords: lead, electrolysis lead, pyrometallurgy, lead solutions, electrolysis of aqueous solutions, hydrometallurgy, ecologically friendly.

Introduction

Nowadays, lead consumption in the world is growing every year, especially for the following fields: lead-acid batteries accounted for 80% of the apparent consumption of lead [Mordor Intelligence, 2023], ammunition (3%) [Mineral Commodity Summaries, 2023], lead oxides in glass and ceramics (3%) [Lead Statistics and Information, 2023], foundry metals (2%) [Mineral Commodity Summaries, 2023], also corrosion protection cables, x-ray machines, etc.

There are two main methods to produce lead: pyrometallurgical and hydrometallurgical. The pyrometallurgical method, namely refining, is considered the traditional thermal method. However, this method is a threat to the environment, leading to several problems: global warming (due to high temperatures and emissions), pollutes ecosystems, including air, soil, and water with its particles and harmful products. During sintering, hot air or oxygen oxidizes the sulfur in the raw material to sulfur dioxide (SO_2). That is why it is important to know which methods are practiced in the world and which are in process to develop the idea of environmentally friendly production of lead. In this regard, for a greener approach to lead production, the authors propose to consider the hydrometallurgical electrochemical method. This method offers a more sustainable alternative to traditional smelting.

Main body

Overview of methods obtaining lead

Lead, a prevalent metal in non-ferrous metallurgy, is naturally distributed across more than 180 ores

[AKB, 2022], including lead sulfide (PbS), galena (PbS), lead carbonate ($PbCO_3$), and waste [Kolosova V.A., Sluki N.A., 2016]. Therefore, Kazakhstan, endowed with substantial lead reserves totaling 11.7 million tons, secures its position as the sixth-largest lead reserve holder globally, trailing behind Russia, Australia, Canada, the United States, and China (table 1). These reserves are strategically located in over 50 deposits, with active lead-containing ore extraction occurring at 15 of them [Kolosova V.A., Sluki N.A., 2016].

Table 1

Top 5 leading countries by lead production in the world
[Lead Statistics and Information, 2023]

Country	Estimated production	Mining method
China	2 million metric tons	Blast furnace smelting (70%) and reverberatory furnace smelting (25%), for both primary and secondary lead production, electrolysis (5-10%)
Australia	440,000 metric tons	Blast furnace smelting (70%) and reverberatory furnace smelting (20%), for both primary and secondary lead production
Peru	250,000 metric tons	Blast furnace smelting (70%) and reverberatory furnace smelting (25%), electrolysis (less than 5%)
United States	280,000 metric tons	Sintering and blast furnace smelting are used for primary lead production (95%), recycling (50%), electrolysis (5-10%)
Mexico	270,000 metric tons	Pyrometallurgical methods (60%)

In the global context, the year 2018 witnessed a total lead production of 271,000 metric tons, with Kazakhstan contributing significantly at an annual range of 90-110 thousand tons [Kolosova V.A., Sluki N.A., 2016]. Consequently, this places Kazakhstan at the eighth position in the international hierarchy of lead-producing nations.

To start with, Kazzinc [KazZinc, 2022] stands out as the leading producer of lead in Kazakhstan, where 129,000 tons [GlobalData, 2022] of the metal were produced in 2019. Ore containing lead is mined at the company's mines in Ridder and Altai, with particularly significant reserves at the Zhairem polymetallic deposit in the Karaganda region. The extracted ore is processed at the company's three enrichment plants, and then the concentrates containing lead are sent to the Ust-Kamenogorsk metallurgical complex. There, after technological smelting and pyrometallurgical processes, refined lead is produced and ready for sale. This company uses the isasmelting [GlobalData, 2022], which produces a total of 150,000 tons annually.

Kazakhstan utilizes lead in a variety of applications:

1. Transformers: due to its unique conductivity at high temperature, lead is used to wind superconducting transformers.
2. Paints: as a component of whitewash, lead protects metal structures from corrosion. For example, a bright red paint called "broom" made with lead is used to paint underwater parts of ships.
3. Plastic windows: lead compounds prevent the compound from decomposing during the manufacturing process of window profiles.
4. Rhinestones: lead oxide adds luster and transparency to glass products, making them like gemstones [GlobalData, 2022].

All pyrometallurgical operations encompass a meticulous process comprising sintering and smelting within a blast furnace, executed at elevated temperatures. This intricate sequence of thermal treatments is imperative for the extraction and refinement of metals, particularly in the context of lead production.

Sintering and Blast Furnace Smelting

The conventional approach to lead production involves a systematic process encompassing the crushing and beneficiation of lead ore, succeeded by sintering, a heat-intensive treatment with additional materials, and culminating in smelting within a blast furnace, where coke acts as the primary fuel source [Davis B.R. et al., 2018]. Through this intricate sequence, the lead ore undergoes transformation into molten lead ingots, separated from impurities in the process.

This traditional method boasts several advantages. It is underpinned by well-established technology and readily available equipment, ensuring operational feasibility. A notable strength lies in its ability to amalgamate fine ore particles with fluxing materials like limestone, creating a porous "agglomerator" shell. This attribute enhances the process's efficiency, promoting the productive bonding of components. Moreover, the method prioritizes environmental safety by effectively removing impurities, such as sulphur dioxide, resulting in cleaner production.

However, this method is not without its drawbacks. The considerable energy consumption associated with sintering and blast furnace smelting raises environmental concerns, contributing to air and water pollution and the release of harmful gases, including notorious "greenhouse gases". The environmental impact extends further to potential health hazards, including the risk of lead poisoning, particularly detrimental effects on the kidneys, nervous system, and reproductive system. Additionally, the method poses risks of respiratory diseases, as lead dust generated during the process can irritate the lungs. The heightened exposure to harmful elements also significantly amplifies the risk of cancer, underscoring the need for comprehensive health and safety measures in this production paradigm.

Another pyrometallurgical method is isa smelting

This technology refines lead sulphide concentrate in a single reactor using molten salts and oxygen. It offers several environmental advantages over traditional smelting. This sophisticated process refines lead sulfide concentrate in a single reactor, utilizing molten salts and oxygen, offering distinct environmental advantages compared to traditional smelting methodologies.

The advantages of ISASMELTING are multifaceted. Its capacity to efficiently process large volumes of ore contributes to higher productivity, a boon for plants aiming to meet escalating demand [Davis B.R. et al., 2018]. Notably, the technology exhibits improved energy efficiency when contrasted with certain older smelting methods, resulting in potential cost savings and a reduced environmental footprint. The operational flexibility of ISASMELTING is another asset, allowing the handling of a broader range of ore types and feed stocks in comparison to traditional smelting methods.

However, the advantages come with their set of challenges. The operation of an ISASMELTING unit demands specialized skills and knowledge, posing potential difficulties in locating and training qualified personnel in certain locations. Moreover, the maintenance and repair of the complex equipment involved can be expensive, contributing to elevated operating costs.

From a financial perspective, ISASMELTING presents both high capital investment requirements and ongoing operating costs. The initial construction and installation of an ISASMELTING plant necessitate a substantial upfront investment, rendering it less affordable for smaller businesses. Despite potential energy efficiency gains, ongoing operating costs associated with resource consumption remain a consideration.

Environmental impacts resulting from ISASMELTING must also be scrutinized. While emissions and waste generation are potentially lower than some conventional methods, responsible management is imperative to minimize environmental repercussions. This entails the implementation of air and water pollution control systems, coupled with conscientious waste management practices. Furthermore, resource consumption, inherent in every industrial process, necessitates careful planning and responsible management to minimize environmental strain.

Hydrometallurgical Processes

Electrolytic refining, a hydrometallurgical method, presents a cleaner alternative to pyrometallurgical processes in lead production. This process involves dissolving lead in an electrolyte solution and subsequently depositing pure lead onto cathodes through electrolysis. It is complemented by three key stages: the decomposition of concentrates in aqueous ferric chloride solutions, nitrate-ferrite stripping, and autoclave leaching.

The advantages of hydrometallurgical processes in lead refining are multifaceted. This method allows for the extraction of metals from a diverse range of feed stocks, including challenging-to-enrich, low-lead, and polymetallic feed stocks. Additionally, it offers more automated, less hazardous, and less labor-intensive operations. The transformation of raw materials into high-quality products with high elemental recovery forms the foundation for waste-free and environmentally sustainable processing technology. From an eco-friendly standpoint, hydrometallurgy boasts several merits. It generally consumes less energy compared to red-hot furnaces, resulting in a reduced overall impact on the planet. The process tends to produce fewer harmful emissions, contributing to cleaner air. Furthermore, hydrometallurgy's recyclability is advantageous for recovering metals from recycled materials, minimizing the need for new ore extraction. The purity boost it provides is particularly valuable for producing super-pure metals, crucial for applications such as delicate electronics or medical equipment. Its flexibility extends to a wide variety of metals, offering resource extraction from diverse sources. Notably, hydrometallurgy creates a safer workplace environment when compared to conventional methods.

However, hydrometallurgical processes have their share of challenges. The complex and costly preparation of concentrates through sulphatizing or chlorinating roasting limits the current utility of hydrometallurgical methods. Leaching is problematic due to the limited solubility of lead compounds, resulting in the generation of large solution volumes. Lead precipitation processes from chloride solutions may yield a lead "sponge", requiring additional processing like briquetting to obtain satisfactory lead yield for remelting. Hydrometallurgical lead also necessitates subsequent refining, adding to the process duration.

In comparison to smelting, hydrometallurgy tends to be a slower process, especially for complex ores requiring multiple extraction steps. The capital investment required for setting up a hydrometallurgical facility can be substantial, encompassing expenses related to specialized equipment, chemical storage, and wastewater treatment infrastructure. Additionally, operating and maintaining a hydrometallurgical facility demand specialized knowledge and skills in areas such as chemistry, engineering, and safety protocols.

Literature review

In electrolytic refining, the purity of the deposited metal at the cathode is a key factor, despite the potential impurities in the dissolved metal at the anode. The success of this refining method hinges on this aspect. Electrolytes used in this process commonly comprise salts of the specified metals, usually accompanied by the presence of free acid. The fundamental concept of electrolytic refining entails the removal of metals that rank lower than the main metal in the hierarchy, depositing them as metal particles in the anode slime. Simultaneously, metals higher in the series are eliminated either as dissolved salts in the solution or through precipitation. Lead ranks higher in the hierarchy than all the impurities it contains in significant quantities. Therefore, there is no need to change the solution. Considering this, along with the ease of casting lead into anodes, melting cathodes [Gardner A., 1908], the efficient transport of a relatively large quantity by the current requiring a relatively small amount of power, and the rapid production, lead possesses the most favorable physical and electrochemical constants for electrolytic refining among common metals. Several research is conducted to realize electrochemical way of obtaining lead from lead salts solutions.

Lead Chloride ($PbCl_2$)

Anson Gardner Betts suggests that the most effective conducting electrolyte is likely to be found in a melted salt, with melted lead chloride [Gardner A., 1908] identified as an exceptionally good conductor. At a temperature of 580°C, lead chloride ($PbCl_2$) exhibits a resistance of approximately

0.0373 ohms for a specified column dimension. In comparison, an aqueous electrolyte with a resistance of 1.3-1.4 ohms are significantly less conductive. With fused lead chloride and the same voltage and electrode separation, the current density could reach around 210 amperes per square foot. This efficiency is highlighted by the fact that a 4000-ampere vat would only require about 19 square feet of surface. The power consumption for such a system is estimated to be 1-1.5 kilowatts, which is relatively low, maintaining the apparatus at the required temperature.

However, Hisashi ITO, Tsutomu YANAGASE, and Kei HIGASHI in their study found that electrolysis using lead fluoride as an anode leads to passivation of the lead fluoride bath [Ito H. et al., 1961], making it impractical even if the electrolysis conditions are changed.

Acetate solutions ($M(CH_3COO)_x$)

Professor N.S.Keith, as early as 1878, devised a lead refining process utilizing an electrolyte containing 180 grams of sodium acetate (CH_3COONa) per liter, with the addition of 18.5 to 22.2 grams of lead sulfate per liter. His method involved the use of 20-pound anodes measuring 15 by 24 inches and having a thickness of 1/3 to 1/2 inches. These anodes were wrapped in muslin cloths to capture the anode slime [Gardner A., 1908], preventing it from dropping to the tank's bottom along with the refined lead crystals descending from the cathodes.

In addition, Tommasi, in 1897-98, published ideas for refining lead using an acetic acid [Trautz M., 1913] solution. His main suggestion was to 19use a rotating disc made of aluminum-bronze as the cathode in the electrolytic cell. This disc would spin just above the solution, collecting lead on its surface. A scraper would automatically remove the lead from the disc and send it to a press for further processing.

Hexafluorosilicic acid (H_2SiF_6)

The Bureau of Mines created a new method to recycle lead from old batteries using electricity instead of high heat melting [Cole E.R. et al., 1982]. This is way better for the environment because it uses less energy and doesn't release harmful fumes, making super pure lead. This method, unlike current pyrometallurgical smelting, reduces energy consumption, eliminates toxic emissions, and produces pure lead suitable for maintenance-free batteries. Anodes cast from molten lead scrap were electro refined using an electrolyte of 70 g/L Pb and 90 g/L free H_2SiF_6. batteries [Cole E.R. et al., 1982] The process included the use of cathode starting sheets made from refined lead, with gelatin and calcium lignin sulfonate as additives. The sludge left after separating lead metal underwent a two-step leaching process for lead recovery by electrowinning. Optimal conditions for both processes involved a current density of 170 amp/m² and a cell temperature of 25°C to 35°C, resulting in cathode purity ranging from about 99.9 to 99.99+ percent Pb.

The Betts Electrorefining Process typically employs an electrolyte comprising fluosilicic acid (H_2SiF_6) with lead fluosilicate to electro refine impure lead anodes into pure lead cathodes [Dominguez González J.A., 1992]. The fluoborate and sulphamate processes are essentially the same as the fluosilicate process, except for the electrolyte substitution. It's worth noting that the use of fluoboric acid has been limited due to its relatively high cost. He stated that HBF is characterized by its stability as an acid, favorable electrolytic conductivity, and high solubility of the lead salt.

Though Hisashi ITO, Tsutomu YANAGASE, and Kei HIGASHI conducted a study and determined that lead silicofluoride baths are unsuitable for direct electrolysis [Ito H. et al., 1961] of lead monoxide due to lead passivization.

Sulfuric acid (H_2SO_4)

The utilization of bipolar lead electrodes in the electrolysis process by A.K.Bayeshova [Bayeshova A.K., 2019], subjected to alternating current at an industrial frequency (50 Hz) in sulfuric acid solutions, has been investigated for the first time. The study reveals that during the anode half-period of alternating current, lead undergoes oxidation to the bivalent state on both monopolar and bipolar electrodes. Subsequently, the anode half-period transitions to a cathode half-period, transforming the lead electrode into a cathode, where hydrogen is released. The reaction of lead (II) ions with sulfate anions near the electrode space results in the formation of lead (II) sulfate. The total loss of electrode mass increases with rising current density up to 1200-1400 A/m² [Bayeshova A.K., 2019] and then significantly decreases at 2000 A/m² due to heightened adverse reactions. Over the experimental duration of 0.5-2 hours, the total loss of electrode mass rises, but after 2 hours, it remains relatively constant. This stability suggests that lead (II) sulfate accumulation on the electrodes may impede the dissolution process. Additionally, when using bipolar electrodes, the mass of lead (II) sulfate is approximately 2.4 times greater [Dominguez González J.A., 1992] at the same current strength compared to electrolysis conducted with only two monopolar electrodes.

HBF_4

Engitech Process [Sahu K.K., Agrawal A., 2018] was developed a special composite anode using HBF_4 leaching. Conditions revealed an anodic current density of 320 A/m^2. The method is designed for sludge to remove PbO_2 deposition.

$HClO_4$

Hisashi ITO, Tsutomu YANAGASE, and Kei HIGASHI in their study said that the cause of passivation [Ito H. et al., 1961] is lead silicate solution. They confirmed this in a bath with lead perchlorate, if residual lead is present in the electrolyte, passivation occurs extremely quickly regardless of the concentration of perchloric acid. Having thus found out that there is a risk of passivization in long-term electrolysis, they came to the result that lead concentrates in bath electrolysis with lead perchlorate using lead concentrates as anodes showed a stable state of dissolution, while ores with large amounts of impurities sometimes caused an increase in bath voltage during the process. However, of course this can be avoided by removing the slimes.

Methodology and methods

Secondary Lead Process

The world's total lead reserves are 220.2 million tons, with proven reserves of 136.6 million [Metallurgiya svinca, 2022] tons. Lead is consumed less than other non-ferrous metals during industrial production, which allows the metal to be used as secondary raw material (about 52% [Kolosova V.A., Sluki N.A., 2016], which is one of the highest indicators in non-ferrous metallurgy. Currently, lead recovered from recycled materials accounts for more than half of the total metal produced worldwide. In the US, more than 80% of lead [Mirovoj rynok svinca, 2012] is recovered through recycling, and in Europe, more than 60%. This is because most of the lead after primary processing is used in products suitable for recycling. recycling of many other materials, lead recycling is economically viable. For example, in North America, more than 80% of mined lead is used in the production of battery packs, of which more than 95% [Mirovoj rynok svinca, 2012] is subsequently recovered and recycled.

The world leader in the production of refined lead is China, which accounts for about 50% [Mirovoj rynok svinca, 2012] of the metal produced in the world. In China, one of the most progressive companies supporting recycling projects, Yuguang Gold & Lead, produces 400,000 tons [Lead industry, 2022] per year. The company uses a refining method: blast furnace used, namely recovery, where liquid lead slag is directly recovered through four processes in a sintering machine. However, they see secondary production as one of the most important for the near future.

Results

In the realization of lead production methods, electrolysis emerges as a method that not only generates this essential metal but also contributes to environmental sustainability and operational safety. Foremost, electrolysis distinguishes itself through its significant emission reductions compared to traditional smelting processes. Unlike smelting, which relies on burning ore and releases harmful substances such as sulphur dioxide and lead oxide into the atmosphere, electrolysis operates without the use of fossil fuels. This not only minimizes emissions but also aligns with contemporary environmental standards.

Additionally, electrolysis enhances resource recovery by efficiently separating valuable by-products as impurities during the process. This strategic separation minimizes the need for additional extraction of precious metals, demonstrating a commitment to resource efficiency and sustainability. Automation plays a pivotal role in the increased safety of lead production through electrolysis. The use of automated processes reduces risks to personnel, providing a safer working environment when compared to manual labor-intensive methods. The quest for higher purity is addressed by electrolysis, yielding lead with a purity level of 99.9%. This elevated purity surpasses that of molten lead (98%) and positions electrolytic lead as an ideal material for use in the production of batteries and accumulators, where purity is a critical factor. Energy efficiency becomes a key advantage of electrolysis, as it operates at significantly lower temperatures compared to smelting. This results in lower energy consumption, offering the potential for cost savings and contributing to a reduction in environmental impact, as we can see in the overview (table 2) furthermore.

Table 2

Overview on past studies of lead production

	Study	Electrolyte	Electrode	Method	Results
1	Electrolysis of $PbCl_2$	Molten lead chloride ($PbCl_2$)	Lead electrodes	Molten salt electrolysis	Molten lead chloride at 580°C has a significantly lower resistance than aqueous electrolytes
2	Bipolarly lead electrolysis of H_2SO_4 [Bayeshova, A.K., 2019]	H_2SO_4	Bipolar lead electrodes	Hydrometallurgy, electrolysis	Using bipolar electrodes results in about 2.4 times more lead sulfate formation compared to using only monopolar electrodes
3	Betts process – [Dominguez, 1992]	Mixture of lead (Pb) and fluorosilicic acid (H_2SiF_6) dissolved in water	Anode: Made from recycled lead scrap. Cathode: Made from pure lead sheets, where the refined lead is deposited	Current is passed through the cell, dissolving lead from the anode, and depositing it onto the cathode in a purer form	recycling lead from old batteries using electricity can be a cleaner method
4	Electrolysis of acetate solutions [Gardner, Anson. Wiley, 1908]	Sodium acetate (CH_3COONa)	Anode: Made of lead scrap. Large: 20 pounds, 15x24 inches, and 1/3-1/2 inches thick. Cathode: Not explicitly mentioned in the passage, but likely made of pure lead	Lead from the anode to dissolve into the solution. Pure lead to deposit on the cathode. The muslin cloths around the anode capture impurities ("anode slime")	Refined lead crystals form on the cathode and can be collected. Anode slime containing impurities is separated from the process

Discussion

The provided research explores various electrolytes for lead production and refining via electrolysis.

Apparently, it turned out that depending on the optimum conditions, electrode materials, electrolyte, and purity of the metal and solution it can be reached high unreversible lead or its oxides.

Electrolyte Efficiency:
Melted Lead Chloride ($PbCl_2$): Highest conductivity (0.0373 ohms) compared to aqueous solutions, enabling higher current densities and potentially smaller cell sizes [Gardner A., 1908].

However, high temperature operation (580°C) requires energy for maintaining heat.

Hexafluorosilicic Acid (H_2SiF_6) [Cole E.R. et al., 1982]: Efficient for recycling lead from batteries, producing high purity lead (99.9-99.99%). Environmentally friendly with lower energy consumption and no harmful fumes.

Acetate Solutions [Gardner A., 1908]

Used historically but have limitations like anode slime formation and complex apparatus (rotating disc cathode).

Sulfuric Acid (H_2SO_4) [Bayeshova A.K., 2019]

Investigated with bipolar electrodes but suffers from higher electrode mass loss at high current densities and lead sulfate formation.

Challenges and Passivation:

Lead Fluoride (PbF_2): Found to passivate the lead bath, making it unsuitable for direct electrolysis [Sahu K.K., Agrawal, A., 2018].

Lead Silicate Solution: Identified as a potential cause of passivation in perchlorate electrolytes. Residual lead in the electrolyte can also accelerate passivation.

The research demonstrates that various electrolytes can be effective for lead electrolysis, each with its own advantages and limitations. Additionally, to look for the overall pros and cons throughout this article we can see the table 3. Choosing the right electrolyte depends on factors like desired purity, efficiency, environmental impact, and cost. Further research is needed to address challenges like passivation and develop even more sustainable and efficient methods for lead production and recycling. Moreover, in real electrolysis, even higher voltages are expected to be required for reasons such as polarization, changes on the anode surface, and anode sludge accumulation.

Table 3

Table of pros and cons of two existing methods

Method	Description	Advantages	Disadvantages
Pyrometallurgy	High-temperature smelting using furnaces	Established technology, efficient production	High emissions, energy-intensive, potential health risks for workers and nearby communities
Electrolysis	Separating lead ions using an electric current	Lower emissions, cleaner process, potential for resource recovery	Less common, higher initial costs, lower production capacity

Conclusion

Hydrometallurgy and electrolysis are emerging as greener ways to process lead, with potential benefits like reduced energy use, lower emissions, and cleaner recycling. These methods can be more efficient, taking up less space than traditional smelting. In some cases, they can even produce extra-pure lead for demanding applications. However, there are still challenges to overcome. Some electrolytes can create a barrier on electrodes, making the process less efficient. And like any work with chemicals and electricity, safety is paramount. While some initial costs might be higher, the long-term benefits of sustainability and purity shouldn't be overlooked.

Overall, hydrometallurgy and electrolysis offer exciting possibilities for a cleaner and more efficient future for lead processing. Ongoing research and development can address the existing challenges and pave the way for a more sustainable future for this essential metal.

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Қорғасын тұздарының сулы ертітінділерінен электрохимиялық қорғасынды алу

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Аңдатпа
Мақала қорғасынды өңдеудің қолданыстағы әдістерін, атап айтқанда пирометаллургиялық әдіспен, соған қоса әлемде маңызды экологиялық проблемаларды зерттеумен таныстырады. Жаһандық экологиялық проблемаларды ескере отырып, авторлар гидрометаллургиялық әдісті перспективалы балама ретінде қарастырады. Америка, Англия, Германия, Қытай, Жапония, Ресей, Қазақстан және т.б. сияқты әртүрлі елдерде бар зерттеулер мен өндіріс нәтижелерін талдау негізінде қорғасынды дәстүрлі балқытуға балама ретінде гидрометаллургиялық әдіс ұсынылды. Екі әдістің артықшылықтары мен кемшіліктерін әртүрлі бақылауларға әдеби шолумен салыстыру жүргізілді. Қорғасынның экологиялық таза өндірісін уәде ететін перспективалық әдіс ретінде электролизге ерекше назар аударылады. Электролизге қорғасынның экологиялық таза өндірісін уәде ететін перспективалық әдіс ретінде аса назар аударылады, бұл оны болашақ зерттеулер мен өнеркәсіптік қолдану үшін маңызды етеді.
Түйін сөздер: қорғасын, қорғасын электролизі, пирометаллургия, қорғасын ерітінділері, сулы ерітінділердің электролизі, гидрометаллургия, экологиялық таза.

Электрохимическое производство свинца из водных растворов солей свинца

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Аннотация
Статья представляет обзор существующих методов обработки свинца, сосредотачиваясь на пирометаллургическом подходе, несмотря на его потенциально негативное воздействие на окружающую среду. В свете глобальных экологических проблем авторы рассматривают гидрометаллургический метод как перспективную альтернативу. Основываясь на анализе исследований и опыте различных стран, включая Америку, Англию, Германию, Китай, Японию, Россию, Казахстан и другие, проводится сравнительный анализ преимуществ и недостатков обоих подходов. Особое внимание уделяется электролизу как перспективному методу, обещающему экологически чистое производство свинца, что делает его значимым для будущих исследований и промышленного применения.
Ключевые слова: свинец, электролиз свинца, пирометаллургия, растворы свинца, электролиз водных растворов, гидрометаллургия, экологически чистый.

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