March 11th 2026

Factsheet on Ferrous Slags

Executive Summary

- Ferrous slags are REACH-registered valuable raw material inherent to iron and steel making process. Steel cannot be produced without production of slags.
- Ferrous slags are established secondary raw materials in Europe for over 100 years which their use from 2000-2024 has prevented 1.21 billion tons natural rock extraction and 319 million tons of CO_2 emissions.
- BOS and EAF (including carbon (EAF C) and stainless steel (EAF S)) slags are members of ferrous slag family and have been used as secondary raw material in road construction by up to 61% as major downstream use compared to cement, metallurgical processes, and fertilizers in 2024 in EU and UK.
- Depending on the steel production route, different volumes of limestone and dolomite are required. EAF carbon steel slags typically contain negligible or no free CaO, as lime is incorporated into stable mineral phases. BOS slags may contain limited free CaO; however, it is largely embedded within silicate matrices, significantly reducing bioavailable alkalinity.
- Ferrous slags are rock-like crystalline materials in which trace metals are structurally bound within mineral phases, so total elemental content is not a valid proxy for hazard and any metal-related concern depends on leaching under specific environmental conditions.
- Current available GLP-compliant toxicological tests with solid and eluates of BOS and EAF do not support automatic classification for eye/skin irritation based solely on high pH values resulted from high free lime content.
- RFSC acknowledges remaining dossier data gaps and generation of additional tests results for scientific based registration.

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1. Steel production and types of ferrous slags

Ferrous slags are process-derived materials formed during steel production, where they fulfil essential metallurgical functions by binding oxidic constituents of the molten metal and forming a protective top layer that limits heat loss and prevents oxidation.

Steel is produced through two main routes: ore-based steelmaking (about 60% of EU production [1]) and scrap-based steelmaking (about 40% [1**Fehler! Textmarke nicht definiert.**]). The co-production of slags is an inherent part of both processes to produce steel.

In ore-based steelmaking, iron ore is reduced to metallic iron and then converted into steel. Typical inputs include iron ore, coal and limestone. The main ore-based production route is ironmaking via the blast furnace (BF) with air cooled (ABS) or glass granulated slags (GBS) followed by steelmaking in the basic oxygen furnace which basic oxygen or Linz Donawitz slags (BOS or LD slag) are parallelly produced in it.

In scrap-based steelmaking, recycled steel scrap is melted in an electric arc furnace (EAF). Main inputs are steel scrap (optionally: Direct Reduced Iron (DRI), hot metal, or other sources of metallic iron). Fluxes (e.g., lime, limestone, dolomite) are added to remove impurities. During melting, the fluxes combine with non-metallic scrap components and incompatible elements to form a liquid slag. Depending on the steel grade, two slag categories are produced:

EAF C – Slag from carbon steel production (~80% of the EAF slag volumes in Europe)

EAF S – Slag from stainless / high-alloy steel production (~20% of the volumes)

Further processing of crude steel in secondary metallurgical vessels results in additional secondary metallurgical slags (SMS).

In any case, all different ferrous slags categories are produced after the process at a very high temperature (>1500 °C), as an industrial mineral lava.

In total, five main slag families can be distinguished (see table 1).

Table 1: Slag families and corresponding EINECS- and CAS-numbers

No	IUPAC Name	Abbreviation	Other names	EC Number CAS Number
1	Slag, ferrous metal, blast furnace (granulated)	GBS	Granulated Blast Furnace Slag	266-002-0 65996-69-2
	Slag, ferrous metal, blast furnace (air-cooled)	ABS	Air-cooled Blast Furnace Slag	266-002-0 65996-69-2
2	Slags, steelmaking, converter	BOS	Basic Oxygen Furnace Slag (converter slag)	294-409-3 91722-09-7
3	Slag, steelmaking, elec. furnace (carbon steel production)	EAF-C	Electric Arc Furnace Slag (from Carbon steel production)	932-275-6 -
4	Slag, steelmaking, elec. furnace (stainless/high alloy steel production)	EAF-S	Electric Arc Furnace Slag (from Stainless/ high alloy steel production)	932-476-9 -
5	Slags, steelmaking	SMS	Steelmaking slag	266-004-1 65996-71-6

Each ferrous slag type is fully registered under Regulation (EC) No 1907/2006 (REACH) at present without any hazard classification under Regulation (EC) No 1272/2008 (CLP). It is important to recognize that slags belong to the substance category *unknown or 'variable composition, complex reaction products or biological materials (UVCB)' substances,* and not mixtures. These substances contain numerous components which, in the case of slags, are mineral phases just like those found in natural rocks. Their exact composition and amounts may vary as a result of differences in raw materials and manufacturing processes. However, they share strong similarity in main compositional elements and mineralogy which allows grouping of the five members under Ferrous Slag category and read across approaches.

2. Ferrous slags and their sustainable use

Ferrous slags have been used for over 100 years in Europe and in downstream industries which has avoided 1.21 billion tons of natural rock extraction and prevented 319 million tons of CO_2 emissions over the 2000-2024 period [2, 3].

In the year 2024, 36 million tons of ferrous slags were produced in the EU and UK: 19.6 million tons of ABS/GBS, and 16.5 million tons of Steel furnace slag, including BOS (~60 %) and EAF (~30 %). While ABS/GBS were mainly used in Cement Production, BOS and EAF were used on different markets, such as road construction (61 %), cement/concrete additives (12.3 %), recycling into metallurgical processes (12.1 %), fertilizers (8.1 %), and hydraulic engineering (4.7 %) [1, 2].

More specifically in Netherlands, in 2024, Tata Steel IJmuiden produced approximately 1,200 kilo tons of GBS and 575 kilo tons of BOS. Nearly all produced GBS are utilized in cement production. BOS slag, however, has a more diversified application profile: 100 kilo tons is used in cement and concrete, 515 kilo tons in civil engineering works such as road construction, and 120 kilo tons is recycled internally in the BOF process for metallurgical purposes.

Due to recently imposed Dutch restrictions on the use of steel slag in civil engineering applications, the market of BOS in such works within the Netherlands has effectively come to a halt. Since slag formation is inherent to steelmaking, alternative outlets must be found. Identifying new applications is challenging due to the need for technical validation and market development, as well as uniformity in European, national and regional laws and regulations. These constraints carry significant implications for Tata Steel IJmuiden, the Netherlands' sole steel producer and employer of 9,000 people.

3. Free lime content

Lime, limestone ($CaO/CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$) is added in steelmaking as a flux to form slag and remove elements unwanted in the steel such as phosphorus (P), and silica (Si). In electric arc furnace (EAF) carbon steel production, the required lime addition is typically lower than in basic oxygen steelmaking (BOS), reflecting generally lower requirements for tramp elements for typical EAF carbon steel products (often long products) compared with BOS products (often flat products). Furthermore, the higher iron oxide content in EAF slag compared to BOS slag means that lime has a higher solubility. Consequently, EAF C slags usually contain negligible or no free lime, as the calcium (Ca) is fully incorporated into the mineral phases in the slag matrix.

In BOS slags, the added lime or limestone does not always fully dissolve or react during slag formation. As a result, free lime may be present in varying amounts. However, the free CaO is mainly embedded within silicate and ferrite matrices (C_2S, C_3S, Ca–Mg silicates). On air exposure, surface CaO rapidly hydrates and carbonates, forming a $Ca(OH)_2/CaCO_3$ layer that strongly limits hydroxide release. Thus, the bioavailable alkalinity of slag particles is far lower than that of pure free lime (CaO) or portlandite ($Ca(OH)_2$) dusts.

The distinction concerning free CaO in different slag types is well recognized in technical standards and guidelines. Due to the free lime, BOS slags can show volume stability issues, whereas EAF C slags are generally volume-stable (e.g. [4], [5], [6]). These findings are supported by decades of analytical data from the FEhS Institute (see Appendix to this Factsheet) and international literature on ferrous slags.

4. Heavy metal content and leaching from ferrous slags

Oxides and heavy metals in the slag do not occur in isolated form, neither as a pure metallic element nor as a potentially harmful chemical compound. Slags are not mixtures of chemical substances. Instead, slags are complex structures consisting of individual mineral phases that interlock with each other. Exactly like natural igneous rocks, these mineral phases represent the fundamental building blocks of slags. The inner texture of slags and the interlocking of mineral phases is comparable to a natural basalt rock as an example (see Backscattered Electron (BSE) images included in [7] and [8]). Typical mineral phases present in BOS and EAF slags is already presented in Appendix 1 of the join statement [9] published on 7th October 2025.

Each mineral phase in ferrous slags consists of a solid crystalline lattice formed by an ordered, repeating arrangement of atoms or ions, which gives rise to characteristic crystal structures and shapes. The principal elements, oxygen, silicon, aluminium, iron, calcium, and magnesium, govern the fundamental mineral properties, including crystal structure and physical characteristics such as hardness, colour, and density. In addition to these major constituents, minerals also contain minor and trace elements (<5 wt% and <1 wt%, respectively). Depending on ionic radius and charge, these elements may partially substitute for the main elements within the crystal lattice, a process known as substitution or diadochy. As a result, numerous trace elements are incorporated into existing mineral structures rather than forming separate mineral phases. Notably, the mineral phases present in ferrous slags are also commonly found in natural igneous rocks, meaning that steelmaking does not generate fundamentally new mineral components.

Considering total content of minor and trace elements to conclude whether these components pose adverse effects is scientifically not accepted. These components are incorporated in stable mineral phases and their release upon contact with water depends on many factors such as grain size distribution, liquid to solid ratio (L/S), pH values, and solubility of each specific mineral phase [e.g., 10]. Therefore the leaching heavily depends on environmental factors and use conditions.

To ensure that the hazards from potentially harmful heavy metals within the ferrous slags is identified, RFSC has performed reliable OECD-guided toxicological and eco-toxicological tests (see tables 2 to 5 for examples of these tests). While in eco-toxicological tests the organisms are exposed to released bioavailable fraction of potentially harmful heavy metals, none of the test reports indicate signs of heavy metal relevant acute toxicity. Consequently, under the tested relevant leaching conditions, metal release is not causing toxicity. Any potential concern is scenario specific and does not show intrinsic hazard.

5. Toxicological data on skin, eye and oral irritation potential of steel slags

The REACH Ferrous Slag Consortium (RFSC) has performed many toxicological tests on eye-, skin- and respirator irritation, as presented in the respective REACH registration dossiers. More than 25 irritation/corrosion studies (skin + eye) have been completed with the principles of Good Laboratory Practice (GLP) across ferrous slag types. Nine of these studies have reliability score of one.

Some slag types were tested as finely ground solid and for some (e.g., BOS and EAF-S) testing was performed with eluates instead of finely ground solids. This deviation from standard guidance was scientifically justified because the fine grinding required for direct solid testing generates artificially sharp-edged particles that are not representative of the material under realistic exposure conditions. Such particles may cause mechanical injury to the eye and would confound the assessment of irritation related to chemical effects such as free lime content or pH value.

Table 2 summarizes the studies performed on the original solid materials, while Table 3 provides an overview of the tests conducted with eluates.

Overall, the available data indicate that ferrous slags — including materials containing free lime and slags whose eluates exhibit elevated pH values above 11.5 do not per se cause irritant effects neither on skin nor eye, demonstrating that a high pH value alone does not lead automatically to corrosion/irritation properties. According to the CLP Regulation (EC) No. 1272/2008, Annex I, Section 3.3.2.2.4, substances and mixtures with extreme pH values (≤2 or ≥ 11.5) are presumed to cause serious eye/skin damage or irritation. However, this presumption can be overruled if scientifically valid test data demonstrate that the material does not cause skin or eye corrosion/irritation.

At the same time, the RFSC recognises that certain data gaps remain in the REACH dossiers and is actively working to address them. Additional studies are being prepared, including tests on slags with higher free lime contents, to further strengthen the scientific basis of the registrations.

6. Available scientific data on potential inhalation irritation effects

GLP-compliant inhalation studies in rats with ground granulated blast furnace slag (GGBS) (see Table 2), used as a worst-case analogue for ferrous slags (GGBS is usually used in finely ground form), do not cause respiratory irritation or tissue damage. In an acute OECD 403 study at 5,235 mg/m³ - exceeding realistic workplace exposure and the regulatory limit concentration - no mortality and no signs of respiratory irritation were observed, only transient physical dust loading of the nose.

Due to this dust loading and prevention of the animal suffering due to suffocation, a second acute study extended post-exposure observation with lower exposure concentrations was performed. Detailed histopathology confirmed the absence of lung injury, while quartz as positive control induced severe inflammation. A 28-day inhalation study with full examination of all regions of the respiratory tract likewise showed no adverse effects.

Although BOS slags contain some amounts of free CaO, the total dust concentrations already tested with GGBS would, under worst-case assumptions, correspond to or exceed the levels at which CaO-related irritation would be expected, yet no such effects occurred. Testing at even higher dust loads would be technically impossible and ethically unacceptable due to suffocation and particle overload.

Supplementary in vitro studies using lung cell models and covering all registered ferrous slag types, including BOS slags, likewise showed no relevant cytotoxic or pro-inflammatory responses, with results comparable to natural mineral reference materials.

Taken together, the currently available data indicates that BOS and EAF slags are not expected to cause respiratory irritation, making additional animal testing scientifically unnecessary and ethically unjustified under the REACH principle to avoid vertebrate animal testing wherever possible.

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Table 2: Tests conducted using solid slag test item

	ABS/GBS	**EAF-C**	**EAF-S**	**BOS**	**SMS**
Free lime in tested slag	<1%	< 1 %	2.5%	2.3 %	3.3 %
Eye irritation / serious eye damage					
Eye irritation in vivo (OECD TG 405)	not classified for eye irritation or serious eye damage	not classified for eye irritation or serious eye damage			
Eye irritation in vivo (OECD TG 405)		Sample: mix of EAF-C/S Free lime: NA not classified for eye irritation or serious eye damage		Sample: mix of BOS/SMS Free lime: NA not classified for eye irritation or serious eye damage	
Eye irritation in vitro Hen's Egg Test on the Chorio-Allantoic Membrane Recognized by ECHA to identify substances causing serious eye damage (corrosive)	not corrosive to eyes	not corrosive to eyes	not corrosive to eyes		
Skin irritation / corrosivity					
Skin irritation in vivo (OECD TG 404)	Sample: grinded crystalline blast furnace slag Free lime: NA pH: NA not classified as skin irritant or corrosive to skin	not classified as skin irritant or corrosive to skin	not classified as skin irritant or corrosive to skin		
Eye irritation in vivo (OECD TG 404)		Sample: mix of EAF-C/S Free lime: NA not classified for skin irritation/damage		Sample: mix of BOS/SMS Free lime: NA not classified for skin irritation/damage	
Skin corrosion in vitro (OECD TG 431)		not corrosive to skin	not corrosive to skin		
Oral route of exposure					
OECD 401 In vivo testing on rats Administration of finely ground material in a dose of > 2000 mg/kg body weight	No classification and labeling for acute oral toxicity	No classification and labeling for acute oral toxicity		No classification and labeling for acute oral toxicity	No classification and labeling for acute oral toxicity

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Table 3: Tests conducted using slag eluate

	ABS/GBS	**EAF-C**	**EAF-S**	**BOS**	**SMS**
pH value, batch test L/S 10:1	11.2	11.4	12.2	11.8	11.9
Eye irritation / serious eye damage					
Eye irritation in vitro (OECD 437)				No evidence of irritation	No evidence of irritation
Eye irritation in vivo (OECD TG 405)			No evidence of irritation	No adverse effects on the conjunctiva, cornea and iris were observed	No evidence of irritation
Eye irritation in vitro Hen's Egg Test on the Chorio-Allantoic Membrane Recognized by ECHA to identify substances causing serious eye damage (corrosive)			No evidence of irritation		
Skin irritation / corrosivity					
In vivo skin sensitization guinea pig Buehler test (OECD 406)	Not sensitizing	Not sensitizing	Not sensitizing	Not sensitizing	Not sensitizing
In vivo acute dermal irritation/corrosion test (OECD 404)				Not irritant/corrosive	Not irritant/corrosive
Human skin model test (EU-method B.46) (eluate after ISO 10993-12)				Not irritant	Not irritant

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Table 4: Tests conducted using solid slags

	ABS/GBS	EAF-C	EAF-S	BOS	SMS
	Inhalation toxicity studies				
Acute inhalation toxicity (OECD TG 403)	Sample: GGBS Test concentration: 5000 mg/m3 (limit test). Mass median aerodynamic diameter: ~ 3 µm. Results: The only clinical signs were reflective of overload with inert particles.				
Acute inhalation toxicity (OECD TG 403)	Sample: GGBS Test concentration: 10 and 250 mg/m3 (limit test). Mass median aerodynamic diameter: 2-3 µm. Results: Focus on assessment of dissolution/clearance in the lungs. Exposure was tolerated without specific clinical observations.				
Sub-chronic inhalation toxicity study (OECD TG 412)	Sample: GGB Test concentrations: 4, 8 and 24 mg/m3 (aimed at avoiding overload). Mass median aerodynamic diameter: 2-3 µm. Results: no signs of respiratory irritation, merely observations reflective of particle insult and an adaptive response by macrophage clearance.				
In-vitro inhalation study	No cytotoxicity No inflammatory response	No cytotoxicity No inflammatory response	No cytotoxicity No inflammatory response	No cytotoxicity No inflammatory response	No cytotoxicity No inflammatory response

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Table 5: a selection of examples for performed eco-toxicological tests with slags

	ABS/GBS	EAF-C	EAF-S	BOS	SMS
Aquatic toxicity					
Short term toxicity to fish (OECD 203) with L/S 10:1	Not toxic to fish	Not toxic to fish	Not toxic to fish	Not toxic to fish	Not toxic to fish
Freshwater toxicity on aquatic invertebrates, Daphnia magna (OECD 202) with L/S 10:1	Not toxic to aquatic invertebrates	Not toxic to aquatic invertebrates	Not toxic to aquatic invertebrates	Not toxic to aquatic invertebrates	Not toxic to aquatic invertebrates
Toxicity to aquatic plants and algae (OECD 201) with L/S 10:1	No toxicity to aquatic plants	No toxicity to aquatic plants	No toxicity to aquatic plants	No toxicity to aquatic plants	No toxicity to aquatic plants
Toxicity to microbial communities in river sediments, long-term toxicity (field study) flow-through field study				No adverse effect on diversity and population density	
Toxicity to aquatic microorganisms, activated sludge (OECD 209) with L/S 10:1	No toxicity	No toxicity	No toxicity	No toxicity	
Photobacterium phosphoreum Saltwater static Microtox test		No toxicity			No toxicity
Terrestrial toxicity					
Toxicity to soil invertebrates, earthworms (OECD 207) with solid slags in different concentrations	No toxicity	No toxicity	No toxicity	No toxicity	No toxicity
Toxicity to soil microorganisms, EU Method C.22 (Soil Microorganisms: Carbon Transformation Test) EU Method C.21 (Soil Microorganisms: Nitrogen Transformation Test)	No toxicity			No toxicity	No toxicity
Toxicity to terrestrial plants (OECD 208)	No toxicity				
Toxicity to terrestrial plants, artificial soil (ISO 11269-2 and NF X 31201)	No toxicity	No toxicity	No toxicity		

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