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Soil improvers and growing media - Guidelines for the safety of users, the environment and plants

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Introduction

This CEN report has been drawn up by CEN/TC 223, Soil improvers and growing media, Working Group 2, Safety. This report is primarily intended to inform the other Working Groups of CEN/TC 223 on significant health and safety issues related to soil improvers and growing media (SI/GM). It also classifies the hazards and risks from soil improvers and growing media so that technical information is available for manufacturers, users and regulators to refer to when evaluating the necessary risk minimization strategies to be adopted.

This comprehensive information is also intended as a resource to manufacturers, to assess their own products in relation to the markets that they sell in, to retailers and suppliers and to users of these products.

The objective of Working Group 2 of TC 223 was to examine aspects of soil improvers and growing media that are related to safety, and to propose to TC 223 the measures to ensure the protection of users and the environment from risks derived from the use of soil improvers and growing media.

WG 2 adopted the definition of safety of ISO/IEC Guide 51 (1990) *Guidelines for the inclusion of safety aspects in Standards*, as 'freedom from unacceptable risk of harm'.

1. Scope

This document contains an assessment of the safety implications of soil improvers and growing media. This assessment provides a framework in which guidelines have been suggested to protect users (the exposed human population in general), the environment (flora, fauna, and ecosystems in a broad sense, including soil and water) and plants that are grown in the soil improver or growing medium.

Each hazard is discussed separately and includes:

- a description of the hazard;
- existing regulations that are relevant;
- a discussion of the applicability of the hazard to soil improvers and growing media; and;
- recommended safety guidelines formulated by WG 2 of CEN/TC 223.

This is summarized with a list of the hazards and corresponding recommended actions. The annexes contain references and background information.

Not included in WG 2's investigations were those quality aspects that are:

- commonly referred to as 'fitness for purpose', i.e. the commercial quality, composition or formulation that makes a product suited to satisfy a specific market application;

- pertaining to consumer protection from commercial fraud including product conformity to a stated composition and tolerances of deviations from it.

2. Terms and definitions

For the purposes of this report, the following terms and definitions apply :

2.1 soil improver
material added to soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity. [CR 13456 : -]

2.2 growing media
Material, other than soils in situ, in which plants are grown. [CR 13456 : -]

2.3 harm
physical injury or damage to the health of people or damage to property or the environment. [ISO/IEC Guide 51]

2.4 hazard
potential source of harm. [ISO/IEC Guide 51]

2.5 risk
combination of the probability of occurrence of harm and the severity of that harm. [ISO/IEC Guide 51]

2.6 contaminant
a substance, material or agent that is unwanted in a soil improver or growing medium or their constituents.

2.7 pollutant
a contaminant present in a soil improver or growing medium which due to its properties, amount or concentration causes harm.

2.8 potentially toxic element
chemical elements that have a potential to cause toxicity to humans, flora and fauna. Typically this term refers to "heavy metals" and others such as arsenic, selenium, boron, fluorine which exhibit a typical, dose related, sharp toxicity curve.

2.9 user
anybody exposed to the product, including professional and non-professional (amateur) users, and general public exposed not from an user standpoint.

2.10 intended use
the use of a product, process or service in accordance with information provided by the supplier. [ISO/IEC Guide 51]

2.11 reasonably foreseeable misuse
the use of a product, process or service in way not intended by the supplier, but which may result from readily predictable human behaviour.

2.12 safety
freedom from unacceptable risk. [ISO/IEC Guide 51]

3. Description of hazards and products

The hazard posed by a product and the risk of that hazard being expressed depend on the:
- product type;
- conditions of use of the product, (including both intended use and reasonably foreseeable misuse);
- user; and
- victim of harm.

The hazards from soil improvers and growing media considered in this report are the following categories:

a) physical hazards (inhalation, ingestion, or contact with harmful physical agents);
- traumatic (e.g. laceration, punctures, abrasion),
- dust,
- radiation (including ionizing),

b) fire and explosion hazard (hazards immediately linked with fire or explosion, or incurred as their secondary consequences, including damage to property);

c) physicochemical hazard (pH);

d) chemical hazards (inhalation, ingestion or contact with harmful chemical agents) of inorganic or organic nature;
- main chemical constituents,
- contaminants or additives,
- microbial by-products (e.g. mycotoxins),

e) biological hazards (inhalation, ingestion, or contact with harmful biological agents);
- pathogenic,
- allergenic.

The exposure scenarios considered are:

- hazards pertaining to safety for users (domestic and professional user, general public);
- hazards pertaining to the environment (fauna, flora, soil, water, air);
- hazards pertaining to the health and growth of the plant grown as crop.

However, since most constituents or contaminants of SI/GM can pose a hazard to more than one group of organisms, the hazards were then evaluated in a comprehensive manner in order to generate guidelines meant to protect at the same time the users, the general public, the environment and the plants grown in these products.

The risk of any particular hazard can be significantly different depending on conditions of use such as:

- type of user (professional or non professional);
- type of plant grown (food or non-food);
- place of use (indoor/outdoor, restricted or non-restricted access, in container or open soil);
- degree of misuse (typical misuses are over-application, bad storage, use for the wrong crop,
- ingestion, wrong or careless disposal, use without adequate protective clothing, mixing with incompatible materials).

For the purpose of evaluating hazards and their risks, soil improvers and growing media are classified in three distinct groups based on origin, natural or man-made, and main components, inorganic or organic.

Organic soil improvers and growing media are products made mainly of organic material of vegetable or/and animal origin. They include virgin materials such as peat, and recycled materials such as organic waste, composted or otherwise treated, and by-products from wood manufacturing, such as bark and wood fibres.

Inorganic soil improvers and growing media are products without any significant amount of organic matter. They are typically made of minerals. They can be unprocessed, such as sand clay, gravel, and similar, or processed, such as thermally expanded clay like perlite, and mineral wool fibres.

Synthetic soil improvers and growing media are man-made products, usually resins or polymers, generated by organic synthesis and polymerization. They share a high uniformity, typical of industrially derived products, and the potential for presence of traces of chemical organic impurities (such as monomers of the polymerized product).

Each of these groups can carry hazards and associated risks which are distinctive of a specific, typical component. The classic example is the susceptibility to catch fire, and the likelihood of this event, which is definitely possible in organic and synthetic materials, but not in inorganic ones. Other examples are the presence of pathogenic micro-organisms and the risk of infection (high in organic materials of waste origin or other organic products which can support their life but low in inorganic and synthetic materials), and the presence of crystalline silica or asbestiform fibres, likely to be present in varying degrees in inorganic products but not in organic ones.

The CEN/TC223 Report "Soil improvers and Growing media - Labelling, specifications and product schedules" (CR 13456 WI 00223076) contains a schedule of products.

4. Product safety assessment

4.1 Fire

4.1.1 Description of hazard

Fire hazard is identified as the spontaneous or flame/spark activated ignition and combustion of a product. It can also be generated by exothermic reaction of two or more incompatible chemicals or materials. The hazard involves exposure risks to burns and inhalation of toxic/noxious or oxygen-displacing (suffocating) fumes. It also involves risk of property damage. Hazard to the environment means destruction or degradation of habitats and ecosystems, and the emission of combustion products in to the atmosphere.

While several parameters quantify the flammability of a liquid/gas (flash point, flammable limit), the flammability of a solid material of the type used as soil improvers/growing media is more difficult to define. Calorific value (heat content) can be of help in the identification of the products and situations at risk, although no precise correlation is used for fire-prevention.

4.1.2 Existing regulations

The EEC Directive 91/325/EEC relates to Council Directive 67/548/EEC which aims at approximating the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, an analogous rule for dangerous preparations is in EC Directive 88/379/EEC. These directives define and list dangerous substances and preparations, classify them according to the nature of the danger, and define the danger itself by setting criteria for the choice of phrases indicating risks and safety advice to address on the label/package. Flammability is one of many characteristics that can classify a substance or preparation as 'dangerous'.

Directive 91/325/EEC (Appendix VI, 2.2.4) defines as 'highly flammable solid substances and preparations which can readily catch fire after brief contact with a source of ignition and which continues to burn or to be consumed after removal of the source of ignition'. This definition relies on the testing of materials, and test methods are described in Appendix V of the same directive. No other definition concerning flammability of solid materials is given in this Directive.

A definition of 'combustible' materials, more appropriate for products used as soil improvers/growing media, is not available in Dir. 91/325/EEC.

Directive 91/155/EEC (p. 35) states that 'any person established within the Community who is responsible for placing a dangerous substance or preparation on the market, whether the manufacturer, importer or distributor, should supply the recipient who is an industrial user of the substance or preparation with a safety data sheet containing the information set out in Article 3. The safety data sheet need not be supplied where dangerous substances or preparations offered or sold to the general public are furnished with sufficient information to enable users to take the necessary measures as regards the protection of health and safety.' (Art.1). Fire-fighting measures and stability and reactivity information are included in the obligatory information to be contained in the safety data sheet (Art. 3).

Flammability standards for soil improvers and growing media are not present in the UK. The closest reference is for toys (BS EN71-2:1994), and for certain furniture (BS 5852:1990, BS 7175:1989 and BS 7177:1996). No closer reference was available from experts from other european countries.

4.1.3 Discussion of hazards

None of the materials listed as soil improvers and growing media by WG 2 is specifically mentioned in the list of dangerous substances or preparations for what concerns fire and reactivity danger, therefore the applicability of the rule relies on specific testing of material of concern according to the procedures described in Appendix V of Directive 91/325/EEC.

While inorganic soil improvers and growing media are non-flammable and non-combustible, a fire hazard is present for organic and synthetic SI and GM. In addition, synthetic materials can present incompatibility with certain specific chemicals which can be used in the same activities, thus creating a reactivity hazard. Such hazard, of interest mainly of the industrial/professional user, must be accurately addressed in the safety data sheet by the manufacturer.

Fire hazard is present in both domestic and professional uses of soil improvers and growing media. However, the associated risk in a domestic situation is estimated to be no greater than the one posed by potentially combustible household items such as paper, books, furniture, and similar. Therefore no specific requirement other than those normally applicable to such goods is needed.

Organic materials used as soil improvers or growing media can have calorific values of around 11–12 MJ/kg (peat). They are usually combustible and can ignite when exposed for example to the following conditions:

- when the product is dry;
- in case of excessive heat;
- in the presence of open flames, sparks, electrical arc, cigarette, welding operation, or hot piece of equipment.

Organic soil improvers and growing media are usually placed in the market in a moist state, therefore reducing the risk of ignition. Self-ignition (auto-combustion), however, can happen in certain storage conditions of moisture, and when large amounts of biologically unstable material are stored. For example, in professional use, risk can become higher if dry organic and or synthetic materials are stored in large amounts, or if biologically unstable bulk material should slowly ferment, generating flammable gas or reaching temperatures of spontaneous combustion. The risk of fire induced by chemical reaction of organic materials with oxidizers (which are unlikely to be present in significant amounts in typical domestic and professional situations), is less probable.

The combustion of organic soil improvers and growing media such as sphagnum peat usually generates products that are commonly generated by natural products (wood, vegetable matter), and fire fighting can involve any extinguishing media. Fire can persist inside bags or piles until they are separated or broken [1].

Synthetic materials are usually combustible and potentially reactive or unstable in the presence of certain other chemicals. Their combustion can (depending on the specific product) generate acrid and/or toxic fumes in addition to those generated by burning of natural products. For example, when heated to decomposition, polystyrene emits acrid smoke and fumes [2] and can not be steamed [3], polyurethanes emit acrid smoke and fumes of CN^- and NO_X [2], urea–formaldehyde heated to decomposition emits toxic fumes of NO_X [2]. If the products are free from fire retardants to reduce phytotoxicity, the risk of fire is higher.

4.1.4 Recommended safety guidelines

No specific standard requirement has been deemed necessary by WG 2, based on the consideration that:

- rules are already set;
- there is no practical way to reduce the combustible characteristics of the products other than keeping them moist; and
- typically the products of interest of WG 2 are sold in a moist form.

A generic phrase such as 'be aware that organic matter burns' can be suggested on packages of materials where risk of fire is high but not immediately evident to the user (such as necessarily dry or synthetic materials).

Directly applicable requirements from Directive 91/325/EEC and subsequent amendments should be followed, also for what concerns chemical reactivity and therefore indications of compatibility (e.g. expanded polystyrene which should not be treated with chemical sterilizers, chloropichryin, methylbromide) for professional users.

4.2 Dust explosion

4.2.1 Description of hazard

The hazard is defined as explosion following ignition of flammable dust suspended in the air. The injury and damage are comparable with those attributed to fire, plus the ones induced by the air pressure increase generated by the explosion.

Dust explosion requires the following factors:

- combustible dust (at Lower Explosive Limit concentration) in fine fractions (risk increases with decreased particle size);
- oxygen (oxygen, air is sufficient);
- an ignition source (open flame, spark, electrical arc, cigarette, welding operation).

Also important in the hazard of dust explosion is the static electricity that can accumulate on dust particles and increase risk of sparks. The minimum concentration of dust able to give explosion vary between 10 and 600 g/m^3. The cereal dust explosive limit concentration is around 25–50 g/m^3, whilst those for synthetic materials is in the order of 25 g/m^3 polyphenols, 15 g/m^3 polystyrene, and 70 g/m^3 formaldehyde resins.

The risk of dust explosion of soil improvers and growing media is mainly related to manufacturing phases when mixing of relatively large amounts of material can generate dust. The risk associated to professional uses is also only related to dust-creating phases of loose media mixing. The risk in domestic use is believed to be minimal.

4.2.2 Existing regulations

No direct regulation for soil improvers and growing media is available at this time. Since the risk of dust explosion is minimized by proper handling of materials and use of equipment, the closest regulatory instruments for the minimization of this risk pertain to the safety specifications of electrical and mechanical equipment, and to the control of dust (particulate matter) in the workplace. Directives 76/117/EEC, 79/196/EEC and their amendments regulate electrical equipment for use in potentially explosive atmospheres. Safety of machines is addressed in Directive 89/392/EEC (p.9) and is being standardized in CEN/TC 114. More information is reported under the chapter 'Dust' in this report on the maximum admissible concentrations of dust in the workplace.

4.2.3 Discussion of hazards

Dust explosion is a typical concern in the wood (sawdust) and food (cereal dust and flour) industries. Any organic/synthetic soil improver or growing medium that is in a solid form and able to generate high amounts of dust when handled presents a certain, unquantified degree of risk.

4.2.4 Recommended safety guidelines

No specific safety criteria is deemed necessary by WG 2 to protect the user from this specific hazard, in consideration of the existing legislation and of the low risk associated with the use of the products. Since dust is also considered a health hazard, a warning phrase against the hazard of dust is however included in the recommendations against 'Dust', 'Minerals', and 'Microbial by-products – allergens'. Other recommendations on storage such as 'keep dust away from sources of ignition' and good housekeeping practices should be recommended in the label especially in the case of dust-forming, bulk delivered products.

4.3 Potentially Toxic Elements

4.3.1 Description of hazard

The hazards associated with Potentially Toxic Elements (PTEs) in soil improvers and growing media products are generally related to toxicity when the elements are in over supply and impaired growth when in under-supply. However these impacts on man, crops and the environment can be achieved by a number of pathways:

- direct toxicity/deficiency;
- indirect toxicity;
- environmental migration.

4.3.1.1 Direct toxicity/deficiency

Direct toxicity occurs when application of a product produces a toxic effect on the crop, or when the product is ingested (a reasonably foreseeable misuse for young children). This could lead to acute poisoning of the individual human, plant or animal.

Deficiency effects will generally be limited to growing media where the product is the only provider of trace elements or on sites where there are existing metal deficiencies. The two most important trace elements that can also cause toxicity effects in the products covered by this report are copper and zinc. As different plant species may have different nutritional requirements, deficiency is better considered as a "fitness for purpose" aspect of product quality, and therefore outside the scope of this document, it is only mentioned in this context briefly for completeness and perspective.

4.3.1.2 Indirect toxicity

Indirect toxicity is poisoning of organisms who use the plants grown in the product. This in general can be represented by health effects in humans via intake of PTEs through the food chain although other animals such as grazing animals or predatory birds could also be affected.

4.3.1.3 Environmental migration

Release of PTEs from anthropogenic sources will generally be dispersed into the environment. Many of the plants grown on soils treated with products containing PTEs and the animals that eat them will not be affected. However, the elements will find their way into the general environment in a dispersed form and will affect more remote, sensitive organisms as well as being concentrated in animals higher up the food chain due to the effects of bio-accumulation.

4.3.2 Factors affecting the hazard

The main factors influencing the hazard of the individual PTEs are:

- Concentration of element in the soil/growing medium
- Biological availability of element
- Sensitivity of organism to element (species specific)

4.3.2.1 Concentration

In general, and in respect to the other factors discussed later, as concentration increases, the risk from a PTE increases. However, the detailed chemistry is not fully understood for many elements and it is not known definitively whether there are threshold concentrations below which no effect occurs or whether any amount of the element has an effect and thus no level is wholly safe.

In some cases there are antagonistic relationships between the elements and increases in the concentration of one element can reduce the toxicity of another. The most common example of this in soil improvers and growing media is copper and zinc where a balance between the two elements should be maintained. The precise proportions of each element required is dependent on the availabilities of the metals. A similar situation exists between iron and many other metals and this relationship is particularly important for sewage sludge based materials where phosphate and ammonium also modulate bio-availability.

4.3.2.2 Biological availability

To become toxic, the PTEs have to enter the biological cycle and be absorbed into either a plant, animal or micro-organism. This usually happens once the PTE is in solution. The rate of absorption is controlled by the form of the PTE. The bio-availability generally follows the order: water soluble organic (the most bio-available); inorganic soluble salts; water insoluble organic; inorganic insoluble compounds, (the least bio-available).

For example, when ingested by humans, metallic mercury is only slowly absorbed through the gut wall and as such much of that ingested is directly excreted without any impact on the individual. In addition, the metallic mercury that is absorbed is not stored for long in the body and is also then excreted quickly, hence reducing the effect of the metal still further. Organically bound forms of mercury such as methyl mercury, however, are easily absorbed and so a large proportion of the ingested mercury in this form is taken up by the body. Methyl mercury is also more easily stored within the body so that it can remain in the body to affect the biological functions over longer time and therefore exacerbates the toxic effects.

Once in the biological cycle the PTEs are generally more easily absorbed, by chelation or conversion into organic forms and this can give rise to bio-accumulation where the tissues of species higher up the food chain accumulate the PTE contained in their food.

The composition and nature of the receiving soil will also have a major impact on the availability of the PTEs in soil improvers with the pH, mineralogical analysis, cation exchange capacity and content of organic matter having a major effect on the absorption of elements into the soil structure and therefore their biological availability.

Unfortunately chemical analysis techniques have not been particularly effective at modelling PTEs bio-availability. A wide variety of extraction systems based on water, solvents, chelating agents, electrolyte solutions, alkalis and acids have been tried but none of these to date has provided a reliable model to biological availability. This is in part due to the complex and species specific nature in which plants and animals take in material from their environment.

4.3.2.3 Species differences

Different types of organism have different requirements and therefore absorb PTE more or less effectively. For example, plants such as tobacco, lettuce and spinach absorb certain metals strongly whilst crops such as cereals, potatoes etc. only absorb small amounts of metals. This is represented by the soil/plant transfer rate. In addition to this, different parts of the plants accumulate elements in varying proportions with generally the roots accumulating the most, followed by the vegetative parts and least in the generative parts.

4.3.3 Difficulties of evaluating the hazards

The Scope of CEN/TC 223 covers a wide range of products that will be used in a multitude of applications. Many of these products have been used for many years without any concerns over their safety. However new products that continually being introduced to the markets and little may be known about their safety.

The differences in the composition of the many soil improvers and growing media, and in particular of their:

- proportion of organic matter;
- cation exchange capacity;
- concentration and form of the PTEs;
- form of organic matter;
- pH;

will change the biological availability of the PTEs present in these products. While the total PTE levels is the only measurement that is widely accepted, it has been proved very hard to unambiguously relate this measurement to the PTEs biological availability, which is the best indicator of the PTEs behaviour, and thus of the safety of the products. Measures of biological availability have not been developed that are reliable and broadly applicable and so analytical 'available' measurements are impossible to relate to the response achieved by the full range of plants.

'Available' measurements also have the disadvantage that they do not take account of changes once the material is deposited. This is most uncertain as some PTEs will be in very stable forms and thus are unlikely ever to change and become available. On the other hand, other forms of the PTE could be more mutable and therefore alter their availability, becoming either more or less available with changing conditions. It is impossible to predict these changes which will be affected by factors such as climate, land use, soil type, other materials added to the soil. Nevertheless, risk assessment should encompass worst case situations and therefore total PTE loadings in relation to accumulation through repeated use is one of the factors that should be assessed.

4.3.4 Methodologies of establishing limit values for acceptable risk

The way in which limit concentrations in products for PTEs (that are considered to have acceptable risk) are determined, can vary according to the viewpoint adopted. Thus there is a number of different protocols that can be adopted to establish limit values with respect to the safety of the product. These can be simplified into the following:

- risk assessment based on no observable adverse effect levels (NOAEL);
- precautionary approach;
- no net accumulation (NNA);
- best available technology;
- hybrid systems that utilize toxicity assessments or embody soil protection without quantifying risk.

When considering the environmental safety provided by the limit values selected, many other factors should be taken into the equation. For example, many organic waste materials can be converted into soil improvers but if the limits set are impossible to meet for either economic or technical reasons then they will be disposed of via traditional disposal routes such as landfill or incineration. This could lead to an overall decrease in environmental quality. Too lax limits, conversely, could lead to eventual soil pollution and would not provide any incentive for improvement in organic waste treatment technology. Any limits have to also be considered in relation to the location as in areas where the soil quality is poor and few sources of organic matter, in this case overly stringent limits can result in organic wastes not being used and soil erosion occurring. This highlights the need for any limits to be considered in a wide context including other disposal options, soil quality and availability of other soil improvers.

4.3.4.1 Risk assessment - NOAEL - No Observable Adverse effect Level

This approach tries to determine the impact of adding potential pollutants to a soil by examining experimental results and utilizing the result to determine the risk levels to the relevant parts of the population considered. This is evaluated on the basis of determining the levels at which a defined adverse effect is observed, and as such is sensitive to the definition of 'adverse effects' adopted. The normal approach is to select a number of scenarios or in the case of pollutants and pathways, and to calculate the risk to the most exposed individual under each pathway (scenario). Given this information the limits are set to achieve a given risk level. Typical risk levels selected are in the range 1×10^{-3} to 1×10^{-6}.

The most notable example of this is the US EPA sewage sludge regulations [4] (Rule 503), which adopted this type of approach. The investigation was based on a number of exposure pathways that could be used to model the impacts of substances on man and the environment. The study that supported the development of these regulations spanned 15 years and involved a great number of experts from around the world. However, it was limited to sewage sludge and the recommendations of the peer review group that assessed the work was that the results should not be used for other materials such as composted waste. This advice was given due to the specific nature of the chemical compound and the matrix in which it is contained.

The results of the study have provided a range of limit values that are high when compared with other limit values determined on other protocols. The limit values for uncontrolled use generated by the Rule 503 are given in Table 1. It should be pointed out that this is based on USA diet, soil type and agricultural practices, and can not reflect correctly an European scenario, but is useful as an example of the approach especially if the European characteristics are incorporated in to the models. The study was still uncertain about some aspects as there are few data on soil biota and the only soil organisms considered were earthworms. Accepting these limitations it is still a very good example of the risk based approach to setting of limit values.

Table 1. USEPA Rule 503 sewage sludge distribution and marketing limit values

PTE	limit concentration mg/kg dry matter
As Arsenic	41
Cd Cadmium	39
Cr Chromium	1200
Cu Copper	1500
Hg Mercury	17
Mo Molybdenum	18
Ni Nickel	420
Pb Lead	300
Se Selenium	36
Zn Zinc	2800

This study only used results from unadulterated sludges as the availability of the compounds was found to be different in sludges that had been artificially contaminated for experimental purposes. Thus experiments using artificially contaminated sludges (even where ameliorated by long times or processing of the sludge) were shown to be not representative of sludge metal availability in the field. Similarly, pot trials were not considered appropriate as root exploitation is significantly different to that of field grown plants. Obviously this is possible with sewage sludge due to the availability of an extensive data set for this material, which may not exist for other materials.