Joint statement against restrictions imposed by the Dutch government on use of Ferrous Slags

– Requirements for provisional measures not fulfilled –

October 7th, 2025

Executive Summary

- The recent move by the Dutch government to temporarily restrict the main uses of LD and EAF slags is unjustified. It does not meet the requirements for appropriate provisional matters according to Art. 129 (1) REACH.
- The stop on use of LD slags is based on unsubstantiated and speculative claims rather than scientific evidence, while the stop on use of EAF slags lacks any justification at all.
- If these main uses for LD and EAF slags are prohibited, there are no realistic alternative applications left. As a result, large volumes of these slags would have to be landfilled.
- This decision sets a dangerous precedent for the European Steel Industry and threatens not only the sustainable use of valuable by-products but also undermines decades of progress in circular economy and resource efficiency. A future restriction under REACH (on certain uses of slags) would have a severe impact on the entire steel industry, as without the ability to market slags, steel production itself would be at risk of coming to a halt.
- REACH registration is a complex and evolving process, and the REACH Ferrous Slag Consortium (RFSC) has always acted in good faith by continuously improving the dossier to ensure accuracy and reduce uncertainties.
- We therefore respectfully ask the European Commission to reject the provisional measure of the Dutch government on LD and EAF slags.

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Ferrous slags have been safely, environmentally friendly and sustainably used in Europe and worldwide for many decades in cement and concrete, transport infrastructure (roads, waterways, pavements), and fertilizers. Between 2000 and 2023, the use of ferrous slags avoided the extraction of **1.17 billion tons of natural rock** and prevented **416 million tons of CO_2 emissions.**

Ferrous slags are by-products of iron and steel production and include blast furnace slags (ABS/GBS) and steel furnace slags (SFS), the latter comprising electric arc furnace slags (EAF), Linz-Donawitz/basic oxygen slags (LD/BOS), and secondary metallurgical slags (SMS).

Like all other raw materials and products, ferrous slags are continuously monitored according to technological and ecological criteria and approved for use under national and international regulations. When applied in accordance with national guidelines regulating the use of steel slags in particular applications, steel slag poses no risk to human health or the environment.

Facts and figures (2023) [[1,2]]

- 38 million tons of ferrous slags were produced in the EU and UK (21.7 million tons ABS/GBS, 16.9 million tons SFS).
- 94% (33.7 million tons) were used as by-product.
- 99% of ABS/GBS served as building material, mainly granulated for cement production.
- SFS slags consisting of 60% LD/BOS and 27 % EAF were used in different products such as road construction (63 %), hydraulic engineering (3,8 %), fertilizers (7,5 %), metallurgical processes (9,8 %), cement/concrete additives (3,3 %).

Like natural igneous rocks, ferrous slags consist of interlocking mineral phases that form their fundamental structure. The main elements – oxygen, silicon, aluminium, iron, calcium, and magnesium – define the essential properties of these minerals. Trace and minor elements (including some heavy metals) are always present, substituting for the main elements depending on their ionic size and charge. Their presence is a natural characteristic of mineral structures, not unique to slags. The release of elements from slags and rocks depends on the solubility of the individual mineral phases. In most cases, trace elements are bound in resistant minerals, where their release is rather low (see Appendix I).

[1] www.euroslag.com
[2] www.worldsteel.org

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The REACH Ferrous Slag Consortium (RFSC) has over the past two decades, committed substantial resources to performing toxicological and ecotoxicological testing in slags according to the requirements of the Regulation (EC) No 1907/2006 (REACH). The tests cover human-related endpoints (e.g., acute toxicity through dermal, oral, and respiratory route) as well as environmental impacts such as effect on plants and soil invertebrates (Appendix II). All the tests performed were carried out according to internationally recognized and validated guidelines developed by the Organization for Economic Co-operation and Development (OECD). The results demonstrate that the ferrous slags do not exhibit hazardous properties under the foreseeable conditions. Hence, there are no justifiable grounds for believing that urgent action is essential to protect human health or the environment in respect of ferrous slags – which are necessary for a provisional measure as imposed by the Dutch government.

Ferrous slags based on the current available evidence are:

- **fully registered under Regulation (EC) No 1907/2006 (REACH),**
- **classified as "non-hazardous" under Regulation (EC) No 1272/2008 (CLP).**

Despite decades of safe use and extensive testing, the RFSC was recently informed that Dutch Human Environment and Transport Inspectorate (ILT), supported by the National Institute for Public Health and the Environment (RIVM), has conducted a review of the classification and of the registration dossier. In this review, the validity of the tests performed are questioned and a classification as "causes serious eyes damage" (H318) and "may cause respiratory irritation" (H335) is proposed. Additionally, speculative evidence has been given that human and animal health has been adversely affected by free $CaO/Ca(OH)_2$ content of LD slags used in some areas of Netherlands. Based on this, the Dutch government imposed a temporary restriction on certain uses of LD and EAF slags in road construction with layers >50 cm and in mixtures with >20% slag content.

Based on the current available data, the imposed restriction cannot be accepted, as it is not scientifically justified and could have significant consequences.

- **Limited evidence:** The initiative to act against the use of LD slags was originally based on poorly documented human case reports drawn from media articles. This caused several statements by RIVM which do not provide conclusive evidence. The RFSC literature review confirmed that there is no reliable scientific basis to support the claims made by these articles.

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- **Speculative classification**: RIVM bases its proposed classification (H318, H335) solely on $CaO/Ca(OH)_2$ content and the resulting pH-value above 11.5 without any toxicological evidence. In contrast, current available RFSC animal studies on eluates of LD/BOS slags with pH above 11.5 show no irritation/corrosion effects, making RIVM conclusions speculative and unsupported. Thus, the findings of the Dutch government are not sufficient to justify the assumption that urgent action is necessary to protect human health or the environment in respect of ferrous slags – which, however, is required under Art. 129 (1) REACH.
- **Matrix effects**: The mere presence of $CaO/Ca(OH)_2$ does not justify classification. The slag matrix has strong buffering effects, which prevent hazards otherwise associated with pure $CaO/Ca(OH)_2$.
- **UVCB substance**: Slags are 'unknown or variable composition, complex reaction products or biological materials (UVCB)' substances. Unlike a "simple mixture," in UVCBs the $CaO/Ca(OH)_2$ is bound in a complex matrix (slag minerals). Due to this it is very little bioavailable and the threshold for mixtures does not apply for classification.
- **EAF slags:** There is no justification for including EAF slags in the restriction decision. EAF slags generally do not contain $CaO/Ca(OH)_2$ and the RIVM report does not suggest any potential hazardous effects from their use. Hence, in this respect the provisional measure can in no way be appropriate.
- **Proven safe use**: BOS (containing free lime) and EAF slags have been used safely for many decades in many applications without documented health impacts.
- **Official classifications**: In Germany, ferrous slags are designated "not hazardous to water," as recorded in the RIGOLETTO substance database of the Federal Environment Agency (UBA).
- **Main applications targeted:** The Dutch restriction effectively eliminates the main practical uses of LD and EAF slags. Most road construction projects require layers thicker than 50 cm of mixtures with a slag content above 20%. If these uses are prohibited, there are no realistic alternative applications left. As a result, large volumes of LD and EAF slags could no longer be used beneficially and would instead have to be landfilled, which is not only wasting valuable by-products but also contrary to circular economy principles.

- **Supply chain effects:** Any imposed ban without scientific evidence would undermine Europe’s circular economy and climate goals, disrupt industrial symbioses, and hit construction and steel value chains. If slags must be landfilled instead of being used, disposal costs of €50–150/t would burden the EU steel industry with €0.8–2.55 billion annually only for 17 million tons of SFS.

Summary Statement

In conclusion, the imposed stop on the use of LD slags by the Dutch government is based on scientifically unsubstantiated and suggestive evidence, while the stop on EAF slags lacks any justification at all. As therefore the requirements of Art. 129 (1) REACH are not fulfilled, it cannot be upheld by the Commission according to Art. 129 (2) REACH. A restriction on use of slags would have a severe impact on the entire steel industry, as without the ability to market slags, steel production itself would be at risk of coming to a halt. We respectfully ask the European Commission to reject the provisional measure from the Dutch authorities, imposing a temporary ban on the use of LD and EAF slags for certain uses. While we recognize the importance of ensuring safety and environmental protection, such a ban would be a disproportionate measure with severe impact on the entire steel industry, as without the ability to market slags, steel production itself would be at risk of coming to a halt.

For questions and any support, please contact Thomas Reiche - Managing Director FEhS-Institute (www.fehs.de) and Chairman EUROSLAG (www.euroslag.com) -, email: t.reiche@fehs.de, mobile: +49-1737366089.

Joint statement against restrictions imposed by the Dutch government on the use of ferrous slags
– Requirements for provisional measures not fulfilled –
Appendix I
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Appendix I provides detailed information about the physicochemical characteristics of the slags such as mineral phases and structure with focus on metals such as chromium, vanadium, titanium and manganese.

In its dossier evaluation, RIVM[1],[2] denied the validity of tests and questioned the reliability of the REACH registration for ferrous slags. In one of its reports, it listed transition metals from a Tata Steel dataset (2022–2023). These elements were described as "impurities" with harmonized CMR classifications, which in principle could trigger substance classification. Elements exceeding Generic or Specific Concentration Limits (GCL/SCL) were highlighted in bold.

Comment from the REACH Ferrous Slag Consortium (RFSC):

First, it is very important to note that slags should not be considered as a 'mixture of individual chemicals'. 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. As can be seen in Figure 1, the inner texture of slags and the interlocking of mineral phases is comparable to a natural basalt rock (Figure 1). The individual mineral phases that are commonly the constituents of BOS and EAF slags and their equivalents in natural rocks are given Table 1.

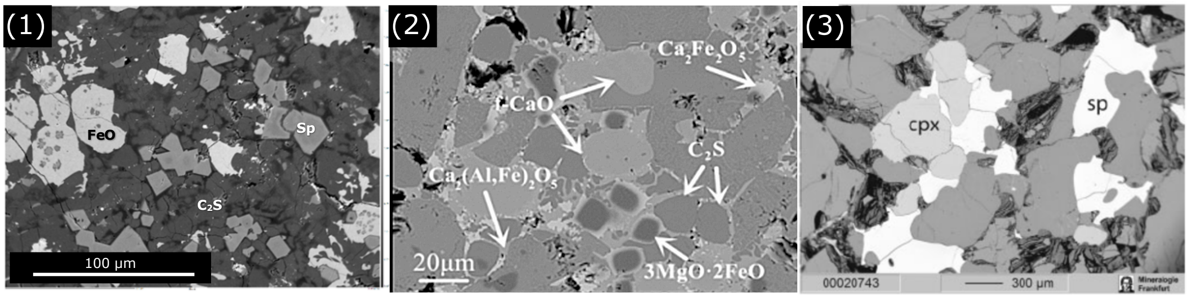

Figure 1: Backscattered electron (BSE) images of representative areas of polished thin section of (1) EAF-C (from [1]), BOS (source: Yin et al., 2018 [2]), and natural mafic mantle rock (peridotite, source: Dowes and Altherr, 2012 [3]); FeO = wuestite, Sp = spinel, C_2S = dicalsiumsilicate, cpx = clinopyroxene.

1 https://www.rivm.nl/publicaties/milieuhygienische-kwaliteit-ld-staalslakken

2 Advice on the classification of Slags, Steelmaking, Converter as put on the market by Tata steel IJmuiden bv (LD staalslakken), Draft Confidental, RIVM Letter report 2024- XXX

Table 1: Typical mineral phases in BOS and EAF C slags (according to the RFSC sameness document) and their equivalents in natural rocks

		BOS	EAF C	Natural rocks
larnite, beta-dicalcium-silicate	beta-Ca_2SiO_4	x	x	Dicalcium silicate occurs in the β-modification in metamorphosed calcitic contacts in the tertiary lava pile on Mull and in the dolerite-limestone contact at Scawt Hill, both in Ireland [4]. The latter occurrence is near the town of Larne, which is why the mineral is named Larnite. The Larnite found at Scawt Hill and one found in Hatrurim, Israel, contain 0.3% and 2.7% P_2O_5, respectively, similar to the dicalcium silicate in BOS slags [5].
srebrodolskite, calcium-iron-oxide	$Ca_2Fe_2O_5$	x	x	Dicalcium ferrite is known as Srebrodolskite and is related to brownmillerite. Its occurrences are also reported from Ettringer-Bellerberg and Chelyabinsk Oblast in the Ural [6][7].
hatrurite, tricalcium-silicate	Ca_3SiO_5	x	-	Tricalciumsilcate Hatruite typically forms in metamorphosed limestone or marble It is often found in contact metamorphic environments where limestone or dolostone has been subjected to high temperatures and pressures due to nearby igneous intrusions.
spinel group minerals	$Me^{2+}Me^{3+}{}_2O_4$	x	x	Spinels occur in many igneous and metamorphic rocks. Iron and chromium spinels form well-known ore deposits, such as those at Kiruna, Sweden, and Bushveld, South Africa.
wuestite, solid solution of iron(II)-oxide with MgO and MnO	$(Fe_{1-x-y},Mg_x,Mn_y)O_z$	x	x	Wuestite crystallizes in the same crystal class as periclase, with which it forms a complete solid solution series. Wuestite occurs only under extremely reducing conditions. Meteorites and the Frohnbachtal in the Black Forest are noted as occurrences [8].
brownmillerite, calcium-aluminium-iron-oxide	Ca_2AlFeO_5	-	x	Brownmillerite can form in contacts between limestone and volcanic rock through thermal metamorphism. One occurrence is at Ettringer-Bellerberg, north of Mayen in the Eifel [9].
gehlenite, calcium-aluminium-silicate	$Ca_2Al_2SiO_7$	-	x	Gehlenite and akermanite, the end-members of the melilite solid solution series, are components of SiO_2-poor rocks that form either through the reaction of basic magmas with carbonate rocks or through the thermal metamorphism of silicate limestones [7].
bredigite, calcium-magnesium-silicate	$Ca_{14}Mg_2Si_8O_{32}$	-	x	Bredigite is a high-temperature modification of Larnite (α-dicalcium silicate) [7]. In its formula, Ca is partially replaced by Mg. The Bredigit found at Hatrurim, Israel, contains 4.6% P_2O_5.
free lime, calcium oxide	CaO	x	-	In principle, the presence of free lime in natural rocks is also possible. Due to the very rapid reaction of free lime with water to form Portlandite and the subsequent carbonation to form Calcite, such a mineral are unlikely.

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Each of these mineral phases forms a solid, crystalline structure composed of an ordered arrangement of atoms or ions. This regular structure, where atoms or ions are arranged in a repeating pattern, leads to the formation of characteristic crystal shapes. The main elements such as oxygen, silicon, aluminium, iron, calcium, and magnesium determine the fundamental properties of a mineral, including its crystal structure and physical characteristics such as hardness, colour, and density. In addition to the main elements, minerals always contain minor and trace elements (< 5 wt% and < 1 wt.-%, respectively). Depending on ion size and charge, these elements can partially replace the main elements, a phenomenon known as substitution or diadochy. Due to this property, numerous trace elements are present in the slags, which do not form independent mineral phases but integrate into the structure of the emerging mineral phases. Importantly, all mineral phases of ferrous slags can also be found in natural rocks; no new component is created during steel processing.

In conclusion, it is not reasonable to designate slag as hazardous solely based on its individual constituents, which, while potentially harmful in isolation, pose no threat when bound within mineral phases.

In the following, the individual parameters identified as concerning in the RIVM report will be addressed.

Chromium

Regarding the table on page 41 of the RIVM[3] report, it is important to clarify that it is not total chromium (Cr_total) that is mutagenic or carcinogenic, but specifically chromium in its hexavalent state (Cr-VI). But in steel slags, chromium occurs in the trivalent form. There are several reasons why chromium is unlikely to be present in the hexavalent form: steel slag is a material that, despite treatment with oxygen during production, possesses reducing properties. It contains a high content of divalent iron (and it forms in an excess of metallic iron, which has strong reducing properties). Bulk chemical analyses as well as data from the literature, including X-ray absorption near edge structure (XANES), thermodynamic modelling, and theoretical considerations, confirm that chromium in steel slags exists exclusively in the trivalent form (e.g., 10, 11, 12, 13).

Moreover, Chromium is incorporated into stable mineral phases that are resistant to weathering and not soluble in water [14]. As can be seen from results of the electron microprobe (EMP) analyses in Table 2, the mineral phase spinel contains significantly higher levels of chromium than the other mineral phases (the high standard deviation in EAF C sample 1 is due to the presence of both Cr-rich and Cr-poor spinels). Based on the results from the bulk mineral composition (quantitative X-ray diffraction and total digestion with ICP-MS measurements) and the EMP data, the relative distribution of total chromium in a sample (expressed as Cr_2O_3) across individual mineral phases can be determined. The calculated values are presented in Table 3. This analyses clearly demonstrates that spinel

[3] Advice on the classification of Slags, Steelmaking, Converter as put on the market by Tata steel IJmuiden bv (LD staalslakken), Draft Confidental, RIVM Letter report 2024- XXX

accounts for most of the total chromium (>90 %), while the remaining 10 % is distributed among other mineral phases. Although the specific analysis in this study were conducted on EAF C slags, it is reasonable to assume a similar distribution for BOS slag, given the closely related mineralogical composition (see Table 1).

Spinel has been identified as the main carrier of chromium in several other studies (e.g., [15, 16]. The crystal structure of spinel ($Me^{2+}Me^{3+}{}_2O_4$) allows for the incorporation of trivalent or divalent metals into the lattice sites, enabling the successful integration of chromium-III. In contrast, chromium-VI cannot be incorporated into the spinel structure, ([17], see also figure 2).

Similarly, in wuestite, where a significant amount of chromium is also present (7,2 %), Cr-VI does not fit into the crystal lattice. Cr-III is more likely to be incorporated into the crystal structure as the ionic radius of Cr^{3+} (approximately 0.62–0.67 Å) is closer to that of Fe^{2+} (0.78 Å). By contrast, Cr-VI has a much smaller ionic radius (around 0.44 Å) and a significantly higher charge (+6), making its incorporation into the wuestite structure more difficult.

It can be concluded that the incorporation of most chromium into spinel and wuestite further confirms the presence of Cr-III rather than Cr-VI.

For the sake of completeness, it should be noted that high chromium contents can also be found in natural rocks. For example, Cr-rich basalts in komatiitic volcanic associations exhibit chromium concentrations exceeding 2000 ppm (i.e., > 0.2 wt.%) [[18]]. Similar to slags, the chromium in these rocks is bound in stable mineral phases in its trivalent form. No one would consider such rocks as containing toxic impurities.

Table 2: Average electron microprobe analyses of individual mineral phases in two different EAF C samples (Data from [1])

EAF C sample 1								
	spinel		**ca-silikate**		**wuestite**		**gehlenite**	
	mean (n= 20)	σ	mean (n =21)	σ	mean (n=7)	σ	mean (n=9)	σ
Si	-	-	14,7	0,97	0,02	0,01	2,7	5,3
Ca	0,55	0,25	44,2	0,35	0,96	0,39	26,4	10,4
Fe2+	11,1	2,99	0,74	0,29	58,4	1,07	-	-
Fe3+	17,4	11,8	0,00	-	-	-	7,3	12,3
Al	12,0	9,54	0,15	0,37	0,35	0,10	20,4	10,3
Cr	**13,8**	22,0	**0,02**	0,02	**0,51**	0,47	**0,27**	0,75
Mg	5,9	1,84	0,07	0,04	5,0	1,36	0,98	2,7
Mn	**4,10**	1,43	**0,29**	0,12	**8,9**	0,23	**1,8**	1,6
Ti	**0,35**	0,43	**0,06**	0,04	**0,04**	0,03	**0,11**	0,14
V	**0,09**	0,17	**0,13**	0,09	**0,01**	0,01	**0,02**	0,04
P	0	0	1,46	0,43	0	0	0,56	0,18
F	0,03	0,04	0,48	0,30	0,00	0,01	0,72	0,83
O	33,3	1,0	34,8	0,19	23,60	0,27	35,93	0,15
Total	98,68		97,15		97,82		96,61	

EAF C sample 2								
	spinel		**ca-silikate**		**wuestite**		**gehlenite**	
	mean (n= 5)	σ	mean (n =9)	σ	mean (n=7)	σ	mean (n=9)	σ
Si	0,03	0,01	14,7	0,59	0,02	0,01	6,8	3,14
Ca	0,49	0,11	44,2	0,56	1,84	0,25	24,4	5,42
Fe2+	9,4	0,74	0,74	0,37	56,1	2,69	10,8	8,76
Fe3+	2,5	1,16	-	-	-	-		
Al	6,0	0,94	0,15	0,35	0,35	0,09	16,4	4,92
Cr	38,5	2,31	0,02	0,15	0,94	0,38	0,05	0,05
Mg	6,4	0,10	0,07	0,03	4,8	1,54	0,68	0,79
Mn	4,4	0,46	0,29	0,08	10,4	1,56	1,97	1,64
Ti	0,15	0,06	0,06	0,03	0,06	0,01	0,26	0,18
V	0,14	0,02	0,13	0,02	0,05	0,00	0,04	0,02
P	0,009	0,01	1,5	0,76	0,03	0,01	0,54	0,31
F	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,14
O	32,84	0,8	35,11	0,6	23,9	0,32	36,55	0,15
Total	100,93		96,94		98,52		98,51	

n = number of analysed points on the thin section, σ = standard deviation, n.a. = not analysed

Table 3: The relative distribution (%) of elements (oxide notation is only a convention, as all mineral phases contain oxygen) across the individual minerals in two different EAF C samples (Data from [1])

EAF sample 1									
	SiO_2	CaO	FeO/Fe_2O_3	Al_2O_3	**Cr_2O_3**	MgO	MnO	TiO_2	V_2O_5
Ca-Silikat	95	90	1,81	0,8	**0,3**	1,3	4,3	25,9	83
Wüstit	0	1,4	87,1	3,8	**7,2**	68	79	16	5,8
Spinell	0	0,2	5,5	46	**91**	25,3	12,1	44,1	7,1
Gehlenit	5,4	8,4	5,3	49	**1,8**	5,1	4,2	14,3	4,3
EAF sample 2									
Ca-Silikat	83,6	78,2	1,4	2,1	**0,5**	0,7	1,7	17,7	44,2
Wüstit	0,1	2,7	81,5	2,9	**4,5**	56,7	74,7	18,9	20,2
Spinell	0,1	0,4	9,0	25,5	**95**	38,5	16,3	22,8	27,7
Gehlenit	16,3	18,7	8,1	69,5	**0,1**	4,1	7,3	40,6	7,9

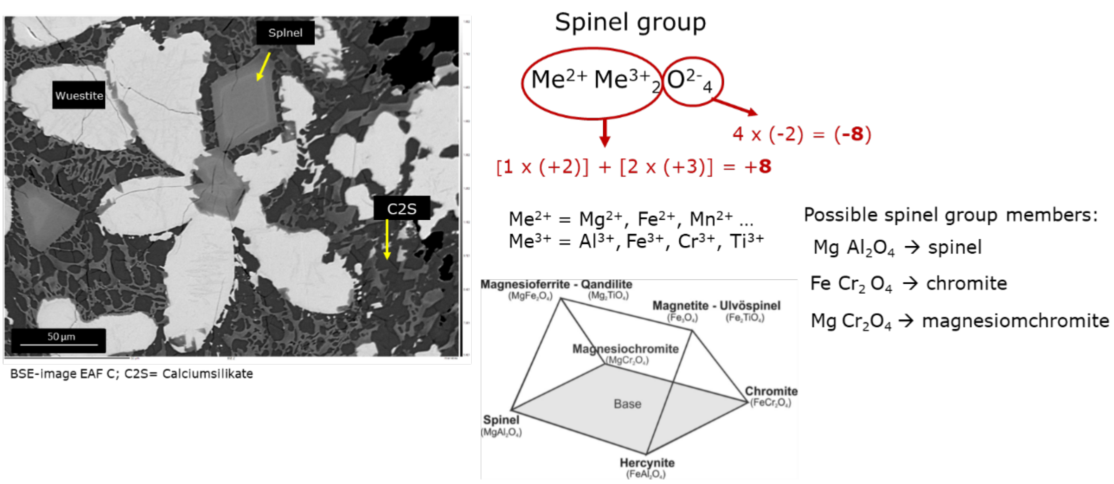

Figure 2: Backscattered electron (BSE) image of a polished thin section of an EAF C sample, showing the mineral phases wüstite and spinel in a matrix of calcium silicates (left side). The spinel group includes minerals with a cubic structure, featuring divalent and trivalent cations. The "magnetite or ulvöspinel prism" is taken from [19].

Vanadium

Vanadium occurs in steel slag as a minor or trace element, bound within various mineral phases. As shown in Table 3, vanadium is distributed among several mineral phases, predominantly in calcium silicate, but also in spinel, wuestite, and melilite.

While vanadium pentoxide (V^{5+}) is considered hazardous, the other oxidation states, V^{4+} and V^{3+}, are far less concerning. Given the conditions present in slag melt and based on modelling and calculations [10], it is much more likely that V^{3+} and V^{4+} are the dominant valencies in the slag.

Stoichiometric considerations provide an estimate of the oxidation states in which vanadium is incorporated into the mineral phases. The ionic radius of V^{3+} (approximately 0.64 Å) is larger than that of V^{5+} (approximately 0.54 Å). This makes V^{3+} more compatible with the crystal lattice of the above-mentioned minerals, as they are better suited to accommodate the slightly larger ion. In contrast, V^{5+}, with its smaller ionic radius and higher positive charge, would be less stable in the conditions typical of steel slag. The incorporation of V^{5+} would require significant structural adjustments and additional charge-balancing mechanisms, which are not easily achieved under such conditions (e.g. [20]).

Even if the total vanadium concentration in the slag exceeds 0.1%, it does not necessarily indicate the presence of significant amounts of vanadium pentoxide. Furthermore, toxicological and ecotoxicological evaluations using slag as the substance have not demonstrated any of the hazardous properties listed in Annex III of the EU Waste Framework Directive (WFD), known as Hazardous Properties (HP). No classification under the CLP Regulation [21] is required.

Additionally, it is important to note that Regulation (EU) 2017/997 [22] stresses that assessments based on ecotoxicity tests should take precedence over alternative approaches, such as summing the individual ecotoxicity classifications of the constituents.

Titanium

On 23 November 2022, the EU Court of Justice ruled that the classification of titanium dioxide (TiO_2) as a Category 2 carcinogen was unlawful, overturning this classification. As a result, titanium dioxide is no longer classified as a hazardous substance in the EU, and the associated regulatory obligations will no longer apply in the future.

Additionally, titanium, in its metallic form, has never been classified as carcinogenic. The concerns were specific to titanium dioxide (TiO_2), which is not present in steel slags.

Steels slags may contain minor (e.g., < 1 wt.-%) concentrations of titanium which is often found as trace element incorporated in other minerals as magnetite (Fe_3O_4) partly substitution the lattice of iron.

Importantly, steel slags **do not** contain free TiO_2 in the form of the mineral phases rutile or anatase. Both **rutile** and **anatase** are naturally occurring polymorphs of titanium dioxide, sharing the same chemical composition but differing in their crystal structures.

Rutile is the more stable and denser form with a compact tetragonal structure, while anatase is less stable, has a more open tetragonal structure, and can convert to rutile at higher temperatures.

Manganese

Manganese is also present as a minor or trace element within various mineral phases. As shown in Table 3, manganese is distributed among several mineral phases, predominantly within iron-rich phases such as wuestite.

It is also important to note that manganese (Mn) and iron (Fe) behave similarly from a chemical perspective due to their comparable ionic sizes and oxidation states. Both Mn^{2+} and Fe^{2+}, as well as Mn^{3+} and Fe^{3+}, have similar ionic radii (0.80 Å and 0.74 Å for Mn^{2+} and Fe^{2+}, respectively), which allows them to readily substitute for each other in mineral structures [23]. This chemical similarity extends to their roles in slag and mineral phases, where both elements often participate in the same crystal lattices, such as in magnetite, where manganese can partially replace iron. Consequently, the behavior of manganese in steel slags is analogous to that of iron, and their combined presence does not result in the formation of hazardous compounds.

Toxic manganese compounds, such as MnO_2, $MnSO_4$, $MnCl_2$, and $Mn(CH_3COO)_2$, are not present in steel slags. Their occurrence can be ruled out based on mineralogical and chemical analyses, as well as logical considerations. Additionally, the study in [24] concluded that the absence of systemic manganese delivery to the striatum or lungs from EAF slag indicates that incidental ingestion of manganese from EAF slag is unlikely to pose a health hazard. These findings are also applicable to BOS slags, due to their similar mineralogical properties and behaviour.

[1] Konzeptentwicklung zur Reduzierung der V-Auslaugung aus EOS. Inno-Kom Research Project 49VF210006

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Joint statement against restrictions imposed by the Dutch government on the use of ferrous slags
– Requirements for provisional measures not fulfilled –

Appendix II

October 7th, 2025

Appendix II summarizes the performed (eco-)toxicological tests used in registration dossier by REACH Ferrous Slag Consortium (RFSC). Results of the performed tests do not exhibit any adverse effects that lead to restriction under REACH or classification under CLP regulation.

Table 1. Name, abbreviation, EC number and CAS number of the members of REACH registered "Ferrous Slag" category.

IUPAC Name	Abbreviation	EC Number	CAS Number
Slags, ferrous metal, blast furnace	ABS/GBS	266-002-0	65996-69-2
Slags, steelmaking, converter	BOS	294-409-3	91722-09-7
Calcium-Iron-Silicium-Magnesium-Manganese-Aluminium oxide equivalent Slags, steelmaking, electric arc furnace (carbon steel)	EAF-C	932-275-6	-
Calcium-Silicium-Magnesium-Aluminium-Iron-Manganese oxide equivalent Electric-Arc Furnace Slag, Electric Oven Slag (Stainless Steel)	EAF-S	932-476-9	-
Slags, steelmaking	SMS	266-004-1	65996-71-6

Table 2. List of performed ecotoxicological studies by RFSC

Aquatic compartment (including sediment)		
Short-term toxicity to fish		
Method	**Tested material**	**Results**
Leuciscus idus, freshwater static OECD Guideline 203 (Fish, Acute Toxicity Test)	ABS, GBS, BOS, EAF-C, EAF-S, SMS	Essentially not toxic to fish in acute testing
Short-term toxicity to aquatic invertebrates		

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Daphnia magna, freshwater, static OECD Guideline 202 (Daphnia sp. Acute Immobilisation Test)	ABS, GBS, BOS, EAF-C, EAF-S, SMS	Ferrous slags of all types tested are not toxic to aquatic invertebrates in short term studies
Daphnia magna, freshwater static NF EN ISO 6341 (Determination de l´inhibition de la mobilité de Daphnia magna Strauss)	ABS, EAF-C, EAF-S	
Daphnia magna, freshwater, static DIN 38412-L30	ABS, BOS, EAF-C	
Long-term toxicity to aquatic invertebrates		
Daphnia magna freshwater, semi-static EU Method C.20 (Daphnia magna Reproduction Test) (Method equivalent to OECD Guideline 211)	ABS	No toxic effect, due to high pH population of the hydrozoan Cordylophora caspia were slightly lower than in controls with almost neutral pH
Ceriodaphnia dubia, freshwater, static Etude inter-Agences de l´Eau "Test de toxicité chronique - Ceriodaphnia dubia à 7 jours. Rapport des essais inter-laboratoires" Déc. 1995	ABS, EAF-C, EAF-S	
Macroinvertebrates, freshwater, flow-through Several methods applied e.g. collection of organisms in the environment from areas covered with slag or natural material (Greywacke)	BOS	
Hydra littoralis, freshwater, static Karbe L (1972) Marine Hydroiden as test organisms for examining the toxicity of wastewater substances. The effect of heavy metals on colonies of Eirene viridula. Marine Biology 12, 316-328	EAF-C	
Cordylophora caspia (Pallas), freshwater static Chronic test with the Hydrozoan Cordylophora, in principle similar to chronic Daphnia test	EAF-C	
Periphyton, brackish water, flow-through Several tests on hydrology, ecotoxicology, periphyton (Aufwuchs) as indicator of ecological behaviour of slag; determination of biodiversity of periphyton on slags in comparison to periphyton on diabase	EAF-C	
natural population of invertebrates, brackish water, field study The colonization of EAF C and natural rock fields on banks of the Elbe River by sessile animal populations was examined qualitatively and quantitatively in field experiments.	EAF-C	
Algae and aquatic plants		
Scenedesmus subspicatus (new name: Desmodesmus subspicatus) (algae), freshwater, static OECD Guideline 201 (Alga, Growth Inhibition Test)	ABS, GBS, BOS, EAF-C, EAF-S, SMS	No acute toxicity to algae. The ecological properties of slag are virtually the same as these of natural rock e. g. basalt, diabase, granodiorite, and greywacke. substantiating that

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Desmodesmus subspicatus (algae), freshwater, static DIN 38412-L33	ABS, BOS, EAF-C	slag stones are an excellent substrate for algal growth
Pseudokirchnerella subcapitata (algae), freshwater, static NF EN 28692 (Essay d´inhibition de la croissance d´algues d´eau douce avec Pseudokirchneriella subcapitata)	ABS, BOS, EAF-C, EAF-S, SMS	
natural population of algae (algae), brackish water, field study The colonization of EAF C and natural rock fields on banks of the Elbe River by sessile algal populations was examined qualitatively and quantitatively in field experiments by microscopic determination of algal species and counting of cells.	EAF-C	
Sediment organisms		
microbial communities in river sediments, freshwater, long-term toxicity (field study) flow-through field study	BOS	Organisms growing on slags (BOS) exhibited even greater species diversity and population density than on natural rock

Terrestrial compartment		
Toxicity to soil macro-organisms		
Eisenia fetida (annelids), short-term toxicity (laboratory study) Substrate: artificial soil, OECD Guideline 207 (Earthworm, Acute Toxicity Tests)	ABS, BOS, EAF-C, EAF-S, SMS	the results confirm that slags exert no acute toxicity to earthworms. All slags were not toxic against Eisenia fetida within 14 days. From studies with other soil invertebrates there is no evidence that slags may have a relevant inhibitory effect on terrestrial arthropods
Eisenia fetida (annelids), short-term toxicity (laboratory study) Substrate: artificial soil, ISO 11268-1 (Effects of Pollutants on Earthworms. 1. Determination of Acute Toxicity Using Artificial Soil Substrate)	ABS, EAF-C, EAF-S	
Toxicity to terrestrial plants		
Triticum aestivum (Monocotyledonae (monocots)), *Sinapis alba* (Dicotyledonae (dicots)) *Lepidum sativum* (Dicotyledonae (dicots)), short-term toxicity (laboratory study) seedling emergence toxicity / vegetative vigour test Substrate: artificial soil, OECD Guideline 208 (Terrestrial Plants Test: Seedling Emergence and Seedling Growth Test)	ABS	Ferrous slags are not toxic to terrestrial plants. Slags are efficient fertilizers for plants.
Hordeum vulgare (Monocotyledonae (monocots)), *Lactuca sativa* (Dicotyledonae (dicots)), short-term toxicity (laboratory study) seedling emergence toxicity / vegetative vigour test Substrate: artificial soil ISO 11269-2 and NF X 31201 (Determination of the effects of pollutants on soil flora - Part 2: Effects of chemicals on the emergence and growth of higher plants)	ABS, EAF-C, EAF-S	
natural vegetation (Monocotyledonae (monocots), (Dicotyledonae (dicots), Gymnospermae (conifers), (Cryptogamae, vascular (ferns and allies), Bryophyta or Hepatophyta (mosses or liverworths)) long-term toxicity (field study) Substrate: pure slag Ecological field study using the Zeigerwerte of Ellenberg (indicator values according to Ellenberg) to plants growing on a blast furnace slag deposit	ABS	
Tilia cordata (Dicotyledonae (dicots)) *Acer pseudoplatanus* (Dicotyledonae (dicots)) long-term toxicity (field study) vegetative vigour test Substrate: natural soi	ABS	
Brassica rapa (Dicotyledonae (dicots)) *Triticum aestivum* (Monocotyledonae (monocots)), long-term toxicity (field study) fertilisation study Substrate: natural soil Field studies examine the effects of ABS/GBS, BOS, and SMS (ladle slags) on plants and agricultural yield	ABS	

Sorghum (species not reported) (Dicotyledonae (dicots)) short-term toxicity (extended laboratory study) agricultural yield Substrate: natural soil Evaluation of the effect of steelmaking slags (SMS), added to oxisol soil, on sorghum yield	SMS	
Tilia cordata (Dicotyledonae (dicots)) *Acer pseudoplatanus* (Dicotyledonae (dicots)) long-term toxicity (field study) vegetative vigour test Substrate: natural soil no guideline available for road-side planting of trees	SMS	
Sorghum bicolor (Dicotyledonae (dicots)) short-term toxicity (extended laboratory study) agricultural yield Substrate: natural soil Evaluation of the effect of steelmaking slags (SMS), added to oxisol soil, on sorghum yield	SMS	
Toxicity to soil micro-organisms		
Species/Inoculum: soil EU Method C.22 (Soil Microorganisms: Carbon Transformation Test) EU Method C.21 (Soil Microorganisms: Nitrogen Transformation Test)	ABS	Ferrous slags are not inhibitory to key metabolic activities of soil microorganisms
Species/Inoculum: soil Review of studies done at the Sommerland Agricultural Research Station. Measurement of metabolic potential of soil microorganims as respiration rate and cellulose degradation.	ABS, BOS, SMS	
Toxicity to aquatic micro-organisms		
activated sludge, freshwater static OECD Guideline 209 (Activated Sludge, Respiration Inhibition Test)	ABS, BOS, EAF-C, EAF-S	No relevant effect was observed
Vibrio fisheri, brackish water, static DIN EN ISO 11348-2	ABS, BOS	
Vibrio fisheri, saltwater, static NF T90320	ABS, EAF-C, EAF-S	
Vibrio fisheri, saltwater, static DIN EN ISO 11348-1-3	ABS, EAF-C	
Photobacterium phosphoreum Saltwater, semi-static Krebs F 1985 Oekotoxikologische Bewertung von Abwaessern und Umweltchemikalien. Forschungsvorhaben W 10205115 BfG Koblenz	BOS	
microbial communities in Rhine water freshwater, semi-static, DIN 38414-12 Assimilation respiration test	BOS	
Photobacterium phosphoreum Saltwater static Microtox	EAF-C, SMS	

Conclusion on the environmental hazard assessment and on classification and labelling: No classification required for the environmental properties of slag

Table 3. Human toxicological study on the oral route of exposure performed by RFSC.

Method	**Principle**	**Tested material**	**Results**
OECD 401 In vivo testing on rats	Administration of finely ground material in a dose of > 2000 mg/kg body weight	ABS, GBS, BOS, EAF-C, SMS	No classification and labeling for acute oral toxicity are required for all ferrous slag.

Table 4. Human toxicological study on the dermal route of exposure performed by RFSC.

Method	**Principle**	**Tested material**	**Results**
OECD 431 In vitro testing for skin corrosion	Finely ground material (moistened with H_2O) is applied to a skin model	EAF-C, EAF-S	Not corrosive
EU-Method B.46	A shake eluate (L/S = 5, 24 h) was prepared from 1 g of material (< 90 µm) and applied to a skin model.	BOS, SMS	Non-irritating
OECD 404 In vivo testing on rabbits	Both finely ground material and the shake eluate (L/S = 5) were applied to the skin of a rabbit.	ABS, BOS, EAF-C, EAF-S, SMS	Non-irritating
OECD 406 In vivo guinea pig test (Buehler test)	The shaken eluate (L/S = 10) was repeatedly applied to the skin of guinea pigs	ABS, BOS, EAF-C, EAF-S, SMS	Not sensitizing
OECD 402 In vivo testing on rats	Finely ground material was applied to the skin of rats	BOS, SMS	No acute toxicity: LD50: > 4000 mg/kg

Table 5. Human toxicological study on the respiratory route of exposure performed by RFSC.

Method	Principle	Tested material	Results
OECD 412 In vivo testing on rats (repeated dose)	Rats were exposed to inhalation (aerosol)	GBS	No evidence of absorption and no signs of toxicity
In vitro tests Advance Liquid Interface (ALI) IUF Institut in Düsseldorf, Germany	Investigation using cultured cells (primary macrophages and NR8383 cells) Use of fine particles directly on different lung cells	ABS, GBS, BOS, EAF-C, EAF-S, SMS	Ferrous slag behaves similarly to natural rock used as control, and inhaled slag particles can be efficiently removed by physiological cleansing mechanisms.
Cohort study on long term occupational exposure	Done by the Finnish stainless steel production chain from chromite mining to cold rolling of stainless steel during the period 1967–2004 The risk of cancer was assessed, with special reference to cancers of the nose and lung.		No adverse effect observed

Table 6. Human toxicological study on genotoxicity of slags performed by RFSC.

Method	Principle	Tested material	Results
EU Method B.13/14 OECD Guideline 471 In vitro Ames Test	Reverse Mutation Test Using Bacteria S. typhimurium	ABS, BOS, EAF-C, EAF-S, SMS	No genotoxicity
EU Method B.17 In vitro mammalian cell gene mutation assay	Chinese hamster lung fibroblasts (V79)	ABS	No genotoxicity
OECD Guideline 473 In vitro mammalian chromosome aberration test	lymphocytes: human (all strains/cell types tested)	ABS	No genotoxicity
OECD Guideline 474 In vivo testing on mouse	Mammalian Erythrocyte Micronucleus Test with 3 consecutive concentrations including 2000 mg/kg body weight using a single treatment	BOS, SMS	No mutagenicity

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