

# The Impact of Fine-Dispersed Metallurgical Waste on Environmental Pollution

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**Received:** 23 February 2025; **Accepted:** 19 March 2025; **Published:** 22 April 2025

**Abstract:** The article examines the issue of the formation of fine-dispersed waste during foundry production and its impact on environmental pollution. The text analyzes the sources and physical and chemical characteristics of such waste, which complicate their disposal and increase their ecological hazard. Particular attention is paid to the challenges of handling fine fractions and the risks they pose to soil, water, and air. The article emphasizes the importance of developing advanced and efficient recycling technologies and highlights rotary tilting furnaces as one of the most promising solutions. These technologies not only reduce the negative environmental impact but also make it possible to return valuable metals into the production cycle.

**Keywords:** Fine-dispersed waste, environmental pollution, metallurgy, waste recycling, industrial emissions, sustainable processing, metal recovery.

## Introduction:

Today, environmental pollution is one of the most urgent global problems. Rapid industrial growth, population increase, and the expansion of production volumes have led to a rise in the amount of waste released into nature. A large part of this pollution comes from the metallurgical industry, which plays a key role in modern infrastructure but also generates harmful by-products.

One of the most difficult types of pollution to manage is fine-dispersed waste. These are particles released during drilling, grinding, smelting, and gas cleaning processes. Because of their small size and chemical activity, such particles are easily carried by wind and water, spreading over large areas. They can accumulate in soil, enter water systems, and remain suspended in the air, causing long-term harm to ecosystems.

The danger of fine-dispersed waste lies in both its mobility and its chemical composition. These particles often contain metals like lead, zinc, and cadmium, which are toxic to humans and wildlife. If not properly handled, such waste can stay in the environment for years, gradually breaking down and releasing harmful

substances.

For this reason, more attention is being given to finding effective and safe methods for collecting and recycling fine fractions. One of the most promising technologies is the use of rotary tilting furnaces, which allow for more efficient melting and recovery of valuable metals while reducing environmental impact.

## Classification and Properties of Fine-Dispersed Waste

Fine-dispersed waste from foundry and metallurgical processes includes a wide range of materials: aspiration dust, sludge, scale, shavings, metal oxides, and other particles generated during the handling and melting of raw materials. These wastes are usually the result of operations like cutting, drilling, grinding, gas purification, and ore processing.

One of the main difficulties in handling such waste is its physical structure. Fine particles have a very small size and low density, which makes them easy to spread by air and difficult to collect. Their ability to stay suspended in the air or be carried with water runoff increases the risk of environmental pollution.

In addition, these materials have complex chemical

compositions, often including oxides of iron, zinc, lead, copper, and other heavy metals. These compounds are chemically active and can enter into reactions with the environment, making the waste not only persistent but also dangerous to living organisms.

The classification of such waste usually depends on the source of its formation, particle size, and metal content. For example, dust from electric arc furnaces contains a high percentage of iron and zinc, while waste from ore grinding may include silica and other non-metallic impurities. Understanding these properties is essential for selecting the right recycling or disposal method.

#### **Environmental Impact of Fine-Dispersed Waste**

Fine-dispersed waste has a strong negative effect on the environment due to its ability to travel through air and water and accumulate in different parts of the ecosystem. These particles are often too small to be caught by regular filters, which allows them to spread easily and remain in the environment for a long time.

**Air pollution:** When dust is released into the atmosphere during smelting, transportation, or grinding, it can stay in the air and travel over large distances. People and animals can inhale these particles, which may contain toxic metals such as lead or cadmium. Long-term exposure can lead to serious health problems.

**Soil contamination:** Dust and small waste particles settle on the ground and mix with the soil. Over time, this changes the chemical composition of the soil and reduces its fertility. Plants may absorb harmful elements through their roots, which allows these toxins to enter the food chain.

**Water pollution:** Rain and melting snow can carry dust and waste particles into rivers, lakes, and groundwater. In the water, these substances affect fish and aquatic plants, and may even reach drinking water sources.

Fine-dispersed waste is especially dangerous because it can enter biological systems and stay there for a long time. Its small size and chemical reactivity make it difficult to remove once it has spread. That is why modern foundries must develop better ways to capture, neutralize, and recycle such waste before it can harm the environment.

#### **Current Recycling Methods and Their Limitations**

Several methods are currently used to manage fine-dispersed metallurgical waste. However, their effectiveness depends heavily on regional infrastructure, economic feasibility, and environmental regulations. In Uzbekistan, where large-scale modernization of metallurgical plants is still ongoing, many traditional methods are widely used despite their limited efficiency.

**Landfilling:** This is the most accessible and frequently used method in Uzbekistan due to its low cost and

minimal technical requirements. However, landfilling is not suitable for fine-dispersed waste. These particles are easily dispersed by wind and rainfall, especially when placed in open or poorly managed sites. Over time, heavy metals leach into the soil and groundwater, posing risks to nearby agricultural lands and residential areas.

**Advantages:** Simple and inexpensive, requires no complex equipment.

**Disadvantages:** High environmental risk, loss of valuable metals, not a long-term solution.

**Dust Suppression and Surface Sealing:** Some Uzbek enterprises use water spraying or chemical surfactants to control airborne dust during material transport or storage. While this reduces immediate air pollution, it is a temporary measure and ineffective for long-term disposal. In arid climates like Central Asia, water-based methods require frequent reapplication and may contribute to resource waste.

**Advantages:** Easy to apply, reduces dust on-site.

**Disadvantages:** Short-term effect, does not address heavy metal content, not scalable for large volumes.

**Briquetting:** This method is practiced at a limited number of metallurgical plants in Uzbekistan. It allows partial reuse of metal-containing dust by compressing it into solid blocks. However, briquetting requires drying equipment, binders, and pressing systems—many of which are outdated or absent at local facilities. Additionally, the briquettes are often weak and prone to damage.

**Advantages:** Enables partial recovery, compact format.

**Disadvantages:** High energy demand, fragile output, rarely used due to lack of equipment.

**Direct Reuse in Furnaces:** At some foundries, fine waste is mixed directly with raw material in small quantities. While technically simple, this method is inefficient: fine particles oxidize quickly at high temperatures, leading to low metal recovery and excess slag. For most Uzbek enterprises, maintaining optimal furnace conditions is already a challenge, and this method often causes more problems than benefits.

**Advantages:** No additional infrastructure needed.

**Disadvantages:** Metal losses, higher slag formation, not recommended for unstable production lines.

**Electrostatic Filters and Air Purification Systems:** Modern air cleaning systems are installed at several newer plants in Uzbekistan, especially in Tashkent and Navoi regions. They reduce emissions effectively, but collected dust still needs to be treated or stored, which is often done through temporary storage or burial. Without proper downstream recycling, this becomes just another waste stream.

**Advantages:** Reduces emissions, protects health.

**Disadvantages:** Generates secondary waste, expensive to maintain, rarely paired with full recycling chains.

While these methods are still in use, none of them provide a complete or sustainable solution for fine-dispersed waste in Uzbekistan. Their limitations—whether due to lack of technology, financial constraints, or environmental risk—highlight the urgent need for more advanced and regionally adaptable solutions. In the next section, we explore one such solution: rotary tilting furnaces (RTFs), which offer higher efficiency and better environmental performance.

#### Modern Technologies and the Use of Rotary Tilting Furnaces

Given the limitations of traditional recycling methods, many metallurgical enterprises are beginning to consider more advanced technologies. One of the most promising solutions for processing fine-dispersed

waste is the use of rotary tilting furnaces (RTFs).

RTFs are designed to provide uniform heating of fine particles in a rotating chamber, creating a dynamic layer that allows for complete melting and controlled atmosphere. This makes them especially suitable for recycling dust, scale, and oily or contaminated residues that are difficult to process using conventional furnaces.

In addition, RTFs are compact and energy-efficient, making them a practical option for integration into existing production lines, even in regions with developing industrial infrastructure like Uzbekistan. They offer flexibility in handling a wide range of metal-bearing waste with minimal environmental impact.

**Table 1. Comparative Performance of Traditional and Rotary Tilting Furnaces**

Parameter	Traditional Furnaces	Rotary Tilting Furnaces
Thermal efficiency (%)	25	55
Energy consumption (kWh/ton)	1500	800
Metal losses (%)	20	5
Specific fuel use (m <sup>3</sup> /ton)	20	8
Ability to process oily waste	Limited	High
Suitability for fine fractions	Low	Excellent
Atmosphere control	Poor	Controlled (reducing)
Equipment size	Large	Compact
Maintenance and integration	Difficult	Flexible
Initial investment	Low	Moderate
Environmental compliance	Low	High
Metal recovery rate	Medium	High

Rotary tilting furnaces significantly outperform traditional methods in terms of energy efficiency, waste versatility, and environmental performance. Their ability to recover valuable metals while processing complex fine waste makes them ideal for modern recycling systems. While initial investment may be moderate, long-term economic and environmental returns justify the transition to RTFs, especially in regions aiming to modernize foundry infrastructure.

#### Environmental Monitoring and Soil Contamination Assessment

To assess the ecological impact of fine-dispersed waste from metallurgical operations, a series of soil samples were collected at different depths in the area surrounding the foundry site. The aim was to determine the concentration of heavy metals and metalloids across various soil layers and compare the results to national maximum permissible levels (MPLs).

**Table 2. Concentration of Heavy Metals and Metalloids in Soil Samples at Various Depths**  
(mg/kg)

Depths, cm	0–15	15–50	50–70	Avg 0–70	70–120	120–180	180–200	Avg 70–200	MPL*
Element									
As	12,9	10,2	12,9	12,00	15	10,2	13,1	12,77	2
Cd	0,135	0,128	0,134	0,13	0,11	0,105	0,189	0,13	0,7
Cr	51,9	59,1	55,1	55,37	40,9	34,3	50,4	41,87	200
Cu	94,8	84,1	80,4	86,43	91,8	129	83	101,27	55
Mn	670	700	848	739,3	615	296	563	491,33	1500
Mo	14,8	10,7	15,7	13,7	1,9	5,44	8,44	5,26	
Pb	16,8	20,3	21,5	19,5	13,5	16,3	12,5	14,10	30
S	805	737	631	724,33	1330	748	2380	1486,00	160
Sb	0,601	0,591	0,56	0,58	0,547	0,554	0,752	0,62	4,5
Sn	5,52	1,68	1,92	3,04	3,5	4,08	11,2	6,26	
V	87,8	92,4	104	94,7	83,9	42,8	82,4	69,70	150
Zn	84,4	83	99	88,8	65	32,9	62,9	53,60	100

\*MPL – Maximum Permissible Level according to national soil safety standards (mg/kg)

The data clearly show that several heavy metals, including arsenic, copper, and sulfur, exceed their regulatory limits across both surface and deeper soil layers. For instance, copper levels reach over 101 mg/kg, nearly double the MPL of 55 mg/kg. Arsenic concentrations exceed permissible values sixfold, and sulfur levels are more than nine times the MPL. These results confirm deep and persistent contamination, highlighting the failure of surface-level remediation efforts and the need for integrated strategies involving dust suppression, waste recovery, and long-term soil monitoring.

#### CONCLUSION

This study has revealed the significant role that fine-dispersed waste from metallurgical industries plays in

contributing to environmental pollution. Traditional approaches to waste handling have shown limited efficiency and often lead to long-term ecological damage. While some progress has been made in reducing emissions, the current state of waste management systems requires a more integrated and strategic approach.

In order to reduce the environmental impact associated with metallurgical waste, it is advisable to consider a range of complementary strategies. One such approach involves improving emission control systems by incorporating modern purification technologies and filtration units capable of capturing harmful substances before they are released into the environment. Equally important is the enhancement of

waste processing technologies, including the use of secondary casting methods and more efficient slag recycling processes, which can decrease the overall volume of hazardous residues. Attention should also be given to the proper collection, storage, and transportation of waste materials, particularly through the application of dust suppression and sealing techniques that help limit the spread of fine particles. Continuous environmental monitoring—covering air, soil, and water—can serve as a valuable tool for assessing potential risks and informing management decisions. Finally, progress in this area depends on the long-term commitment to investing in cleaner production technologies, along with public education, stakeholder engagement, and the gradual strengthening of environmental regulations.

Based on the conducted analysis, fine-dispersed particles represent a significant threat to both soil and aquatic ecosystems due to their ability to migrate through natural media and accumulate over time. Their toxic composition further exacerbates the risk to plant and animal life. Therefore, the development and implementation of environmentally safe and efficient handling strategies for metal-containing waste should be viewed as a strategic priority within industrial practice. In the long term, the adoption of innovative and sustainable waste treatment technologies will play a key role in improving environmental quality, reducing industrial emissions, and conserving natural resources. Addressing the issue of fine-dispersed waste requires coordinated efforts from industry stakeholders, government bodies, and the broader community. Through joint action and effective waste management policies, it is possible to promote sustainable development and ensure the long-term integrity of ecological systems. This research contributes to the foundation for more advanced recycling strategies in metallurgy and underscores the importance of transitioning toward environmentally responsible and resource-efficient industrial models.

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