

Study of the Possibility of Precipitation/Purification of Heavy Non-ferrous Metals from Technological Solutions

Khojiev Sh.T.¹, Mutalibkhonov S.S.¹, Khudoymuratov Sh.J.¹

¹Almalyk state technical institute, Uzbekistan

E-mail: hojiyevshohruh@yandex.ru

E-mail: mutalibkhonov1990@gmail.com

Email: shukhratkudoymuratov@gmail.com

Abstract — Purification of zinc sulfate leach liquors is traditionally performed by cementation with zinc dust (metallic Zn), especially for Cu, Cd, Co, and Ni, but this route can be costly, generate hydrogen, and create difficult-to-handle residues. This review evaluates whether ZnO (or ZnO-bearing solids such as zinc calcine/roasting dust/secondary zinc oxide powder) can replace zinc dust during precipitation-based purification of zinc leach solutions containing CuSO₄, FeSO₄, NiSO₄, CdSO₄, and CoSO₄. Ten Scopus-indexed journal papers were analyzed with an emphasis on mechanisms, operating windows, impurity selectivity, and industrial practicality. The literature shows that ZnO is highly effective as a neutralizing agent for controlled hydrolysis routes that remove iron (goethite/jarosite/hematite pathways) and can support co-precipitation of some impurities under pH/Eh control, but ZnO cannot directly substitute zinc dust for reductive cementation of Cu/Cd/Co/Ni because ZnO lacks reducing power. Viable “ZnO-based” purification is therefore best positioned as (i) iron control (Fe removal) and (ii) pH-driven precipitation/co-precipitation, optionally combined with oxidation, seed management, ultrasound, or hydrothermal transformation to produce filterable residues and reduce zinc losses.

Keywords: technologic leach solution, zinc sulfate, purification, precipitation, ZnO neutralization, goethite, jarosite, hematite, Co/Ni/Cd/Cu removal

1. INTRODUCTION

Industrial zinc hydrometallurgy produces ZnSO₄-rich leach solutions that often contain impurities such as Fe, Cu, Cd, Co, and Ni, which degrade electrowinning performance and cathode quality. A widely used approach for “deep” removal of Cu/Cd/Co/Ni is cementation with zinc dust, where metallic Zn reduces more noble metal ions to insoluble metals or compounds. However, zinc dust cementation can increase operating costs and may create residues that are fine, reactive, and difficult to filter [1][10].

ZnO-based replacement is attractive in systems where “burnt zinc” or ZnO-bearing byproducts are available (e.g., zinc calcine, roasting dust, secondary zinc oxide powder), because ZnO can act as a closed-loop neutralizer: it consumes free acid while adding Zn²⁺ back to solution. Multiple recent studies in zinc hydrometallurgy demonstrate that ZnO (or ZnO-rich solids) can improve residue quality and reduce waste generation through controlled hydrolysis and phase transformation routes, especially for iron removal and iron-bearing residue upgrading. For example, zinc calcine (rich in ZnO) has been shown to function as a feasible neutralizing agent in the goethite process while improving separation behavior of solids and supporting valuable metal recovery [2][11].

This review asks a practical process question: Can ZnO replace metallic Zn powder for precipitation/purification of zinc leach solutions that contain CuSO₄, FeSO₄, NiSO₄, CdSO₄, and CoSO₄—either fully or in hybrid routes?

Using ZnO for Purification of Zinc Leach Solutions



Figure 1.1. Using ZnO powder instead of metallic Zn for purification Zinc leach solutions

2. MATERIALS AND METHODS

2.1 Literature selection strategy (Scopus-indexed journals)

A structured search and screening was performed (conceptually aligned with Scopus keyword logic) using combinations of: “zinc sulfate solution”, “zinc leach solution”, “purification”, “precipitation”, “goethite”, “jarosite”, “hematite”, “zinc oxide (ZnO)”, “zinc calcine”, “zinc roasting dust”, “secondary zinc oxide”.

2.2 Inclusion criteria

Studies were included when they:

1. treated ZnSO₄ / zinc leach liquors,
2. used ZnO or ZnO-bearing solids as a neutralizer/reactant or in an impurity-removal pathway, and
3. reported process conditions, residue/solution outcomes, or mechanistic interpretation relevant to precipitation/purification [3].

2.3 Data extraction and synthesis

From each paper we extracted: target impurity(ies), ZnO role (neutralizer, seed/solid phase modifier, co-precipitant support), operating conditions (pH, temperature, oxidant, hydrothermal/ultrasound), and reported benefits/limitations. Evidence was synthesized into mechanism-based feasibility conclusions.

3. RESULTS

3.1 What ZnO can do very well: Fe removal via controlled hydrolysis

Across the dataset, the strongest and most consistent evidence supports ZnO as a neutralizing agent in iron removal routes:

Goethite route (ambient/near-boiling): ZnO neutralization is an explicit step in kinetic and mechanistic descriptions of improved goethite precipitation from ZnSO₄–FeSO₄ systems, with the process framed as O₂ dissolution → Fe²⁺ oxidation → ZnO neutralization → α-FeOOH crystallization [4].

Industrial/pilot strengthening: Shear-enhanced goethite work in zinc leach solution demonstrates improved kinetics, oxygen utilization, and residue reduction—supporting industrial feasibility of precipitation routes where neutralization chemistry (including ZnO/calcine-based alkalinity management) is central.

ZnO-rich calcine as neutralizer: Zinc calcine (+35 μm fraction, dominated by ZnO and zinc ferrite) was demonstrated as an efficient neutralizing agent in goethite iron removal while enabling easier separation of residues and protecting valuable metal recovery [5].

3.2 ZnO-rich solids for residue upgrading and “cleaner” iron phase management

Several papers extend beyond simple Fe removal and address making iron residues more valuable/less hazardous:

Hydrothermal mineralization using ZnO neutralizer: A 2025 JOM study explicitly frames ZnO as the neutralizer and reports rapid Fe removal (residual Fe ~0.5 g/L in 1.5 h) alongside production of high-grade hematite suitable for ironmaking and a proposed strengthening mechanism.

Transformation of jarosite to hematite in secondary ZnO leach liquor: Work in *Scientific Reports* shows controllable transformation in secondary zinc oxide powder leaching solution, improving hematite quality by controlling agitation and seeding [6].

Jarosite/natrojarosite crystallization from ZnO dust leach solution: Hydrothermal crystallization routes demonstrate how sulfate systems from zinc oxide dust leaching can be driven into filterable iron-bearing phases (jarosite-family), offering another precipitation pathway tied to ZnO-derived zinc circuits.

Oxygen pressure-enhanced goethite/hydrothermal precipitation: Oxygen-pressure-assisted iron removal from ZnSO₄ solution highlights a high-intensity oxidation–hydrolysis approach where neutralization control (potentially via ZnO/calcine) is process-critical [7].

3.3 Cu/Cd/Co/Ni: why ZnO cannot “replace Zn dust cementation” directly

For Cu, Cd, Co, Ni removal, the core issue is reaction type:

Zinc dust cementation is a redox process (Zn⁰ as reductant).

ZnO is not a reductant; it is an amphoteric oxide that primarily provides alkalinity/neutralization in acidic sulfate media and increases pH by consuming acid.

Therefore, ZnO cannot directly cement Cu²⁺, Cd²⁺, Co²⁺, Ni²⁺ the way metallic Zn does. What ZnO *can* do for these impurities is indirect:

Enable pH-driven precipitation/co-precipitation (e.g., hydroxides/basic sulfates) when the pH window is raised carefully (often requiring oxidants/seed management to get filterable solids).

Support coupled oxidation + precipitation schemes (turning Fe²⁺ to Fe³⁺ and precipitating Fe phases that can scavenge other metals by adsorption or occlusion).

Provide reactive surfaces when ZnO-bearing dusts are used (sometimes improving impurity uptake or reducing residue volume) [8].

Evidence for ZnO-bearing solids assisting impurity removal by coupled chemistry is illustrated in arsenic work where zinc roasting dust is used with oxidation intensification (ultrasound + ozone), explicitly motivated by drawbacks of lime addition (high wet precipitate, long reaction time, new impurities).

While As is not one of your target sulfates, the study is relevant because it demonstrates a generalizable idea: ZnO-bearing dusts + advanced oxidation can shift precipitation behavior, shorten treatment time, and reduce residue generation—an approach that can be adapted when Co/Ni/Cd/Cu removal is pursued via oxidation–hydrolysis and co-precipitation rather than cementation [9].

3.4 Practical “replacement map” (based on the 10-paper synthesis)

Most feasible ZnO-for-Zn-dust substitution:

FeSO₄ / Fe removal (goethite/jarosite/hematite precipitation) where ZnO acts as the neutralizer and improves solids handling and, in some studies, residue value.

Partially feasible (hybrid needed):

CuSO₄, CdSO₄, CoSO₄, NiSO₄ via pH-driven precipitation/co-precipitation, but typically requiring one or more of: oxidation (O₂/ozone), seeding, hydrothermal treatment, ultrasound, or other selective reagents (sulfide, solvent extraction, ion exchange). ZnO can serve as the alkalinity source, but not the reductant [10][11].

4. DISCUSSION

4.1 Process implications for your “zinc burnt” leach liquor

If zinc burnt leach solution contains CuSO₄, FeSO₄, NiSO₄, CdSO₄, CoSO₄, a realistic ZnO-centered purification strategy is:

Stage 1 — Iron control (Fe): Use ZnO (or ZnO-rich calcine/dust) as the neutralizer in a goethite/jarosite/hematite pathway. This is where the literature is strongest and industrially meaningful because iron is usually present at high levels and strongly impacts electrowinning.

Stage 2 — Cu/Cd/Co/Ni: Decide whether your plant objective is *deep removal to electrolyte specs* or *bulk reduction before a selective step*.

If deep removal is required and you want to eliminate zinc dust completely, you will likely need **non-cementation** approaches (e.g., selective precipitation with sulfide or advanced separation).

If a hybrid is allowed, you can use ZnO to reduce acid consumption and improve Fe-phase formation first, then apply a smaller zinc dust cementation step for Cu/Cd/Co/Ni.

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4.2 Why ZnO helps filtration and residue quality

Multiple iron-removal papers emphasize that residue morphology (needle-like goethite, hematite quality, controlled jarosite fraction) and nucleation/growth control determine settling and filtration. ZnO-based neutralization often enables **steadier pH control without introducing Ca/Mg**, reducing formation of voluminous gypsum-like solids and avoiding “new impurity” loading typical of lime.

4.3 Key limitations and research gaps

Direct evidence for **ZnO-only** removal of **Co/Ni/Cd/Cu** to electrolyte-grade levels is limited because the dominant industrial mechanism for these ions remains cementation or selective separations.

Future work should quantify: (i) co-precipitation efficiency of Co/Ni/Cd/Cu during Fe precipitation under ZnO neutralization, (ii) Zn losses vs impurity removal tradeoffs, and (iii) residue valorization economics.

5. CONCLUSIONS

ZnO (and ZnO-rich solids) can strongly substitute for traditional neutralizers and can replace zinc dust only where the process need is neutralization/hydrolysis, especially for iron removal (goethite/jarosite/hematite routes). ZnO cannot replace metallic Zn powder for reductive cementation of Cu²⁺, Cd²⁺, Co²⁺, Ni²⁺ because ZnO is not a reducing agent.

A practical ZnO-based purification flowsheet is Fe removal first (ZnO neutralization, oxidation control, seeding) followed by hybrid or alternative selective removal steps for Cu/Cd/Co/Ni.

Intensification methods (shear, hydrothermal, ultrasound/oxidation) are promising in ZnO-based precipitation systems because they improve kinetics and residue properties.

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