PUBLISHED DOCUMENT

PD CR 13455:1999

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

ICS 65.080

National foreword

This Published Document reproduces verbatim CR 13455:1999.

The UK participation in its preparation was entrusted to Technical Committee AW/20, Top soil and other growing media, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the CR title page, pages 2 to 82 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

This Published Document, having been prepared under the direction of the Consumer Products and Services Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 November 1999

Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 35157 2

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CEN REPORT
RAPPORT CEN
CEN BERICHT

CR 13455

July 1999

ICS

English version

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

This CEN Report was approved by CEN on 17 March 1999. It has been drawn up by the Technical Committee CEN/TC 223.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. CR 13455:1999 E

Contents

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 EN 71-2:1994), 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	1 200
Cu Copper	1 500
Hg Mercury	17
Mo Molybdenum	18
Ni Nickel	420
Pb Lead	300
Se Selenium	36
Zn Zinc	2 800

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.

4.3.4.2 *Precautionary approach*

The Precautionary approach takes the view that the risks from PTEs are not fully understood, and that limit-setting should be in accordance with sustainable behaviour or growth. The promotion of sustainable growth respecting the environment is one of the primary objectives of the Treaty of the European Union.

Precautionary limit values are to allow long term environmental protection against future adverse impacts. In this context, adverse impacts should be avoided or reduced where this is a reasonable requirement, also with respect to the use of the site. Long-term protection is aimed at preserving the possibility of different uses of soils. The derivation of soil precautionary values follows the notion that any soil will be protected against contaminants if ecotoxicological effect thresholds (balanced with data on background values) are not exceeded, and if at this concentration level no evidence arises of unwanted or hazardous effects on plants and groundwater, and if there is sufficient difference (safety factor) from the trigger values proposed for the pathway “soil to humans”.

From the viewpoint of soil protection, there are various possible technical options for limiting substance inputs. Brought to its extreme interpretation, the precautionary approach may be read as avoiding any increases of soil PTEs concentrations above current values. This means that additions of PTEs from soil improvers, fertilizers and the atmosphere should equal the losses via leaching, plant uptake and erosion. Although support exists for this approach [5], there are no regulations yet that follow this extreme interpretation, given the severe consequences it would have on agriculture and other sectors of the economy. An alternative to this extreme interpretation would be to set acceptable accumulation levels of accumulation in the soil, and then to define loading rates and/or concentrations in the materials that will satisfy this objective. Two examples of limit-setting that follow the precautionary approach are found in Annex C and Annex D.

4.3.4.3 *Best available technology*

An alternative to a fully fledged precautionary approach is a compromise where the lowest practical/achievable limits are selected. While the presumption that lower values are to be preferred is often used, allowance is made for the inadequacies of the processing technology or organic matter generation system. These limit levels are often between risk based and precautionary limits.

The most common approach is therefore to set the limits at the level that the technology/system can achieve, without any reference to the level of risk associated with those limits. This is obviously a political decision as all technological solutions have economic implications either on the soil improver/growing media industry or other more remote industries such as waste disposal, forestry or agriculture. One example of limits that have been set on this basis are those set by the German RAL standard [6] (Table 2).

Table 2 — German RAL GZ 251 standard for composted material, PTE limits

PTE	limit concentration[a] mg/kg dry matter
Cd Cadmium	1.5
Cr Chromium	100
Cu Copper	100
Hg Mercury	1.0
Ni Nickel	50
Pb Lead	150
Zn Zinc	400

[a] Normalized to 30 % organic matter

4.3.4.4 *Hybrid approaches*

In some cases none of these approaches is entirely appropriate in that factors other than those directly related to safety should be considered. For example, stringent adoption of the precautionary approach would limit a great deal of materials that could be applied to soil such as fertilizers, animal manures, sewage sludges, waste based materials such as composted products from separately collected organics, as the metal concentrations would add to the soil loading. This reduction in applied materials would lead to a greater use of other disposal methods such as landfill and incineration and potentially a reduction in soil fertility. These alternative disposal techniques also place burdens on the environment and thus there is a trade-off between the environmental burdens placed by the deposition of wastes as soil improvers and the disposal of those wastes when precluded by stringent environmental controls.

A compromise has to be achieved in the protocols of devising the limit values. Three different approaches (Annex B, Annex C, Annex D) are attached to this report as examples, none of which is preferred or commended by WG2. One such attempt was the CEN document *PTE limits in soil improvers and growing media, note for discussion* (Annex B) which calculated the limit values using a number of different approaches. These approaches were:

- acute human toxicity by the most toxic form assuming direct ingestion by a child;
- chronic toxicity assuming direct ingestion by a child;
- food intake, 100 % of food (excluding meat and milk) grown on soil treated with soil improver;
- application of soil improver equivalent to 50 % of the soil so as to reach EC sewage sludge directive soil quality limits.

In general these approaches showed that direct ingestion was less of a threat than environmental pollution through the food chain. However to provide a safety factor, this conclusion was based on the totally unrealistic set of assumptions, that all the most exposed individual's food is grown on treated soil and the toxicity indices were taken for the most toxic form of the PTE for which data was found. It would have been appropriate to use only a proportion of food to be grown, but there were insufficient data on this aspect to determine the appropriate proportions of home grown food.

The other most important deficiency of this work is that it only applied to "soil like materials" and thus products with high organic matter contents would be inappropriate to the calculations used. However, the calculations narrow the area of uncertainty and provide a range in which a realistic compromise can lie, but it should be emphasized that this only applies to a limited range of materials and alternative limit values would have to be developed for soil improvers and growing media containing composted materials, peat, bark, animal manures, vermiculite, perlite etc., as well as for mixtures of these materials. The details of this analysis are given in Annex B.

To show how greatly limits can vary depending on the criteria that are adopted for their formulation, the range of limit values suggested in this discussion document is given in Table 3.

Table 3 — Range of estimates of possible limit values for soil like materials (Annex B)

PTE	Class III Professional non-food use		Limit concentration dry matter mg/kgDM					
			Class II Professional		Class 1 Domestic			
	SI	GM	SI	GM	Acute toxicity	Chronic toxicity	Food intake basis	
							SI	GM
Cd Cadmium	[c]	[c]	1.1–5.5	1–3	10	100	1.5	1.2
Cr Chromium	[c]	[c]	162–262	100–150	220 (VI) 3 400 (III)	100–400	[b]	[b]
Cu Copper[a]	[c]	[c]	82–262	50–140	880–1 240	70 000	982	500
Hg Mercury	[c]	[c]	1.9–2.9	1–3	320	30–71	10.7	5.4
Ni Nickel	[c]	[c]	39–129	30–75	200	1 000	[b]	[b]
Pb Lead	[c]	[c]	52–552	50–300	60–4 000	300	210	129
Zn Zinc[a]	[c]	[c]	215–515	150–300	800	[b]	1 027	556

[a] copper and zinc are significant essential micro nutrients.

[b] Not determined due to lack of data.

[c] Refer to national regulation.

An alternative approach (proposed by the Austrian experts and attached as Annex C), used the idea of balancing inputs and outputs to limit the accumulation in the soil and to calibrate this against soil limit values which can be found within a corresponding range in Austria, Germany and some other European countries. On a broad data basis derived from several investigations on availability and soil/plant transfer rates, this approach uses the assumption that the soil levels quoted are scientifically proven as "safe".

This proposal states that the functionality of the agricultural soils has to be maintained in the long term. Thus, the input of PTEs stemming from organic fertilizer applications should be minimized. Exceeding toxicologically determined PTE limit concentrations within periods of 45–100 years by applying excessively contaminated soil improvers does not appear to be a reasonable strategy and thus it is suggested that the limits are reviewed after 10 years. A proposal from Austrian experts for PTE limits based on these principles is given in Table 4.

Table 4 — Austrian compromise proposal for general PTE limits in soil improvers
(based on 30 % organic matter)

PTE	limit concentration (mg/kgDM)
Cd Cadmium	1.5
Cr Chromium	150
Cu Copper	200
Hg Mercury	1.0
Ni Nickel	75
Pb Lead	150
Zn Zinc	750

However, limiting PTE loads for composted products need to be combined with the evaluations of the soil concentration to provide a sustainable agro-ecological approach to soil protection.

This approach adopts the following assumptions and recommendations:

a) knowledge of the background levels of PTEs in the soil;

b) repeated application of soil improver at a rate of 10 t DM/ha/year:

- meets the demand of a general agricultural management (humus balance),
- proposed values guarantee (even if organic matter is mineralized) that the upper soil limit will not be attained for at least 150 years,

c) normalization of the organic matter to 30 % DM in order to provide comparable calculations;

d) restriction of validity of limits to 10 – 15 years due to potential for advances in technology and knowledge of risks.

Annex D provides an example of a precautionary approach-driven proposal for establishing PTE concentration limits in soils. These limits, which take into consideration soil texture as a discriminant actor in assessing ecotoxicological risk, would be used as a basis to draw maximum concentration values and/or application rates of soil improvers.

4.3.5 *Problems of the regulatory approaches*

As stated, all these approaches have deficiencies. None fully considers the impacts of the different materials themselves and the effect of the soil improver on the bio-availability of the PTE. In addition, this does not fully reflect the full range of factors that modulate the bio-availability of PTEs in soil improvers, such as antagonistic relationships, proportion of clay (mineralogical analysis), nature of the organic matter present, cation exchange capacity, pH, etc.

In addition the provision of limits on the product does not protect the soil from repeated applications or applications at higher rates as these situations lead to accumulation within the soil and hence higher concentrations. The Austrian proposal suggests an annual application rate of 10 tDM/ha whilst the other hybrid protocol assumes a total application of 50 % of the soil mass (top 150 mm).

Any set of limit values cannot be applied to the whole range of soil improver and growing media products covered by CEN/TC 223. This creates difficulties in that either limit values have to be developed for each product type, or any limit values that are applied are restricted to a subset of the full range of products covered. In the first case this would seem an impossible task as there is insufficient experimental evidence to develop rational limit concentrations for all products and mixtures of ingredients. Alternatively, some formula to adjust the limits to the different products may be established but the precise relationships between the factors and bio-availability are not known at present.

If, however, the limits are restricted to a group of products, this would be prejudicial to these products as they would have additional costs to the manufacturers for analysis and would restrict their use or sale. At the same time, products outside the specified group could have unsafe levels of PTEs whilst being unrestricted by the standard, hence being able to take advantage of a better marketing position.

Thus, under either situation the use of limit values would bias the market by either penalizing the products that are safe with higher concentrations, or limit those products which would be covered by the limit values. In both situations the safety of products could not be assured as under a limit value system applicable to all media some products could still be toxic whilst some safe products could be proscribed.

4.3.6 *Existing regulations*

The Directive 86/278/EEC defines sewage sludge quality for the protection of soil when sludge is applied to land, and several countries have adopted the Directive or have set analogous rules. Table 5 lists the legislative references found for sludge, soil and composted materials.

Composted materials and other waste related products are not, for the moment being, regulated by the EC, but most countries have adopted rules that set quality parameters and use criteria for the protection of the environment.

Few rules were found for other products. Norway regulates the cadmium content of inorganic fertilizers, setting the limit to 100 mg Cd/kg P [7].

Indirect references are EEC Directives concerning water quality (79/869/EEC and 80/778/EEC) and World Health Organization (WHO) recommendations for maximum concentration in food and drinking water [8].

Annex B includes very detailed and exhaustive references on inorganic contaminant toxicity levels. Acceptable daily intake (ADI) dose, levels in food and drink and plant uptake and food consumption statistics. The complexity of achieving meaningful concentrations of “safe” limits has been expressed by both the UK experts (19.12.93) and the Swedish experts (17.12.93) who also provided additional reference data on tolerable daily intake values for PTEs.

4.3.7 *Recommended safety guidelines*

Working group 2 was unable to reach agreement on any limit values or other mechanism that would adequately protect the safety of users as well as not discriminating against products that pose little or no risk to users or the environment. WG 2 therefore limited its scope to providing a discussion of the issues of PTE and the protocols for setting limits.

4.3.8 *Products at risk*

Potentially all materials are at risk contamination with PTEs. The potential for contamination is dependent on origin (e.g. production process, season, source of material, etc.). Risks should be assessed for each material on a case by case basis.

4.4 Organic contaminants

4.4.1 *Description of hazard*

The hazard is generated by the presence in soil improvers and growing media of man-made organic compounds that pose a hazard to humans, environment and plants due to their toxicity or other environmental adverse effect (e.g.: Volatile Organic Compounds, (VOCs) and their effect on ozone layer depletion). Organic compounds can constitute a hazard due to their volatility, mobility (also water-solubility), persistence (low biodegradability), and bio-availability.

Hazard to humans is related to the inhalation, ingestion, and/or contact of contaminated products during a) the manufacturing of synthetic growing media and composted materials from municipal solid waste (occupational hazard, probably the most serious exposure, is out of CEN/TC 223’s scope of work, [9]), during b) the use of products that are contaminated (both a professional and domestic hazard) and c) during consumption of food products that have bio-accumulated or adsorbed significant amounts of the organic contaminant. The hazards to the environment relate both to the dispersion of volatile compounds into the atmosphere and to the bio-accumulation of persistent organic compounds up to doses of ecotoxicological significance. In addition, a number of organic compounds have shown to induce toxicity in plants.

Table 5 — Standards and guidelines for "total" potentially toxic elements (PTEs) in composted materials, sludge or soil (mg/kgDM)

Document	Zn	Cu	Ni	Cd	Pb	Hg	Cr^{total}	Cr^{VI}	Mo	Se	As	B	Co
Austria ON S2022 MSW compost 1986	1 000	400	100	4	500	4	150					100/25	
Austria ON s2200													
Bio-waste compost 1993													
(30 % organic matter basis) class I	210	70	42	0.7	70	0.7	70					10	
class ii	400	100	60	1	150	1	70					10	
Austria S2021 (Growing media) 1994	200	100	60	1	100	1	100		10		20		
Austria L1075 Orientation soil values[a]	300[b]/150	100/50	60/40	1/0.5	100/50	1/0.2	100/50						
Austrian Fertilizer Ordinance LGB6160:1994 Soil amendment (org. Matter > 20 % dm)	300[b]	100[b]	60	1	150	1	100	2					
Austria sewage sludge regulation 1994													
(lower Austria) sludge limit	2 000	500	100	8	400	8	500						100
sludge limit after 1/1/2005	1 500	300	25	2	100	2	50						10
soil limit	200	60	50	1.5/1[c]	100	1	100						
Austria Compost Ordinance draft Oct 1998													
agriculture	500	150	60	1	150	0.7	100						
non food, land reclamation	1 200	400	100	3	250	3	250						
Belgium- compost, VLACO/Min of Agriculture	300	90	20	1.5	120	1	70						
EC ECO-label -Soil Improver (488/98/EEC)	300	100	50	1	100	1	100				10		
EC- Ecological agriculture "organic household waste" (2092/91/EEC)	200	70	25	0.7	45	0.4	70	0					
Germany								n/a					
Data Sheet M10/non-food	750	200	100	2.5	250	2	200						
RAL GZ251	400	100	50	1.5	150	1	100						
Blauer Engel	300	75	50	1	100	1	100						
bio-waste Ordinance (i)	300	70	35	1	100	0.7	70						
bio-waste Ordinance (ii)	400	100	50	1.5	150	1	100						
Bark soil standard RAL GZ250	300	50	30	2	80	0.5	50						
EC soil protection directive (86/278/EEC)													
soil limit pH 6–7	150–300	50–140	30–75	1–3	50–300	1–1.5							
soil limit pH > 7	225–450	75–210	45–112	1–3	50–300	1–1.5							
sewage sludge	2 500–4 000	1 000–1 750	300–400	20–40	750–1 200	16–25	100–200						

NOTES
"total" implies extraction with hot concentrated strong acid

underlined values are water extractable levels

[a] 2nd values assumes a man caused enrichment of natural background levels

[b] when exceeded should be declared on label.

[c] Cd 1.0 when soil pH < 6.0
n/a not allowed in fertilizers

Table 5 — Standards and guidelines for "total" potentially toxic elements (PTEs) in composted materials, sludge or soil (mg/kgDM)

Document		Zn	Cu	Ni	Cd	Pb	Hg	Cr^{total}	Cr^{VI}	Mo	Se	As	B	Co
Italy L 99/92	sludge	2 500	1 000	300	20	750	10							
	soil	300	100	75	1.5	100	1							
Italy L 748/84 and modif 27/3/98 (various soil improvers including compost)		500	150	50	1.5	140	1.5		< 0.5	20				60
Netherlands BOOM 1998														
	compost	200	60	20	1	100	0.3	50				15		
	very clean compost	75	25	10	0.7	65	0.2	50				5		
	sewage sludge	300	75	30	1.25	100	0.75	75				15		
Norway Si, GM based on org. waste, sludge (Regulations concerning trade..1996)	class I	400	150	30	0.8	60	0.6	60						
	class II	800	650	50	2	80	3	100						
	class III (non-food)	1 500	1 000	80	5	200	5	150						
Spain, compost (Min. Ord. 12731, 28/5/98)		1 100	450	120	10	300	7	400						
Spain, sludge		2 500–4 000	1 000–1 750	300–400	20–40	750–1 200	16–25	100–200						
Spain, soil	pH 6–7	150–300	50–140	30–75	1–3	50–300	1–1.5							
	pH > 7	225–450	75–210	45–112	1–3	50–300	1–1.5							
Sweden (SFS 1985:840)		800	600	50	2	100	2.5	100						
Switzerland Stoffverordnung, 1992														
	compost	400	100	30	1	120	1	100						
	sewage sludge	2 000	600	80	5	500	5	500						
Canada mixed organics compost		315	128	32	2.6	83	0.83	210						
Canada BC Yardwaste compost		315	100	50	2.6	150	0.8	210		5	2	13		26
Canada BC Source separated mixed org		315	100	50	2.6	150	0.83	210		5	2	13		26
Canada Ontario yardwaste compost		500	60–100	60	3–4	150–500	0.15–0.5	50		2–3	2	10–20		25
Canada–Ontario– sludge		4 200–840	1 700–380	420–80	34–4	1 100–220	11–1.4	2 800–500		94–1.2	34–6	170–35		340–77
USA- USEPA Part 503 — sludge		2 800	1 500	420	39	300	17	1 200		18	36	41		
USA Florida 17–709	*1*	900	450	50	15	500								
	2	1 800	900	100	30	1 000								
	3	10 000	3 000	500	100	1 500								
	4	> 10 000	> 3 000	> 500	> 100	> 1 500								
USA Maine – mulch, topsoil		2 000	1 000	200	10	700	10							
USA New Hampshire not direct human food uses		2 500	1 000	200	10	250	10							
USA Minnesota 1991 compost		1 000	500	100	10	500	5							
USA New York 1991		2 500	1 000	200	10	250	10	1 000						

NOTES "total" implies extraction with hot concentrated strong acid

Italicized standards are those which the original standard documents are not available and reported values have been used.

For a complete listing of current USA and Canadian standards on compost see Compost Standards. Composting Council Fact Sheet. Alexandria, VA, USA April 1996.

4.4.2 *Discussion of hazards*

Organic contaminants are typically derived from human activity. Their presence in soil improvers and growing media can be ascribed to the following causes:

- voluntary addition as additives to improve specific qualities in the final product;
- trace impurities, as residues of production processes;
- generalized background presence from non-point source pollution of the environment;
- localized, point-source pollution of the site of extraction;
- present as contamination of the base ingredient of the soil improver or growing medium.

One problem that is very specific of this hazard is the difficulty of screening at a reasonable cost for such a broad spectrum of contaminants.

Composted materials and waste derived products can contain organic contaminants according to the origin of their base ingredients. Both volatile and persistent organic contaminants can be of concern in these products, whereas degradable organics can be subject to total or partial microbial decomposition during the composting process. It is to note in this respect that degradation metabolites in some cases are more toxic than the original product. VOCs are potentially present in discarded containers and other components of the waste stream, and can be volatilized during the waste sorting and composting phases [9].

Persistent organic contaminants that can be present in composted materials and waste-derived products include pesticides (including residues of banned products), polychlorinated biphenyls (PCBs), aryl-, and aryl/alkylphosphotryesters (used in hydraulic fluids, plasticizers, flame retardants etc.), and polychloro-dibenzodioxines and furans (PCDD/Fs). Fricke and Vogtmann [10] report ubiquitous presence of chlorinated pesticides in the environment, and that lindane is frequently found in biogenic composted material when woodchips are added. These lindane levels, however, are usually too low to influence composted material quality. Degradation studies reported by the same Authors have shown that composting can degrade HCH to a quite large extent (86 %), DDX at 64 %, and Polyaromatic hydrocarbons (PAHs) at 56 %. PCBs were however degraded at a 45 % rate, while PCDD/F degradation studies are still at an inconclusive stage.

A relatively larger literature is available on organic compounds found in sewage sludge. Studies funded or published by the EEC [11] list as possible contaminants of sewage sludge aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, organo-chlorine pesticides, PCBs, PAHs, phthalates, and surfactants. A substantial analytical problem is identified in these studies in the large number and range in chemical form of compounds which can potentially justify examination. Also, as previously mentioned, the presence of degradation products should be considered.

Regarding PAHs, there is a general consensus that "airborne emissions are of greater importance for soil contamination than the input from sewage sludge, although a slight but permanent increase of soil concentrations of PAHs had been observed over the last decades" [11]. Webber and Goodin [12] studied VOCs in sludge, and Hembrock-Heger [13] evaluated transfer factors of persistent organic contaminants in soil, plants, and food. Welp and Brümmer [14] measured the toxicity of organic contaminants to soil micro-organisms, obtaining a wide variety of responses among which the most relevant was the one to pentachlorophenol.

The human exposure to PCDD/Fs via sewage sludge application to land has been evaluated by Wild et al. [15], who concluded that human exposure to those contaminants is elevated if sewage sludge contains typical concentrations of 33–37 I–TEQ (Toxicity Equivalence Factor, which expresses toxicity of a single PCDD relative to the most toxic 2, 3, 7, 8-T4CDD). The application of sludge to arable land appears to these authors, however, to have only a minor effect on human exposure. The most important transfer mechanism for PCDD/F and other lipophilic compounds (e.g. PAH, PCB, organochlorine pesticides, aliphatic and aromatic hydrocarbons, chlorinated hydrocarbons, phthalates, surfactants) has been identified in the livestock ingestion of sludge adhering to vegetation. The study concludes that the current WHO/EURO TDI guide-line value (REF) of 10 µg I–TEQ/kg per day is exceeded only when the sludge considered has a high concentration, and an individual consumes products exclusively obtained from sludge treated areas.

The United States Environmental Protection Agency (USEPA) has promulgated the sludge disposal rules [16], for the preparation of which a series of potential pollutants were investigated. Some of these (dimethyl nitrosamine and tetrachlorophenol) were found not to interfere with land application at the highest concentration found in sludges, and other organic contaminants have been deferred to a future investigation because of insufficient data. Among these are benzo(a)anthracene, bis(2-ethylhexyl phthalate), PCDDs and PCDFs, methylene bis(2-chloroaniline), methylene chloride, pentachlorophenol, and tricresyl phosphate. PCDD/Fs sampling in sludge and analysis for future rule making are ongoing at the present time.

Antibiotics and other medicaments can be found in products derived from animal and fish waste. The Norwegian delegation to WG 2 of TC 223 reported the presence of residues of oxolinic acid from medical treatment in fish waste.

Background concentrations of chlorinated pesticides (DDT, lindane) can be found in naturally derived products such as bark and wood fibres or, more significantly, from use as pest killer during timber cultivation outside of the EC. Lindane may be a less significant contaminant in countries where its use has been banned. German experts report that the limits of lindane, cypermethrin and DDT are often exceeded in bark and jute fibres, and that straw can be contaminated with fungicides. There was a consensus among WG 2's experts that most of the lindane-contaminated products (above generalized background concentrations) are found in bark products imported from the Eastern European Countries.

Herbicides have been found in peat as a residue of medium preparation for harvesting (Communication of French experts). While more precise data on this subject was available, their presence is reportedly expected to decrease in the future given the increasing adoption of modern peat extraction systems that do not rely on the use of herbicides.

Wood/fibres derived products can contain traces of persistent wood preservatives (pentachlorophenol, PCP) when treated wood is used. However, possible PCP concentration levels in such materials were not available to WG 2.

Inorganic, processed soil improvers and growing media such as slagwool and rockwool can contain phenol-formaldehyde resins as binders, mineral oil, and polypropyleneglycol as dedusting agents [17]. These compounds added during their manufacturing phases to promote certain characteristics such as water-repellency, durability, and handling. No data were however available on their levels in the final products, in order to evaluate the potential risks to the users, plant and environment.

Synthetic soil improvers and growing media can contain residuals of monomers, plasticizers and flame retardants that can be harmful (toxic) to users and plants. In particular, polyurethane foam can contain urethane and aromatic amines, ureaformaldehyde can contain free formaldehyde, polyphenol can contain free phenol and styrene monomer can be found in polystyrene. WG 2 agreed that data concerning such organic contaminants are extremely limited, sparse, as well as difficult to evaluate and compare.

4.4.3 *Existing regulations*

Existing regulations on composted products are summarized by Raninger [18]. Organic contaminants that are regulated in some, but not all, EU and EFTA countries are HCH (lindane), PAHs, PCBs, PCDD/Fs, and AOX (halogenated organic compounds). According to the same source there is no need to establish limits in soil improver and growing media, "given the data available and the assessment of the situation".

The German standard RAL GZ250 sets a voluntary limit for bark products of "residues of insecticides (lindane, cypermethrin)" at < 0.5 mg/l fresh substance.

An indirect reference on what contaminants are controlled in other fields, is found in Directive 80/778/EEC (water for human consumption), which identifies organic compounds that are unwanted in drinking water, and sets for those restrictive limits Maximum Admissible Concentration (MAC) or Guide Levels (GL) as summarized in Table 6.

4.4.4 *Additional information*

A number of specific contaminant limits and regulatory approaches have been proposed at different times by WG 2 documents, these are summarized in Table 7 [19,20,21,22,23].

Table 6 — Controlled contaminants in drinking water Directive 80/778/EEC

Compound	MAC or GL	Limit
Substances extractable in chloroform	GL	0.1 mg/l dry residue
dissolved or emulsified hydrocarbons; mineral oil	MAC)	10 µg/l
phenols, excluding natural phenols which do not react to chlorine	MAC	0.5 µg/l
surfactants (MBAS)	MAC	200 µg/l laurylsulphate
organochlorine compounds other than pesticides	GL	1 µg/l
pesticides and related products includes insecticides (persistent organochlorinated, organophosphorated, carbamates), herbicides, fungicides, PCBs and PCTs	total MAC each group MAC	0.5 µg/l 0.1 µg/l
PAHs	MAC	0.2 µg/l

Table 7 — Examples of materials with potential for contamination with organic compounds and control approaches adopted or proposed

Material	Contaminant	Notes
Bark	Pesticides, lindane, DDT, cypermethrin	Less or equal to 0.5 mg each of lindane and cypermethrin per litre of fresh matter (German proposal)
Straw	Pesticides, growth regulating substances	
Organic fibres	Wood preservatives	
Sawdust	Pentachlorophenol	
Jute fibres	Lindane, DDT, cypermethrin	
Synthetic products	Monomers, plasticizers	
Polyurethane		Dutch experts proposed a declaration on the label: “free of organic impurities”, and “free of additives that reduce burning”
Polyurethane	Aromatic amines, urethane	
Polyphenol:	Phenol	
Ureaformaldehyde	Free formaldehyde	
Polystyrene	Styrene monomer	
Polyacrylamide	Acrylamide monomer	
Aquaculture waste	Antibiotics (e.g. oxolinic acid)	Norway recommends the suspension of use of aquaculture waste that contains dead fish possibly containing traces of antibiotics as ingredient of SI/GM
Soil	PCB	France proposes max. input in soil of 1 mg/ha/year. (proposal EEC 91/C/299/05),
Sewage sludge	nonylphenol max 50 mg/kg DM Toluene max 5 mg/kg DM 3PAH max 3 mg/kg DM 3 PCB max 0.4 mg/kg DM	voluntary agreement in Sweden [19]

Other regulatory approaches proposed are setting loading rate target values for soil (calculated by the Belgian experts in an internal document), declaration of origin from uncontaminated source (proposed by the Dutch experts as a declaration of quality), the potential use of bioassays such as Microtox [25] [26] to screen at less cost for toxic compounds has also been proposed. After a review of the available documentation WG 2 experts were not satisfied that sufficient testing had been performed on the materials of interest, and therefore adoption for the purpose of screening organic contaminants' toxicity in soil improvers and growing media is premature at this stage.

4.4.5 *Recommended safety guidelines*

General agreement was reached that the available information is very limited (in fact no precise data were provided in support of the limits that were proposed) and does not represent a valid basis on which to create a safety standard. Special consideration was also given to the extreme variability of analytical conditions at which the available data were obtained, and to the extreme cost that a meaningful organic contaminants analytical screening would have compared to the envisaged benefits.

In conclusion, although generally organic contaminants are undesirable in soil improvers and growing media, no recommendation for limits can be proposed at this time due to the technical and commercial reasons explained above.

4.5 Mineral constituents

4.5.1 *Description of hazard*

All minerals in a crushed form have the potential to create dust, and the inhalation over long periods of substantial amounts of any inert (or so called nuisance dust), can overload the lung clearance mechanism, making the lungs more vulnerable to respiratory disease.

Toxic components in a mineral could increase the hazard from exposure to respirable dust.

Silica is a very abundant material in a variety of forms and accounts for approximately 20 % of the earth's crust with 95 % being quartz. It is present in nearly all mining operations, and as an extremely common mineral has been the subject of many detailed studies, summarized in the Crystalline Silica Primer published by the US. Bureau of Mines [27].

Trace amounts of free silica are found in some silicate minerals while materials such as sand and gravel consist mainly of free silica as quartz. It has been known for centuries that prolonged and excessive exposure to high concentrations of respirable free silica in dust can cause a related lung disease of occupational origin, silicosis [28]. This is a non-cancerous, but extremely serious, lung disease. Recent attention has focused on the possibility of a relationship between silica exposure and lung cancer. Confounding factors in human studies and flaws in animal studies leave the issue unresolved. In the USA minerals containing more than 0.1 % free silica are subject to Federal guidelines concerning hazard communication.

Asbestiform fibres are a known carcinogen and the use of asbestos in Europe is closely controlled by EC Directives. Among these are Directive 91/382/EEC which amended Directive 83/477/EEC on the protection of workers from risks related to exposure to asbestos. Also Directive 90/394/EEC, the carcinogens directive, regulates mineral constituents.

Man made mineral fibres are the object of a vast number of international studies and publications. Some authorities have considered these materials as possible carcinogens based on studies which have shown some association between man made mineral flares and lung cancer but only after intraserosal injection. The international Agency for Research on Cancer (IARC) classified mineral fibres as possible carcinogens. In their 1988 report [29] IARC indicates sufficient evidence for carcinogeniaty of glass wool in animals if injected, but inadequate evidence for carcinogenicity of glass wool in humans and limited evidence or inadequate evidence related to rock wool and slag wool. In 1997 the EC has classified mineral wool fibres as "possible carcinogenic (class3)" [30]. In some European countries occupational exposure regulations exist and limits are placed on the long term exposure to mineral fibres e.g. in the UK. 5 mg/m^3 (8 hour TWA reference period) [31].

4.5.2 *Products at risk*

All soil improvers (SI) and growing media (GM) could be considered a hazard since under some conditions of use a dust can be created. However, the risk from this hazard is eliminated by simple measures.

Perlite and vermiculite are silicates and can contain trace amounts of free silica but the amount present even in high dust concentrations will be low and eliminated by normal dust control precautions.

Health studies that have been carried out on perlite workers going back over 40 years, and other scientific work concluded that perlite is not harmful to health. Some of the relevant published work relating to health risk associated with perlite is found in Weil (1990) [32], Cooper and Sargent (1986) [33], WIL Research Laboratories (1982) [34], Rosner-Hixson Laboratories (1977) [35], National Academy of Sciences (1981) [36], Association of American Feed Control Officials (1992) [37], and United States Department of Agriculture [38].

The presence of asbestiform filers in certain known deposits of raw vermiculite is well defined and understood by EC exfoliaters of vermiculite. All major vermiculite suppliers ensure that studies have been made to verify that asbestiform fibres are absent or, if present, are at a level which does not constitute a known health hazard. From published studies and other information it can be concluded therefore that exfoliated vermiculite produced in Europe does not present any known health problem.

Relevant published data includes Hunter and Thomson (1973) [39], Parks (1974) [40], Goldstein and Rendall (1969) [41], Swenson (1975) [42].

For materials such as rock wool, glass wool etc., suitable dust control precautions are necessary to prevent inhalation of the dust fibres in line with all the mineral constituents. However in horticultural situations exposure levels are decreased since the mineral wool products are normally used in a wet state. Exposure is also decreased whenever they are used wrapped in a polyethylene growing bag. Nonetheless there are cases when the products are used unwrapped, and exposure may occur when the product is discarded and/or allowed to dry out.

A number of countries have occupational exposure limits for man made mineral fibres which relate to the use of dry unwrapped material. In general the man made mineral fibres industry consider that normal levels of exposure do not pose a carcinogenic risk of any practical consequence to health. This is supported by mortality and morbidity studies on workers in the production and user industries. The International Programme on Chemical Safety (IPCS) in 1988 [43] reviewed man made mineral fibres and concluded that the possible risk of lung cancer among the general public is very low if there is any at all, and should not be a cause for concern if the current low levels of exposure continue. The International Labour Office in 1989 [44] agreed with the IPCS.

Relevant published data includes Brown et al. (1991) [45], Chiazze et al. (1993) [46], Hughes et al. (1993) [47], Marsh et al. (1990) [48], Simonato et al. (1988) [49], Wong et al. (1991) [50], and the European Insulation Manufacturers Association (1994) [51].

4.5.3 *Existing regulations*

There are no existing regulations on mineral constituents in soil improvers and growing media.

With mineral products the total quantity of toxic component is of lesser importance than the amount inhaled and in particular the respirable fractions inhaled and many countries have occupational exposure limits for total inhalable and respirable dust fractions. These limits at present can vary slightly from country to country but have as their basis regulations to support various EC directives which include Directive 80/1107/EEC "Protection of workers from the risks related to exposure to chemical physical and biological agents at work", and Directive 91/659/EEC which adapted to technical progress Appendix 1 of Directive 76/769/EEC on the approximation of laws regulations and administrative provisions of Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations.

Care needs to be taken in the interpretation of so called limits or detected concentrations of free silica and also asbestiform fibres in minerals and associated dust. Both are very difficult to detect at low levels and at present there are no internationally recognized standard test methods for them. Current techniques can detect free silica at around 1 % (although some methods claim lower levels), and asbestiform fibre at about 0.001 %, but methods are only partially validated.

4.5.4 *Recommended safety guidelines*

In commercial applications the use of basic dust control procedures when handling the dry SI or GM or wetting the material before use will eliminate risks associated with most of these materials. Exposure levels are generally very much below national limits. Mandatory protection or control will be required if exposure approaches the national standards.

In domestic use the risks will be eliminated by using soil improvers and growing media in areas with good ventilation and by maintaining a reasonable standard of personal hygiene.

Manufacturers of soil improvers and growing media are required by existing legislation to supply safety data sheets and give adequate guidance to ensure the safe use of their products.

4.6 Biological hazards, pathogens to humans and animals; microbial by-products and allergens

4.6.1 *Description of hazards*

Viruses, bacteria, including actinomycetes, moulds, protozoa and helminths can contaminate or grow in organic materials during their production, decomposition or composting and storage. Some of these can cause infection and others, especially moulds and actinomycetes, can cause allergy or other diseases, such as mucous membrane irritation, rhinitis, asthma, allergic alveolitis or inhalation fever, either directly or through their products. Of these, the most important are, probably, Gram-negative and faecal bacteria, thermophilic actinomycetes and the fungus, *Aspergillus fumigatus*. Hazards from ingestion and skin contact can occur during both domestic and professional use but those from inhalation are much greater during manufacture and mixing than during use. Pathogens and allergens present different hazards but their sources and the species concerned are not clearly distinguished and their methods of control are similar.

4.6.2 *Hazards associated with micro-organisms and their products*

Infection occurs through ingestion of contaminated material, penetration of skin through open wounds, punctures and scars.

Mucous membrane irritation commonly results in a dry cough, irritation of the eyes, nose and throat and can represent an irritant effect not involving immune responses or mediators [52]. It can be caused by extended exposure to low concentrations of endotoxins or other components of bio-aerosols.

Bronchitis and chronic obstructive lung disease can also result from exposure to endotoxin, perhaps to larger doses than cause mucous membrane irritation, but perhaps also from non-specific reactions to dust or other components of the bio-aerosol. The role of fungal spores is uncertain but there can be an inter-relationship in the disease with atopy (a constitutional predisposition to sensitization by normal, everyday exposure to airborne allergens, including pollens, fungal spores, insects, mites and their products, animal furs and other proteinaceous materials).

Allergic rhinitis and asthma are inflammatory and obstructive diseases of the larger airways and upper respiratory tract in atopic subjects. Symptoms develop rapidly on exposure and are mediated by specific lgE antibodies.

Extrinsic allergic alveolitis is a T-lymphocyte dependent granulomatous inflammatory reaction, predominantly of the peripheral gas exchange tissue of the lung that does not depend to any great extent on constitutional predisposition [53]. Acute symptoms of allergic alveolitis develop several hours after exposure to the offending dust and include chills, fever, a dry cough, malaise and, with repeated exposure, increasing breathlessness and weight loss. Eventually, permanent lung damage can occur.

Diagnosis is based on a history of exposure to the relevant antigen, clinical, radiographic and functional changes typical of the disease and the presence of precipitating lgG antibodies (precipitins) to the causal antigen, with the possible presence of basal crepitant rales, impairment of pulmonary diffusing capacity, decreased arterial oxygen tension, a restrictive ventilation defect, increased lymphocytes and granulomatous infiltrations and with reproduction of the disease in inhalation challenge with a relevant antigen [54] [55]. Precipitins are indicative of exposure to antigen and their relevance to the disease has to be proved.

Extrinsic allergic alveolitis is characteristically an occupational disease and the names given to different forms of the disease usually reflect the environment in which they occur or the source of the antigenic aerosol. It is caused by a range of bio-aerosols which often contain both fungal and actinomycete spores. Farmer's lung is the classic example of an allergic alveolitis.

Inhalation fever or organic dust toxic syndrome (ODTS) can share some of the features of allergic alveolitis. It again results from intense exposure to bio-aerosols which gives symptoms resembling influenza, with leukocytosis and fever but does not appear to require prior sensitization or antibody development while respiratory symptoms and radiographic changes may or may not occur. Often, a group of workers exposed at one time may be affected and their ages are usually less than those associated with allergic alveolitis.

Fungi, bacteria, mycotoxins and endotoxins have all been suggested as possible causes for ODTS [54] [56] [57] [58] [59] [60] [61] [62] [63]. It can be caused by large doses of endotoxins which are known to produce febrile reactions on inhalation. However, the aero-biology of environments in which this syndrome has occurred has never been defined, and the roles of the different micro-organisms have not been established.

Endotoxin can cause febrile symptoms like endotoxin fever and significant dose-response relationships have been demonstrated between the level of endotoxin in the air and impairment of lung function in workers in different environments [64] [65] [66] [67].

Gram-negative bacteria

Species of Gram-negative bacteria of plant origin present potential respiratory hazards as sources of endotoxin and allergens. The best known is the epiphytic *Enterobacter agglomerans* (synonym *Pantoea agglomerans, Erwinia herbicola)* [65] [68] [69] [70] [71] which occur on a range of plants and plant products [72]. The species is characterized by chromogenic yellow, facultatively anaerobic, fermentative rods with peritrichous flagella and the cell walls contain lipopolysaccharides known as endotoxin which has been associated with a range of occupational diseases. Febrile and respiratory responses are associated with concentrations greater than 1 000 Gram-negative bacteria or 0.1 μg endotoxin/m^3 air. Small doses of endotoxin can cause mucous membrane irritation and larger doses bronchitis or inhalation fever (organic dust toxic syndrome) [65] [73] [74]. Endotoxins in sewage treatment workers are associated with symptoms similar to influenza, with tiredness, fever and irritation of the upper respiratory tract and eyes [75] but these are most likely to occur during the production of SI and GM [76].

Other gram-negative bacteria that are common in organic dusts and potential hazards to exposed workers belong mostly to the genera *Pseudomonas, Klebsiella, Alcaligenesl* and *Acinetobacter*. [68] [77] [78]. *Alcaligenes faecalis* can be common in bio-aerosols on animal farms and in herbage processing plants [79] [80] and cause respiratory disorders in both environments [81] [82].

Faecal bacteria

Faecal pathogens, such as *Salmonella* spp, in SI or GM will constitute a hazard of infection to those handling these materials. The risk is probably greatest in materials derived from composted sewage. Raw sewage contains a wide range of micro-organisms, of which total coliforms, number $1.6 \times 10^4 – 6.2 \times 10^5$ colony forming units (cfu)/ml faecal coliforms, $3.4 \times 10^3 – 4.9 \times 10^5$, and faecal streptococci, 6.4×10^2 0 4.5×10^4/ml [83]. The ratio of faecal coliforms to total coliforms ranges from 8.3 – 47.6 %. *Salmonella spp* can occur in concentrations up to $10^3 – 10^6$/l [84] [85]. The activated sludge process decreases total coliform bacterial faecal coliforms, faecal streptococci, *Salmonella, Shigella* and *M tuberculosis* by 25 – 99 %, polio virus by 90 % and coxsackie virus A9 by 98 %. Treatment efficiency depends not only on efficient degradation but also on complete separation of activated sludge micro-organisms from purified secondary effluent by sedimentation. Extended survival of pathogens in dry sludge can be eliminated by high temperatures prior to disposal. Composting results in high temperatures, usually about 55 °C, which can effectively pasteurize materials contaminated with faecal material. However, it is essential that the entire bulk reaches the required temperature for the period necessary to kill all enteric pathogens and for the process parameters to be carefully monitored.

The health risk from aerosols is difficult to determine as many of the bacteria have sources in the natural environment. Gastrointestinal symptoms, "Sewage Workers Syndrome" have been reported in workers exposed to numerous airborne Gram-negative bacteria [86] and enterotoxins from *Kelbsiella, Citrobacter, Enterobacter, Ecoli, Aeromonas, Proteus* and *Pseudomonas* have been reported [87] [88]. However, infection rates do not differ between people living near sewage treatment plants and those living elsewhere [89] [90] [91] so that the risk of such infections in people handling soil improvers or growing media is likely to be very low. However, the situation is at its most sensitive in domestic garden use of such materials and producers have a duty of care to the consumer.

Salmonella in soil

The principal habitat of *Salmonella* is the intestinal tract of humans and other animals. Contamination of water, soil and plants with excrement can lead to its dissemination through the natural environment. Except, perhaps, for *S. Bareilly, Salmonella* spp. do not appear to multiply significantly in the natural environment but can survive several weeks in water and several years in soil, if conditions of temperature, moisture and pH are favourable [92]. Survival of *Salmonella Dussledorf* in soil was decreased by the bactericidal effect of streptomycin and by growth of the known streptomycin producer, *Streptomyces bikiniensis*, but was increased by the presence of *Stm. lividans* [93]. *Salmonella* was detected in commercial soil amendment products derived from composted sewage sludge but not in bulking agents and only in small numbers in the composted sewage sludge used to produce the products. The distribution of *Salmonella* serotypes did not suggest a strong correlation between the occurrence of *Salmonella* in the composted products and the incidence of *Salmonella* infections in the community. The results suggest minimal need for concern that sludge based soil amendments could provide a source of *Salmonella* infection but the products were not risk free. Analysis of exposure demonstrated that the probability of infection was low in most scenarios. However, the frequent isolation of *Salmonella* and predominance of a serotype commonly isolated from infected children supported the need to continue the requirement that the products meet bacterial standards prior to their use by the general public [94].

Comparisons of plate counts and enzyme-linked immunosorbent assay (ELISA) and microwell fluorescent antibody (FA) assay of *Salmonella* in the soil indicated the production of viable but non-culturable salmonellas in non-sterile soil. When monitored by plate counts, the survival of *Salmonella* was greater in sterile than in non-sterile soil. In non-sterile soil, plate counts dropped rapidly with time, but FA direct counts and ELISA remained level. The *Salmonella* cells became progressively smaller and rounder with time. Dead *Salmonella* cells introduced into soil rapidly disappeared [95]. Extended periods above 55 °C during composting decreased numbers of *Salmonella* to acceptable levels [96]. However, possible regrowth of *Salmonella* after composting waste suggested by Burge et al. (1987) [97]. Only most probable number techniques are reported to have the sensitivity required to detect down to one cell per 100 g soil although the method generally requires 72 h, and longer for a confirmed result. A more rapid variant utilizes luminescent (*lux*-) bacteriophage [95].

Escherichia coli in the natural environment

The coliform count has become established as an important means of assessing levels of faecal contamination although procedures need to be carefully controlled since isolation can be affected by the presence of other organisms. However, the chief concern has usually been the occurrence of *E coli* in water and there is little data on its occurrence and survival in soil. In water, 10 coliforms/100 ml is allowed for small community water supplies by WHO [98] but 0 coliforms/100 ml is the limit in the USA [99]. It is said that large concentrations of faecal coliforms can be detected in most samples of soil conditioners derived from composted sewage sludge but Andrews et al. (1994) [100] found no *E Coli* or *Salmonella* spp among 10^7 to 10^9 thermophilic and metal and antibiotic tolerant bacteria in samples of raw and cured composted material from a large scale urban composter. However, *E Coli* can be detected in the absence of any human faecal contamination, especially in tropical countries. *E. Coli*, phenotypically very similar to faecal isolates, have even been isolated from epiphytes 15 m above ground level in tropical rainforest. It is possible that such contamination could come from birds or other animals [101].

Legionella

Legionnaires' disease or legionellosis is an atypical form of pneumonia which does not spread from person to person but infection is usually associated with the inhalation of aerosols of water containing viable *Legionella* bacteria. However, a series of outbreaks has been reported associated with handling GM in Australia [102]. These could possibly have resulted from aerosols formed during vigorous watering but there is good evidence that the bacteria were present in the potting mix and could persist there for several months. *Legionella* are widespread in natural sources of water, including lakes, rivers, streams and ponds, and can also be found in soils and rotting vegetation. They can possibly be present in animal and farm waters but there is no evidence that these sources are more important than other environmental sources. In England and Wales, there are about 100 – 200 cases of legionnaires' disease annually, mostly in people who have recently travelled abroad although clusters of cases are often associated with air-conditioning systems and cooling towers of hotels, hospitals and other buildings. However, many cases are sporadic and sources of infection cannot be identified. There have been no tests for *Legionella* in composted timber products in the UK but the evidence from Australia suggests that it could be present in materials from warmer climates. These are likely to present a small but definite hazard to users from aerosols produced during the watering, but the risk of contracting legionnaires' disease from this is believed to be minute.

Thermophilic actinomycetes

Actinomycetes are filamentous Gram-positive bacteria with many of the morphological characteristics of fungi but with the structure and physiology of bacteria. Many species have spores about 1 µm diameter that can easily become airborne. They are thus well suited for deep penetration into the lung on inhalation.

Some Actinomycetes, e.g. *Nocardia asteroides*, can cause infection but the pathogenicity of strains growing saprophytically in soils or stored products has never been established. Other species are important because they have been implicated in allergic alveolitis, a well recognized occupational lung disease, especially of farmers and mushroom workers exposed to large numbers of spores from mouldy feeds and from composts. The species implicated include *Saccharopolyspora rectivirgula* (Synonyms: *Faenia rectivirgula, Micropolyspora faeni), Thermoactinomyces vulgaris, T. thalpophilus, Saccharomonospora viridis* and *Thermomonospora* spp. [103] [104] [105].

In stored hay and cereal grains, actinomycetes, especially *S. rectivirgula* and *Thermoactinomyces* spp are most numerous after storage with more than about 35 % water content and with heating to 50–65 °C. Such hays can contain up to 10^9 spores/g dry weight which are released in clouds when the hay is disturbed giving concentrations up to $10^{10}/m^3$ in the air. *Thermomonospora* spp., especially *T.fusca, T.curvata* and *T.chromogena*, become abundant in mushroom composts, prepared from horse and poultry manure and straw, and in municipal waste composts, prepared from the complex mixture of materials found in household garbage, during spontaneous and peak heating or "pasteurization" processes at about 55–60 °C [106] [107] [108].

Other heated materials that could be included in soil improvers or growing media can also become colonized by actinomycetes. For instance, sugar cane bagasse, the squashed, chopped fibre from sugar cane, can contain large numbers of *Thermoactinomyces sacchari*, the cause of bagassosis [109] [110]. However, nothing is known of the risk of actinomycetes in coir. However *Streptomyces* spp. can form an important part of the microflora of soils and composts and have also been implicated in allergic alveolitis [84] [111] [112].

Aspergillus fumigatus

Aspergillus fumigatus is a filamentous fungus (mould) which produces a thread like mycelium that ramifies through the growth medium and gives rise to spore producing structures which produce very large numbers of almost spherical spores, mostly 2.5 – 3.0 µm diameter. The fungus grows over a wide temperature range, from 15 – 55 °C, and over most of this range it can grow rapidly through suitable substrates. It is ubiquitous in the natural environment, colonizing dead plant litter, and is often common in composted materials that have heated.

A. fumigatus is most numerous in heated hay and cereal grains when these have been placed in storage with more than about 30 % water content and have heated to above 45 °C. Similar numbers can occur in composted materials, e.g. municipal waste composts, that have heated to about 55 °C. These materials can contain 1 – 10 million spores per gram and when disturbed can give 10 – 100 million spores per cubic metre air. However *A. fumigatus* is often present in outdoor air, but concentrations are sometimes as high as 7 – 35 spore bearing particles per cubic metre of air and more often only one or two such particles per cubic metre.

The small size of the spores (2.5 – 3 µm diameter) permits them to penetrate deeply into the lung where they are the cause of a range of respiratory symptoms in man and animals, the nature of which depends on the immunological reactivity of the subject. On exposure to *A. fumigatus*, atopic subjects can develop asthma and allergic bronchopulmonary aspergillosis, in the latter with the fungus often growing saprophytically in the airways. Non-atopic subjects require intense exposure to spores before they become sensitized and develop symptoms of extrinsic allergic alveolitis and aspergilloma (fungus ball). In aspergilloma, the fungus grows in cavities in the lung, especially in old tuberculosis cavities. Subjects whose immune response is impaired by drug or radiation therapy or by underlying disease, e.g. AIDS, can develop invasive aspergillosis, in which the fungus grows actively through the lung tissue and can eventually spread to other organs. *Aspergillus fumigatus* can also produce toxins which can be inhaled with the spores but the hazard from these is unknown although a role has been suggested for them in respiratory disease among Swedish sawmill workers.

Aspergillus fumigatus is classified as a Class 2 pathogen which can sometimes cause human infectious disease but which can be treated. Occupations in which exposure to *A. fumigatus* can occur are therefore subject to the Control of Substances Hazardous to Health (COSHH) Safety Regulations.

Sporothrix schenckii in peat and soil

Sporothrix schenckii, the cause of sporotrichosis, has been reported several times from the USA and Canada. Keyon et al. (1984) [113] isolated *S. schenckii* from two out of 12 (17 %) national brands of potting soil in Texas during routine screening for *Aspergillus* spp. While other publications refer to its occurrence in *Sphagnum* moss, D'Alessio et al. (1965) [114] reported infection of 14 people who had handled *Sphagnum* moss in the USA from which *S. schenckii* was isolated, while Staplin (1981) [115] reported infections among gardeners in Canada and discussed precautionary measures. Powell et al. (1978) [116] reported sporotrichosis of the hands and arms of 17 workers packing pine seedlings in *Sphagnum* moss and Grotte and Younger (1981) [117] treated lesions on the hands and arms of three women and isolation of the fungus from moss used to pack plants.

Products at risk

All organic materials used in SI and GM are potentially at risk but the greatest hazard is undoubtedly from waste-derived and composted materials which can contain pathogenic viruses and bacteria or, if heating has occurred, abundant thermophilic actinomycetes and *Aspergillus fumigatus*. There is little evidence of growth of *A. fumigatus* in peat but allergenic moulds can occur in wood derived products. Also the hazard is probably greatest during production than during end use providing the material is stable during storage. Spores are likely to be retained in moist materials unless superficial growth occurs during storage when they can be released into the air when bags are opened and the material handled. Spores of moulds, which can include Gram-negative bacteria, actinomycetes and *A. fumigatus*, are all likely to be dispersed in large numbers with other dust when handling material in which they have grown which has dried out during storage or use.

4.6.2.1 *Thermal resistance of pathogenic bacteria, viruses and intestinal parasites*

The periods of heating and temperatures necessary to kill many pathogenic bacteria, viruses and intestinal parasites are known and are shown in Table 8. The most resistant to moist heat are the spore-forming bacteria and scrapie virus which can survive prolonged treatment with 100 °C.

4.6.3 *Existing regulations, standards and codes*

Sewage sludge and biowaste national regulations address the hazard from pathogenic micro-organisms directly, by setting hygiene levels, and indirectly, through recommending hygiene practices. There are no EEC directive regarding composted material safety although national regulations or proposals set either contamination limits [118] [119] or define process performance criteria. These are summarized in Table 9.

The Directive 92/118/EEC (chapter 14) gives requirements for processed animal manures that state that they should:

- be exempt of *Salmonella*, absent in 25 g;
- exempt of enterobacteriaceae, < 1 000 cfu/g (aerobic bacteria count);
- reduced spore forming bacteria and toxin formation, < 14 % moisture, W value < 0.7.

In addition requirement on the storage to prevent reinfection are prescribed (e.g. sealed containers).

Table 8 — Lethal conditions for selected pathogens

Disease	Organism	Lethal conditions (Moist heat)
Non-spore forming bacteria		
Brucellosis	*Brucella abortus*	10 min – 60 °C
Cholera	*Vibrio cholerae*	15 min – 55 °C
Contagious abortion	*Vibrio fetus*	5 min – 56 °C
Diphtheria	*Corynebacterium diptheriae*	10 min – 58 °C
Dysentery	*Shigella* spp.	60 min – 55 °C
Food poisoning	*Salmonella* spp.	20 min – 60 °C
Leptospirosis (Weil's disease)	*Leptospira* spp.	10 min – 50 °C
Plague	*Yersinia pestis*	5 min – 55 °C
Staphylococcal infections	Staphylococci	30 min – 60 °C
Streptococcal infections	Streptococci	30 min – 55 °C
Tuberculosis	*Mycobacterium tuberculosis*	20 min – 60 °C
Typhoid fever	*Salmonella typhi*	20 min – 60 °C
Spore-forming bacteria		
Anthrax	*Bacillus anthracis*	10 min – 100 °C
Botulism	*Clostridium botulinum*	5 h – 100 °C 5 min – 120 °C
Gas gangrene	*Clostridium* spp.	6 min – 105 °C
Tetanus	*Clostridium tetani*	3–25 min – 105 °C
Viruses		
Foot and mouth disease		30 min – 56 °C
Scrapie		withstands 2 h – 100 °C
Serum hepatitis		10 h – 60 °C
Swine fever		1 h – 78 °C
Intestinal worms		
Round worm	*Ascaris lumbricoides*	1 h – 55 °C
Tape worm	*Taenia saginata*	few min – 55 °C

Related references can be found in:
Directive 79/869/EEC (surface water for abstraction of drinking water) which requires determination of:

- total coliforms;
- faecal coliforms;
- faecal streptococci;
- *Salmonella.*

Directive 80/778/EEC (quality of water for human consumption) which sets microbial parameters (Appendix 1).

Directive 90/667/EEC (veterinary rules for animal waste except excreta) addresses hygienic problem in the processing/disposal of animal waste, and the production of pet food.

Norway's Regulation 15/10/82 amended 27/7/83 (Animal, Disease Act) bans importation of animal manure, peat, soil, hay and straw except some items from other Scandinavian countries.

Norway's Regulations on waste derived products and sewage sludge (Regulations concerning trade in Fertilizers and Soil Improvers. Norwegian Ministry of Agriculture, 11.09.96) require the absence of Salmonella and viable eggs of parasites; < 2 500 thermotolerant coliform bacteria per gram dry solids

The UK Coir Association Code of Practice [120] requires absence of *Salmonella* in 25 g, *E. Coli* 5 determinations none > 1 000 MPN/g, at least 3 < 100 MPN/g, up to 2 100 – 1 000 MPN/g.

The French Arrete of 30/12/91 (transformation of animal waste) set a voluntary declaration of absence of parasites.

Italian law (ACT 748–84) sets treatment of hydrolysed animal products at 130 °C. It's modifications of 27.03.98 set microbiological requirements for composted and non composted soil amendments, including green waste and peat compost (see Table 9).

There are no existing regulations for bacteria, actinomycetes or moulds in soil improvers and growing media but occupational exposure to organic dusts and micro-organisms is governed by the Control of Substances Hazardous to Health Regulations (COSHH) in the UK and relating to the handling of pathogenic micro-organisms [121].

Table 9 — Provisions for the exclusion of pathogens in Europe

	Indirect			**Direct methods**		
	°C	% H_2O	**days**	**Application area**	**pathogens**	**Product (P)/Approval of Technology (AT)**
EC/"eco-label" 488/98 EEC				gardening	*Salmonella sp* *E. coli*	None < 1 000 MPN (*most propable number)*/g
Austria	60	40	7	land reclam.	*Salmonella sp.*	none
draft compost	55		14	agriculture	*Salmonella sp.*	none
ordinance				sacked,	*E. coli*	if found, recomm. for the safe
10/98				sport/play	*Salmonella sp.*	use
				ground	*E. coli,*	none
					Campylobacter,	none
					Yersinia sp.,	none
				technical	*Listeria*	none
				use		no requirements
					—	
Belgium *VLACO*	60	40	3		*general* Eelworms	none none
Denmark	55		14			
France	60		4			
Germany	55	40	14			**(AT)**[c]:
					Salmonella senft.	none
Bio waste ordinance	60	40	7		*Plasmodoph.*	infection index:< 0.5
	[a]	40	7		*brass.*	guide value bio-test:< 8/plant
	65				*Nicotiana virus 1*	**(P):**
	[b]					none in 50 g sample
					Salmonella senft.	
Italy	55		3		*Salmonella sp.*	none in 25 g sample
					Enterobacteriaceae	< 1.0 × 10^3 UFC/g
Fertil. law					*Fecal Strptococcus*	< 1.0 × 10^3 MPN/g
748/84 modif.					*Nematodes*	none in 50 g sample
27.03.98					*Trematodes*	none in 50 g sample
					Cestodes	none in 50 g sample
The Netherlands	55		4		*Eelworms*	none
					Rhizomania virus	none
					Plasmodoph.	none
BRL K256/02					*brass.*	

[a] in vessel composting

[b] open windrow composting

[c] 2 approvals (1 in winter) for windrow composting

4.6.4 *Recommended safety guidelines*

WG 2 discussed this subject at length, and while it is probably unreasonable to expect soil improvers and growing media to be completely free of harmful bacteria, standards have been invoked as necessary to assure consumers that the risk is minimal. Testing for a wide range of pathogenic bacteria is not economically viable but microbiological analyses of “indicator organisms” will indicate the effectiveness of treatments in eliminating pathogens. *Escherichia coli* type I bacteria are used commonly in water and food bacteriology to indicate potential risks from pathogenic enteric Gram-negative bacteria and could be valuable indicators of the safety of soil improvers and growing media.

Products that claim to be treated should state treatment process and conditions. The standard is for the product and cannot address more precisely process performance conditions but only the results. This makes the choice of significant pathogens to control difficult, and good indicators are required.

Respiratory protection should be worn by production workers handling composted and other dusty materials and exhaust ventilation used to minimize exposure. Once the material is sufficiently wetted, the risk is likely to be decreased.

In domestic use, risks will be minimal if soil improvers and growing media are used in well ventilated areas, inhalation of any dust is avoided and good hygiene is practised.

Manufacturers should be aware of and comply with existing legislation, supply health and safety data sheets and give adequate guidance in the safe storage and use of their products.

4.6.4.1 *Indicator organisms*

WG 2 agreed that soil improvers and growing media should not contain detectable *Salmonella* in 25 g (method to be determined by WG 4).

Another suitable indicator has been found to be *E. coli.* Although there are various national regulations for the analysis of *E. coli* the methods currently available have been found to be problematical with highly variable results. Many methods such as the ISO method and BSI methods state that the results should be used with caution. In the light of this WG 2 was unable to conclude any reliable limits or guidance. At this stage manufacturers should state the hygiene precautions taken and WG 2 hopes that methods will be developed which are inherently more reliable.

4.7 Traumatic hazard

4.7.1 *Hazard description*

This hazard concerns with abrasion, cuts and wounds provoked by contact with sharp particles in soil improvers and growing media. Particles can be sharp portions of the product itself (splinters, debris, fibres, coarse particles) or impurities such as glass, metal debris, needles, nails and similar.

This hazard is present both in domestic and professional uses, in all phases of work that imply direct manipulation of the product. Also, eye irritation can develop following eye contact and skin irritation following contact with, non-respirable mineral wool fibres (> 5 µm diameter). While major emphasis is given to hazard to humans, the hazards are also present to other fauna, when the product is applied outdoors.

4.7.2 *Discussion of hazards*

Composted waste is the product that presents the greatest risk of sharp impurities, while organic fibres, mineral fibres, sand and other coarse abrasive materials can pose a hazard of lesion or irritation of the eye, and minor skin irritation, often connected with the dust fraction (see **5.8**).

4.7.3 *Existing regulations*

Current regulations on composted waste were evaluated by WG 2. It is important to underline that most of the regulations in force in the Member Countries do not take action specifically on this hazard, but treat it together with what in this document is classified as “impurities” such as plastic, glass metal that also cause an aesthetic hazard (are visually unattractive), and/or intervene on the granulometry of the product. Typically, a maximum allowed amount of impurities such as glass and metal of a given size is defined. An exception is found in the French Rule (NF U 44-051) that establishes an obligatory statement of the absence or presence in composted materials of pricking and cutting materials.

Applicable Community documents found are the Directive 92/59/EEC “on general product safety”, and Directive 89/656/EEC “on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace”.

4.7.4 *Recommended safety guidelines*

WG 2 agreed that safety standards relating to particle size are not effectively protective against the hazard, since smaller-sized sharps and splinters, being less visible, can present a higher risk. Limits on impurities such as plastic, glass, metal etc in composted waste are therefore considered as a necessary measure to protect principally from a hazard of different nature (see **5.11**).

Tests in use in the UK by the Consumers Association for other products (such as puncture tests on chicken legs or inflated balloons, used to determine razor blades sharpness) have been evaluated by the UK Delegation and have been deemed impractical for detecting sharps such as wires, wood splinters, glass, nails, etc. in products of interest of CEN/TC 223.

While professional (industrial) workers are protected and informed by Health and Safety Data Sheets mandated by the directive 80/1107/EEC (Protection of workers against chemical, physical and biological agents), the general public, consumer of the products in a domestic situation, should be alerted and protected against the risk. No applicable Risk (R) phrases are found in EU Directive 91/325/EEC. Therefore, materials that contain abrasives and sharps which cannot practically be removed, must be provided with a safety data sheet and/or appropriate labelling that addresses the hazard and states precautionary measures. As related by the UK delegation, in some circumstances a typical protective measure, such as wearing gloves, can actually increase the exposure of the skin to dusts and fibres. Therefore the definition of protective measures is best when left to the responsibility of the single product manufacturer.

4.8 Dust

4.8.1 *Hazard description*

The hazard is generated by the presence of airborne particulate matter. Dust is a generic term that defines particulates that are not classified otherwise. It represents a hazard via inhalation (upper respiratory irritation) of inhalable dust, eye and skin contact (minor abrasion), and penetration through open wounds (irritation) of inhalable and higher dimension particulate. Dust has also been associated with a biological hazard of allergic sensitization/reaction in sensitive individuals (see **5.6**).

Dust is mainly an occupational hazard during the manufacturing of the products and in professional uses during mixing of different substrates with creation of dust. WG 2 agreed that in a domestic situation the risk is very low.

4.8.2 *Existing regulations*

A precise EC reference to Dust particle size and limits is not available. The Directive 80/1107/EEC and derived Directive n. 88/642/EEC cover the protection of workers from the risk related to exposure to chemical, physical and biological agents at work. They also require Health and Safety Data Sheets to address risks and protective measures. Directive 89/391/EEC obliges the employer to ensure the safety and health of the worker in all aspects related with their occupation (Art. 5). A series of measures to be taken by the employer are listed in this Directive, among which are protection and information of the worker, and prevention of hazards.

4.8.3 *Discussion of hazards*

Any product that is susceptible of creating dust presents a risk of variable intensity. Although some products are dedusted at the manufacturing plant, storage and transportation can cause partial breakdown with re-creation of dust.

4.8.4 *Recommended safety guidelines*

In general, dust concentrations of above 10 mg/m^3 total inhalable, and 5 mg/m^3 respirable are considered a risk to health. Safety criteria for airborne dust are detailed in national regulations and guidelines. However, some materials could create a risk at lower concentrations. Although professional use is covered by cited regulation of industrial hygiene, information on proper handling as part of the obligatory labelling of soil improvers and growing media is deemed necessary to instruct the user to prevent dust creation and decrease his/her exposure to dust, dust explosion, minerals, and allergens.

4.9 Radiation

4.9.1 *Description of hazard*

Radiation hazard is defined as the exposure of humans, plants and the environment to radioactive sources in naturally radioactive or contaminated soil improvers and growing media. Exposure can be direct, or indirect through the food chain.

4.9.2 *Existing regulations*

The EEC Euratom Regulation 3954/87 and EEC Regulations 737/90/EEC and 598/92/EEC and their modifications regulate the maximum radioactivity in food at 370 Bq/kg (^{134}Cs and ^{137}Cs) (milk, milk products, food for babies) and 600 Bq/kg (other foods and drinks).

World Health Organisation (WHO) standards [122] on radiation from foodstuffs reflect the International Committee for Radiological Protection (ICRP) general recommended limit for radiation exposure of less than 1 mSv (long term), and of less than 5 mSv/year [123]. These limits translate into actual limit values depending on the radioisotope of concern. The only limits set so far relate to the Chernobyl accident, and were set by Sweden for commercially available foodstuffs at 300 Bq/kg based on the activity of the isotopes ^{134}Cs, ^{137}Cs, and ^{131}I, Limits on hay were also in force for a transitional period based on conversion factors of caesium from hay to milk. No limits for soils were set (Communication of Swedish expert 6.4.93).

The revised generalized derived limits for radioisotopes of strontium, iodine, caesium, plutonium, americium and curium are described in document NRPB–GS8 issued by the UK Radiological Protection Board [124].

4.9.3 *Discussion of hazards*

Inorganic materials can reflect background concentration of the site of origin. Radioactive isotopes from the Chernobyl accident can contaminate products originated in areas of fallout. There are currently no soils in Western Europe which are known to have such high concentration of radioisotopes (either from natural sources in the soils parent material, or as a result from nuclear accidents) that they are unsuitable for production of foodstuff. It is considered that there is negligible likelihood that growing media or soil improvers would have excessively high contamination. Only in the case of import of contaminated soils (e.g. peat) from polluted areas affected by the Chernobyl accident from e.g. Russia or Ukraine could there be a perceived risk. In the present climate, this scenario seems, however, highly unlikely. In any case, the available information is an insufficient basis for setting a meaningful limit.

4.9.4 *Recommended safety guidelines*

WG 2 agreed that no safety standard could be considered at the present time, given the presumed low risk and also given the lack of knowledge about contamination levels, the uptake of radioisotopes from growing media and soil improvers by plants, and risk to consumers and environment. This lack of information would make any chosen limit highly questionable.

4.10 Physicochemical

4.10.1 *Description of hazard*

Physicochemical hazard is defined as the corrosive and/or irritant effect of products on live tissues of the user and plants. Both professional and domestic uses can present a certain degree of risk. When considering hazard to users, the pH value alone may not be suitable to represent an appropriate measure of the risk. The pH is only one of many factors that determine irritant/corrosive or harmful effects to the exposed live tissue (Communication of the UK experts, 22.3.93).

Although exposure is mainly by skin and eye contact (domestic and professional), inhalation of alkaline/acidic dust can also occur as an occupational hazard. Ingestion can occur in domestic use by children or due to improper handling. Extremes of acidity or alkalinity can also be a hazard to plant health; however, tolerance and sensitivity to pH is very plant-dependent. For this aspect, the hazard is to be considered as a fitness-for-purpose issue.

4.10.2 *Discussion of hazards*

Naturally existing soil improvers and growing media have pH values that do not pose a significant risk associated to this hazard. A higher risk can be present in case of incorporation of liming agents for special purpose products. Liming agents are not in the scope of work of CEN/TC 223 and their presence is usually declared. All soil improvers and growing media, when limed or otherwise treated, can present a physico-chemical risk due to alkaline or acidic pH.

4.10.3 *Existing regulations*

In order to limit soil improvers or growing media that can be unfit for purpose, several countries regulate the range of pH acceptable in soil improvers and growing media derived from wastes.

The Directive 91/325/EEC sets the criteria for the proper classification of a product with respect to its potential danger, in terms of harmful, corrosive, irritant effects. It also gives the appropriate Risk and Advice phrases to be included on the label/package. Safety Data Sheet and/or proper labelling are required in case of materials that are classified as “dangerous” (Directive 91/155/EEC) described also in “fire”.

4.10.4 *Recommended safety guidelines*

While a statement of pH value can be required by WG 1 to inform the user of the fitness for purpose of a soil improvers and growing media, users health concerns are already covered by mentioned existing regulations.

4.11 Seeds and propagules

4.11.1 *Description of hazard*

The hazard presents itself as the presence in soil improvers and growing media of undesired viable seeds and/or propagules that can interfere with the growth of the crop, or provide aesthetic damage with decreased value of the product and produced crops.

Although it can be considered as a fitness-for-purpose issue, the control of seeds and propagules in soil improvers and growing media can also be considered as an indirect environmental and user safety issue since its control can significantly help in reducing the use of herbicides.

4.11.2 *Discussion of hazards*

Organic and naturally derived, non-treated inorganic (e.g. clay, loam, silt and dredgings) soil improvers and growing media will contain viable seeds and propagules depending on the site of origin, and of the production and purification methods. Peat producers in the UK consider, based on experience, that *Erica tetralix* and *Juncus spp.* are endemic in peat. Juncus is increasingly becoming a weed problem that needs attention.

Composted products can contain seeds/propagules from the waste of origin, however a well performed composting process appears to be satisfactorily efficient at reducing their viability.

4.11.3 *Existing regulations, standards and codes*

CEN/TC 223, WG 2 studied the national laws and standards on soil improvers and growing media in several european countries. No mention is made in these rules on weed seeds with the exception of:

- Austria's Draft compost ordinance of 10/98 requires < 3 germinating plants/l;
- Belgium's VLACO tolerates no weeds;
- Germany's RAL GZ250 (bark soil), and Biowaste ordinance set a limit of < 2 germinant seeds or sprouting plants per litre of substrate, the Biowaste ordinance also sets a germination rate for tomato seeds at < 2 %;
- Germany's RAL GZ 252 < 1 germinant seed or sprouting plant per litre of growing medium;
- France Pr U 44–551 provides for a voluntary declaration of "free of germinating seeds" for composted material and peat;
- The Netherlands' voluntary standard BRL K256/02 sets the limit to 2 germinating plants per litre of product;
- Norway's regulations on waste-derived products (Regulations concerning trade in fertilizers and soil improvers etc. Ministry of Agriculture 11 September 1996) sets a requirement of max. 2 viable seeds or propagules per litre; no viable seeds of wild oats;
- UK BS 4156 states that "undisturbed peat is relatively free from viable seeds and other plant material and from soil. Care should be taken to avoid contamination".

Table 9 summarizes process condition requirements that are aimed at reducing the biological hazard and may also be effective in inactivating seeds and propagules.

Requirements for the hygiene and quality of potting media have been set by the Netherlands' Technical Commission of the Stichting Regeling Handelspotgronden (Indelling Grondstoffen Bechijfshygriene Bedrijfsinrichtig) that are to be met by SRHP members. Media should be free from weed seeds.

There was general agreement in WG 2 that terms like "free from" or "absent" should not be used because of their difficult and controversial interpretation and that preferred phrases of "not detected" or "less than x %" should be used instead.

4.11.4 *Recommended safety guidelines*

A low or zero level of viable seeds and propagules in soil improvers and growing media will increase the overall quality of the products and can also be helpful by reducing the need for herbicide use. Although this is substantially a fitness-for-purpose issue rather than one of safety, if a medium is claimed to be "free from viable weed seeds or propagules", a provisional maximum acceptable limit is:

- < 1 seedling/litre (Growing media);
- < 3 seedling/litre (Soil improvers).

These limits are based on the provisional method described in Önorm S2023 (Analytical methods and quality control of compost, Austria 1993). If an alternative method of analysis is adopted by CEN TC 223 for standardization then these numerical limits should be reassessed. This method is based on the incubation for a total of 17 days of the substrate brought to a set conductivity level, and placed into a tray of standardized dimensions. After the incubation time, the number of seedlings is counted.

4.12 Plastic, glass, metal and other undesirable materials

4.12.1 *Description of hazard*

This hazard is represented by the presence of objects capable of causing aesthetic damage to the environment. Plastic particles create an aesthetic damage, while glass, metal and other sharp debris can cause also trauma (see **5.8**). Biodegradable natural materials such as roots and other vegetable debris in peat and bark are not considered an aesthetic hazard, but a fitness-for-purpose issue.

The exact description of the hazard is debated, because it has mostly been coupled with the traumatic hazard, and often the regulation of such contaminants has the objective of increasing the consumers acceptance of the product (composted material) rather than of protecting from specifically identified hazard of impurities released in the environment.

4.12.2 *Existing regulations, standards and codes*

Existing regulations examined by WG 2 are tabulated in Table 10.

The Dutch voluntary standard BRL K256/02 defines terms for composted products as:

“free of..”	(< 0.1 % w/w dry matter);
“almost free of...”	(0.1 – 0.5 % w/w dry matter);
“substantial amount of..”	(0.5 – 2 % w/w dry matter);
“clear content of...”	(> 2 % w/w dry matter).

4.12.3 *Discussion of hazards*

This hazard is mainly related to waste-derived products, especially composted waste. Peat can contain contaminants such as roots, wood, woodsticks. WG 1 has set a limit of 20 % wood in bark as a fitness-for-purpose requirement. However, the presence of roots, wood, woodsticks is not considered a safety issue, and given their degradability, not even a relevant aesthetic hazard.

4.12.4 *Recommended safety guidelines*

A provisional limit of 0.5 % in weight of glass, metal and plastic contaminants larger than 2 mm (in dry material), and of 5 % stone dry weight has been agreed upon by WG 2, pending WG 4’s development of a suitable analytical method. Materials which are added intentionally, that do not have deleterious effect, are by definition not contaminants and should be identified in the product label according to WG 1 decisions.

4.13 Eutrophication agents

4.13.1 *Description of hazard*

This is a hazard to the environment caused by the addition of nutrients (nitrogen, phosphates) into water bodies due to excessive or improper use of soil improvers and growing media. Improper use includes also improper disposal, and use in unrestricted areas at short distance from water bodies. Eutrophication risk is strongly dependent on local conditions.

4.13.2 *Discussion of hazards*

The risk is related to the use of organic soil improvers. Unlike fertilizers, soil improvers (except waste-derived such as animal manure and sewage sludge, and intentionally fortified products) usually do not contain significant amounts of readily soluble nutrients. Growing media are usually added with balanced amounts of fertilizers to sustain the growth of plants, which are depleted by plant uptake during their use.

Improper use of any product added with nitrogen and phosphate can contribute to water eutrophication. The chemical form of nitrogen and phosphate can change the intensity of the risk.

4.13.3 *Existing regulations*

The EEC Directive 91/676/EEC, also known as the Nitrate Directive regulates the addition of nitrates in vulnerable areas when fertilizers are used.

The North Sea treaty set a target 50 % reduction of input of nutrients between 1985 and 1995 into areas where inputs are likely to cause pollution.

The Netherlands (Dutch Royal Decree, Quality and use of Remaining Organic Fertilisers) set a maximum amount of phosphate derived from manure, sewage sludge, and/or compost, that may be applied to land in kg/ha/year of P_2O_5 according to the type of land use and year. The total content of N and P_2O_5 should be stated.

The German Fertilizer Ordinance, in close connection with the EC Nitrate Directive, prohibits soil improvers that contain more than 0.5 % N, 0.3 % P_2O_5, and 0.5 % K_2O.

Norway regulation (The Requirement For Care) addresses storage requirements: storage should be at least 150 m from drinking water, and 50 m from all other water bodies.

Other sewage sludge national rules similarly set minimum distances from wells and water bodies to be respected while applying sludge to agricultural land.

Table 10 — National limits on various impurities in composted materials, % dry weight

Country		**Impurities**	**∅ Mesh size**	**Limit values** % d.m. (m/m)	
Austria	*Draft compost ordinance 10/98*	total; agriculture	2 mm	≤ 0.5 %	
		total; land reclamation	> 2 mm	< 1 %	
		total; technical use	> 2 mm	< 2 %	
		plastics; agriculture	> 2 mm	< 0.2 %	
		plastics; land reclamation	> 2 mm	< 0.4 %	
		plastics; technical use	> 2 mm	< 1 %	
		plastics; agric, excl. arable land	> 20 mm	< 0.02 %	
		plastics; technical use	> 20 mm	< 0.2 %	
		metals; agriculture	—	< 0.2 %	
Austria *ON S2200*		glass, metal, plastic	> 2 mm	0.5	
		glass	> 2 mm	2	
		plastic	> 2 mm	0.2	
		plastic	> 20 mm	0	
Austria *ON S2022*		glass	> 2 mm	2	
		plastic	> 4 mm	4	
		ferrous metals	> 6.3 mm	0	
		non ferrous metals	> 6.3 mm	0.5	
Belgium	*Flanders*	total	> 2 mm	< 0.5 %	
		stones	> 5 mm	< 2 %	
Finland	*Fertil. Law*	total	—	< 0.5 %	
France *AFNOR [125]*		glass, plastic, metal	> 2 mm	< 20–35	
		plastic	> 4 mm	0.5–1.2	
France	*NF U 44-051*			(A)	(B)
		plastics	> 5 mm	< 0.5 %	< 1.2 %
		heavy materials		< 6 %	< 12 %
		total inert material		< 20 %	< 35 %
Germany *Bio waste ordinance*		glass, plastics, metal	> 2 mm	< 0.5 %	
		stones	> 5 mm	< 5 %	
Germany *RAL GZ251*		glass, metal, plastic	> 2 mm	0.5	
		stones	> 5 mm	5	
Italy *Fertil. law 748/84/mod. 27.03.98*		plastics	< 3.33 mm	< 0.45 %.	
		plastics	> 3.33 < 10	< 0.05 %.	
		other inert material	< 3.33 mm	< 0.9 %	
The Netherlands *BRL K256/02*		glass, metal, plastic	> 2 mm	0.5	
		glass	> 16 mm	0	
		stones	> 5 mm	3	
The Netherlands	*BOOM*	total	> 2 mm	< 0.2 %	
		glass	> 2 mm	< 0.2 %	
		glass	> 16 mm	0	
		stones	> 5 mm	< 2 %	
Norway (*Regulations concerning trade... 11.9.96*)		impurities	> 4 mm	< 0.5	
Spain *Ministerial Order 12731*		plastic and other inerts	> 10 mm	0	

4.13.4 *Recommended safety guidelines*

An obligatory declaration of the soil improvers' total nitrogen (Kjeldahl) is necessary to allow the user to take the appropriate measures to comply with existing EEC and local rules, and to use the product in a sensible manner. A declaration of the total phosphorus content is also necessary to market products in countries that, to protect local conditions, regulate phosphate loading of soils.

Growing media are exempt from this safety requirement since their nitrogen and phosphorus content is usually depleted by the crop, and they are less likely to be used in unconfined situations.

Other additional information on nitrogen and phosphorus content may be written in the voluntary (optional) part of the label.

The document CEN/TC223 Report "Soil improvers and Growing media — Labelling, specifications and product schedules" (CR 13456 WI 00223076) places method of use/application among the obligatory labelling requirements, and additional information on how to prevent eutrophication may be addressed in this part of the label.

4.14 Gaseous emission

4.14.1 *Description of hazard*

This hazard is defined as the emission into the atmosphere of toxic or harmful compounds. This hazard is mostly related to manufacturing phases of soil improvers and growing media. Gaseous emission can develop in case of fire during combustion of organic and synthetic products, and Volatile Organic Compounds emissions have been reported during municipal solid waste sorting and composting operations.

Greenhouse gases (CO_2, methane) generation is related to mineralization of organic fraction in organic products. Although a significant amount of greenhouse gases are generated from agricultural sources, its control is not within the scope of work of CEN/TC 223. Similarly, ammonia emissions from animal manure are outside TC 223's scope of work.

Odour can develop mainly during preparation, but also during the storage and application of organic soil improvers and growing media. While rarely a direct threat to health, odour can represent a definite nuisance to the exposed population. Principal products that are present in the odorous fraction are sulphur compounds, fatty acids, ammonium compounds and amines, and terpenes.

4.14.2 *Discussion of hazards*

No gaseous emission are associated with inorganic soil improvers and growing media. Organic products can develop odour during manufacturing (composting), storage and application.

In the case of combustion, organic products typically generate products not different from naturally burning wood, while the combustion synthetic products can generate noxious or toxic fumes. Reactions due to incompatibility of synthetic products with pesticides can generate gaseous emissions.

While traces of residual volatile monomers can develop from synthetic products (see organic contaminants hazard), no precise information was obtained that better quantifies this occurrence.

4.14.3 *Recommended safety guidelines*

While no safety standard is deemed advisable at this time, risks related to potential gaseous emission by combustion or chemical reaction can be decreased by implementing the proper rules (see *Fire hazard **5.1***.). To minimize odour related concerns it is recommended that manufacturers include odour control measures when laying down use direction for potentially odorous products.

4.15 Phytotoxic factors

4.15.1 *Description of hazard*

The hazard is generated by the presence in soil improvers and growing media of elements or compounds that can induce toxicity in the plant grown in the substrate. Potential causes of phytotoxicity are excessive salinity, PTEs, herbicides and other organic contaminants, degradation or fermentation by-products, root excreta. Some of the phytotoxic factors (e.g.: salinity) are extremely dependent on plant sensitivity, therefore the definition of safety levels interferes drastically with issues pertinent to fitness-for-purpose, and as such they have been excluded from the work of WG 2. Nutrient immobilization deriving from unbalanced C/N ratio or other factors is likewise not considered a phytotoxic factor.

Toxicity to plants can also be induced by inorganic and organic contaminants previously described. This section, however, relates specifically to other toxic components that are unknown or whose analytical determination via chemical/physical methods is economically or technically impossible, or whose toxicity is induced by synergistic effect of two or more simultaneous factors.

Identification of unspecified phytotoxic factors mainly relies on the adoption of bioassays that use germinating seeds, vegetating test-plants, algae, or bioluminescent bacteria (the latter is a non plant-specific toxicity bioassay, see Organic contaminants, **5.4**.). Several tests aim at evaluating composted material maturity and stability by measuring its effects on plant growth and self-heating characteristics [126] [127].

4.15.2 *Existing regulations*

National regulations address phytotoxicity in composted material and bark products. France gives a test method, the active vegetal coal method, based on Bouhot (1982) [128]. The Netherlands propose a root elongation test (method is not available yet) with summer barley. Austria has developed a method for plant compatibility for composted products that uses cress and timothy [129]. Italy has developed a test on the root elongation of *Lepidium sativum* (cress) for the determination of composted product maturity [130].

The most pertinent International Standard Reference is ISO/TC 190, Draft Standard DIS 11269-1: *Soil quality — Determination of the effects of pollutants on soil flora: Part 1: method for measurement of inhibition of root growth*. This test aims at determining toxic effects to plants. The method is defined to be applicable to all soils, soil-forming materials, waste residues or chemicals which can be applied to soil except where the contaminant is highly volatile or only affects photosynthesis (from Document's scope).

Directive 91/325/EEC, Appendix VI mentions criteria for the determination of toxicity to flora, that leaves the method to be developed at a later date.

4.15.3 *Discussion of hazards*

All soil improvers and growing media are susceptible to phytotoxicity.

4.15.4 *Recommended safety guidelines*

A statement of the actual analytical range of values is obligatory to inform the user of the characteristic of the product for fitness-for-purpose related parameters of pH and conductivity.

WG 2 has concluded that there is a need for a phytotoxicity test that protects against otherwise unquantifiable toxics. When developing the test or tests, the following criteria should be considered:

a) It should allow for the determination of phytotoxic effects that are difficult or too expensive to quantify via chemical analysis.

b) It should be fit for the matrices of which soil improvers and growing media are composed.

c) It should not confuse lack of nutrients with phytotoxicity.

d) It should not be negatively affected by the presence of high ammonium salts and high salinity levels (as often recorded in case of germination tests applied to soil improvers).

e) It should be able to be routinely performed at an acceptable cost.

f) It should respond positively to the presence of phytotoxic unwanted herbicides and other organic man-made chemicals, including monomers of polymerized soil improvers/growing media.

g) It should respond positively to fermentation products that can indicate a bad composting process or a bad stabilization of the composted material.

Because of the different products matrices more than one method may necessary.

4.16 Plant pathogens

4.16.1 *Hazard description*

Potential presence in the soil improvers and growing media of infectious plant disease agents, microbial, viral, fungi, insects, nematodes. A list of potential parasites and their analysis is in documents [131] [132].

4.16.2 *Discussion of hazards*

All soil improvers and growing media present a risk of carrying plant pathogens. Composting and other treatments (especially high temperatures) seems to efficiently reduce the risk.

4.16.3 *Existing regulations*

Directive 77/93/EEC and modifications establish protective measures against the introduction into the Member States of harmful organisms. The EEC Directives n. 92/10/EEC and 92/103/EEC modify the Appendixes containing the technical requirements and the pathogens for which control measures are necessary.

The European and Mediterranean Plant Protection Organisation (EPPO) has issued specific quarantine requirements and methods [133].

The Dutch delegation proposed that no plant pathogen be allowed in peat, and this requirement be fulfilled by setting required limits on the origin of the peat (should be from virgin bogs). Analytical methods for parasite fungi in the soil are described elsewhere [134]. The CEN Report "Soil improvers & Growing media — Labelling, specifications and product schedules" recommends declaration of origin as an optional labelling requirement.

In Spain, the Ministerial Order 12731 of 28 May 1998 (BOE 2 June 1998) establishes that organic amendments, including composted material, must comply with Directives 77/93/EC, 91/683/EC, 92/76/EC, 92/103/EC, AND 92/98/EC as it is stated in Royal Decree 2071/1993 of 26 November 1993 (BOE 16 December 1993).

4.16.4 ***Recommended safety guidelines***

Soil improvers and growing media should conform to existing directives and rules, which address absence of plant pathogens in soil adhering to roots, in container substrates, and in wood materials such as bark and wood.

Additional information of absence of specific pathogens may be placed in the voluntary part of the label (as a Fitness-for-purpose quality information), provided that analytical data or other proof is available and verifiable to support the statement. Analytical methods used should be accepted by the EEC, CEN or EPPO and should be indicated.

5 Summary of hazards and corresponding recommended actions

Table 11 summarizes the hazards identified in this report, using a practical method of classification. The actions to be undertaken by TC 223, manufacturers, users and regulators, deemed necessary by WG 2 in order to achieve the necessary product safety are also listed here.

Table 11 — Hazards and corresponding recommended actions[a]

Section	Hazard due to	Recommended action[b]
5.1	Fire	None
5.2	Dust explosion	None, see also dust
5.3	Potentially Toxic Elements (PTEs)	See this document
5.4	Organic contaminants and pollutants	See this document
5.5	Mineral constituents	Obligatory labelling, guidance for safe use
5.6	Biological hazard	See this document
5.7	Microbial by-products, allergens	See this document
5.8	Physical — traumatic	Obligatory labelling (safe handling)
5.9	Dust	Obligatory labelling (safe handling)
5.10	Physical — radiation	None
5.11	Physico — chemical (pH)	Obligatory statement of range
5.12	Seeds — propagules	Germination testing
5.13	Plastic, glass, metal, stones[c]	Compositional analysis
5.14	Eutrophication agents	Obligatory declaration of total Nitrogen value (other declarations voluntary), for SI only
5.15	Gaseous emissions	None
5.16	Phytotoxic factors	Obligatory statement of pH and conductivity ranges, Phytotoxicity testing
5.17	Plant pathogens	None (compliance to existing rules)

NOTES

[a] Safe handling includes specifying of the most appropriate Personal Protective Equipment, this is the responsibility of the manufacturer

[b] In addition to any already existing pertinent rules and regulations.

[c] Materials which are added intentionally, that do not have deleterious effect, are by definition not impurities.

Annex A (informative) Background

WG 2 started its activities during January 1992, and has since then held seven meetings during which experts nominated by CEN Member Countries discussed the approach to take in the development of the workplan, and the issues in the agenda. They also evaluated the method for the selection of the proposed safety measures and gathered and evaluated scientific and regulatory data. Composted material safety issues, and particularly inorganic contaminants issues, were dealt with for a limited period of time by an "ad hoc group", given the enormous amount of data, issues, and need for in-depth discussion that was generated on this specific subject.

The general principles described in the ISO/IEC Guide 51, were adopted, and a workplan was developed that included them in working priorities.

With the intent of achieving a common area of discussion and allowing all the participating experts to refer to commonly agreed concepts, common uses and reasonably foreseeable misuses were reviewed during the early meetings, and a list of general categories of hazards was then defined, and applied to three main areas (users, environment, plants). Products were then examined, and divided into homogeneous groups according to their composition and origin, with the purpose of evaluating hazards and safety issues in a more uniform way across the wide range of products that are the object of CEN/TC 223.

Once a matrix of product groups and hazards was delineated, an extensive search of existing regulations was conducted, in which each national expert contributed with his/her country's laws, rules, codes of practice, voluntary standards, and any other document that in any case concerned the topics of safety in soil improvers, growing media, and close products. The search was also extended to EU directives and regulations, and ISO standards already existing on specific subjects. Rules and regulations are constantly changing and the information reported in this report is based on the information that was available at the time of writing. The user should be aware that rules and regulations may have changed.

It was decided that subjects (hazards and/or products) already regulated by pre-existing International Standards and regulations would not be the object of further study by WG 2, which, therefore, concentrated its efforts in those areas where no International Standard or rule was present. A major problem encountered was however the presence of several national documents in the field of environmental regulations, which address environmental protection in ways often very different in approach and policy among countries. While a general desire was present among the participating experts at the beginning of the WG 2 activities to harmonize those approaches, it became evident as the works progressed that such harmonization is extremely difficult, and beyond the power and scope of WG 2. An example of this situation is the case of Potentially Toxic Elements, for which many Countries have adopted stringent regulations related to composted materials and sewage sludge for the protection of the soil and the definition of acceptable limits of pollutants. Such limits are derived in ways that vary among countries, according to local soil conditions, uses and practices, and broader scoped policies on the management of land and waste. It became quite clear as the work progressed that a standardization of these aspects was not only extremely arduous to achieve, but also inappropriate in principle.

The issues considered within this document often relate to soil quality as the products are likely to be applied to land either in use or during disposal. Soil quality limits are often seen as the responsibility of national governments and therefore outside of the scope of CEN. However, as soil improvers are intended to be applied to the soil, the sustainable use of the soil should be taken into account when assessing safety. In addition, manufacturers need to ensure that their products are suitable for sale and do not pose unacceptable risks to their customers or the environment. It was therefore decided that instead of proposing safety measures WG 2 would generate a document reporting on the work done and its findings.

Some of the hazards identified at the beginning of the work were later identified as a fitness for purpose issues and therefore deleted from the agenda. This case was particularly frequent when considering aspects related to effects on plants, since plant tolerance and requirements for certain conditions (such as salinity, for example) can vary dramatically among species and thus are more correctly dealt with under fitness for purpose criteria. The typical recommendation of WG 2 in this case is for the manufacturer to indicate the actual values of the parameter of concern in the product label, and to indicate the optimal application of the product.

Where regulations and rules were not present, experts contributed with scientific data. Another problem was the lack of information on analytical methods and the difficulty of relating available data to them. The area of organic contaminants was dramatically affected by this problem, to the point that WG 2 deemed premature the proposal of quantitative standards until data related to standardized or at least defined analytical methods are available as a basis for scientifically sound standards.

Annex B (informative)
Metal limits in soil improvers and growing media note for discussion

P A Wheeler
Warren Spring Laboratory, Stevenage, UK

1 Introduction

At the last meeting of CEN 223/WG2 in Milan, 6–7 May 1993 it was decided to a risk based approach to the establishment of the metal limits. As discussed the limit values in the three classes of use would be established as follows

Class I	Domestic use This would be based on the recommended intake values from WHO and elsewhere to represent direct ingestion.
Class II	Professional food use This would be established using the criteria of the final soil concentration should not exceed those laid down in the sewage sludge directive and assuming that the total amount added would be 50 % to the soil. (above this amount it would be considered a growing medium).
Class III	Professional non-food use This limit would be determined by national regulation.

To aid the discussion of the limit values presented here worked examples of the calculations to determine these limits are provided along with the supporting data. Much of the data comes from the USEPA or UK studies (background soil concentrations, national diet etc) and thus may need slight changes if these national characteristics are markedly different in other European countries. All the relevant data is supplied here so that if more up to date data is available then the figures can be revised. These calculations also include the micronutrients copper and zinc, however it had been agreed that the limits would not be needed to be applied in precisely the same way as there are required minimum values for these metals in all soil improvers and growing media. It should be pointed out that this is just an illustration of the methodology and these calculations should be repeated by experts in these subjects if they are to be formally considered.

These values have been calculated using bio-availabilities derived for soil-like materials. Other materials that are significantly different from this in terms of organic matter, pH, etc such as the inorganic materials (pearlite, vermiculite) will require the values to be reworked using the appropriate bio-availability factors.

Additionally materials with significantly different density will also need to be recalculated as the zone of uptake within the soil or pot is essentially determined by the volume enclosed by the roots of the plant. Thus with materials with low density this root volume would hold less mass of soil/growing media and correspondingly a lower total amount of toxic element than a soil/growing media with the same concentration (expressed on a weight basis) but higher density. The greater amount of toxic element may influence the uptake of the element and hence will require a different bio-availability factor.

2 Class III professional non-food use

As was stated earlier this will be based on national regulation. In the UK there is no national regulation and it is likely that the regulations for sewage sludge application would be used as a guideline.

3 Class II Professional food use

This limit is to be based on the “safe” soil levels given in the sewage sludge directive and then assuming a 50 % maximum addition of the soil improver product. The limit in the soil improver is calculated such that when accounting for the average existing soil concentration the final soil concentration does not exceed the levels in the sewage sludge directive, this is calculated by the following equation:—

$$L_{si} = \frac{L_{soil} - 0.5C_{soil}}{0.5}$$

where

L_{si} limit concentration in soil improver

L_{soil} limit concentration for soil from sewage sludge directive

C_{soil} background concentration in soil (national average)

Table 1 lists the average soil concentrations for the metals of concern of WG2. In addition this table lists the allowable soil concentrations from the sewage sludge directive.

Table 1 — Soil concentrations in the UK

		average soil concentration in UK µg/g DM	Allowable soil concentration from sewage sludge directive µg/g DM	
			lower limit	upper limit
Cadmium	Cd	0.9	1	3
Chromium	Cr	38	100	150
Copper	Cu	18	50	140
Lead	Pb	0.1	1	1.5
Nickel	Ni	21	30	75
Mercury	Hg	48	50	300
Zinc	Zn	85	150	300

Using these values and an assumed dilution of the added material of 50 % the following limit values can be calculated using cadmium as an example.

$(0.5 \times 0.9) \quad + \quad (0.5 \times L) \quad = \quad 1$

from soil from improver soil limit

Using this equation and the data in Table 1 gives the limit as 1.1 µg/g DM, similarly solving for the upper soil limit (3 µg/g DM) gives a limit value of 5.1 µg/g DM, following the same principals the following values can be calculated for the other metals and are given in Table 2.

Table 2 — Limit values for soil improvers for class II uses

		Limit value calculated on basis of sewage sludge soil limits and average UK soil concentrations µg/g DM	
		using lower directive limit	using upper directive limit
Cadmium	Cd	1.1	5.1
Chromium	Cr	162	262
Copper	Cu	82	262
Lead	Pb	1.9	2.9
Nickel	Ni	39	129
Mercury	Hg	52	552
Zinc	Zn	215	515

As discussed these would apply to class II soil improvement applications (professional food use). For growing media the 100 % application rate would result in the use of the soil level from the sludge directive. However, growing media applications could be more complicated as the medium is subject to significantly different conditions to that of soil, for example, water conditions, root exploitation etc and thus the use of the sewage sludge soil limits can only be a provisional measure.

4 Class I domestic use

As was discussed earlier the class I levels are to be considered on the basis of direct ingestion. This route can give rise to two forms of toxicity, acute and chronic. The acute toxicity has used the basis of as 20 kg child consuming 500 g of the product within a relatively short period. Chronic toxicity is based on the long term exposure and accounts for effects such as accumulation and retention within the body, etc. The basis for the chronic calculation is an ingestion rate of 500 mg per day which is taken from studies of *pica* children. This therefore assumes a lifetime exposure to ingestion of nearly 13 kg of the product. Recommended daily intake values of various metal are published by bodies such as WHO and these are used where available.

4.1 Cadmium

4.1.1 *Acute toxicity*

Acute toxicity level LDL_0 (lowest human lethal dose) for unspecified ingestion of cadmium is 15 mg/kg and thus the lethal dose for a 20 kg child would be 300 mg[1]. Thus assuming 500 g dose of product limit would be 600 µg/g DM. Cadmium chloride has a LD_{50} 5 mg/kg (oral, mouse) which result in a limiting concentration of 10 µg/g DM.

4.1.2 *Chronic toxicity*

USEPA[2] determined that 150 µg/day was a safe dosage from all sources. IPCS showed that health effects were shown at lifetime intakes of 140 – 250 µg/day.

Very heavy smokers (3 packs a day) can receive approximately 75 µg/day, thus the intake from all food, air and water sources should be less than 75 µg/day.

WHO have a recommended maximum daily intake of 57 – 71 µg/day[3].

Studies of background sources of Cd in the environment have been calculated to be

- for water at 2 µg/l adult consumption is 2 l/day and thus total of 4 µg/day
- average air concentration is .007 µg/m^3 with a respiration rate of 23 m^3/day adult and thus intake from the air is 0.161 µg/day for adults.
- food intakes are more complicated as it is dependant of diet but using the USEPA study and thus US diet the average uptake has been calculated to be 2.9 µg/day for adults.

Thus total intake from background sources is 7.1 µg/day. Now assuming a consumption rate of 500 mg/day of soil and an allowable additional dosage of 49.9 (57 – 7.1) µg/day the safe concentration would be 99.8 μg/g DM.

4.2 Copper

4.2.1 *Acute toxicity*

Figures available[1] for the most toxic forms by oral ingestion are:

copper acetoarsenite	LD_{50} (rats, oral) 22 mg/kg
copper chloride	LD_{50} (guinea pig, oral) 31 mg/kg

Thus to protect a 20 kg child when eating 500 g dose the limiting concentration should be 880 – 1 240 µg/g DM.

4.2.2 *Chronic toxicity*

No information could be found on limits of maximum amounts of copper in the diet and more concern was about reaching target minimums. WHO suggested that minimum intake of copper should be 2 mg/day, whilst in the UK the average was approximately 1.8 mg/day. The codex alemtarius commission has set a limit of 0.5 mg/kg.day which would be 35 mg/day for an adult. Using this limit and the 500 mg per day average consumption the limit in the product should be 70 000 µg/g DM, well above any fitness for use limit.

4.3 Chromium

4.3.1 *Acute toxicity*

No oral toxicity information has been found but the following subcutaneous (scu) and intravenous (iv) figures have been found for chromium II and VI compounds

Chromium VI oxychloride	scu mouse	LDL_0 5.5 mg/kg
Chromium III sulphate	iv mouse	LDL_0 85 mg/kg

Using the 500 g ingestion criteria the limit for Chrome VI would be 220 µg/g DM and chromium III would be 3 400 µg/g DM.

4.3.2 *Chronic toxicity*

WHO have stated that normal intake of this metal 50–200 µg/day and state that this coincides with the dietary requirement. The WHO state that chronic effects have not been seen apart from workers in ferrochrome factories exposed to atmospheric chrome VI. The main concern was related to the deficiency of chrome in diet of malnourished children.[4]

Using the assumption that the safe limit is double the normal intake of 50 – 200 µg/day then this will allow 50–200 µg/day to come from direct ingestion. Thus this gives a limit of 100 – 400 µg/g DM in the soil improver or growing medium.

4.4 Nickel

4.4.1 *Acute toxicity*

The most appropriate toxicity level found is for nickel metal with an LDL_0 5 mg/kg for oral ingestion by pigs, this will result in a limit for 20 kg child consuming 500 g of product being 200 µg/g DM.

4.4.2 *Chronic toxicity*

No defined limit on daily intake of nickel has been identified. However normal intake estimated to be in the range 100 – 800 µg/day with the majority in the range 100 – 200 µg/day. up to 100 µg/day can come from cooking utensils. Making the assumption that 800 µg/day is the “safe” limit and 200 µg/day comes from food and a further 100 µg/day from cookware, thus 500 µg/day is the allowable additional intake. Using this assumption the concentration in the compost must not exceed 1 000 µg/g DM.

4.5 Lead

4.5.1 *Acute toxicity*

The most stringent lead toxicity limit found is for tetraethyl lead LDL_0 1.5 mg/kg (human). Using the standard conditions the limit in the product is 60 µg/g DM. However it must be remembered that in a compost material little if any of the lead present will be in this form and thus this limit may well be overly stringent other compounds such as the oxide, nitrates and cyanide etc have lethal doses in the range 100 – 500 mg/kg which would result in limit values significantly higher eg over 4 000 µg/g DM.

4.5.2 *Chronic toxicity*

WHO acceptable daily intake limit is 400 – 500 µg/day. In the UK dietary intake of 200 – 250 µg/day has been measured. Thus using these figures the allowable additional intake from regular ingestion of the product is greater than 150 µg/day. Using the assumption discussed above this would result in a safety limit of 300 µg/g DM.

4.6 Mercury

4.6.1 *Acute Toxicity*

Mercury II nitrate. LD_{50} 8 mg/kg (intraperitoneal, mouse)[1]. The safe limit assuming a 500 g dose for a 20 kg child is 320 µg/g DM.

4.6.2 *Chronic toxicity*

The WHO/FAO report stated that a safe dose of mercury was 0.3 mg/week (42 µg/day), USEPA study assumed a safety factor of 21 µg/day. Normal daily intake from background sources etc is approximately 6 µg/day thus safe additional dosage from direct ingestion would be 15 – 36 µg/day. Assuming a 500 mg/day ingestion rate in the same way as the other metals, the limit concentration in the compost is 30 – 71 µg/g DM.

4.7 Zinc

4.7.1 *Acute toxicity*

The highest toxicity level identified for oral intake is for Zinc Phosphide LDL_0 20 mg/kg (woman)[1]. Thus using this level for the 20 kg child the concentration limit would be 800 µg/g DM.

4.7.2 *Chronic toxicity*

WHO and codex alemtarius commission have not set levels to limitation as they stated that there was a wide safety margin between the normal intake levels from food and other background and the levels at which toxic effects could be observed. They stated that certain groups such as vegetarians could possibly be affected by a deficiency of zinc. Therefore no limit can be established via this method.

5 Toxicity via food chain

Although it was agreed to base class 1 product limits on the effects of direct ingestion, this has provided figures for most of the metals but the data is incomplete. An alternative approach can be used to provide rational limits which is based on the implications of applied metals on the concentration of metals in a food crop grown using it. The limit can be calculated by evaluating an average uptake factor for plants and then comparing this to the regulated limit concentrations in the average food grown on the soil. The average values must be calculated by using the proportion of foods within the direct of the population rather than specific plants which may not represent the range of foods that are normally eaten.

This route applies to domestic gardeners who grow **all** their vegetables and fruit on land treated with maximum amounts of soil improver. This is a highly unlikely condition and must represent the extreme case of the most exposed individual.

National acceptable limits of metals in foods are reproduced in the attached pages as in the relevant part of the UK national dietary survey and the USEPA uptake factors for various plant groups.

To calculate the limiting concentration in the soil improver or growing media, the limit value is calculated by the following equation.

$$L_{gm} = \frac{L_{food}}{f_{uptake}}$$

where

L_{gm}	Limit concentration in growing media
L_{food}	Limit concentration in food
L_{uptake}	Uptake factor for metal in plants (conc in plant tissue/conc in soil).

For soil improvers assuming 50 % maximum application rate the application rate is modified thus:—

$$L_{si} = \frac{\frac{L_{food}}{f_{uptake}} - 0.5C_{soil}}{0.5}$$

where

L_{si}	Limit concentration in soil improver
C_{soil}	Background soil level.

From the UK survey of food consumption and purchase the proportion of the various food groups is shown in Table 3.

Table 3 — Results of UK national food survey

	Consumption g/person·week		distribution (%)	distribution of "homegrown" crops
Potatoes	1 096		12.3	24.0
Leafy green veg	276		3.1	6.1
Legumes dried	9		0.1	0.2
Legumes non-dried	246		2.8	5.4
Root veg	347		3.9	7.6
Fruits	1 075		12.0	23.6
Cereals	1 510		16.9	33.1
Other products	2 047		22.9	nhg
milk (1)	2 182	(2.182)	24.5	nhg
eggs (nos)	133	(2.21)	1.5	nhg
Total	8,932		100.0	100.0

nhg = not "homegrown".

Combining these data with the food limit values from the national regulations, a weighted average can be calculated as shown in Table 4.

Table 4 — Calculation for average food limit value for cadmium

	Limit value from regulations (most stringent of German, Dutch and UK limits) µg/g DM	Distribution (%)	Average food limit µg/g DM
Potatoes	0.1	24.0	0.024
Leafy green veg	0.1	6.1	0.006
Legumes dried	0.1	0.2	0.000
Legumes non-dried	0.1	5.4	0.005
Root veg	0.1	7.6	0.008
Fruits	0.03	23.6	0.007
Cereals	0.1	33.1	0.033
Total			0.083

Using the same procedure the average plant uptake factor can be calculated using the uptake factors published by the USEPA. It should be noted that these uptake factors are based on sewage sludge applications, uptake factors derived from experiments using metals applied as salts can achieve much higher values although these may not be representative of those in the field as metal availabilities are very different depending upon the chemical species. If factors from experiments using other materials such as peat, municipal waste derived compost etc are available then these can be included.

Table 5 — Calculation of the average uptake factor for cadmium

	Uptake factor $\frac{\mu g/g\ DM\ plant}{\mu g/g\ DM\ soil}$	Distribution (%)	Average food limit µg/g DM
Potatoes	0.03	24.0	0.007
Leafy green veg	0.43	6.1	0.026
Legumes dried	0.01	0.2	0.000
Legumes non-dried	0.01	5.4	0.001
Root veg	0.22	7.6	0.017
Fruits	0.05	23.6	0.012
Cereals	0.016	33.1	0.005
Total			0.068

Thus, inserting the calculated values into the equations for the soil improver and growing media limit values:

L_{food} is 0.083 µg/g DM
f_{uptake} is 0.068
C_{soil} is 0.9 µg/g DM

Thus for cadmium,

L_{gm} = 1.2 µg/g DM
L_{si} = 1.5 µg/g DM

Continuing these calculations for the other metals of concern are listed in Table 6.

Table 6 — Limit values for soil improvers and growing media on the basis of food chain intake

Metal		L_{food} µg/g DM	f_{uptake}	C_{soil} µg/g DM	L_{gm} µg/g DM	L_{si} µg/g DM
Cadmium	Cd	0.08	0.07	0.9	1.2	1.5
Chromium	Cr	nd	nd	38		
Copper	Cu	20	0.04	18	500	982
Lead	Pb	0.31	0.0024	48	129	210
Nickel	Ni	nd	0.10	21		
Mercury	Hg	0.02	.0037	0.1	5.4	10.7
Zinc	Zn	50	0.09	85	556	1 027
nd not determined due to lack of data.						

6 Conclusion

Given the three modes of ingestion of heavy metals and the limits that can be calculated from various sources, the combined limits for each metal are given in Table 7. The values for copper and zinc have been calculated here, but due to the requirements of these elements as micronutrients, a fitness for use criteria would apply resulting in minimum values as well. These minimum values in some cases will be above the limit values quoted in Table 7. This is a result of the limits having been calculated on very broad simplifications which, in general, have vastly over-estimated the risks involved and hence relaxation of the limits in this way is unlikely to affect the safety of the product. The values in Table 7 are shaded to reflect this.

Table 7 — Limit values (in µ/g DM calculated for soil improvers and growing media

		Class III Professional non-food use		Class II Professional		Class 1 Domestic			
		SI	GM	SI	GM	Acute toxicity	Chronic toxicity	Food intake basis	
								SI	GM
Cadmium	Cd	*	*	1.1–5.5	1–3	10	100	1.5	1.2
Chromium	Cr	*	*	162–262	100–150	220 (VI) 3 400 (III)	100–400	nd	nd
Copper	Cu	*	*	82–262	50–140	880–1 240	70 000	982	500
Lead	Pb	*	*	52–552	50–300	60–4 000	300	210	129
Nickel	Ni	*	*	39–129	30–75	200	1 000	nd	nd
Mercury	Hg	*	*	1.9–2.9	1–3	320	30–71	10.7	5.4
Zinc	Zn	*	*	215–515	150–300	800	nd	1 027	556

* refer to national regulations

nd not determined due to lack of data.

References

1 Department of the Environment, “Waste management paper no 23. Special waste: a technical memorandum providing guidance on their definition”, HMSO, London, 1981, ISBN 0 11 751555 8.

2 US Environmental Protection Agency, “Technical support document — land application and distribution and marketing of sewage sludge”, report No PB89-136576, US Dept of Commerce, NTIS, Springfield VA, 1988.

3 “Evaluation of certain food additives and the contaminants mercury, lead and cadmium. 16th report of the joint FAO/WHO expert committee on food additives”, FAO nutrition meeting report series No. 51, WHO Technical report series No. 505 (1972) Geneva.

4 IPCS International Programme on Chemical Safety, “Environmental Health Criteria 61. Chromium”, WHO, Geneva 1988.

Annex C (informative)
Heavy metal limits in soil improvers: discussion guidelines

The following notes concerning safety standards for heavy metal limits in soil improvers for general use (food, non-food, professional, household) are based on the recent discussion within CEN/TC223/WG 2 and were formulated in a framework of a scientific expert hearing in Vienna.

1 Introduction

The main factor that must be addressed in limiting heavy metals in the environment is their ecotoxic impact. Due to the fact that organic soil improvers and fertilizers in general perform higher heavy metal contamination than the soil, an accumulation at least within the uppermost 20 cm of the soil may occur. Internationally heavy metal limits are based on acid extraction (aqua regia: $HNO_3 : HCl = 3 : 1$). Today it is well proven that the correlation to mobilisation and availability of heavy metals as well as the uptake rate by plants is unsatisfactory.

The soil represents a dynamic equilibrium. The introduction of soil properties that are relevant for heavy metal dynamics for an ecological and sustainable risk evaluation is an essential approach when setting standards for the safe application of contaminated soil improvers.

First, the paper presents several scenaria for heavy metal accumulation based on the recent discussion. Second, it provides some examples and references for the ecotoxic significance of soil contamination. Based on this, a proposal for general heavy metal limits in soil improvers is made.

2 Scenarios of heavy metal accumulation in soil

The calculations are based on

- background concentration in soil (average values in Austria; (AMLINGER et al., 1990)

- average airborne deposition and Cd-impact by phosphatic fertilizer
- potential accumulation by soil improvers based on compost

The following heavy metal concentrations in compost, related to 30 % organic matter (O.M.) have been assumed:

- Limit Class I; ÖNORM S2200 in Austria **[KI.I/A]**
- Limit Class II; ÖNORM S2200 in Austria **[KI.II/A]**
- Limit-proposal Class 2; CEN/TC 223/WG 2; 5th February 1993; (N.75; p. 3) **[CEN/Feb. 93]**
- Limit-proposal WHEELER (1993) based on EC-sewage sludge directive/upper limit (N.99; p. 5; Table 2, right column) **[EC/U.L.]**

Airborne deposition rates/ha/a according to KÖCHL (1987), ISERMANN (1992), ANONYMOUS (1993a), ANONYMOUS (1993b), see Table 1.

Table 1 — Average airborne deposition of heavy metals/ha and year

metal	deposition in g/ha/a
Cd	3.5 (+ 2.1)*
Cr	20
Cu	75
Hg	1
Ni	20
Pb	130
Zn	500

*......input by phosphate fertilizer (ISERMANN, 1992)

For **heavy metal export**, the available data refer to (cited from KÖCHL, 1987; ISERMANN, 1992; ANONYMOUS, 1993a):

- uptake by plants
- surface erosion
- leaching rate

Table 2 — Export and balance of heavy metals in g/ha/a (compost freight not considered)

	export in g/ha/a by				balance in g/ha/a	
metal	plant 1	erosion[a] 2	leaching 3	total 1 + 2 + 3	with erosion	without erosion
Cd	2	2.6	1.5	6.1	– 0.5	+ 2.1
Cr	20	260		280	– 260	0
Cu	41	217		258	– 183	+ 34
Hg		0.87		0.87	+ 0.13	+ 1
Ni	18	260	12	290	– 270	– 10
Pb	19	217	3.7	240	– 110	+ 107
Zn	298	607	115	1 020	– 520	+ 87

[a] Cd export by erosion is documented as 45 % of the total (after ISERMANN, 1993). This is equivalent to 0.289 % of the background concentration in 20 cm of the upper soil horizon. The same percentage was used to calculate the heavy metal export of all metals by erosion.

Table 3 — Heavy metal limits in soil improvers (compost) related to 30 % and 3,5 % organic matter

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EG/U.L.[c]	
	30 %	*3.50 %*	*30 %*	*3.50 %*	*30 %*	*3.50 %*	*30%*	*3.50%*
Cd	0.7	0.96	1	1.38	1.5	2.07	5.1	7.03
Cr	70	96.50	70	96.50	150	206.79	262	361.19
Cu	70	96.50	100	137.86	200	275.71	262	361.19
Hg	0.7	0.96	1	1.38	1	1.38	2.9	4.00
Ni	42	57.90	60	82.71	75	103.39	129	177.84
Pb	70	96.50	150	206.79	150	206.79	552	760.97
Zn	210	289.50	400	551.43	750	1 033.93	515	709.96

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table 3 gives heavy metal concentrations for compost at the limit values concerned. As common in Austria and Germany, 30 % O.M. was assumed for all data. Based on that the second column takes into account further degradation of the organic matter down to 3.5 % d.m. when applied to the soil.

The calculations are based on an application of 10 t d.m./ha and year.

The change of heavy metal concentration in the soil is calculated according to the following equation:

$$mg/kg(s+c) = \frac{mg/kg(s).t(s) + mg/kg(c).t(c)}{t(s)+t(c)}$$

mg/kg(s) ..... heavy metal concentration in the soil in the horizon concerned (mg/kg d.m.)

mg/kg(c) ..... heavy metal concentration in the compost, related to the content of soil organic matter (mg/kg d.m.)

t(s) .... Soil weight per ha related to the horizon concerned (tons)

t(c) .... tons of compost application calculated on the basis of soil organic matter (t/ha d.m.)

In Table A.1a – Table A.1c and Table A.2a – Table A.2c (see Appendix), **heavy metal accumulations for the periods 30, 50 and 100 years** are calculated on the basis of the data in Table 1, Table 2 and Table 3 based on the assumption of application of 10 t compost/ha/a (d.m.). Table A.1a – Table A.1h was calculated with consideration of the decrease by erosion, Table A.2a – Table A.2h without this decrease.

The average background load of agricultural soils in Austria was used as a basis.

Table A.1e – Table A.1d and Table A.2e – Table A.2d show the number of years of continuous compost application required, until the limit values assumed (A1d & A2d: Austria ÖNORM L1075[1)]; A1e & A2e:EC-sewage sludge directive — upper limit) is reached. Finally, Table A.1f – Table A.1h & Table A.2f–Table A.2h show the percentages of the limit values reached in all scenaria with and without consideration of the reduction by erosion. Table 4a & Table 4b summarise the percentages relative to the Austrian limit value for soil (L.V./A).

For the calculation of the reduction by erosion see, Table 2. The net increase is significantly less without considering erosion, particularly if low limit values for compost are assumed.

Table 4a and Table 4b clearly show that — based on the conditions of the scenaria described in this paper — in a period of 100 years the limit values of soil will only be exceeded if compost with a heavy metal level according to EC/U.L. (WHEELER. 1993) is assumed (except Zn). Even under the most favourable conditions, soil limits for Cd and Pb are already exceeded after 50 years by 7.5 and 8.8 %, respectively. After only 30 years the 70 % level is exceeded by both elements.

Using the Austrian limits ÖNORM S 2200 (1993) KI.I/A & KI.II/A, a 70 % level of the soil limit is not reached in any case (except Pb: 70.9 % after 100 years).

[1)] Section 3 and 4 deal with the scientific data sources for using the Austrian soil limit values.

Table 4a — *Balance 1 — with erosion:* Percentage attainment of the Austrian soil limits according to ÖNORM L 1075 after 30, 50 und 100 years of continuous compost application of 10 t d.m./ha/a. All values > 70 % of the soil limits are included (in mg/kg d.m.)

	Limit value soil (A) *mg/kg d.m.*	% of soil limits in 30 years (EC/U.L.)	50 years (EC/U.L.)	100 years (CEN/Feb.'93)	100 years (EC/U.L.)
Cd	*1*	76.5 %	**107.5 %**	—	**185.0 %**
Cr	*100*	—	—	—	98.4 %
Cu	*100*	—	—	77.3 %	97.2 %
Hg	*1*	—	—	—	**101.2 %**
Ni	*60*	—	71.2 %	—	92.4 %
Pb	*100*	75.3 %	**108.8 %**	—	**192.7 %**
Zn	*300*	—	—	92.4 %	—

Table 4b — *Balance 2 — without erosion:* Percentage attainment of the Austrian soil limits according to ÖNORM L 1075 after 30, 50 und 100 years of continuous compost application of 10 t d.m./ha/a. All values > 70 % of the soil limits are included (in mg/kg d.m.)

	Limit value soil (A) *mg/kg d.m.*	% of soil limits in 30 years (EC/U.L.)	50 years (EC/U.L.)	100 years (CEN/Feb.'93)	100 years (EC/U.L.)
Cd	*1*	79.1	**111.8**	78.2	**193.7**
Cr	*100*	—	—	71.2	**107.1**
Cu	*100*	—	—	84.5	**104.4**
Hg	*1*	—	—	—	**104.1**
Ni	*60*	—	78.4	77.9	**106.8**
Pb	*100*	77.5	**112.4**	70.9[a]	**199.9**
Zn	*300*	—	—	99.1	74.0

[a] ....valid also for Class 2 after ÖNORM S2200 in Austria [KI.II/A]

Assuming the compost limits of Cd (5.1 mg/kg d.m.) and Pb (552 mg/kg d.m.)(EC/U.L.), the soil limits established in Austria are attained within 45 years. Table 5 summarises the situation for CEN/Feb.'93 and EC/U.L.

Table 5 — Attainment of the Austrian soil limits in years assuming the limits suggested for soil improvers CEN/Feb.93 and EC/U.L.

	Soil limit Austria mg/kg d.m.	**CEN/Feb.'93** **limit S.I.** mg/kg d.m.	**years until soil limit**	**EC/U.L.** **limit S.I.** mg/kg d.m.	**years until soil limit**
Cd	1.0	1.5	145	5.1	43
Cr	100	150	170	262	91
Cu	100	200	126	262	94
Hg	1.0	1.0	272	2.9	96
Ni	60	75	179	129	88
Pb	100	150	163	552	43
Zn	300	750	101	515	151

3 Ecotoxicological assessment

Based on a number of investigations, the ecotoxicological relevance of the above calculations will be considered.

Table 6 lists some data concerning the uptake of heavy metals by plants as well as relevant limit values.

Table 6 — Data and standards relative to heavy metal uptake by plants

	1	2	3	4	5	6	8
	pH limit of higher availability	**Transfer-coefficient soil ? plant** [c]	**Normal plant values**	**Harvest related toxicity limits in plants**	**Limits in food**	**Limits in fodder**	**WHO maximum weekly uptake**
			mg/kg d.m.	**mg/kg d.m.**	**mg/kg f.m.**	**mg/kg f.m.**	**(70 kg)**
Cd	6.0	0.01 – 10	< 0.1 – 0.5	2.5 – 10	0.1 – 0.2[a]	1.0	490 µg
Cr	4.5	0.01 – 0.5	< 0.1 – 1.0	1 – 2	—	—	—
Cu	4.5	0.01 – 2.0	2 – 20	15 – 20	—	50	—
Hg	4.0	—	2.6 – 86 ppb	0.5 – 1.0	0.3 – 0.5	0.1	350 µg
Ni	5.5	0.01 – 0.5	0.1 – 2.0	20 – 30	—	—	—
Pb	4.0–4.5	0.001 – 0.5	0.1 – 10	10 – 20	0.3 – 0.5[b]	40	3.5 mg
Zn	5.5	0.01 – 10	2 – 100	150 – 200	—	250	—

[a] ..... fruit: 0.05; spinach: 0.5 mg/kg

[b] .... kale: 2.0 mg/kg

[c] .... mg/kg in plants/mg/kg in soil (d.m.)

1) ANONYMOUS (1988); 2) SAUERBECK & STYPEREK (1988); 3) MAIER et al. (1993); 4) SAUERBECK (1983); 5) ANONYMOUS (1986); 6) HECHT (1982)

A considerable number of investigations describe **the dynamics of mobilization and availability of heavy metals in relation to specific soil properties**.

Referring to ANONYMOUS (1988), the sorption of heavy metals is mainly carried out by

- adsorption at exchange compounds
- chemical precipitation
- organic sorption.

The strength of specific sorption at hydroxilised Fe-, Al- und Mn-oxides follows the order Cd<Ni<Zn<<Cu<Pb. Due to the soil organic matter the order of sorption by metalo-organic complexing agents is Zn<Co<Ni<<Pb ≤ Cu. Both forms of sorption are closely related to pH.

HERMS and BRÜMMER (1984) showed that the availability in soils with low humus level and between pH 3–6 decreases by the order Cd>Zn>Cu>Pb. In soils with an high level of high molecular organic matter of high stability at low pH range, the immobilisation decreases in the order Cu>Cd>Zn>Pb.

The mobilisation by soluble organic complexing compounds follows the order Cu>Cd>Zn>Pb.

This phenomenon may be accelerated by phases of intensive microbial decomposition of organic matter (e.g. degradation of fresh manure).

Furthermore the application of chlorides as compounds in mineral fertilizer may increase the availability of Cd.

On the whole, Cd and Zn — but also Cu and Ni -must be given particular consideration due to the pH dependence of desorption and transfer coefficient soil: plant > 1.

Considering Cadmium's chronic (accumulative) toxicity and its relatively higher mobility in soil and plants the significance of soil limits are described.

Table 7 lists plants that reach a transfer ratio for Cd > 1

Table 7 — Transfer coefficient for Cd soil to plant > 1 (after LÜBBEN & SAUERBECK, 1992)

Crop	T.C. Soil to Plant
Leek	1.20
Carrot	1.29
Radish	1.61
Leaf lettuce	3.21
Leaf celery	3.73
Spinach	5.34
Celery root	7.09

For Cd, particularly in soils with pH < 6.0 and low sorption capacity, the possibility of accumulation in leaves and root occurs (SAUERBECK and STYPEREK, 1988). Field forrage plants are thus subject to considerable impact.

A soil level of 2 mg/kg d.m. may lead to a Cd concentration in spinach of 1.5 mg/kg f.m., i.e. three times the German limit value (0.5 mg/kg f.m.)

HORAK et al. (1994) discuss the joint effect of increasing heavy metal concentrations in soils, and describe the accumulation of Cd in the grain of wheat as well as a negative effect on microbial parameters in the soil even if the Cd level in the soil is moderate.

Table 8 — Cd impact as a combined effect with the heavy metals Cu, Ni, Zn and V on the contents in the grain of wheat and on microbiological soil parameters (HORAK et al., 1994)

Soils (pH-Wert)	Cd in soil aqua regia mg/kg d.m.	Cd in soil NH_4-acetate mg/kg d.m.	Contents in grain of wheat mg/kg d.m.	Inhibition of respiration in % of control	Inhibition of *arylsulphatase activity* in % of control
Control[a]	0.2 – 0.3	0.03 – 0.07	0.05 – 0.11	—	—
A (7.5)	2.2	0.37	0.4	30 %	29 %
B (6.9)	2.3	0.50	0.92	35 %	60 %
C (7.7)	2.6	0.20	0.38	28 %	70 %

[a] ..... range of the soils A, B and C

As a result of the joint effect of Cd, Cu, Ni, Zn and V, toxic effects were already found at Cd values of 0.28 mg/kg d.m. extracted by ammonium acetate. This refers to a value of 1.9 mg/kg d.m. in a weakly acidic, somewhat humous, silty sandy soil using acid extraction.

A Zn:Cd antagonism as cited in CHANEY (1991) was not confirmed: no suppression of Cd uptake was observed with increasing Zn concentrations in the soil.

Figure A.1 – Figure A.4 (see Appendix) summarise a diminishing effect to microbial parameters such as C-mineralisation, respiration, arylsulphatase activity and dehydrogenase activity due to increasing soil contamination with Cd, Cu, Ni and Zn.

Heavy metals were added in mineral form to 3 soils (A, B and C) in 3 levels 4 years prior to analyses.

During this period they were transformed into soil-specific compounds.

Table 9 shows that the dynamics of availability are comparable with the results of untreated soil samples.

Table 9 — Relationship between mobilised (NH_4-acetate) and total content (aqua regia) in test soils treated with heavy metal salts and in natural sites (after HORAK et al., 1994)

	Cd		Cu		Ni		Zn	
	Total mg/kg	NH_4-ac. in % tot.	Total mg/kg	NH_4-ac. in % tot.	Total mg/kg	NH-ac. in % tot.	Total mg/kg	NH_4-ac. in % tot.
Soils, 4 years after input of heavy metal salts	2.2	21.7	90	1.4	62	2.1	273	2.7
	2.3	16.8	142	1.5	78	1.4	263	1.3
			232	1.6			303	1.4
			239	1.8			435	2.0
Natural sites	0.4	35	124	1.0	96	1.2	212	1.7
	1.2	30	352	1.8			491	1.5
			4 416	1.3				

Thus if heavy metal minerals have enough time to react with the medium (in our case 4 years), such experimental results are also clearly relevant for practical agriculture.

KÖCHL (1984) reported similar results in a comparison of **Cd** levels in spring wheat, spring barley and maize after applying cadmium sulphate (660 g Cd/ha) and sludge (112 t d.m./ha = 660 g Cd) to two different sites (Table 10).

Table 10 — Cd levels in green plants of spring wheat, spring barley and maize at 2 sites after a Cd input of 660 g/ha as Cd sulphate and 112 t/ha of sludge (after KÖCHL. 1984)

	Cd concentration in green plant mass (mg/kg d.m.) after input of 660 g Cd/ha as	
	112 t d.m. sludge/ha	Cadmium sulfate
site 1 (pH=7.5)	0.085	0.096
site 2 (pH=5.4)	0.288	0.455

It was evident here that the mobilisation potential is influenced only to a limited degree by the type of Cd input, while site conditions (pH value) play a more important role.

In the framework of a long-term study, WIMMER (1984) showed that a 5-year fertilisation period with sludge (100 m3/ha/a) and garbage compost (50 t/ha/a) led to a 1.3- to 3-fold increase in heavy metal concentrations (Cu, Cr, Ni, Pb, Zn) in the soil. Table 11 compares the soil values in the controls and the fertilisation variants with the concentrations in the grain of oats in the 4th year of harvest.

Table 11 — Heavy metal values in the soil and in the grain of oats after 4 years of garbage compost application (after WIMMER, 1984)

	Cu	Ni	Pb	Zn
Soil (mg/kg d.m.)				
Control	31	41	30	72
MSW-Compost (50t/ha/a)	84	54	45	111
In % of control	271 %	131 %	155 %	154 %
Oat grains (mg/kg d.m.)				
Control	4.4	0.8	0.09	24.0
MSW-Compost (50t/ha/a)	5.2	3.2	0.11	36.5
In % of control	118 %	400 %	122 %	152 %

This experiment showed that in particular the **Zn and Ni** fractions of the garbage compost are easily taken up by the plants.

V. BOGUSLAWSKI (1987) examined the heavy metal concentrations in the soil and in the grains and straw of winter barley after an 18-year-long application of sludge in Germany. The results for **Cd, Ni and Zn** are summarised in Table 12.

Table 12 — Cd, Ni and Zn levels in soil as well as in the grain and straw of winter barley after 18 years of sludge fertilisation (after V.BOGUSLAWSKI, 1987)

mg/kg d.m.		Variants				
		Control	**1**	**2**	**3**	**4**
Cd	**Soil**	0.10	< 0.10	0.20	0.36	0.40
	Straw	0.023	0.035	0.053	0.053	0.072
	Grain	0.015	0.019	0.022	0.024	0.04
Ni	**Soil**	35.6	21.4	33.8	24.6	28.2
	Straw	0.25	< 0.2	0.24	0.29	0.28
	Grain	< 0.125	< 0.125	< 0.125	0.13	0.66
Zn	**Soil**	57.5	77.0	77.5	75.0	85.0
	Straw	6.05	9.93	13.1	23.2	37.3
	Grain	32.1	37.5	38.8	53.2	61.5
Controls:	without sludge					
1	approx. 2.5 t sludge/ha d.m. every 2 years					
2	approx. 2.5 t sludge/ha d.m. every year					
3	approx. 5 t d.m. sludge/ha d.m. every 2 years					
4	approx. 5 t d.m. sludge/ha d.m. every year					

In the case of **Zn**, an increase in the soil concentration of 49 % (Var. 4) led to an elevated increase of 516 % in straw and 91 % in the grain. Using Variant 4 as an example, **Cd showed a uniform relative increase in concentration:** soil + 300 %; straw + 231 %; grain + 266 %. Even in the generally moderate total levels within the framework of the soil limit values established in Austria, **it is evident that plant uptake reacts sensitively to changes in the elements Cd and Zn**.

The evaluation of a total of 25 long-term field studies (SAUERBECK and STYPEREK, 1987) led to the following results:

Zn, similar to Cd, showed the highest uptake rates, particularly in the vegetative parts; this also holds true for monocotyledonous plants. **Soil values of 300 mg/kg were sufficient to exceed the phytotoxic Zn concentration of > 200–300 mg/kg in the plants**. In acidic soils low in clay, toxicologically disturbing plant concentrations were already attained in dicotyledonous plants at soil values of 100 mg/kg.

The situation is similar for **Cu. Soil concentrations of 100 mg/kg (limit value in Austria and Germany) in sandy soils are sufficient to lead to a phytotoxically critical accumulation** of 20 mg/kg in dicotyledonous plants (i.e., sugar beets).

In a 5-year study programme on the impact of municipal wastes on soil, soil organisms and plants (SAUERBECK and LÜBBEN, 1991), the limit values of Cd in food (see also Table 6) are compared with the concentrations actually attained in plants in relation to soil levels. These results are summarised in Table 13:

Table 13 — Percentage of samples with Cd levels exceeding the food limit values (ZEBS) in relation to soil concentration (after SAUERBECK and LÜBBEN, 1991)

Soil concentration	Wheat	Oat	Radish	Carrot	Spinach	Leaf lettuce	Leaf celery
mg/kg d.m.	grain						
ZEBS:	0.12	0.12	1.0	1.0	5.0	1.0	1.0
0.0 – 0.3	22	22	0	0	0	67	44
0.3 – 0.5	25	50	17	0	8	33	83
0.5 – 0.75	50	25	0	0	19	75	63
0.75 – 1.0	63	50	25	0	0	100	100
1.0 – 1.5	82	67	33	17	17	100	100

ZEBS = Food limit value in mg Cd/kg d.m. (ANONYMOUS, 1989)

Table 13 clearly demonstrates that:

1. **the Cd concentrations in grain of wheat, leaf lettuce and leaf celery frequently reach or exceed the food limit value,**
2. **the frequency of these violations increased with the degree of soil contamination.**

Based on those determined soil values above which the food limits could be exceeded, it is evident that the derived reference values for Cd in aqua regia extracts were distinctly below the 3.0 mg/kg d.m. soil limit in effect up to 1992.

Table 14 — Orientation values for soil Cd concentrations (aqua regia extraction) above which food limit values in plants may be exceeded (after SAUERBECK and LÜBBEN, 1991)

Crop	Orientation value in the soil (mg/kg d.m.)
Grain of wheat	0.27
Grain of oats	0.34
Bean pods	1.84
Pea	0.42
Spinach	1.15
Lettuce	0.43
Radish	2.34
Carrot	0.55
Average of all plants (range)	0.70 (0.40 – 1.20)

According to STADELMANN et al. (1984), the microbial activity of various soils reacts — as do plants — in accordance with the key factors pH, clay content and non-living organic matter content. The sensitive parameters listed are:

- bacteria number
- bacterial growth
- bacteria spectrum
- C mineralisation

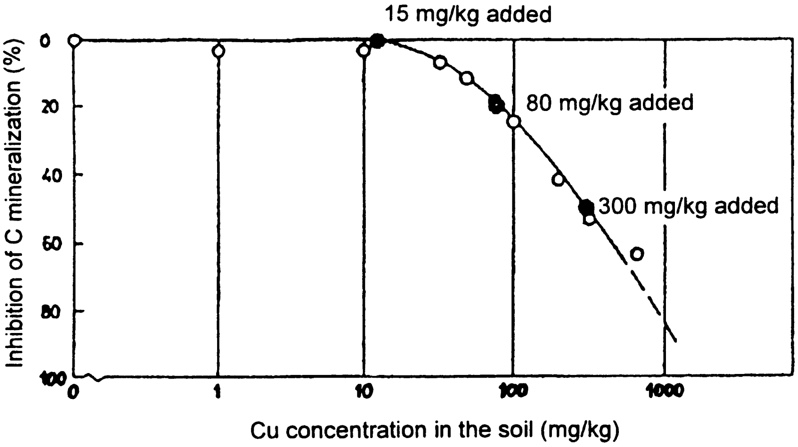

Figure 1 — Interaction between concentration of Cu in the soil and C-mineralisation after 32 days of Cu contamination

STADELMANN et al. (1984) recorded the toxicity limit concentrations of **Cu** for **C mineralisation** in an acidic, humus-poor, sandy clay soil (pH 5.7; Corg 0.724 %; N 0.134 %; clay 14.1 %; silt 39.7 %; sand 46.2 %; CEC 11.3 mmol/100g; Cu 8.5 mg/kg) after application of 15 mg/kg d.m. soil. This is equivalent to a total concentration of 23.5 mg/kg Cu based on d.m. Soil concentrations of 8.5 + 80 mg/kg=88.5 mg/kg d.m. resulted in a 20 % inhibition, while the addition of 300 mg/kg caused a 50 % inhibition in C mineralisation (see Figure 1).

A research study carried out in Germany between 1986 and 1990 (SAUERBECK and LÜBBEN, 1991) reached the following conclusions about the effect of heavy metals on soil fauna and soil microbiology:

Micro-organisms impacted by higher heavy metal concentrations exhibited an elevated respiration and had a correspondingly increased maintenance energy requirement. "*Their biochemical enzyme activities, i.e. their ability to catalyse metabolic processes — were in part considerably reduced*". Accordingly, the soil micro-flora used a greater part of its food substrate for cell repair than to build up biomass. In addition, an impaired growth of *cyanobacteria* and *chlorophytes* as well as a reduction of atmospheric-nitrogen-fixation through *cyanobacteria* was registered.

In laboratory experiments in which soils were treated with heavy metal salts, the basal respiration, along with the activity of various enzymes, was significantly reduced at soil heavy metal concentrations which were only 50 % of the limits in effect in Germany in 1992.

Although the details remain to be proven, SAUERBECK and LÜBBEN (1991) conclude that the heavy metals are primarily responsible for the often considerable impairment of soil organisms.

The **feeding activity of the soil fauna** decreased at high heavy metal concentrations; values at the allowed limits (BRD ABfKlärVo 1982) revealed a certain impairment of this fauna.

In a test soil mixture including sludge contaminated with heavy metals, damage to earthworms (much as on the microbial level) was registered at soil concentrations only 50 % of the maximum values specified in Germany up to 1992.

Since heavy metal concentrations in the range of the original upper limits negatively affected at least a few species, the 5-year study on the behaviour of the soil flora and fauna prompted the authors to recommend a **reduction of the soil limit values for Cd (originally 3 mg/kg) to 1.0–1.5 mg/kg, Zn (originally 300 mg/kg) to 150–200 mg/kg and Cu (originally 100 mg/kg) to 80 mg/kg d.m.**

4 Summary and Conclusions

Accumulation calculations for heavy metals in arable soils and a series of research results enable the ecotoxicological relevance of limit values for soil and soil improvers to be evaluated.

a Heavy metal balance

The heavy metal balances are based on the following factors:

- the average background levels in Austrian arable soils
- the current limits for compost in Austria [KI.I/A and KI.II/A] as well as the proposals discussed in CEN/TC223/WG 2 on Feb. 5, 1992 (N.75;p.3) [CEN/Feb.′93] and those presented by Pat WHEELER (1993; N.99;p.5)[EC/U.L.](Table 3)
- atmospheric inputs and, for Cd, from phosphatic fertilizers (Table 1)
- outputs through harvesting and leaching, both with and without considering erosion (Table 2)
- an annual application of 10 t of soil improver (compost) d.m. per ha corresponding to a balanced humus budget of approx. +/– 3 t organic matter/ha/a.

It is evident that, based on the EC/U.L. values, the Austrian soil limits (except for Zn) will be exceeded significantly after only 100 years, even without incorporating erosion losses.

Table 15 — Exceeding the Austrian soil limit values after only 100 years of compost application (10 t d.m./ha/a) based on the limits of WHEELER (1993; EC/U.L.)

	Background concentration in soils Austria	*Limit value of soils Austria*	CEN/Feb.'93		EC/U.L.	
			Limit val. S.I.	*Soil conc.. in 100 years.*	Limit val. S.I.	*Soil conc.. in 100 years.*
Cd	0.3	***1.0***	1.5	***0.78***	5.1	***1.94***
Cr	30	***100***	150	***71***	262	***107***
Cu	25	***100***	200	***85***	262	***104***
Hg	0.1	***1.0***	1.0	***0.43***	2.9	***1.04***
Ni	30	***60***	75	***47***	129	***64***
Pb	25	***100***	150	***71***	552	***200***
Zn	70	***300***	750	***297***	515	***222***

S.I ..... Soil improvers

In the case of Cd and Pb, the limits are reached after only 43 years. Details see Appendix /Table A.1a to Table A.2h)

b Ecotoxicological evaluation

The first question that arises is the validity of the standards and upper limit values established in Austria or in Germany for universally utilisable soils [Cd 0.1 – 1.5; Cr 100; Cu 80 – 100; Hg 1.0; Ni 50 – 60; Pb 100; Zn 150 – 300 mg/kg d.m.]. They can now be scientifically supported by a number of studies.

b.1 Heavy metal uptake in plants

Empirically determined **soil to plant transfer rates** of heavy metals as well as individual investigations confirm that exceeding the above soil limits entails the danger of accumulation in plants. This is true both for the harvest-related toxicity limits and for food standards according to the Federal Ministry of Health in Germany (ANONYMOUS, 1989). The mobilisation ability and thus the potential **availability of heavy metals for plants** largely depends on the following factors:

- soil properties
- pH value, clay content, content of stable organic matter (availability decreases with increasing values)
- the element and its total concentration
- plant species and plant organs (root > vegetative parts > generative parts: ranked according to decreasing accumulation tendency)

Thus, “worst case” conditions that promote mobilisation of heavy metals are assumed (e.g., sorption-poor, acidic, sandy and humus-poor soils and leaf fruit crops).

In the case of the bioaccumulator **Cd**, whose half-life in humans is 30 – 40 years, numerous examples demonstrate that disturbing concentrations are attained at soil concentrations > 1 – 1.5 mg/kg d.m.. A broad study on a wide range of plant species established that the maximum allowable concentrations in food were exceeded at an average reference value of 0.7 mg/kg Cd d.m. in soil.

Soil concentrations between 1.0 and 1.5 mg/kg d.m. led to an exceeding of the allowable food concentrations in 85 % of the grain of wheat samples, 67 % of the grain of oat samples, and in 100 % of all cases involving lettuce and leaf celery. Another study confirmed these results: soil levels of 2.2 – 2.6 mg/kg Cd d.m. led to concentrations of 0.4 – 0.9 mg/kg d.m. in grain of wheat (standards: 0.12 mg/kg d.m. Cd).

Increasing concentrations in the soil led to corresponding increases in the plant in **Zn, Ni and Cu** as well. In most cases, Zn increased proportional to Ni, in one case significantly stronger.

The comprehensive evaluation of long-term studies using sewage sludge revealed that, in the case of Zn and Cu, soil values near the upper limits (Zn = 300 mg/kg; Cu = 100 mg/kg) led to harvest-relevant toxic levels in plants.

b.2 Soil microbiological parameters and soil fauna

A series of studies involving these parameters, which serve as indicators for the development of the soil as a material cycling system, confirmed the validity of the above soil limit values. An irreversible disturbance of microbial activity is a serious matter, as this forms the basis of soil conservation in the sense of soil productivity. **Cd** concentrations of 2.2 – 2.6 mg/kg d.m. in the soil inhibited respiration by up to 35 % and *arylsulphatase activity* by 70 % of control values in uncontaminated reference soils. In a further study, a total Cu content of 88.5 mg/kg d.m. was sufficient to decrease C mineralization by 20 %.

A broad-based programme in Germany revealed the following **impacts due to elevated heavy metal contaminations:**

- reduction of enzyme activities; reduced biomass production
- impaired growth of *cyanobacteria* and *chlorophytes*
- reduced N-fixation by cyanobacteria
- significant decrease in basal respiration at soil concentrations measuring 50 % of the soil limit values
- reduced feeding activity of soil fauna

These results lead to the recommendation that the soil limits in the German sewage sludge directive be reduced to 1.0 – 1.5 (originally 3.0) for Cd, to 150 – 200 (originally 300) for Zn, and to 80 mg/kg (originally 100) for Cu.

c Conclusions regarding the establishment of limits for soil improvers

An overview of the experimental and practical studies on the ecotoxicological significance of heavy metals shows that the heavy metal limit values in effect in Austria and Germany are justified for universally utilisable agricultural soils.

This leads to the demand that the functionality of agricultural soils be maintained in the long run; specifically, the input of heavy metals stemming from organic fertilizer applications should be minimised. Exceeding toxicologically determined heavy metal limit concentrations within periods of 45 – 100 years by applying too highly contaminated soil improvers does not appear to be a reasonable strategy. Based on the upper limits discussed on February 5, 1993 in the CEN/TC 223/WG in Milan, **the following upper limit values for soil improvers are proposed:**

Table 16 — Proposal for general PTE limits in soil improvers as a compromise on EU level (based on 30 % organic matter)

	Limit values for soil improvers [mg/kg d.m.]
Cd	*1.5*
Cr	*150*
Cu	*200*
Hg	*1.0*
Ni	*75*
Pb	*150*
Zn	*500*

Assuming a continual compost application of 10 t d.m./ha/a, these values guarantee (even if the organic matter is mostly mineralised) that **the above soil limit values will not be attained for at least 150 years.**

Furthermore it appears reasonable to standardise the concentration data to a 30 % organic matter content in order to improve comparability and simplify calculations.

From the environmental protection standpoint, product-specific quality standards are very important in international trade. Risk assessment must be scientifically based and reflect the current state of knowledge; this approach can provide a safety framework for applications that are difficult to control or that may be improperly implemented.

In this sense, **it is recommended that the validity of norms be restricted to max. 10 – 15 years.** This will allow adequate incorporation of innovations modifying heavy metal balances in agriculture and horticulture.

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Appendix

PTE Accumulation *with* Erosion:

Table A.1a — PTE accumulation in 30 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,04	*0,34*	0,07	*0,37*	0,12	*0,42*	0,47	*0,77*
Cr	30,0	2,04	*32,04*	2,04	*32,04*	9,75	*39,75*	20,53	*50,53*
Cu	25,0	3,16	*28,16*	6,05	*31,05*	15,68	*40,68*	21,65	*46,65*
Hg	0,1	0,06	*0,16*	0,09	*0,19*	0,09	*0,19*	0,27	*0,37*
Ni	30,0	– 0,75	*29,25*	0,98	*30,98*	2,43	*32,43*	7,62	*37,62*
Pb	25,0	3,89	*28,89*	11,60	*36,60*	11,60	*36,60*	50,30	*75,30*
Zn	70,0	10,13	*80,13*	28,42	*98,42*	62,12	*132,12*	39,49	*109,49*

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table A.1b — PTE accumulation in 50 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,07	*0,37*	0,12	*0,42*	0,20	*0,50*	0,78	*1,08*
Cr	30,0	3,41	*33,41*	3,41	*33,41*	16,24	*46,24*	34,22	*64,22*
Cu	25,0	5,27	*30,27*	10,09	*35,09*	26,13	*51,13*	36,08	*61,08*
Hg	0,1	0,10	*0,20*	0,15	*0,25*	0,15	*0,25*	0,46	*0,56*
Ni	30,0	– 1,25	*28,75*	1,64	*31,64*	4,04	*34,04*	12,71	*42,71*
Pb	25,0	6,49	*31,49*	19,33	*44,33*	19,33	*44,33*	83,83	*108,83*
Zn	70,0	16,88	*86,88*	47,37	*117,37*	103,53	*173,53*	65,82	*135,82*

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table A.1c — PTE accumulation in 100 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,14	*0,44*	0,23	*0,53*	0,39	*0,69*	1,55	*1,85*
Cr	30,0	6,81	*36,81*	6,81	*36,81*	32,49	*62,49*	68,43	*98,43*
Cu	25,0	10,54	*35,54*	20,17	*45,17*	52,26	*77,26*	72,16	*97,16*
Hg	0,1	0,21	*0,31*	0,30	*0,40*	0,30	*0,40*	0,91	*1,01*
Ni	30,0	– 2,51	*27,49*	3,27	*33,27*	8,09	*38,09*	25,41	*55,41*
Pb	25,0	12,98	*37,98*	38,65	*63,65*	38,65	*63,65*	167,66	*192,66*
Zn	70,0	33,76	*103,76*	94,74	*164,74*	207,06	*277,06*	131,64	*201,64*

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table A.1d — Years until soil limit is reached when compost is applicated with 10 t/ha and year

Soil limit: Austria; ÖNORM L 1075 (1990)

Soil limit (austr.) – Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EG/U.L.[c]	
		accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*
Cd	0,7	0,001	507	0,002	299	0,004	177	0,016	45
Cr	70,0	0,068	1 027	0,068	1 027	0,325	215	0,684	102
Cu	75,0	0,105	711	0,202	372	0,523	144	0,722	104
Hg	0,9	0,002	438	0,003	298	0,003	298	0,009	99
Ni	30,0	—	—	0,033	917	0,081	371	0,254	118
Pb	75,0	0,130	578	0,387	194	0,387	194	1,677	45
Zn	230,0	0,338	681	0,947	243	2,071	111	1,316	175

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table A.1e — Years until soil limit is reached when compost is applicated with 10 t/ha and year

Soil limit: EC-Directive — Upper Limit

Soil limit (EC-dir.) – Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EG/U.L.[c]	
		accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*
Cd	2,7	0,001	1 955	0,002	1 152	0,004	684	0,016	174
Cr	120,0	0,068	1 761	0,068	1 761	0,325	369	0,684	175
Cu	115,0	0,105	1 091	0,202	570	0,523	220	0,722	159
Hg	1,4	0,002	681	0,003	464	0,003	464	0,009	154
Ni	45,0	—	—	0,033	1 376	0,081	557	0,254	177
Pb	275,0	0,130	2 119	0,387	711	0,387	711	1,677	164
Zn	230,0	0,338	681	0,947	243	2,071	111	1,316	175

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

PTE Accumulation *with* Erosion:

Table A.1f — Percentage of soil limit (Austria and EC directive/upper limit) reached after 30 years of compost application (10 t/ha/a)

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EC/U.L.[c]		Soil limits	(mg/kg d.m.)
	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-directive
Cd	34,1	11,4	37,0	12,3	41,8	13,9	**76,5**	25,5	1	3
Cr	32,0	21,4	32,0	21,4	39,7	26,5	50,5	33,7	100	150
Cu	28,2	20,1	31,1	22,2	40,7	29,1	46,6	33,3	100	140
Hg	16,2	10,8	19,1	12,7	19,1	12,7	37,4	24,9	1	1,5
Ni	48,7	39,0	51,6	41,3	54,0	43,2	62,7	50,2	60	75
Pb	28,9	9,6	36,6	12,2	36,6	12,2	**75,3**	25,1	100	300
Zn	26,7	26,7	32,8	32,8	44,0	44,0	36,5	36,5	300	300

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

Table A.1g — Percentage of soil limit (Austria and EC directive/upper limit) reached after 50 years of compost application (10 t/ha/a)

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]		Soil limits	(mg/kg d.m.)
	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-directive
Cd	36,9	12,3	41,7	13,9	49,7	16,6	***107,5***	35,8	1	3
Cr	33,4	22,3	33,4	22,3	46,2	30,8	64,2	42,8	100	150
Cu	30,3	21,6	35,1	25,1	51,1	36,5	61,1	43,6	100	140
Hg	20,3	13,5	25,1	16,7	25,1	16,7	55,6	37,1	1	1,5
Ni	47,9	38,3	52,7	42,2	56,7	45,4	**71,2**	56,9	60	75
Pb	31,5	10,5	44,3	14,8	44,3	14,8	***108,8***	36,3	100	300
Zn	29,0	29,0	39,1	39,1	57,8	57,8	45,3	45,3	300	300

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.1h — Percentage of soil limit (Austria and EC directive/upper limit) reached after 100 years of compost application (10 t/ha/a)

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]		Soil limits	(mg/kg d.m.)
	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-directive
Cd	43,8	14,6	53,4	17,8	69,5	23,2	***185,0***	61,7	1	3
Cr	36,8	24,5	36,8	24,5	62,5	41,7	**98,4**	65,6	100	150
Cu	35,5	25,4	45,2	32,3	**77,3**	55,2	**97,2**	69,4	100	140
Hg	30,6	20,4	40,2	26,8	40,2	26,8	***101,2***	67,4	1	1,5
Ni	45,8	36,7	55,5	44,4	63,5	50,8	**92,4**	73,9	60	75
Pb	38,0	12,7	63,7	21,2	63,7	21,2	***192,7***	64,2	100	300
Zn	34,6	34,6	54,9	54,9	**92,4**	**92,4**	67,2	67,2	300	300

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

PTE Accumulation *without* Erosion:

Table A.2a — PTE accumulation in 30 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.'93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,07	*0,37*	0,10	*0,40*	0,14	*0,44*	0,49	*0,79*
Cr	30,0	4,64	*34,64*	4,64	*34,64*	12,35	*42,35*	23,13	*53,13*
Cu	25,0	5,33	*30,33*	8,22	*33,22*	17,85	*42,85*	23,82	*48,82*
Hg	0,1	0,07	*0,17*	0,10	*0,20*	0,10	*0,20*	0,28	*0,38*
Ni	30,0	1,85	*31,85*	3,58	*33,58*	5,03	*35,03*	10,22	*40,22*
Pb	25,0	6,06	*31,06*	13,77	*38,77*	13,77	*38,77*	52,47	*77,47*
Zn	70,0	16,20	*86,20*	34,49	*104,49*	68,19	*138,19*	45,56	*115,56*

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2b — PTE accumulation in 50 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,11	*0,41*	0,16	*0,46*	0,24	*0,54*	0,82	*1,12*
Cr	30,0	7,74	*37,74*	7,74	*37,74*	20,58	*50,58*	38,55	*68,55*
Cu	25,0	8,89	*33,89*	13,70	*38,70*	29,75	*54,75*	39,70	*64,70*
Hg	0,1	0,12	*0,22*	0,17	*0,27*	0,17	*0,27*	0,47	*0,57*
Ni	30,0	3,08	*33,08*	5,97	*35,97*	8,38	*38,38*	17,04	*47,04*
Pb	25,0	10,11	*35,11*	22,94	*47,94*	22,94	*47,94*	87,45	*112,45*
Zn	70,0	27,00	*97,00*	57,49	*127,49*	113,65	*183,65*	75,94	*145,94*

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2c — PTE accumulation in 100 years; mg/kg d.m. (Compost: 10 t d.m/ha/a; weight of 20 cm soil = 3 000 t/ha)

Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EC/U.L.[c]	
mg/kg d.m.		accumulation	*total*	accumulation	*total*	accumulation	*total*	accumulation	*total*
Cd	0,3	0,22	*0,52*	0,32	*0,62*	0,48	*0,78*	1,64	*1,94*
Cr	30,0	15,48	*45,48*	15,48	*45,48*	41,15	*71,15*	77,10	*107,10*
Cu	25,0	17,78	*42,78*	27,41	*52,41*	59,50	*84,50*	79,39	*104,39*
Hg	0,1	0,23	*0,33*	0,33	*0,43*	0,33	*0,43*	0,94	*1,04*
Ni	30,0	6,16	*36,16*	11,94	*41,94*	16,75	*46,75*	34,08	*64,08*
Pb	25,0	20,21	*45,21*	45,88	*70,88*	45,88	*70,88*	174,89	*199,89*
Zn	70,0	54,00	*124,00*	114,97	*184,97*	227,29	*297,29*	151,88	*221,88*

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2d — Years until soil limit is reached when compost is applicated with 10 t/ha and year

Soil limit: Austria; ÖNORM L 1075 (1990)

Soil limit (austr.) – Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EG/U.L.[c]	
		accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*
Cd	0,7	0,002	311	0,003	218	0,005	145	0,016	43
Cr	70,0	0,155	452	0,155	452	0,412	170	0,771	91
Cu	75,0	0,178	422	0,274	274	0,595	126	0,794	94
Hg	0,9	0,002	383	0,003	272	0,003	272	0,009	96
Ni	30,0	0,062	487	0,119	251	0,168	179	0,341	88
Pb	75,0	0,202	371	0,459	163	0,459	163	1,749	43
Zn	230,0	0,540	426	1,150	200	2,273	101	1,519	151

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2e — Years until soil limit is reached when compost is applicated with 10 t/ha and year

Soil limit: EC-Directive — Upper Limit

Soil limit (EC-Dir.) - Soil background		KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EG/U.L.[c]	
		accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*	accumulation/a	*J bis RW*
Cd	2,7	0,002	1201	0,003	841	0,005	561	0,016	165
Cr	120,0	0,155	775	0,155	775	0,412	292	0,771	156
Cu	115,0	0,178	647	0,274	420	0,595	193	0,794	145
Hg	1,4	0,002	597	0,003	423	0,003	423	0,009	149
Ni	45,0	0,062	730	0,119	377	0,168	269	0,341	132
Pb	275,0	0,202	1361	0,459	599	0,459	599	1,749	157
Zn	230,0	0,540	426	1,150	200	2,273	101	1,519	151

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

PTE Accumulation ***without*** Erosion:

Table A.2f — Percentage of soil limit (Austria and EC directive/upper limit) reached after 30 years of compost application (10 t/ha/a)

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EC/U.L.[c]		Soil limits	(mg/kg d.m.)
	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-directive
Cd	36,7	12,2	39,6	13,2	44,4	14,8	**79,1**	26,4	1	3
Cr	34,6	23,1	34,6	23,1	42,3	28,2	53,1	35,4	100	150
Cu	30,3	21,7	33,2	23,7	42,8	30,6	48,8	34,9	100	140
Hg	17,0	11,4	19,9	13,3	19,9	13,3	38,2	25,5	1	1,5
Ni	53,1	42,5	56,0	44,8	58,4	46,7	67,0	53,6	60	75
Pb	31,1	10,4	38,8	12,9	38,8	12,9	**77,5**	25,8	100	300
Zn	28,7	28,7	34,8	34,8	46,1	46,1	38,5	38,5	300	300

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2g — Percentage of soil limit (Austria and EC directive/upper limit) reached after 50 years of compost application (10 t/ha/a)

	KL. I/A[a]		KL. II/A[a]		CEN/Feb.′93[b]		EC/U.L.[c]		Soil limits	(mg/kg d.m.)
	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-dir.	Austria	EC-directive
Cd	41,2	13,7	46,1	15,4	54,1	18,0	***111,8***	37,3	1	3
Cr	37,7	25,2	37,7	25,2	50,6	33,7	68,5	45,7	100	150
Cu	33,9	24,2	38,7	27,6	54,7	39,1	64,7	46,2	100	140
Hg	21,7	14,5	26,5	17,7	26,5	17,7	57,0	38,0	1	1,5
Ni	55,1	44,1	59,9	48,0	64,0	51,2	78,4	62,7	60	75
Pb	35,1	11,7	47,9	16,0	47,9	16,0	***112,4***	37,5	100	300
Zn	32,3	32,3	42,5	42,5	61,2	61,2	48,6	48,6	300	300

[a] ÖNORM S 2200 (1993);
[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);
[c] Proposal WHEELER (1993)

Table A.2h — Percentage of soil limit (Austria and EC directive/upper limit) reached after 100 years of compost application (10 t/ha/a)

	KL. I/A[a]		**KL. II/A**[a]		**CEN/Feb.'93**[b]		**EC/U.L.**[c]		**Soil limits (mg/kg d.m.)**	
	Austria	**EC-dir.**	**Austria**	**EC-dir.**	**Austria**	**EC-dir.**	**Austria**	**EC-dir.**	**Austria**	**EC-directive**
Cd	52,5	17,5	62,1	20,7	**78,2**	26,1	***193,7***	64,6	1	3
Cr	45,5	30,3	45,5	30,3	**71,2**	47,4	***107,1***	71,4	100	150
Cu	42,8	30,6	52,4	37,4	**84,5**	60,4	***104,4***	74,6	100	140
Hg	33,5	22,3	43,1	28,7	43,1	28,7	***104,1***	69,4	1	1,5
Ni	60,3	48,2	69,9	55,9	**77,9**	62,3	***106,8***	85,4	60	75
Pb	45,2	15,1	**70,9**	23,6	**70,9**	23,6	***199,9***	66,6	100	300
Zn	41,3	41,3	61,7	61,7	**99,1**	**99,1**	**74,0**	74,0	300	300

[a] ÖNORM S 2200 (1993);

[b] Proposal CEN/TC 223/WG 2, 5th Feb. 1993 (N.75, p.3);

[c] Proposal WHEELER (1993)

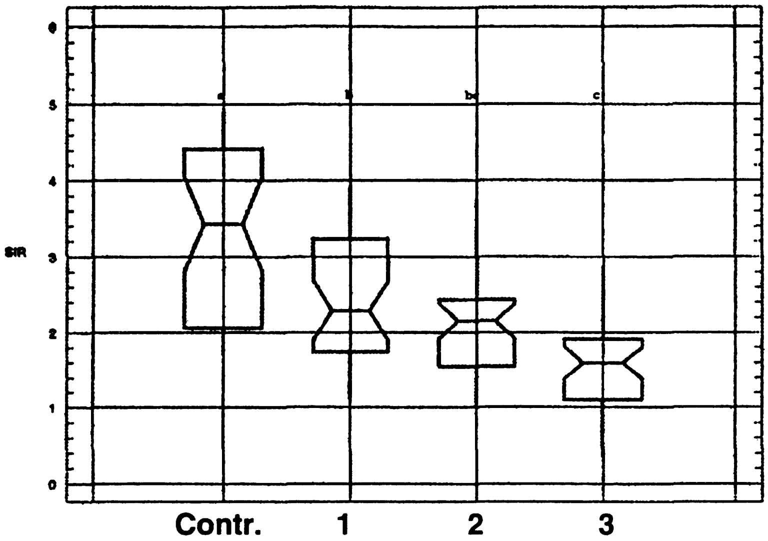

Figure A.1 — Sir of the three trial soils during the entire test period in mg CO_2^a 100 g TS^{-1a} $24h^{-1}$

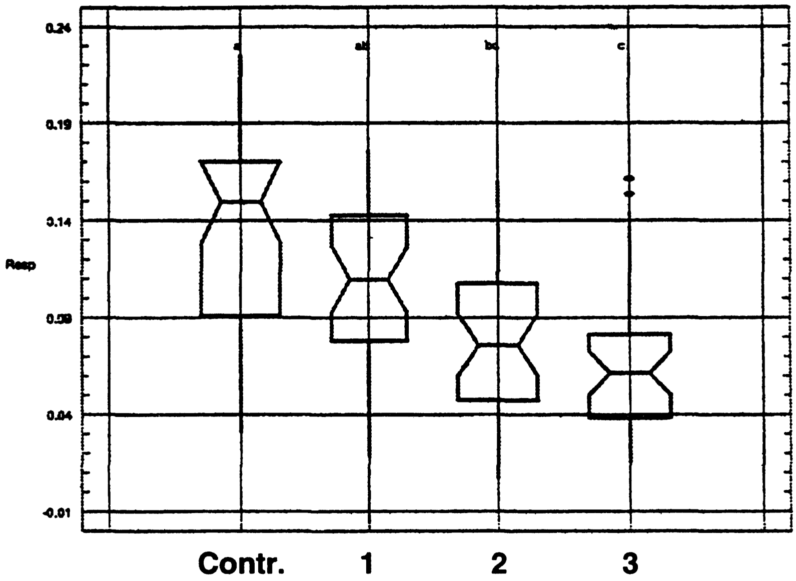

Figure A.2 — Respiration of the three trial soils during the entire test period mg CO_2^a 100 g $TS^{-1a}24h^{-1}$

	Control	1	2	3
Cd	0,2 – 0,3	2,2 – 2,6	3,5 – 4,5	4,6 – 6,6
Cu	13 – 22	82 – 94	134 – 162	191 – 239
Ni	15 – 42	46 – 62	62 – 88	72 – 128
Zn	56 – 94	263 – 303	378 – 477	451 – 699

Contamination (range in mg/kg d.m.)[a]

[a] extraction in aqua regia

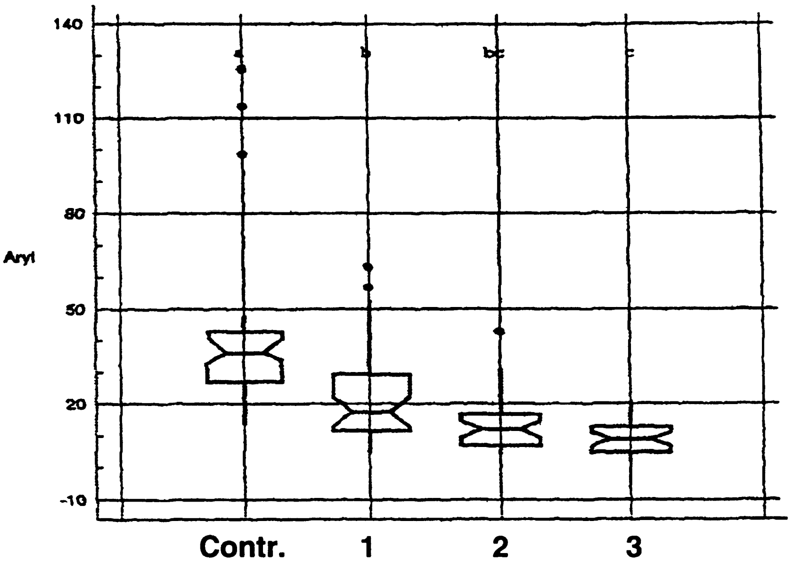

Figure A.3 — Arsuphate activity of the three trial soils during the entire test period in Nitrophenole^a g TS-1^a h-1

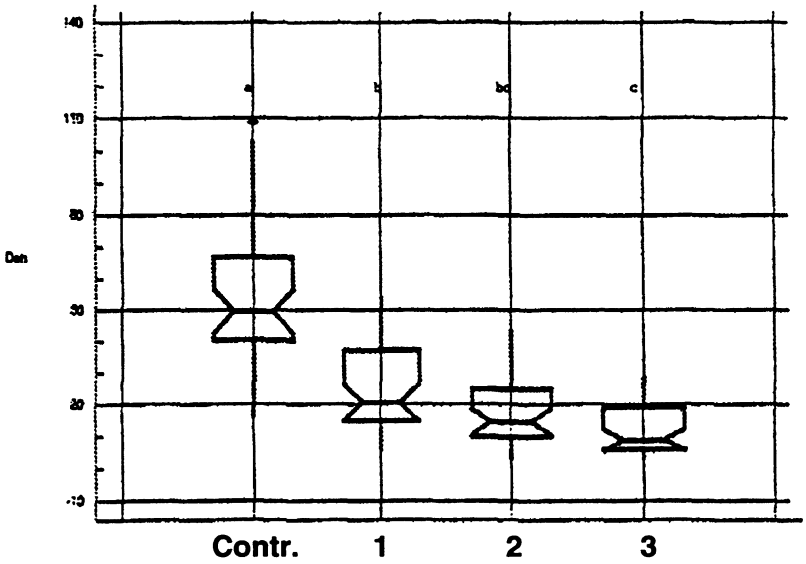

Figure A.4 — Dehydrogease activity of the three trial soils during the entire test period in µg TFP^a g TS^{-1a} 16h^{-1}

	Control	1	2	3
Cd	0,2 – 0,3	2,2 – 2,6	3,5 – 4,5	4,6 – 6,6
Cu	13 – 22	82 – 94	134 – 162	191 – 239
Ni	15 – 42	46 – 62	62 – 88	72 – 128
Zn	56 – 94	263 – 303	378 – 477	451 – 699

Contamination (range in mg/kg d.m.)^a

[a] extraction in aqua regia

Annex D (informative)
Proposal for the elaboration of precautionary soil values

The concept used for precautionary values of soil is different of that which is presently being employed for derivation of trigger and action values to evaluate the dangers from soil pollutions in dependence on the exposure pathway and proposed use.

For trigger values a classification according to utilizations, assets worthy of protection and relevant exposure pathways has been proposed, which, however should not be applied to precautionary values. Precautionary values are to allow long-term protection of soils against future impacts. Long-term protection is aimed at preserving the possibility of different uses of soils. A differentiated confinement of the application of precautionary values to certain limited uses would contradict this requirement. A different use would thus rather lead to less ambitious uses. In contrast to this, a differentiation of soils is however needed with regard to their natural composition and sensibility towards pollutants.

The derivation of soil precautionary values is following the notion that any soil will be protected against pollutants, if ecotoxicological effect thresholds — balanced with data on background values -are not exceeded and if, at this concentration level, no evidence gives rise to assume unwanted or hazardous effects on plants and the groundwater, and if there is sufficient difference to the trigger values proposed for the pathway soil/humans.

Determination of precautionary values at concentrations which are below background values is not regarded useful and would by no means result in useful administrative measures. For this reason, the specifically determined effect thresholds are balanced with representative background values.

For soils having naturally increased background concentrations of substances the concern for hazardous soil changes is only given (and subsequently the precautionary duties are triggered), if these substances have been or will be released by anthropogenic influences (e.g cultivations, utilizations).

For derivation of precautionary values the following technical requirements apply:

1. Data on the accumulation and **effect of pollutants** in soils provide the basis for establishing precautionary values. Reference is made first of all to the variety of data given in literature on ecotoxicological effect thresholds (habitat, buffer, degradation and sink function for substance caused effects). If possible, the effect of soil pollutants on other targets to be protected (e.g. food plants including phytotoxic effects, groundwater and human health) is to be evaluated in addition. The effect thresholds determined shall be checked against soil background values in order to pay regard to the soil as **integral part of the ecosystem**.
2. The sensibility of soils shall be taken into consideration by classification of the soil texture (clay, loam, sand) and by using the pH value. Soils with significantly increased background contents shall be evaluated separately. Classification of a given soil into the categories introduced for precautionary values shall be enforceable.
3. Precautionary values shall be given as total contents for characterization of the long-term ecological relevance of a substance including its potentially mobilizable fraction. In order to particularly consider the soil function as “soil ability to filter, buffer and degrade substances, in particular, for the protection of groundwater” additional data give in mg/l leachate might be used to assess predicted leachate contents (not within the scope of this report).

Methodical considerations for implementation of requirements. In the following two methods for evaluation of ecotoxicological effect data are presented, which, however, are not specifically adapted to the question raised in this context. Subsequently, the reasons for using a different approach are stated.

Different possibilities for determination of the ecotoxicological effects of pollutants on organisms living in soil were investigated and developed in the past. The aim of these studies was the development of a generally applicable method to derive generic soil values. In doing so, particular attention was attached to organic substances in soils, according to regulatory requirements of the Chemicals Act and the Pesticide (Plant Protection) Act, but not to PTE’s, which are being dealt with in this paper.. The relevant facts are given in the annex.

Two methods can generally be distinguished which are presently used to conclude from a measured efficiency date (NOEC or LOEC or EC_x[2]) to an ecological protection target.

1. According to the factor-method a quality objective can be concluded from the lowest empirically determined efficiency date using safety factors of up to 1 000 (mostly used for aquatoxicological evaluation). In the presence of a sufficiently representative NOEC[3] the factor is reduced to 10. The factors 10 – 1 000 are to show interactive effects of substances, the difference between acute and chronic effects and the differences between measurements made in laboratory and those made in the field. Using this method the risk to overlook effects in the low dose range is minimized. This is ensured in particular due to the fact that in chemicals testing this method is not used mathematically and formalistically. Moreover, this method works on the principle to generally employ an assessment factor of at least 10 to pay regard to imponderable insecurities, if required.
2. According to the distribution-method the lowest determined effect data are extrapolated assuming thereby that a) the varying sensibility of the different soil organisms can be depicted by a statistical normal distribution, b) the effect data used indicate the sensibility variations (trophic levels) of organisms, and that c) the protection of 95 percent of species inventory is equivalent to the protection of the soil ecosystem. This method requires a larger amount of effect data as compared to the factor-method. It hence allows the conversion of acute to chronic effect data (e.g. from an EC_{50} to a chronic NOEC), the use of different test parameters or toxicological end points as well as the mathematical conversion of test data obtained from aquatic toxicology to terrestrial ecosystems, which means in this case — to soil.

Worth mentioning is the fact that the factor-method pays regard to insecurities of data, which (might) be the result of the extrapolation of data on monospecies from laboratory tests to the ecosystems to be protected. Both the distribution and the factor method are currently used for assessment of hazards to the environment. Environmental concentration is regarded to be critical, if it exceeds the critical value defined by the methods above mentioned (e.g. as PNEC (predicted-no-effect-concentration) or as HC_5 (hazardous concentration).

From this point of view, a precautionary value, which has the character of a quality objective, should still be below the value regarded to be critical. Because of this, both methods are regarded also generally applicable for the evaluation of substances in soils.

However, the mentioned methods shall not be used in the given context for derivation of soil precautionary values for PTE's, polychlorinated biphenyls and polycyclic aromatic hydrocarbons. The reasons are above all of methodical nature: for these geogenic/pedogenic or anthropogenic substances in soils, the main assumptions of both methods are only insufficient to deduce precautionary standards. In particular, they do not provide for consideration of the complex binding processes of PTE's in soils, the different efficiency pathways on which metals affect soil organisms (as well ingestive uptake and uptake via soil solution) and the partly distinct ability of soil organisms to physiologically regulate the uptake and elimination of PTE's and to thus partly adapt to increased concentrations of PTE's in soils. Likewise, due regard is as well not paid to questions arising for substances such as PCB and PAH from ageing, humification and humus types in soil.

Due to these deficiencies figures are often obtained on the basis of these methods which are unrealistically low in comparison with data on the essentiality or on background concentrations of metals. The applicability of laboratory data to field situations of soils are additional problems which are as well true of other substances.

Therefore, for derivation of precautionary values for the substances mentioned it seems necessary and justifiable to do without a uniform and stringent mathematical formula for all substances[4].

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[2] NOEC — no observed effect concentration, LOEC — lowest observed effect concentration, EC_x — effect concentration for a number (percentage) of the population under investigation

[3] by taking the trophic levels into account

[4] For other pollutants and pollutant groups the usefulness of a procedure according to the factor method or distribution-method shall be proved in detail

Ecological effect thresholds for PTE's, PCB, and PAH shall thus be derived on the basis of direct assessment of data on NO-EFFECT-LEVEL. To this end, the variation range given in literature as to the low/lowest NOECs and LOECs for individual species is used. If available, reference shall be made to data on differentiation of soil texture, metal binding/solution form in soil and sensibility of species to hence assess the significance of the species used and of the effect thresholds (place in the food chain, significance for soil related key processes in ecosystems).

Comparison with data on background contents. Ecotoxicologically founded effect thresholds shall be compared with data on actual soil background contents, which are supposed to reflect the range and frequency distribution of the pollutant contents (background) presently found in soils. In doing so, the following definition is applied: background values are representative values for common background contents of a substance or a substance group in top soils. The background content of a topsoil is composed of the naturally caused (geogenic/pedogenic) content and the ubiquitous substance distribution as consequence of diffuse man-made substance inputs in soils.

The available data bases show the need to differentiate the data on background values according to distinct criteria. Paedogenesis, variety of soils and the type caused by the different uses require the differentiation of background values. From the today's point of view it does not seem useful and appropriate to indicate highly aggregated values in the sense of "one figure for all soils".

As soils exhibit in dependence on their parent substrate and utilization different substance contents and sensibilities a differentiated system of soil values will be required to stipulate regulations covering use of organic materials. The background values show that the lowest pollutant concentrations can generally be found in sandy soils (in particular of pleistocene origin). Loamy soils come next after, which however stand out from clay soils.

Differentiation of soils. The differentiation of soils being essential for derivation of precautionary values is based on the following considerations:

Soils exhibit in dependence on their parent substrate and utilization different heavy metal contents and sensibilities.

For derivation of precautionary values the variety of soils can be combined in certain classes. The classification is based on the main soil type groups. Soil textures are characterized by the grain size of the mineral soil material. The grain size distribution can reliably be determined by relevant laboratory methods as well as by field tests.

The following differentiation of soils seems useful:

Soil type clay: clay content > 25 %
Soil type loam: clay content 12 % to 25 % and silt content > 50 %
Soil type sand: clay content < 12 % and silt content < 50 %

The category "Soils with specifically increased background values", can be defined on the basis of regionally representative background values supported by a supplementary list of european precautionary values or by the individual countries within the frame of the enforcement of soil regulations. The proportion of these soils considering the whole territory of Germany is only small (but sometimes significantly increased in certain areas). Soils generally belonging to this category are as follows:

- soils with geogenic increased contents of e.g. magmatites, metamorphites (e.g. granite, gneiss) as well as of sandstone and limestone
- soils with predominately anthropogenic increased contents (due to the settlement structure)
- soils in marshes and flood areas

Organic soils shall be subject to special considerations.

A differentiation of the pH values of soils is additionally necessary in order to pay due regard to the substance dynamics of PTE's, which in this case is essentially caused by the pH value, which is dependant on the substance. A limit pH value which is given for the mobilization of the relevant PTE's is taken as basis. Within the frame of the derivation of precautionary values the substance-specific pH limit value is used, below which a significantly increased mobilization of cadmium, zinc, nickel and lead is to be expected. For cadmium, zinc and nickel the pH limit value amounts to 6,0 and to 5,0 for lead. For Cd, Zn and Ni, the precautionary values of the category "loam" apply to soils of the category "clay" with pH < 6,0 and for Pb with pH < 5,0; the precautionary values of the category "sand" apply to soils of the category "loam" with pH 6,0, and for Pb < 5,0.

For organic substances not the pH value but rather the humus content of soils is decisive for the mobilization or immobilization of substances. A differentiation of soils according to the humus content has to take into account that — at least in case of agriculturally used soils — the humus content is above all determined by cultivation. The humus content of arable land (topsoils) amounts to 2–3 %, and is sometimes even higher in dependence on the cultivation applied. For grassland, the humus content is in comparison significantly higher and is additionally differentiated according to depth (0 to 10 cm: 6 – 12 %, 10 to 30 cm: 3–6 % and below 30 cm normal content not dependant on use). The humus content of forest soils, which are however not considered in this context, differs in dependence on the horizon.

The differentiation of humus contents required for precautionary values shall be chosen in such a way that in corresponds to the different forms of cultivation. This requirement is fulfilled by the distinction in "greater than or less than 8 %".

Provisional precautionary values expressed as solid material contents as recommended by UBA[5]. Substances and in particular PTE's exhibit different binding forms in soil, which depend on how heavily a substance is bound to the soil matrix and how readily or not readily it can thus be taken up by the plants, whether it is available for soil organisms or can be relocated with soil leachate. In this context soil-related characteristics and processes (above all pH value, soil texture, humus content, redox conditions) play an essential part in addition to substance-related properties.

When evaluating substances in soils it is in particular necessary for PTE's to chose the digestion method appropriate to the proposed aim of the evaluation (extraction method) and to indicate it for the values derived. In general it will be possible to cover separately by using specific extraction methods the different binding forms (fractions) in which a metal is present in soil (can be present). For precautionary purposes of soil protection it is however neither technically feasible nor appropriate in terms of the efforts needed to carry out a sequential extraction with numerous extraction agents. It is rather necessary to determine the total contents or a similar fraction as parameter of the total presumable hazardous potential.

For PTE's the precautionary value is given on the basis of the fraction extracted by aqua regia. By describing the potentially mobilizable substance contents it indicates the ecological-relevant fractions of metal contents in soils.

Aqua regia extraction is often understood to mean total content although, to be exact, the actual total contents are extracted in case of some metals only (e.g. for Cd, Cu, Pb, Zn, Ni between 80 % and 100 %). However, in case of other metals, such as chromium, only a low proportion is extracted. For this reason a difference has to be made between aqua regia extraction and the so-called total digestion (pressure-temperature-digestions with concentrated acids). The advantage of the method is however its high harmonisation degree as it has been defined as standard method both in environmental analysis (ISO 11466) and in the Sewage Sludge Ordinance (86/278EC). The mobile fraction of PTE's includes the proportion soluble in water, the fraction being easily exchangeable due to unspecific adsorption, and the readily soluble metal-organic complexes. Special extraction methods (neutral salt extractions) are available. Their application would be useful for risk assessments of vontaminated sites (e.g. in terms of particular pathways and targets, if there is evidence giving rise to assume soil pollution.

Soil contents extracted by aqua regia offer for soil precaution a standard for evaluation of the substance contents in soil with regard to all ecologically relevant pathways. This is as well true of the pathway soil-leachate, if evident risk factors can be excluded (e.g. presence of solution additives, disturbed soils, unusually high or low pH value, stagnant water.

It has to be taken into account that the data used for determination of soil background values for PTE's have been collected by using different extraction methods (total extraction and aqua regia). As stated above, precautionary values shall be shown for PTE's as contents to be determined by aqua regia, only.

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[5] Federal Environmental Agency (Germany)

As a result of the reasoning given in this report the following soil precautionary values are recommended:

Table 1a — Precautionary values for metals in soils, in mg/kg total content (aqua regia[a])

Soils	Cd	Pb	Cu	Cr	Hg	Ni	As	Zn
Soil texture **clay**	1,5	100	60	100	1	70	20	200
Soil texture **loam**	1	70	40	60	0,5	50	15	150
Soil texture **sand**	0,4	40	20	30	0,1	15	10	60
	soils with specifically increased background contents: established, if required, on the basis of regionally representative background values							
[a] Extraction according to DIN 38 414-7, analysis using ICP OES according to DIN 38 406 22								

Table 1b — Precautionary values for PCB_6, benzo(a)pyrene and $PAH_{(16)}$ in soils mg/kg total content[a]

Soils	PCB_6	Benzo(a)pyrene	$PAH_{(16)}$
Soils with a humus content > 8 %	0,1	1	10
Soils with a humus content < 8 %	0,05	0,3	3
Soils with specifically increased background contents	established, if required, on the basis of regionally representative background values		
[a] Analysis for PCB_6: DIN 38 414-20 for benzo(a)pyrene and $PAH_{(16)}$: method according to *LUA-NW*-Guidance sheet No. 1			

Guidance for application of Table 1a "Precautionary values for PTE's". With regard to Cd, Ni and Zn it is evident that the precautionary values of the category "loam" apply to soils of the category "clay" with pH < 6,0 (pH limit value); the precautionary values of the category "sand" apply to soils of the category "loam" with pH < 6,0. This is also true for Pb using, however, a pH limit value of 5,0.

Annex E (informative)
Working priorities for WG 2

Adopting the general principles expressed in the ISO/IEC Guide 51, these were as follows.

a) List and define the products of interest;

b) Consider the intended use, and reasonably foreseeable misuse of the products;

c) Identify hazards presented by the products;

d) Divide products into homogenous groups, according to their potential hazards related to their composition and intended use, for easier assessment of hazards;

e) Evaluate existing regulations and standards at a National and International level;

f) Set, for each identified hazard, its recommended level of safety (also defined as Intrinsic Safety: the maximum tolerable level of hazardous components);

g) Formulate any additional recommendation to be included in a label, in case the necessary level of safety cannot be achieved by defining or restricting a product's composition. This includes information on proper use, handling, use of protective clothing and equipment, storage, disposal, and warning of unavoidable residual risk;

h) Summarize all findings and recommended actions in a technical report.

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