



BEYOND THE CERTIFICATE: SULFUR QUALITY AND ITS IMPACT

Jan Hermans and Aida Barberena, Elessent Clean Technologies, explain why feedstock quality and handling practices matter for sulfur melting and sulfuric acid production.

Sulfur plays a crucial role in modern agriculture. As a key nutrient for plant growth, it is essential for protein synthesis, enzyme function, and chlorophyll formation. Sulfur is a fundamental component of fertilizers, particularly in the production of sulfuric acid, which is widely used to manufacture phosphate fertilizers such as monoammonium phosphate (MAP) and diammonium phosphate (DAP).

Over the past several decades, the global fertilizer industry has increasingly relied on recovered sulfur from oil and gas refining. This sulfur is widely available and relatively consistent in quality. However, geopolitical developments and supply chain disruptions have introduced a growing variety of sulfur grades into the market. As a result, fertilizer producers and sulfuric acid plants are increasingly likely to encounter new operational challenges related to sulfur purity, handling, and storage.

While sulfur may appear to be a relatively simple raw material, its quality and physical characteristics can significantly influence

the performance of sulfur melting and purification systems. Impurities, contamination during transport, and improper storage can lead to operational challenges, increased energy consumption, environmental concerns, and equipment damage.

Understanding the origins of sulfur, the mechanisms that degrade its quality, and the operational consequences of impurities is essential for fertilizer producers seeking reliable, efficient plant operation.

Origin of the sulfur

Sulfur is supplied to the fertilizer industry mostly in solid form. The primary source of high-quality sulfur is oil and gas refineries, where sulfur is recovered through the Claus process. This process converts hydrogen sulfide (H_2S), a by-product of hydrocarbon processing, into elemental sulfur.

Claus sulfur is typically produced in liquid form and is considered the highest quality sulfur available on the market, with a very high level of purity. The main impurity of concern in

liquid sulfur is residual H_2S , which may remain if the degassing process is incomplete.

The refinery sulfur is solidified to granules or prills and distributed in solid form (see Figure 1). This is mainly because transporting liquid sulfur presents logistical challenges. Since sulfur solidifies at approximately $115^{\circ}C$, long-distance transportation requires heated tanks and specialised infrastructure. In practice, transportation distances for liquid sulfur are usually limited to roughly 500 km. Beyond this range, trucks need to be pre-heated to re-melt the sulfur.

It is important to note that each solid form has specific physical characteristics, including different angles of repose, particle strengths, and susceptibility to breakage or dust formation. These characteristics affect storage, handling, and transport logistics.

Another source of solid sulfur is the re-established Frasch mining process. Although largely phased out globally, a small number of mines remain operational today, and the high sulfur prices encourage more operations to be opened. Sulfur produced by this method has significantly different characteristics compared with refinery sulfur, particularly regarding organic impurities.

Table 1. Sulfur specifications	
Sulfur	Minimum 99.7%
Ash	< 0.02%
Organics	< 0.04%
Water content	< 1
Acidity	< 0.001%
Metals (As, Te, Se)	< 1 ppm



Figure 1. Different sulfur feedstocks.



Figure 2. Sulfur stockpile exposed to environmental and atmospheric conditions.

A changing sulfur market

The sulfur market has become increasingly dynamic recently. Rising fertilizer demand and supply chain disruptions have driven up sulfur prices significantly. In response, lower-grade sulfur is increasingly entering the market.

While such materials may offer short-term economic advantages, they often introduce operational risks. Lower quality sulfur may contain higher levels of organics, ash, acidity, or moisture, which can interfere with melting and filtration processes and reduce plant throughput.

Poor sulfur quality can also affect catalyst lifetime in sulfuric acid plants, increasing operational costs and maintenance requirements.

Sulfur quality

When purchasing sulfur, certain specifications are almost always provided (see Table 1).

But it is key to consider that sulfur quality is measured at the location where solidification occurs. By the time the sulfur reaches the melting plant, its composition may have changed significantly due to various influencing parameters, which will be discussed later.

Causes of sulfur quality degradation after production

When analysing sulfur upon arrival at fertilizer or sulfuric acid plants, it is frequently found that the material no longer meets the specifications stated at the point of production or solidification. These deviations are not necessarily related to the original sulfur source, but rather to degradation mechanisms occurring during transportation, handling, and storage. The most common causes of sulfur quality changes are outlined below.

Transportation effects

Transportation is one of the primary contributors to sulfur quality deterioration. During land transport, repeated loading, unloading, and mechanical handling can increase the presence of ash. Mechanical abrasion during transport can also weaken particle integrity, increasing the formation of sulfur fines that are more susceptible to oxidation and moisture absorption.

Marine transportation introduces additional challenges. Bulk sulfur cargoes transported by sea are exposed to humid air and salt-laden environments, often resulting in increased moisture uptake and external contamination. Furthermore, prolonged exposure to moisture and steel surfaces can promote the formation of iron sulfides (FeS_x), which may later contribute to corrosion issues.

Exposure to rain and atmospheric conditions

Open-air sulfur storage exposes the material to rainfall, wind, and ambient humidity. Depending on the local climate, sulfur stockpiles may absorb significant amounts of water, particularly when fine particles are present (see Figure 2).

Covered or enclosed storage facilities can significantly reduce these risks, but only when properly designed. Adequate ventilation is required to prevent condensation, while corrosion protection of structural steel elements is essential due to the aggressive environment created by sulfur dust and moisture. Although under-roof storage represents a higher capital investment, it is often justified by improved

sulfur quality, more stable melting behaviour, and reduced filtration and maintenance requirements downstream.

Microbiological activity and acidity formation

An often-overlooked mechanism of sulfur quality degradation is microbiological activity. Certain sulfur-oxidising bacteria, most notably *Thiobacillus* species, can colonise sulfur stockpiles. In the presence of oxygen and moisture, these bacteria oxidise elemental sulfur to sulfuric acid.

The rate of acid formation depends strongly on environmental conditions such as humidity, temperature, and oxygen availability. Once acidity levels increase, bacterial activity may accelerate further, creating a self-reinforcing degradation process. Without appropriate monitoring and mitigation measures, sulfur that initially meets acidity specifications can become highly aggressive by the time it reaches the melting system.

Possible quality issues

Hydrogen sulfide emissions and sulfur flour

H₂S emissions are one of the most critical safety and environmental concerns in sulfur melting facilities. Even at low concentrations, H₂S can cause irritation, nausea, and respiratory issues. At higher concentrations, it becomes highly toxic and flammable.

During sulfur melting, solid sulfur is continuously heated and melted, while contained moisture evaporates. The resulting water vapour can carry dissolved H₂S into the gas phase. Airflow through the melting tank then transports these gases to the stack.

In addition to H₂S, sulfur vapour may also be present in the gas stream. When this vapour cools, it condenses and forms extremely fine particles known as sulfur flour. These particles behave as submicron aerosols and tend to deposit on colder surfaces within equipment and piping (see Figure 3).

Sulfur flour deposits can cause serious operational issues, including the blockage of instrumentation, piping, and emission control equipment. H₂S scrubbers may also suffer from clogging of demisters and spray nozzles due to the presence of these fine particles.

Recommended practices

To minimise emissions and sulfur flour deposition, equipment design should ensure that piping, instruments, and nozzles are heat-traced or jacketed so that sulfur remains above its solidification temperature.

Emission control systems must also be designed to tolerate the presence of sulfur aerosols. Maintaining all equipment surfaces above the sulfur condensation temperature helps prevent deposition.

Elsest's own Sulphurnet technology provides sulfur melting mechanisms specifically designed to reduce H₂S emissions to levels compliant with strict environmental regulations while minimising sulfur flour formation.

Organic contamination

Organic impurities present one of the most complex challenges in sulfur processing. These compounds may originate from crude oil residues in refinery sulfur or from geological sources in mined sulfur.

Frasch-mined sulfur in particular may contain high concentrations of viscous organic materials, sometimes reaching

levels as high as 0.5%. These substances interfere with sulfur prilling, melting, and purification processes.

Inside melting tanks, organics tend to accumulate in poorly agitated zones. Over time, they may form sticky layers that block heat exchangers and reduce melting capacity. Organic deposits may also damage liquid sulfur pumps if they accumulate within pump impellers.

Recommended practices

Proper melter design with effective agitation is essential to prevent organic accumulation and ensure uniform mixing within the melting tank.

In situations where organic contamination cannot be avoided, the use of filter aids or body feed materials can help maintain filtration performance by creating more porous filter cakes. However, the use of body feed systems requires additional equipment and should be carefully evaluated during plant design.

Routine monitoring of sulfur sources and selecting feedstock with acceptable organic content remain the most effective preventive measures.

High water content

Moisture in sulfur significantly increases the energy demand of the melting process. Vaporising water requires nearly five times more energy than melting sulfur itself.

Wet sulfur can also cause excessive foaming during melting. While moderate foaming can typically be managed within the melter, large volumes of foam may overflow from the tank, potentially creating environmental contamination and increasing fire risk.



Figure 3. Sulfur flour.

Recommended practices

Preventing moisture ingress during storage and transport is the most effective way to control water content.

Covered sulfur storage facilities can greatly reduce exposure to rain and humidity. Additionally, proper stockpile management and drainage systems can help prevent water accumulation.

Melting systems should also be designed to safely handle moderate levels of moisture by incorporating appropriate venting and gas handling capacity.

Ash and solid particles

Ash particles originate from dust formation during transportation, contamination during handling, or debris introduced during shipping.



Figure 4. Corroded filter leaves.



Figure 5. Brick-lined above-ground sulfur melting tank.

In melting systems, these particles tend to settle in areas with poor agitation. In-ground melting pits are particularly susceptible to ash accumulation in dead zones.

Over time, accumulated ash can cover heating coils, reducing heat transfer efficiency and lowering melting capacity. Solid particles may also enter pumps and cause mechanical damage.

In filtration systems, increasing ash levels shorten filter cycles, requiring more frequent cleaning and increasing sulfur losses.

Recommended practices

Melting tanks should be designed with strong and uniform agitation to keep solids suspended and to prevent settling.

Equipment layouts should avoid dead zones where solids may accumulate. Regular monitoring of ash content in incoming sulfur can also help operators anticipate filtration load and adjust operating conditions accordingly.

Efficient filtration systems capable of handling higher solid loads are essential when processing lower-quality sulfur grades.

Acidity and corrosion

Corrosion is a major concern in sulfur melting and purification systems. One common mechanism involves the formation of iron sulfide when sulfur solidifies within steel equipment. When iron sulfide reacts with oxygen and moisture, aggressive corrosion processes may begin.

Another cause of corrosion is the presence of acidic impurities in sulfur. At operating temperatures around 150°C, acidic sulfur can become extremely aggressive, damaging even high-alloy materials.

If left untreated, corrosion can rapidly degrade piping, valves, filters, and other critical equipment. The impact of such corrosion on filtration equipment is illustrated in Figure 4.

Recommended practices

Brick-lined melting tanks provide the best corrosion resistance and offer the best life-cycle cost (see Figure 5).

Neutralisation systems using calcium hydroxide (Ca(OH)_2) are commonly applied to control acidity levels within molten sulfur.

Regular monitoring of sulfur acidity before and after neutralisation ensures proper chemical dosing and helps prevent excessive lime addition, which could otherwise increase filtration load and operating costs.

Conclusion

Sulfur remains an essential raw material for fertilizer production and the global food supply chain. However, the increasing variability in sulfur quality presents growing challenges for sulfur melting and purification facilities.

Impurities such as organics, ash, acidity, and moisture can significantly impact melting efficiency, filtration performance, and equipment reliability. These contaminants often originate from transportation, storage conditions, or variations in sulfur sources.

Although lower-grade sulfur may offer short-term cost advantages, the operational risks and hidden costs associated with processing contaminated sulfur can quickly outweigh any initial savings.

Careful evaluation of sulfur quality, combined with well-designed melting and purification systems, is therefore essential to ensure stable plant operation. **WF**