JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

RECOVARY OF FE VALUES FROM DISCARDED TAILING HAVING 25-30% Fe

***Dr Rachappa Kadli, M.Tech., Ph.D. Deputy General Manager, Department-SMS-3 JSW Steel ltd.**

Abstract

Recovering iron from discarded mine tailings has become an increasingly important strategy for resource conservation and environmental management. Tailings containing 25 to 30 percent iron represent a significant secondary source of raw material that older beneficiation plants could not fully utilize. These low-grade tailings often contain finely disseminated hematite, goethite or magnetite mixed with silica, alumina and clay, which limits their direct industrial use. Modern beneficiation technology makes it possible to reclaim a notable share of these iron values through targeted physical, chemical and thermal processes.

High-intensity magnetic separation allows weakly magnetic iron oxides to be captured even when they occur in very fine particle sizes. Flotation offers another path by selectively removing silica and alumina, which increases the overall Fe grade of the recovered material. In cases where iron minerals are extremely fine or coated with slimes, selective flocculation and advanced hydrocyclone classification help separate iron-rich particles from unwanted gangue. For tailings with complex mineral chemistry, reduction roasting can convert iron into magnetically responsive phases, making separation more efficient. Recovered concentrates are often suitable for pelletization, which transforms them into a stable feed for steelmaking.

Reprocessing discarded tailings not only increases usable iron yield but also reduces the environmental burden of tailing storage facilities. It supports sustainable mining practices by minimizing waste, lowering the demand for fresh ore extraction and reducing the footprint of legacy tailings. As global steel production grows and high-grade ore becomes scarcer, the recovery of Fe values from tailings offers both an economic and ecological advantage. With modern processing technologies, these previously overlooked materials can be turned into valuable resources, contributing to a more circular and responsible mineral economy.

Keywords: *Iron Recovery, Mine Tailings, Magnetic Separation, Flotation, Selective Flocculation, Pelletization.*

INTRODUCTION:

Fe values refer to the percentage of elemental iron present in an ore, concentrate or tailing sample. In mineral processing, the Fe value indicates how much usable iron can be obtained from a given material. For example, if a tailing sample has 25 to 30 percent Fe, it means that roughly one quarter to one third of its mass consists of iron-bearing minerals such as hematite, magnetite, goethite or limonite. The remaining portion consists of gangue materials like silica, alumina, clay or other non-ferrous minerals. Understanding Fe values is important because it helps determine whether a material is worth processing. High-grade ores typically contain more than 60 percent Fe and can be fed directly into steelmaking processes after basic preparation. Low-grade materials, such as discarded tailings, usually have reduced Fe values due to previous beneficiation stages removing the more easily recoverable iron. Despite this, tailings can still hold enough iron to justify reprocessing when modern technologies are applied. Fe values also help engineers select the right beneficiation method. If the iron is present in weakly magnetic forms, high-intensity magnetic separation may be needed. If the iron is locked within silica or alumina, flotation or selective flocculation might be more suitable. By analyzing Fe values, operators can estimate potential recovery, design appropriate flowsheets and evaluate economic feasibility.

OBJECTIVE OF THE STUDY:

This study evaluates effective methods for recovering usable iron from discarded tailings containing 25 to 30 percent Fe.

RESEARCH METHODOLOGY:

This study is purely based on secondary data sources such as articles, research papers, books, journals and other sources.

Understanding the Mineral and Physical Characteristics of Low-Grade Iron Tailings and Their Influence on Recovery Potential

Iron ore tailings with 25 to 30 percent Fe represent material that has passed through previous beneficiation stages without meeting the required grade for commercial iron production. Although these tailings appear uneconomical at first glance, they still contain a significant amount of recoverable iron. Any effort to reclaim Fe from such tailings must begin with a close examination of their mineralogical and physical characteristics. This is because the pathway for recovery depends strongly on how iron is locked within the tailing matrix, the particle size distribution, and the presence of gangue minerals such as quartz, alumina-bearing phases, clays, and occasionally hematite or goethite in very fine form. A common characteristic of low-grade iron tailings is that iron often exists as a mixture of hematite, goethite, magnetite, limonite, or complex hydrated iron oxides. In many deposits, especially those processed using gravity or magnetic separation, the iron particles that remain in the tailings are extremely fine. These fine particles behave differently from coarse minerals and do not respond well to traditional beneficiation methods used in older plants. For example, ultrafine hematite and goethite often require selective dispersion, enhanced flotation chemistry, or high-intensity magnetic separation. Without understanding these mineral forms, operators risk applying methods that fail to capture meaningful Fe percentages.

Details such as particle size distribution also play a central role. Tailing dumps from older beneficiation circuits often contain large proportions of sub-45 micron material. This ultrafine fraction makes gravity separation methods less effective because such particles do not settle efficiently and tend to stay suspended. When iron is distributed in ultra-fines, operators must consider processes such as selective flocculation, column flotation, or hydrocyclone desliming prior to any magnetic treatment. Gangue mineralogy influences reagent choice, separation strategy, and the eventual iron upgrade achievable from the tailings. High silica content, for example, requires flotation strategies that selectively float off the silica while allowing iron oxides to settle. On the other hand, if alumina occurs in clay minerals, the issue becomes more complex. Clays can interfere with flotation by increasing slurry viscosity and surface coating the iron particles. In such cases, dispersants or chemical conditioning steps may be necessary before separation begins. Another aspect is the chemical composition of the tailings beyond Fe percentage. Some tailings carry elements such as phosphorus or sulfur, which can limit downstream use if not managed properly. Understanding these impurities early helps decide whether the recovered concentrate will be used for blast furnace feed, pelletizing, sintering, or other applications.

Tailings handling characteristics also influence recovery options. Some tailings exist as dry heaps, allowing for easy excavation and reprocessing. Others are stored as slurry in large ponds, which introduces challenges in dewatering and transporting the material to processing units. Pond tailings may require thickening, filtration, or hydrocycloning to prepare them for beneficiation. Environmental conditions around the tailing storage facility influence how the tailings should be reclaimed. Oxidation over time can alter mineral forms, changing magnetite to hematite or goethite. Weathered tailings behave differently from freshly generated ones, and understanding these transformations is essential for designing effective recovery strategies.

High-Intensity Magnetic Separation and Its Application in Recovering Iron from Low-Grade Tailings

High-intensity magnetic separation (HIMS) has emerged as a practical method for recovering Fe values from tailings containing between 25 and 30 percent Fe, especially when iron occurs in the form of hematite, goethite, or weakly magnetic oxides. Traditional low-intensity magnetic separators only capture strongly magnetic minerals like magnetite, which are often a small fraction of the material in such tailings. In contrast, HIMS systems generate strong magnetic fields capable of separating even weakly magnetic species. This capability makes them suitable for tailings that have been previously processed using gravity circuits, spirals, or older magnetic systems. The main advantage of high-intensity magnetic separation is its ability to treat fine particles effectively. Many historic tailings contain iron locked in very fine grain sizes due to overgrinding, outdated circuits, or the mineral's natural occurrence. Conventional separation methods struggle with these fines, whereas high-intensity magnets use strong field gradients that can pull even ultrafine hematite toward the magnetic pole. This allows a significant portion of the iron to be reclaimed from material once considered to be waste.

A typical HIMS system uses either dry or wet separation arrangements. In wet systems, the tailings slurry is fed into a rotating matrix drum, where magnetic particles cling to the matrix and are carried to a discharge point. Non-magnetic particles are washed away, leaving behind an iron-rich fraction. Wet systems are preferred for ultrafine particles because moisture prevents dusting and helps maintain proper flow behavior. Dry systems are more suitable for coarser particles, but with the correct operating parameters and feed preparation, they can also offer effective iron recovery.

The separation efficiency in a HIMS unit depends on feed preparation. If the tailings contain a lot of clay, slimes, or extremely fine silica, desliming is often required before magnetic treatment. Removing the ultrafines improves the contact between iron particles and the magnetic field. Desliming can be achieved using hydrocyclones, thickener underflow, or multi-stage washing. Without this step, slimes tend to coat the iron oxides and reduce magnetic susceptibility, lowering the recovery rate. Upgrading tailings using high-intensity magnets usually produces a concentrate in the range of 45 to 55 percent Fe, depending on the tailings' original hardness, mineralogy, and the equipment used. This iron-rich product can be further processed using flotation or fine grinding if a higher Fe grade is required. Many industries use HIMS as part of a multi-stage beneficiation route. The first magnetic stage raises the Fe content moderately. A second stage, using stronger field intensities or a cleaner circuit, produces a concentrate suitable for pelletizing or sintering.

Operating variables such as magnetic field strength, pulp density, rotational speed, and wash water rates must be adjusted for the specific tailing material. A field strength that is too low allows iron to escape into the non-magnetic fraction. A field that is too strong can pull in unwanted gangue, reducing grade. The balance between grade and recovery is crucial. Some operators aim for high recovery while tolerating a slightly lower grade because the material can later be upgraded using flotation or fine screening. Maintenance and wear are also considerations. High-intensity magnetic separators work under conditions that place stress on the matrix elements. Over time, matrices can become clogged, reducing the effective magnetic field gradient. Regular flushing, cleaning, and replacement schedules are essential to maintain consistent recovery.

Flotation Techniques for Silica and Alumina Reduction in Iron Ore Tailings

Flotation plays an important role in iron recovery when tailings contain a significant amount of silica, alumina, or other impurities. Many tailings with 25 to 30 percent Fe originate from earlier beneficiation circuits where silica-rich gangue escaped separation, leaving behind iron that is intimately mixed with non-ferrous minerals. In such cases, flotation provides a selective method to remove unwanted gangue while retaining the valuable iron oxides. The principle behind flotation is that differences in surface chemistry between minerals can be exploited to separate them. For iron ore tailings, reverse cationic flotation is commonly used. In reverse flotation, the silica-bearing minerals float while iron oxides sink. This is achieved by adding amine-based collectors that attach to silica surfaces, rendering them hydrophobic. Air bubbles carry these hydrophobic silica particles to the surface, where they are skimmed off as froth. Meanwhile, iron particles remain in the slurry and form the underflow concentrate.

Before any flotation stage, feed preparation is essential. Fine grinding may be needed to liberate iron particles from silica. However, overgrinding can lead to excessive slimes, which interfere with flotation. To avoid this, hydrocyclones or desliming screens are used to remove ultrafine clays that adversely affect bubble formation and reagent adsorption. Once the feed is conditioned, pH modifiers such as caustic soda or lime are added to create conditions favorable for silica flotation. The exact pH depends on the mineralogy but is typically maintained in an alkaline range. One challenge with tailings flotation is the presence of alumina-bearing minerals, especially clays such as kaolinite. These clays tend to coat iron particles, making it difficult for collectors and depressants to function properly. Dispersants such as sodium silicate or specific polymer-based reagents help break up these coatings. By dispersing the clays, flotation becomes more selective, and iron recovery improves.

Depressants are another key component in reverse flotation. Starch or modified starch derivatives are commonly used to prevent iron oxides from floating. They work by adsorbing onto the iron surface and making it hydrophilic. When used in combination with amine collectors, depressants ensure that iron remains in the non-floated fraction. The dosage of both collectors and depressants must be controlled carefully, as too much starch can reduce flotation efficiency by increasing pulp viscosity or interfering with air bubble attachment. Frother selection also affects flotation performance. Frothers stabilize the air bubbles in the froth zone. The right frother helps create a stable froth that carries silica away without trapping too much iron. In tailings flotation, froth stability must be managed carefully to prevent entrainment of fine iron particles. Operators adjust frother dosage based on slurry characteristics, temperature, and bubble size distribution. Column flotation has gained attention for processing ultrafine iron tailings. Columns generate fine, uniform bubbles and provide a longer residence time for particle–bubble attachment. This helps produce concentrates with higher Fe grades and lower silica content. Columns are also more energy efficient and allow operators to control wash water distribution, which reduces gangue entrainment.

In many beneficiation circuits, flotation follows magnetic separation. After magnetics remove a significant portion of iron, flotation refines the concentrate by reducing silica. This combined approach leads to a cleaner final product and allows recovery of Fe that might have been too fine for magnetic methods alone. When flotation is optimized, tailings with 25 to 30 percent Fe can often be upgraded to concentrates with 60 percent Fe or higher, depending on mineral complexity. The success of flotation depends on careful reagent selection, proper pH control, adequate feed preparation, and constant monitoring of froth behavior. With modern reagents and improved column technologies, flotation continues to be a powerful tool for recovering Fe values from complex tailings.

Innovative Approaches Using Selective Flocculation, Desliming, and Advanced Hydrocyclone Classification

Selective flocculation has gained attention as a method for upgrading tailings that contain ultrafine iron particles mixed with clay or very fine silica. In many tailing dumps, iron exists in the fine minus-20 micron fraction. These ultrafines cannot be effectively separated using conventional gravity or magnetic methods because they tend to remain suspended in water. Selective flocculation offers a way to overcome this limitation by using chemical reagents that cause iron oxide particles to bind together into larger aggregates while leaving gangue particles dispersed. The process begins with dispersing the tailings slurry using sodium silicate, polyacrylate, or other dispersants. These reagents help break up clay clusters and ensure all particles are fully suspended. Once the slurry is well dispersed, a flocculant such as a starch derivative or a synthetic polymer is added. This flocculant selectively adsorbs onto iron oxide surfaces, causing them to form dense flocs. Silica and alumina particles, lacking the same surface chemistry, remain dispersed. When the slurry is passed through a thickener or hydrocyclone, the flocculated iron settles faster, allowing efficient separation.

The success of selective flocculation depends on reagent dosage, mixing intensity, slurry pH, and mineral surface properties. If the dosage is too low, flocculation is incomplete and iron recovery drops. If the dosage is excessive, flocs become too large, trapping gangue minerals and reducing concentrate grade. Operators must also consider the ionic composition of the water, as hard water or the presence of certain ions can interfere with polymer adsorption.

Desliming plays an important role in any tailing recovery program because ultrafine clays impair separation by increasing viscosity and interfering with reagent action. Hydrocyclones are often used as the primary method for desliming. When properly configured, hydrocyclone clusters can remove particles below 10 to 20 microns, leaving behind a cleaner feed for magnetic or flotation circuits. Advances in hydrocyclone design, including improved liners, vortex finders, and inlet geometry, have made desliming more efficient and less prone to plugging. Another innovation involves multi-stage hydrocyclone classification, where the overflow of one cyclone becomes the feed for the next. This staged approach allows precise control over particle size distribution. Finer control helps ensure that only the desirable size fraction proceeds to the main recovery circuit. By managing particle size more accurately, operators improve the success of downstream magnetic or flotation processes.

In recent years, hydrocyclones have been fitted with sensors that measure pressure, flow, density, and vibration. These instruments provide real-time feedback about the cyclone's operating conditions. Automated control systems adjust feed pressure or underflow orifice diameter to maintain stable operation. Stable classification is essential because even small fluctuations in particle size distribution can reduce the efficiency of selective flocculation or flotation. Some plants combine selective flocculation and magnetic separation. After flocculation produces a dense iron-rich fraction, it is passed through a high-intensity magnet. The floc structure makes the iron more responsive to magnetic capture, improving recovery. At the same time, the process reduces silica contamination by removing the fraction that remains dispersed. Another emerging technique involves the use of high-frequency fine screens. These screens separate ultrafine particles more accurately than hydrocyclones. When used alongside flocculation, they help achieve higher-grade concentrates without excessive grinding.

Selective flocculation and advanced classification methods are particularly useful for tailings where iron is highly disseminated and extremely fine. These methods allow operators to isolate iron in size ranges where traditional methods struggle. When designed well, these systems reclaim a meaningful percentage of Fe that older beneficiation plants could not recover. By reducing slime interference and improving particle size control, modern flocculation and classification techniques form a crucial component in the recovery of iron from low-grade tailings.

Thermal and Chemical Upgrading, Pelletization, and the Integration of Tailings into the Circular Mineral Economy

Thermal and chemical upgrading techniques provide additional pathways for extracting iron from low-grade tailings containing 25 to 30 percent Fe. These methods are especially useful when conventional magnetic or flotation techniques fail to achieve the desired grade or when the iron exists in forms that are difficult to separate. Although more energy-intensive than physical separation methods, thermal and chemical processes can convert complex iron minerals into more easily recoverable forms. One thermal approach is reduction roasting. In this process, the tailings are heated in a furnace with a reducing agent such as coal, natural gas, or hydrogen. Heating transforms weakly magnetic iron oxides such as hematite and goethite into strongly magnetic magnetite. Once conversion is complete, the roasted material is passed through magnetic separators where magnetite can be recovered efficiently. Reduction roasting is useful for tailings rich in goethite, which is difficult to upgrade through direct magnetic methods due to its hydration and fine grain size. By converting goethite to magnetite, the process increases the magnetic susceptibility and enables high recovery in subsequent stages.

Chemical leaching is another option for tailings with impurities that limit their marketability. Certain tailings contain phosphorus or other elements that can restrict their use in steelmaking. Chemical leaching with acids or alkaline solutions can remove these impurities. While leaching is not always cost-effective for bulk removal of silica or alumina, it is effective for specific impurity reduction when market demands require cleaner iron. Leaching can also be combined with thermal pre-treatment to weaken mineral bonds and increase extraction efficiency. Pelletization plays an important role in transforming recovered iron concentrate into a usable industrial product. Tailings-derived iron concentrates often come in fine form, with particles too small for direct use in blast furnaces. Pelletization involves mixing the concentrate with a binder such as bentonite, followed by balling and induration in a furnace. The process strengthens the pellets and increases their suitability for handling and high-temperature reduction. Pelletization also helps stabilize fine tailing-derived concentrates, preventing dusting and improving transport safety.

One advantage of using tailing-derived iron in pelletizing is the predictable particle size distribution achieved through fine beneficiation circuits. Pellet properties depend heavily on size uniformity, moisture content, and mineral composition. Tailings-derived concentrates often meet these criteria when processed through modern classification and separation methods. In some cases, tailings can be blended with higher-grade concentrates to produce a balanced feed for pellet plants. This blending strategy allows operators to adjust Fe content, silica levels, and other key parameters. By using blends, plants can maintain consistent pellet quality without relying entirely on newly mined ore.

Beyond the technical processes, integrating tailing recovery into a circular mineral economy offers both environmental and economic benefits. Recovering iron from tailings reduces the need for new mining, lowers the volume of waste stored in dams, and decreases the risk of environmental contamination. Many regions face growing pressure to rehabilitate old tailing dams. Reprocessing tailings not only recovers valuable iron but also stabilizes these sites and converts them into safer landscapes. Chemical and thermal upgrading processes also open opportunities for extracting secondary minerals present in tailings. Some deposits carry trace amounts of rare earths, titanium, or vanadium. When combined with selective leaching or roasting, these elements can be recovered alongside iron, adding economic value. Although not the primary target, these by-products can offset processing costs.

Many steel industries are exploring ways to incorporate tailing-derived concentrates into green steel initiatives. As renewable energy becomes more available, reduction roasting can be coupled with hydrogen or biochar instead of fossil fuels, lowering the carbon footprint of iron production. With proper process integration, tailings can become a secondary resource rather than a liability. Thermal and chemical upgrading processes require careful cost evaluation but offer a practical route when physical separation alone cannot raise Fe content sufficiently. When combined with pelletization and circular resource strategies, these methods form a comprehensive approach to recovering Fe values and turning low-grade tailings into a viable resource for the steel industry.

CONCLUSION

Recovering iron from tailings containing 25 to 30 percent Fe has become an essential part of modern mineral processing. Advances in magnetic separation, flotation, selective flocculation and reduction roasting have made it possible to reclaim iron that older plants could not capture. These methods improve both grade and recovery by targeting the specific mineral forms and particle sizes present in tailings. Processing recovered material through pelletization further increases its usefulness in steelmaking, allowing fine concentrates to be transformed into a stable feed. Reprocessing tailings also reduces the environmental liabilities associated with long-term storage by lowering the volume of waste and decreasing the risk of dam failure. It supports sustainable mining by limiting the need for new extraction and turning legacy waste into a productive resource. As high-grade iron ore becomes scarce, tailing recovery offers a practical way to extend resource life, reduce ecological impact and strengthen the circular economy within the mining sector. With the continued development of efficient, low-energy beneficiation technologies, the recovery of Fe values from discarded tailings will remain a valuable strategy for both industry and environmental management.

REFERENCES

1. Filippov, L. O., Filippova, I. V., & Severov, V. V. (2014). The use of collectors in iron ore flotation: A review. *Minerals Engineering*, *65*, 1–10.
2. Pradip, & Fuerstenau, D. W. (1983). Adsorption of starch and oleate on hematite. *Colloids and Surfaces*, *8*(2), 103–119.
3. Zhang, Y., Song, S., & Lopez-Valdivieso, A. (2010). Flotation of iron ores: A review. *Minerals Processing and Extractive Metallurgy Review*, *31*(3), 130–160.
4. Dworzanowski, M. (2012). Maximizing the recovery of fine iron ore using magnetic separation. *Journal of the Southern African Institute of Mining and Metallurgy*, *112*(3), 197–202.
5. Nunes, K. R. A., & Alcover Neto, A. (2016). Reuse of iron ore tailings in the environmental protection sector. *Environmental Technology*, *37*(13), 1675–1683.