Wettelijke Onderzoekstaken Natuur & Milieu

Appraising Fertilisers: Origins of current regulations and standards for contaminants in fertilisers

Background of quality standards in the Netherlands, Denmark, Germany, United Kingdom and Flanders

WOt-werkdocument 336

P.A.I. Ehlert, L. Posthuma, P.F.A.M Römkens, R.P.J.J. Rietra, A.M. Wintersen, H. Van Wijnen, T.A. van Dijk, L. van Schöll and J.E. Groenenberg

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Appraising fertilisers: Origins of current regulations and standards for contaminants in fertilisers

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P.A.I. Ehlert

L. Posthuma

P.F.A.M Römkens

R.P.J.J. Rietra

A.M. Wintersen

H. Van Wijnen

T.A. van Dijk

L. van Schöll

J.E. Groenenberg

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Abstract
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The standards for contaminants in fertilisers in Denmark, Germany, Flanders, the Netherlands and United Kingdom, are given in the context of the proposals for new European fertiliser legislation. This EU legislation might result in generic limit values for contaminants and input lists of materials, and importantly specific waste materials, per categories of fertiliser. With the national and European targets of recycling and energy recovery, the sustainable use of waste materials as fertilisers is becoming more and more important. A revision of the fertiliser legislation is therefore not only relevant for agriculture but also for the waste and energy sector. Compared to the surrounding countries the limit values in the Netherlands are low for heavy metals and high for organic contaminants. The origin of the limit values, the basic protection policies and the risk analysis have been traced especially for the Netherlands, and roughly for the surrounding countries. The limits for heavy metals in fertilisers in the Netherlands are based on the protection of the soil, on practice, and in case of organic contaminants, also on a risk analysis. Also in the surrounding countries, the limit values have been derived using the same basic concepts of protection and risk analysis. The differences and similarities between the basic concepts to derive limit values between the countries give a starting point for a revaluation and new limit values for fertilisers.

Keywords: Fertiliser, regulation, soil amendment, liming material, compost, sewage sludge, contaminant, heavy metals, persistent organic contaminants, risk assessment, risk basis, the Netherlands, Flanders, Denmark, Germany, United Kingdom, EU.

P.A.I. Ehlert, P.F.A.M Römkens, R.P.J.J. Rietra, J.E. Groenenberg – Alterra Wageningen UR
L. Posthuma, A.M. Wintersen, H. Van Wijnen - RIVM
T.A. van Dijk, L. van Schöll - Nutriënten Management Instituut (NMI)

P.O. Box 47, 6700 AA Wageningen
Phone: +31 317 48 07 00; e-mail: info.alterra@wur.nl

Rijksinstituut voor Volksgezondheid & Milieu (RIVM)
P.O. Box 1, 3720 BA Bilthoven
Phone: +31 30 274 91 11; e-mail: info@rivm.nl

Nutriënten Management Instituut (NMI)
P.O. Box 250, 6700 AG Wageningen
Phone: +31 088 876 12 80 ; e-mail: nmi@nmi-agro.nl

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Statutory Research Tasks Unit for Nature & the Environment, P.O. Box 47, NL-6700 AA Wageningen, The Netherlands
Phone: +31 317 48 54 71; Fax: +31 317 41 90 00; e-mail: info.wnm@wur.nl;
Internet: www.wageningenUR.nl/wotnatuurenmilieu

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Executive summary

Background

Fertilisers are essential for increasing crop production, especially when soil fertility is low and there are insufficient animal manures, composts or other nutrient containing residues. Fertiliser production in Europe started in 1842. Since then many industrial processes for fertiliser production have been developed. Inefficient production methods were abandoned and replaced by newer production methods. This development still continues, especially when new insights about fertiliser production and use emerge.

High quality fertiliser are commodities of free trade within the European Union (EU), according to the Regulation No 2003/2003 relating to Fertilisers. This regulation sets quality standards for nutrient elements in the fertilisers and prescribes the methods of fertiliser analyses, sampling protocols and tolerances. However, other fertilisers, soil amendments, growing media and other stimulatory products that enhance soil fertility and the yield and quality of the crop are regulated by Member States in national regulations. These national regulations often differ, thereby creating barriers for free trade. In various Member States, both the quality and the dosage of other fertilisers, soil amendments, growing media and other stimulatory products are regulated. Thereby the total input of inorganic and organic contaminants and other risk forming substances is regulated. However, Member States use different approaches of risk assessment and have addressed different contaminants.

Regulation No 2003/2003 is currently under revision, so as to include also regulations about other fertilisers, soil amendments, growing media and other stimulatory products. This revision involves harmonisation of the regulations of Member States. At the same time, the revision will have to consider the initiatives of the Commission related to a resource efficient Europe and a waste free Europe by the year 2030, the 'End of Waste criteria' formulated within the Waste Framework Directive (2008/98) and other EU Regulations and Directives, such as the – under revision - Sewage Sludge Directive 86/278, which regulates heavy metal contents in sewage sludge, and the Water Framework Directive 2000/60.

Purpose of this report

There is little comprehensive information about national regulations on contaminants of 'other fertilisers, soil amendments, growing media and other biostimulants for crops' in EU-27. Therefore, at the request of the Ministry of Economic Affairs an comprehensive overview of current regulations with their origins have been compiled. The purpose of the explorative study reported here was twofold:

- To describe and analyse the concept of 'risk-basis' (in Netherlands *'risico-basis'*), which have been used to derive quality standards for contaminants in fertilisers and (organic) waste materials in the Netherlands and neighbouring countries Denmark, Belgium-Flanders, Germany, and the UK to assess their potential risks in view of impact on the environment in a broader sense i.e. the long-term impact on soil, water, product quality and ecosystems. Specific attention is paid to the conceptual aspects of soil policy in the Netherlands as an example of a system-oriented risk-based approach.
- To make a (technical) description of the history and background of current regulations regarding other fertilisers, soil amendments, growing media and other stimulatory products that enhance soil fertility. This includes both a description of the scientific basis of current legislative frameworks as well the actual numerical values that pertain to fertilising and contaminant loads or

concentrations. The study focusses on the Netherlands but a comparison is carried for neighbouring countries (BE-VLG (Flanders), DE, DK, UK).

This report serves as a background document for the Ministry of Economic Affairs and is focused solely on contaminants.

Principle of derivation of risk basis

The general principle of a risk basis consists of various so-called protection targets. Risk basis for fertilisers aims on protection targets for yield and quality of crops, human health, (farm) animal health, ecosystem health, and so forth. The risk basis ultimately leads to a critical level in soil (which protects all protection targets), and – in the case of fertilisers (figure S1) acceptable levels and/or loads

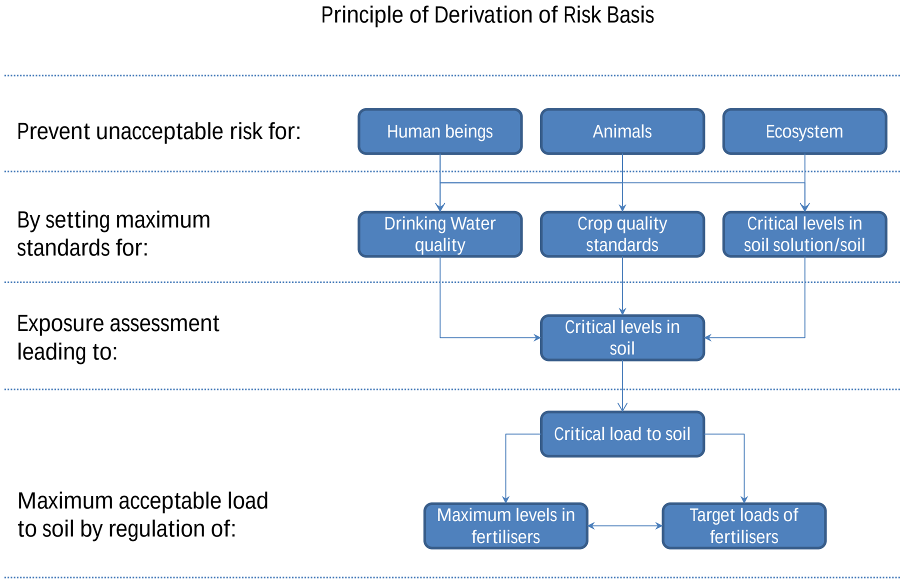


Figure I Concept of risk basis to regulate level or loads of contaminants in fertilisers

Please note that there is a difference between_risk-basis and risk-based:

- Risk-basis: the ***concept*** applied to derive a standard for soil or soil amendments (including fertiliser). An example of a risk-basis is the principle of stand-still. In chapter 2 different concepts of the risk-basis are described. An important aspect is that the risk-basis is not necessarily risk-*based*
- Risk-based: in order for a standard in soil or fertiliser to meet the ***criterion*** of 'risk-based' there needs to be a quantifiable link between the acceptable level (in the fertiliser) and an effect in soil, crop or water which is usually related to a quality criterion in each of these compartments (e.g. food quality standard or water standard).

Concept of 'risk-basis' in The Netherlands

Policies in the Netherlands on agriculture and land use date back to the Constitution of 1798 and have developed into both soil and fertiliser policies. Environmental regulations are commonly risk – rather than effect – based, as the latter implies impacts to occur before action. Historically, legislation on fertilisers was developed independent of those for soil protection against input of contaminant to soils. Specific laws on soil protection were developed some 25 years ago. These initial environmental standards were mostly related to background concentrations and expert judgement. Later on a more formalised framework for deriving Environmental Quality Standards was established based on scientifically derived background values and Environmental Risk Limits. The notion of a specific risk-basis nowadays is the basic principle for the derivation of standards and limits of contaminants in fertiliser (all types) and soils. Chapter 2 of this report presents a description of the development of the risk-basis and regulatory principles in the Netherlands.

Overview of legislations in some EU Member States

In chapter 3, an overview is presented of the legislation about contaminants in fertilisers in the Netherlands, Flanders Belgium, Denmark, Germany and United Kingdom. This overview is a result of bilateral consultation of national experts and our own research. In Europe there is a harmonised regulation on the use of sewage sludge according the EU Sewage Sludge Directive 86/278/EEG. However standards for sewage sludge as well as maximum allowable dosage of sewage sludge differ between reviewed member states (Table I.). The same accounts for compost (Table II.). Both maximum allowable dosage and standards differ between countries that share similar land uses, soils and climates. It is clear from our review that the regulations differ between these countries. Differences between Member States in national regulations relate to types of inorganic contaminants and (persistent) micro organic contaminants. However, there are also common elements in the national regulations, such as the profitable aspects of fertilisers and the potential threats of fertilisers.

Table I. Comparison of standards for sewage sludge in Denmark (DK), Belgium Flanders (VLG), Germany (DE), the Netherlands (NL) and current standards for Sewage sludge by the EU (86/278). For comparison some values have been calculated [d] (between brackets).. Parameters that cannot be compared are omitted [e].

Contaminant	**DK [e]**	**VLG [e]**	**DE [e]**	**NL**	**UK**	**EU**
Maximum dosage of sewage sludge in tonnes dry matter per hectare per year						
	7		1.6	2[c]		
Maximum dosage of contaminants in kg $ha^{-1}yr^{-1}$						
Cd	(0.0056)	0.012	(0.016)	(0.0025)	0.15	0.15
Cr	(0.7)	0.500	(1.5)	(0.15)		
Cu	(7)	0.750	(1.3)	(0.15)	7.5	12
Hg	(0.0056)	0.010	(0.013)	(0.0015)	0.1	0.1
Ni	(0.21)	0.100	(0.3)	(0.06)	3	3
Pb	(0.84)	0.600	(1.5)	(0.2)	15	15
Zn	(28)	1.8	(4.1)	(0.6)	15	30
As	(0.175)	0.3		(0.03)		
PAH	(0.021)	0.00136 - 0.0046 [b]				
PCB		Σ 0.0016 [c]	0.0008 [a]			
limit values for contaminants in mg kg^{-1} dm						
Cd	0.8	6	10	1.25		20 – 40
Cr	100	250	900	75	25	
Cu	1000	375	800	75		1000 – 1750
Hg	0.8	5	8	0.75		16 – 25
Ni	30	50	200	30		300 – 400
Pb	120	300	900	100		750 – 1200
Zn	4000	900	2500	300		2500 – 4000
As	25	150		15		
PAH	3	0.68 – 2.3 [b]				
PCB		Σ 0.8 [c]	0.2 [a]			

[a] given per congener or as a sum of congeners (Σ) in ng/kg.
[b] the range of limit values for different PAHs.
[c] grassland (1 tonnes ha^{-1} yr^{-1}) and arable land (2 tonnes dry matter ha^{-1} yr^{-1}). Here 2 tons dry matter ha^{-1} yr^{-1} are applied.
[d] calculated on the basis of a maximum dosage of sewage sludge and the limit values.
[e] not all parameters are given, as no comparison can be made, for: Denmark (LAS, DEHP, NPE), Germany (AOX, PCB, PCDD/F) and Flanders (see also table 2.4).

Table II. Limit values for contaminants in compost and other fertilisers (mg kg^{-1} dm) in various countries. When a country does not have standards, the voluntary standards are given (see annex 4). For a comparison the values for the Netherlands have been recalculated to mg kg^{-1} dm.

Contaminant	**Waste and residues used as fertilisers and soil improvers**						**Compost**	**Fertilisers**	**EoW**[c]
	DK[g]	**VLG**[g]	**DE**[g] **type1**	**DE**[g] **type2**	**NL**[h, g]	**UK**	**NL**	**DE**	**EU, Jrc**
	s	s	s	s	s	v	s	s	
Cd	0.8	6	1.5	1	1.25	1.5	1	1.5(2.5)	1.5
Cr	100	250	100	70	75	100	50		100
Cu	1000	375	100	70	75	200	90	900	100
Hg	0.8	5	1	0.7	0.75	1	0.3	1	1
Ni	30	50	50	35	30	50	20	80	50
Pb	120	300	150	100	100	200	100	150	120
Zn	4000	900	400	300	300	400	290	5000	400
As	25 [f]	150			15		15	40	
PCB		0.8 [d]			0.74 -3				
PAH	Σ3 [e]	0.68 – 2.3			Σ20 [e]				
Σ PCDD/PCDF					760	[a]		30(5) [a,b]	
Mineral oil		560 – 5600 [i]			37400				
Dosage									
t ha^{-1} yr^{-1}	7		6.9	10	j				

[a] Units for dioxins, in German DüMV ng TEQ kg^{-1}); in the NL in ng kg^{-1}.
[b] Lower value for grassland
[c] For comparison purposes: the EoW criteria
[d] Per congener
[e] DK: Σ11-PAK, NL: Σ10-PAK
[f] Only private gardens
[g] Not all parameters are given, as no comparison can be made, for: the Netherlands (see table 2.3), Denmark (LAS, DEHP, NPE), Germany (Tl, PFC) and Flanders (table 2.4).
[h] Organic contaminants only in organic fertilisers.
[i] For C10-C20: 560 mg kg^{-1}, and for C20-C40: 5600 mg kg^{-1}.
j Compost use is regulated by phosphate use standards.

Information has been compiled on the composition of fertilisers most commonly used in the Netherlands. Some data are from fairly recent research, however most data were collected more than 10 to 20 years ago. When considering all organic waste materials, animal manure is the main source of copper, zinc, mercury, nickel, chromium and arsenic in the total load to soils. Zinc and copper mainly originate from additives in feed; in addition to this copper in waste from hoof disinfection baths is the second most important source but remains poorly quantified. Compost is the main source of lead but also significantly contributes to the total load of arsenic, chromium, nickel, mercury and zinc. Mineral fertilisers are the main source of cadmium. No recent data are available on organic contaminants such as crop protection product, biocides, pharmaceuticals, detergents etc.

The origin of the standards for regulation of contaminants in the aforementioned Member States is discussed in Chapter 4. Again the overview of the origins is the result of consultation of national experts and our own research.

Regulation of fertilisers in the Netherlands has a long history. The main goal that has triggered legislation of fertiliser was the protection of the farmer against poor quality and fraud with fertilisers, soil amendments and liming materials. From 1889 onwards, the quality of agricultural commodities – amongst which fertilisers – was regulated by law. The quality check solely focused on nutrients, acid neutralising value and organic matter. Due to experience and evolution in the field of agronomy, the basics of the system as we know now were laid and published in 1950. In that year, a novel decree came into force, again focussed on the quality of fertilisers. From then onwards this decree was adapted on a regular basis due to national and international (EEG and BENELUX) developments in fertiliser technology, new fertiliser types and analytical procedures as well as the desire to reduce trade barriers between nations.

For a long time, environmental risk assessment of fertilisers was not an issue in the Netherlands. This perception changed due to repeated observations of serious contaminant impacts on human and environmental health and integrity, animal welfare, agricultural production and product quality. Contamination of soils, water bodies and air, as well as the outbreak of animal diseases, triggered the further development of several laws to protect human and environmental health and agriculture (chapter 2).

The concerns of the past period, on both fertilising as well as risk aspects, has led to the definition of various categories of commodities that were regulated in relation to waste, (re-)use as fertiliser, and potential risks. Animal manure is amongst the products that is most heavily regulated in the Netherlands. Regulations are in place for use, dosage, application standards, application methods and trade which partly triggered the decision not to include environmental concerns related to contaminants. Even more so since it presumably would lead to too many administrative costs without a clear prospect on effective contribution to Good Agricultural Practice. Moreover, the focus of regulations changed to a dual focus: profits and risks.

The change that occurred in 2007 was the final introduction of the dual focus in the regulations. Till 2007 the focus was on the protection of the farmer against poor quality and fraud. Since 2007 it was expanded to a more risk-orientated fertiliser decree. The consideration was that, after 120 years of protection on fertiliser quality, the modern farmer is a well-educated and experienced entrepreneur with adequate knowledge of fertilisers, soil amendments and liming materials. The modern farmer is technically supported by the fertiliser industry and agricultural advisory services and certification schemes are into force. Due to this, the need for regulations on profits of fertiliser and quality control received lower priority for further innovation than regulation on possible risks coming from contaminants in fertilisers. This led to a reduction of regulation on fertilisers, soil amendments and liming materials. In this process, the number of categories of fertilisers was reduced.

For categories of fertilisers in the Netherlands, the profitable (fertilising) characteristics were regulated via relatively low minimum requirements for nutrients, acid neutralising values and organic matter. Furthermore only one definition of fertiliser became into force. The previously used concepts of soil amendments (inorganic of organic) and liming materials were abandoned. The definition of fertiliser which, in the Netherlands, only considers nutritional value, acid neutralising value and organic matter, was related solely to beneficial effects on plant nutrition, quality of the growing medium and the improvement thereof.

In 2007 requirements related to maximum acceptable annual load of heavy metals and persistent organic micronutrients in the fertilisers were installed. These requirements were based on average use of nutrients (load per hectare), acid neutralising value and organic matter. These values, when linked with limit values that were set for soil protection, lead to maximum acceptable loads of heavy metals and POP's in the fertilisers themselves. It should be noted however that in the Netherlands initial soil protection limits used to set the maximum load were not based on a specific environmental effect, i.e. not risk-based, but merely related to target levels (in Netherlands: *Achtergrondwaarden*) derived from screening of non-polluted soils. Obviously acceptable contaminant loads aimed to protect soils at such levels can be considered implicitly protective for all risk categories including risks for ecosystem, groundwater quality or product quality.

In essence, now, the fertiliser act changed from a commodity protection measure to a control measure including risk assessment of fertilisers in view of soil quality, and – henceforth – agricultural products and product quality, as well as health protection for man and ecosystems. The derivation of the standards in the Netherlands, Belgium Flanders, Denmark, Germany and the United Kingdom is described in chapter 4. Chapter 4 is the result of consultation of national experts and our own research. A key issue in the discussion is addressing the risk basis employed to derive current and future quality standards for fertilisers in these countries.

Four principles for managing risks related to contaminants in fertilisers and soil amendments have been distinguished:

1) 'Best practices', based on experience i.e. reasonable lowest achievable levels depending on raw materials (e.g. compost) or production processes
2) 'Acceptable accumulation' in soil (not risk based) e.g. in terms of percentage of present contaminant levels in soil
3) 'No net accumulation' in soil, also called the 'stand still principle' of present levels is soil: inputs of contaminants are balanced by outputs (plant uptake, degradation, leaching and erosion).
4) Risk-based evaluations (Figure II).

Where number 1 through 3 are not specifically targeted at environmental receptors, the Risk based approaches serve the protection of one or more specified receptors of protection targets. Usually one or more of the following receptors are considered: human health, animal health, agricultural production (including the quality of agricultural products in view of human- and animal health), ecosystem and ground- and surface water (Figure II).

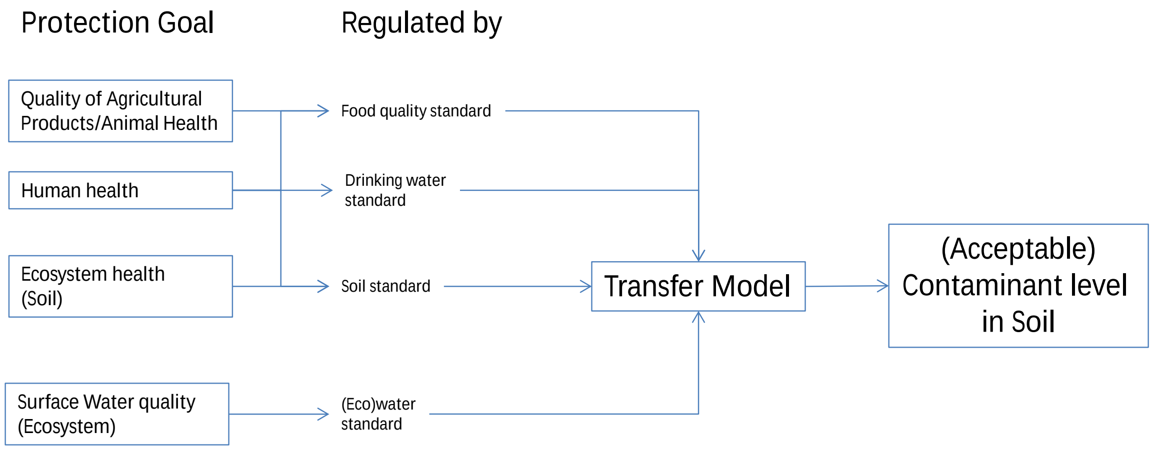


Figure II Relation between acceptors (left) and soil (right). The standards in the middle section refer to protection levels not to be exceeded in order to avoid an effect (i.e. intake of soil, crops, water or exposure to soil or water in case of ecosystem health)

How these concepts of risk management of fertilisers are currently in use in the Netherlands, Belgium Flanders, Denmark, Germany and the United Kingdom is given in Table III.

Clearly, some Member States apply one and the same principle for all materials, while other Member States use different principles for different materials.

Table III. Overview of principles for managing risks related to contaminants in fertilisers and soil amendments in six Member States. Numbers refer to the following principles: 1= Best practice, 2= Acceptable accumulation, 3= Stand still, 4 = Risk-based.

Country	Compost	Digestate	Sewage sludge	Fertilisers*
EU	-[a]	-	2	-
NL	3,1	3	3	3,4[b]
VLG	2	2	2	2
DK	4	4	4	4
DE	3	3	2	4,1
UK	-	-	2	-

* Other fertilisers, i.e., fertilisers not regulated by EC Regulation No 2003/2003

[a] not regulated yet

[b] Protocol version 3.1 for waste and 'reststoffen'

Final concluding remarks

- The current European and national regulations have different definitions of fertilisers and fertiliser appraisal approaches, due to historical reasons but also due to differences in intensity of agricultural practices. This makes harmonisation of legislation difficult.
- Substantial differences exist in numerical values for standards of contaminants between the Netherlands, Flanders, Denmark and Germany. With exemption of sewage sludge, the United Kingdom has no legal standards yet for contaminants in fertilisers.
- Differences originate from different target levels for soil on one hand and acceptable loading rates on the other. This results in a large range of criteria for various fertilisers or organic wastes. Probably this is due to differences in the acceptance of contaminant loading rates, differences in nutrient requirements depending on soil type, climate etcetera as well as intensity of the agricultural production system.
- Member States have developed their own concepts and approaches of risk basis to obtain national guidelines for contaminants in fertilisers. This has led to notable differences in the regulatory basis, which is most visible in advisory values for sludge in different member states. Different definitions and appraisal criteria limit trade across Europe, while they do not earmark responsible application rates.
- The risk basis of contaminants in the Netherlands and Flanders dates from the eighties of the last century. Denmark has adapted their risk basis more recently as well as Germany where the 'negative lists' were converted to 'positive lists'.
- The basis of fertiliser appraisal methods was laid long ago. Progressing scientific insights and data can, via scenario studies, elucidate whether protection targets can be reached under proposed changes of regulations, like EU Regulation No 2003/2003. In many cases the scientific basis of the risk-basis chosen by Member States is based on views and concepts from the 1980's. Although this implies that the approach as such can be improved by considering, for example, a broader and improved risk-based 'systems approach', this does not necessarily imply that current advisory levels are not protective. To assess whether or not current or proposed legal limits are in line with multiple environmental targets, i.e. water quality, ecosystem quality, product quality etcetera, an analysis of the impact of the use and application of fertilisers and other (organic) waste materials should be performed. This obviously requires an appropriate set of tools that are able to quantify the environmental impact of various products in a time frame of

10 to 100 years. Such tools have been developed in the member states (i.e., Denmark, Belgium Flanders, Germany and the Netherlands) which allows for a quantitative evaluation.

- It is advisable to seek a harmonised basis for risk assessment of contaminants in fertilisers. By handling, the same risk basis increases the understanding and dialogue between Member States. Please note that the use of a single risk basis does not necessarily lead to a single EU-wide numerical standard value since differences in land use (e.g. crop type), intensity of agriculture, soil fertilisation and climate can result in ranges of standard values across the EU or in different member states.
- The use of fertilisers is considered commonly for specific combinations of soils, crops and land use, implying the need to define minimum and maximum criteria between which a material can be considered a fertiliser, but also use prescriptions for local application. This can pertain to maximum (macro- and micro)nutrient applications for the situation, as well as specific loads, which can be region- or nation-specific. The aforementioned analysis can result in a flexible system based on either quality criteria of products or allowed annual loads of products which are in line with set protection targets. Considering differences in soil, land use and climate, such quality criteria or loads can be region or nation-specific.
- Beyond the fertilisers themselves, there are major external drivers that imply a need to consider aspects beyond profitable and adverse aspects of fertilisers. Major drivers in the legislation regarding waste, soil and water are:
  - System oriented legislative frameworks (WFD, STT) versus sectorial regulation may result in miss-fits resulting from, on one hand, the desire to obtain a more integral protection of the environment including soil, water and ecosystems versus the sector-oriented approach dealing with specific sectorial protection issues. This is a reply to facts: soil contamination can be a threat to water bodies, the latter being regulated at the European level. Such effects are the main driving force behind e.g. the WFD and Thematic Strategy for Soil protection
  - Sustainable development asks for broadening of scope e.g. to avoid resource depletion:
  - There is a general need or desire to more effectively re-use valuable and non-endless resources, including nutrients and organic matter, in view of a more sustainable land-use. This aspect is relevant for the proposed End of Waste Directive and revisions of the Sludge Directive and Waste Directive.
- Fertiliser quality management and regulations can take various shapes. The actual or desired quality of fertilisers or organic soil amendments can be regulated by various principles:
  - Process control, relevant for organic soil amendments like compost. This then requires less quality control of the product itself provided the process control is sufficient to maintain the desired quality of products.
  - Direct legislative frameworks for product quality or product load based on a risk-based assessment of the environmental impact; at present this can be linked to e.g. the proposed EoW criteria or the (revision of the) Sludge Directive.
  - Indirect legislative frameworks that control the quality of source materials for specific end-products. This is especially relevant for Cu and Zn which are regulated through additives in animal food which ultimately controls levels in manure. Obviously this also requires a system approach that links accepted levels of Cu and Zn in feed additives to levels of Cu and Zn in soil and (surface) waters.
- Benefits and risks aspects both tend to ask for a broader evaluation. The current practical and regulatory drivers make that any revision of the fertiliser regulations have to be seen in view of both benefits – and there: not only crop yield, but a wider evaluation of sustainability issues – of fertilisers as well as potential adverse effects, direct to the soil, or elsewhere, e.g. protection of surface water quality. At present this link between benefits and compliance with multiple environmental targets has not been incorporated in current legislative frameworks. This implies that valuable assets of fertilisers and waste materials at present go unnoticed.

1 Introduction

1.1 Background

Fertilisers have various beneficial effects (supply of nutrients, acid neutralising value and addition of organic matter) but may also contain various contaminants or pathogens which can accumulate in the soil, be taken up by crops and animals or infect various organisms and thus pose a potential threat for man, animal, crop and/or the ecosystem. Since decades, European countries have regulations in place to characterize profits and potential threats of fertilisers in view of both nutritional aspects as well as contaminants. However, on the European level only inorganic fertilisers that meet high quality standards are presently regulated (EU Regulation No 2003/2003) to facilitate free trade. European regulation on maximum levels of contamination in fertilisers is not in force yet, but some member states have obtained a derogation to set maximum allowable contents for Cadmium.

Other fertilisers, soil amendments, growing media and other stimulatory products that enhance soil fertility and the yield and quality of the crop are regulated by Member States in national regulations. These national regulations often differ, thereby creating barriers for free trade. Both the quality and the dosage of other fertilisers, soil amendments, growing media and other stimulatory products are regulated, and thereby the total input of inorganic and organic contaminants and other risk forming substances. However, Member States use different approaches of risk assessment, have addressed different contaminants and use different standards.

A revision of the EU Regulation No 2003/2003 is currently in progress. It is important to define a comprehensive and contemporary regulatory methodology for optimizing trade in the European Union (of which the revenues are estimated at approx. 20 billion Euro) and at the same time safeguard the protection of the environment and its services to men.

The setup of such a regulatory methodology should be in line with the End-of-Waste (EoW) criteria from the Waste Framework Directive (2008/98/EC) that aims at a zero production of waste in 2030 which can lead to an increased re-use in agriculture of various product groups. Applying or recycling of waste materials will thus become increasingly important. Also, the European Commission focusses on smart, sustainable and inclusive growth within the Union, with adaption mechanisms and new production methods with no waste. Fertilisers are seen as a necessary requirement to support this growth. However, the level of contaminants in fertilisers must be restricted because accumulation in time may lead to adverse effects including excess uptake by arable crops, leaching to groundwater or impact on the soil ecosystem.

1.2 The revision of the fertiliser regulation

A revision of fertiliser regulations is only in part triggered by the upcoming revision of EU Regulation No 2003/2003. The following motives also play a role:

- *Agriculture requires the use of nutrients, liming materials and organic matter* to maintain or enhance soil fertility. Reliable, homogeneous and trusted fertilisers are needed. Quality control and assessment safeguards crop production.
- *More sustainable use of nutrients and organic matter.* Organic soil amendments including waste materials such as manure, sewage sludge, and compost are valuable sources of nutrients, neutralising value and organic matter. In view of a more sustainable use of nutrients, notably N and P, in combination with the desire to increase or maintain the soil organic carbon content and pH, an increase of the use of various classes of (in) organic (waste) materials is being considered.

- *Outdated scientific basis for quality assessment.* The basis of the current legislation of contaminants in fertilisers in the Netherlands for instances dates back to the early 1980's. At that time, researchers pointed out that the long-term use of products like sewage sludge could lead to unwanted accumulation of contaminants in soil and subsequent transfer to arable crops, grazing animals or the groundwater, potentially causing unwanted human health and ecosystem impacts. In the Netherlands and other countries, legislations and concerns resulted in a gradual reduction of application of sewage sludge in agriculture. The scientific basis for the assessment of the quality of organic soil amendments, however, is outdated in view of the risk basis applied for the derivation of current standards (TCB, 2012).
- *Lack of harmonisation across EU.* At present, approaches used to derive present limits have not been harmonized (except for pesticides) between various countries and this hampers a clear evaluation of the potentials for re-use of (in)organic waste materials. It also hampers the cross-border trade, and application, of fertilisers and thus the reduction of waste volumes.
- *Need to facilitate trade.* At present (free) trade of fertilisers can be hindered by a lack of European legislation, as only inorganic fertilisers with a high quality are covered by Regulation 2003/3003. Differences in national legislative frameworks lead to a non-level playing field regarding the quality of fertilisers and the regarded maximum levels of contaminants in fertilisers.
- *Re-assessment of contaminants regulated.* Current legislation is often based on contaminants-of-interest from the period 1970-1980. The presence of these contaminants in current-day fertilisers, liming materials or soil improvers etc. may be different, as phasing out may have reduced contents and thus their threats or potential risks. Process control (in case of compost or sewage sludge) can lead to a change or contaminants present in the final products, whereas indirect legislation has induced changes in the quality of and contaminants present in fertilisers (EU, 2003). This is for example relevant for levels of Cu and Zn in animal manure which at present are indirectly regulated by EU directive on additives in animal feed rather than by a direct regulation on the quality of manure.

1.3 Aim of the report

In view of the upcoming revision of EU Regulation No 2003/2003 on the trade regulation of fertilisers on contaminants it is imperative to understand how the current legislation regarding the quality of fertilisers and (organic) soil improvers including waste materials like sludge and compost is organised. The regulation of fertilisers concerns both the profitable aspects as well as potential threats. Contextual data on the amounts and types of fertilisers is provided in Box 1.

Box 1. Key data on current groups of fertilisers in the EU

According to Spaey *et al.* (2012), 5 main categories of fertilisers and soil improvers can be distinguished based on either nutrient supply or other aspects as listed in table 1. In this table an indicative total market values is added to illustrate the obvious differences between the groups distinguished. A detailed list of specific products belonging to these 5 major groups is included in appendix 1.

Overview of (in)organic fertilisers as regulated by EC No 2003/2003 and estimate of market value.

Groups	Function	Type		Revenues (billion €)	% of total
Fertilisers	Nutrient based	Inorganic		17	83
		Organic		1	5
		Mixtures		?	?
	Other	Growing Media		1	5
		Biostimulants		0.4	2
		Soil Improvers	Inorganic (lime)	0.5	2.5
			Organic (compost)	0.5	2.5

Source: Spaey *et al.*,2012

Hence this report has two main aims:
- Describe and analyse the fundamental concepts of the key concept which is known as the 'risk-basis' (in Netherlands '*risico-basis*'), which have been used to derive quality standards for

contaminants in fertilisers and (organic) waste materials in the various countries to assess their potential risks in view of impact on the environment in a broader sense i.e. the long-term impact on soil, water, product quality and ecosystems. This not only pertains to legislation of fertilisers but also soil policy in general. Specific attention is paid to the conceptual aspects of soil policy in the Netherlands as an example of a system-oriented approach. Box 2 and 3 provide in a nutshell some fundamental differences between risk-basis and risk-based concepts.
- A (technical) description of the history and background of current legislation of fertilisers and materials used to improve soil fertility including compost, sewage sludge, digestate etc. This includes both a description of the scientific basis of current legislative frameworks as well the actual numerical values that pertain to fertilising and contaminant loads or concentrations. This has been done for the Netherlands and in comparison to neighbouring countries (BE-VLG (Flanders), DE, DK, UK). Relevant EU directives are addressed in these descriptions and comparisons also.

The report was prepared on request of the Ministry of Economic Affairs (EZ), until 2012 Ministry of Economic Affairs, Agriculture and Innovation, (EL&I) to the Netherlands Scientific Committee of the Manure Act (*Commissie Deskundigen Meststoffenwet* (CDM)). A consortium of Wageningen UR Alterra, the National Institute for Public Health and the Environment (*Rijksinstituut voor Volksgezondheid en Milieu* RIVM) and the Nutrient Management Institute (NMI), covering all relevant aspects of the work, was asked by CDM to execute this work. This report serves as a basis document for the Ministry of Economic Affairs and is solely focused on contaminants. The results of this work can serve in on going policy processes in the EU and as a starting point for a potential subsequent study aimed at the development of improved approaches for the Netherlands, given the broader European context.

1.4 Contents of the report

This report discusses the following topics:
- Overview of relevant environmental standards in the Netherlands with a focus on the origin and development of the soil protection policy. As such, the soil protection and management policy in the Netherlands is much broader than just regulation of inputs from fertilisers. Chapter 2 presents backgrounds on the risk concepts used in the Netherlands and the link between soil protection and human (or ecosystem) health. Then the study focusses on fertilisers and all materials with nutrients, acid neutralising value and organic matter that can support crop production and crop quality and maintain or enhance soil fertility.
- An overview of the current legislative frameworks for contaminants regulated in the Netherlands and neighbouring countries for fertilisers, liming materials and (in)organic soil improvers (Chapter 3). Countries included in this study, besides the Netherlands, are Germany, Denmark, Belgium (Flanders), and the UK;
- Current acceptable levels of loading rates for fertilisers, liming materials, soil improvers and raw materials used for the production of fertilisers as regulated in the above listed countries (Chapter 3);
- Assessment of the current quality of fertilisers produced in the Netherlands in view of current and proposed quality standards (Chapter 3)
- The scientific background of current legislation concerning the maximum allowed content of inorganic and organic contaminants in the 5 countries (Chapter 4). This will also illustrate whether or not current standards are mainly derived from national or international concepts.
- Scientific concepts used in neighbouring countries to derive limits for contaminants in various products applied to arable land and how do standards used in the NL deviate from other countries based on differences in the risk base. Chapter 5 presents the main concepts regarding the risk basis applied in various countries and discusses the main differences and consequences for current legislation.
- A synthesis is given in Chapter 6.

Box 2. Risk-basis versus Risk-based

A key issue in the discussion is the *risk basis* employed to derive current and future quality standards for fertilisers. A risk based approach aims to prevent undesired damage, whereas an effect-based approach is based on observed damage.
The principle of a risk basis is schematically illustrated in figure 1.1 given in box 3; see chapter 2 for a more elaborate description of specific concepts of the risk basis currently used in different EU member states.
Note that there is a difference between risk-basis and risk-based:

- Risk-basis: the ***concept*** applied to derive a standard for soil or soil amendments (including fertiliser). An example of a risk-basis is the principle of stand-still. In chapter 2 different concepts of the risk-basis are described.
- Risk-based: in order for a standard in soil or fertiliser to meet the ***criterion*** of 'risk-based' there needs to be a quantifiable link between the acceptable level and an effect in soil, crop or water which is usually related to a quality criterion in each of these compartments (e.g. food quality standard or water standard).

This report also describes how various concepts of a (only seemingly uniform) risk basis have been used, which partly explains the differences in quality criteria for fertilisers in different countries (further elaborated in chapter 3). It is important to realize that numerical values of fertiliser criteria are of high practical value (that is: a material is judged by these 'hard' values, and cross-European harmonisation is then needed to trade such materials), but numerical differences do not necessarily imply differences in 'real' quality. Two countries can both protect their environment by setting different maximum allowable contaminant contents in fertilisers, but when both these two values are (far) below the content that will have a toxic effect, both will be protective.

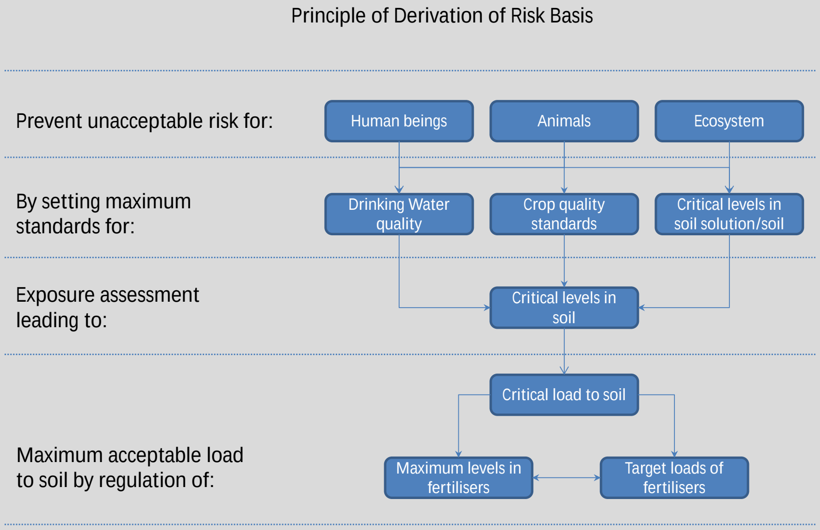
In general, the risk basis consists of various so-called protection targets. Commonly, the protection targets are human health, (farm) animal health, ecosystem health, good quality crops, and so forth. The risk basis ultimately leads to one critical level in soil (which protects all protection targets), and – in the case of fertilisers – to maximum levels in fertilisers (figure 1.1, box 3).

At present the risk basis employed in various countries in the EU is uniform in some basic aspects (e.g., the choice of using risks rather than impacts, the choice of protection targets) but also differs due to historical reasons (independent risk evaluation processes between product categories and countries), which had led to different acceptable levels of contaminants in fertilisers and (organic) waste material. These differences are due to:

1. Difference in policy-chosen *acceptable levels* in soil in view of risk. Examples include differences in so-called (natural) background values of contaminants in soil which are used as no-regret levels in view of accumulation
2. Different scientific *model concepts* to calculate the maximum applicable load of contaminants to soil
3. Different set of underlying data, to address the exposure-effect relationships (like those of figure 1.1)
4. Different application rates of nutrients, liming materials or organic matter leading to different acceptable loading rates to soil of contaminants

In short, it is *a priori* known that environmental regulations commonly follow from the uniform set of principles provided here, but also that they likely differ in their final appearance (practical judgement criteria, definitions), due to historically defined processes.

Box 3. ***Concept of risk basis to regulate levels or loads of contaminants in fertilisers***



2 Overview of environmental standards in the Netherlands

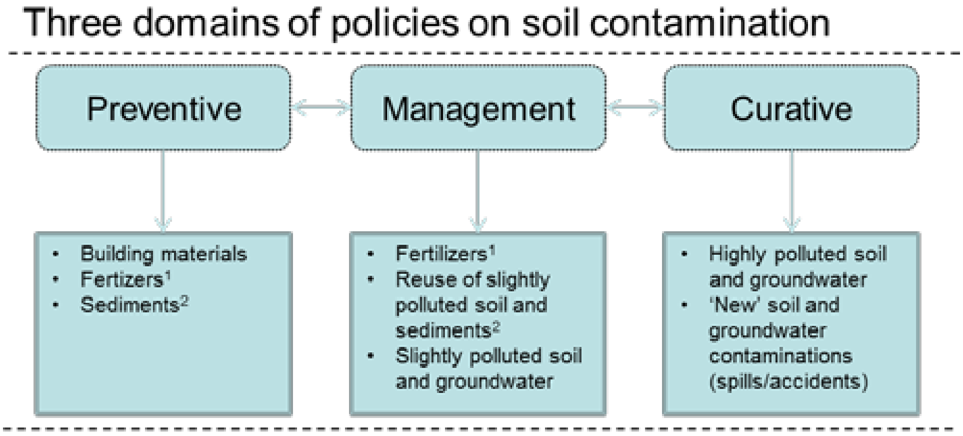
- High-level regulatory principles, such as defined in the Constitution, define a clear over-all policy target as well as a playing field, within which a suite of past, current and future environmental regulations has been derived as operational approaches and tools
- Environmental regulations are commonly risk- rather than effect- based, as the latter implies impacts to occur before action is taken
- Historically, legislation focusing on fertilisers was developed partly independent of those for soil protection against inputs of contaminant to soils.
- Protective soil quality standards can be risk based, or based on other appropriate endpoints like background values from undisturbed areas
- Harmonising soil and fertiliser policies, up-to-date methods for appraisal of soil quality and threats are useful for a comprehensive approach for fertiliser appraisal

2.1 Introduction

This Chapter describes the underpinning of the predominantly risk-based Environmental Quality Criteria that are currently in use in soil and fertiliser policies of the Netherlands. The policies on agriculture and land use date back to the Constitution of 1798 and have developed in to both soil and fertiliser policies. Regulations on soil remediation and management have undergone major developments (Swartjes *et al.*, 2012), with most recently a major revision in 2008 (*Besluit bodemkwaliteit*/Soil decree, Ministry of VROM). Amongst the new elements that were introduced in regulation are land-use specific quality standards for soil management, web tools that enable setting site-specific standards and site-specific risks, and a completely revised set of Background Values which relate to observed compound concentrations in agricultural soils (Section 2.5.1). The criteria that are in use in fertiliser policies date from further back and it is now widely recognized that the criteria and approaches in use are in need of updating (*Technische Commissie Bodem*, 2012). However, the basic principles of problem definition and hazard and exposure assessment that are described in this Chapter apply to all risk-based standards, forming a uniform basis for harmonisation.

In policies in the Netherlands on with environmental contamination, three domains can be distinguished (Figure 2.1). Policies in the preventive domain are aimed at averting the introduction of new contaminations into the environment by, for instance, setting product quality criteria for building materials, fertilisers and sediments.

Soil management policies deal with existing, diffuse pollutions that may pose restrictions on land use. Finally, policies in the curative domain deal with existing pollutions that pose unacceptable risks to men and/or the environment. Additionally, in the Netherlands, new contaminations, due to spills and other incidents need to be remediated regardless of the risks posed by the contaminations.
The horizontal arrows in Figure 2.1 indicate the necessity of the harmonisation of policies across the three domains. For instance, criteria for Fertilisers in the domain of soil quality management may not allow for the introduction of new contaminations necessitating remediation actions according to the policies in the curative domain.



[1] *Fertiliser regulation in the Netherlands is partly in the preventive domain (in the case of the introduction of 'new products' into the environment) and partly in the management domain (in the case of organic fertilisers that are part of a local product cycle).*

[2] *The reuse of sediments is regulated both in the preventive domain (by setting product standards) and in de management domain (using soil-use specific criteria).*

Figure 2.1. Domains of policies on soil contamination. Note the horizontal arrows between the domains indicating the need for harmonisation of policies across these domains

2.2 Environmental policy: from broad targets to specific goals

The Netherlands is a densely populated country with a large agricultural economy as well as a large industrial heritage. It was among the earliest countries to develop nation-wide environmental policies addressing an increasing range of issues.

Since 1983, the Constitution provides the fundamental grounds for environmental protection and management as follows (Article 21): *"The Government's charge is to ensure inhabitability of the country and the protection and improvement of the environment"*[1]. With the Constitution as fundament, a suite of specific laws has been derived. Until the late 1960's, for example, the Nuisance Act of 1875 was the only (rather limited) legislation, authorizing municipal governments to abate serious pollution at the local level. With the passing of the Pollution of Surface Water Act (1969) and the Air Pollution Act (1970), the first steps were taken to define the national boundaries of the ecological arena as an area of concern. Indeed, these laws marked the beginning of a decade in which comprehensive legislation was created to manage numerous aspects of the physical environment. During this first decade after the establishment in 1972 of the Environmental Protection Department, as a separate body within the Ministry of Public Health Care, the following major legislation was passed: Seawater Pollution Act (1975), Wastes Act (1975), Environmentally Hazardous Substances Act (1976), Noise Nuisance Act (1979), Groundwater Act (1981) and Soil Clean Up Act (1982) (Keijzers, 2000).

For all these laws, a key driving force that enabled the translation of protection targets into tools was the concept of risk: instead of reacting to damage, the fundamental choice was to regulate potential threats to the environment on the basis of risk. Risk is a combination of the probability and severity (nature and magnitude) of effects of an action. Risk assessment is the technical support for decision making under uncertainty, the latter reflecting the issue of 'probability' and chance.

[1] Grondwet 1983 tot heden, Artikel 21: De zorg van de overheid is gericht op de bewoonbaarheid van het land en de bescherming en verbetering van het leefmilieu.

2.3 From hazard identification to risk management

All kinds of (risk-based) environmental standards as well as higher tiered instruments are based on the classical risk assessment paradigm, in which both exposure and hazards are assessed to generate a risk characterization (Figure 2.2). The problem definition is here: there can be potential threats of deposition of material on land, such that the environment is – immediately or on the long run – threatened beyond the protection target that is set.

In the case of contaminants which are present in fertilisers, the assessment proceeds as follows. First, the exposure assessment considers whether exposure is likely, and to which extent. Exposure assessments can range from simple (in the case of total concentrations for ecological risks, see 2.5.3), to relatively complex, using advanced multimedia models which, for instance, taking into account substance degradation, repeated applications (Figure 2.4) and soil use. Second, the hazard assessment considers the effects that occur when exposure increases; this step usually considers dose-effect relationships[2]. When the exposure results for a situation are combined with the dose-effect relationship, the risk level of a situation can be derived in the risk characterization. When, furthermore, a policy choice has led to a maximum value of effect (a risk limit), it can easily be seen whether an environmental concentration for a contaminant is below or beyond that limit. Thus, a risk limit (a maximum tolerable effect level that is policy-chosen) can lead to concentration limits in the environment. The latter are different for each chemical, since the dose-effect relationships differ amongst compounds. Risk management is triggered when the exposure is, or may develop to be, higher than the chosen risk limit.

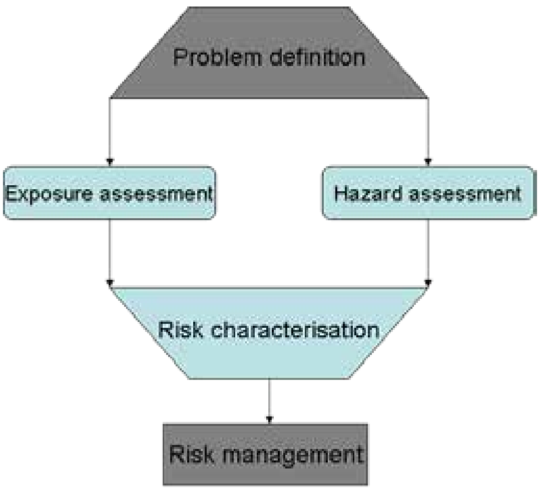


Figure 2.2. From problem definition to risk management (adopted from US National Research Council, 1983)

2.4 Waste, fertilisers and soil as protection target

2.4.1 Overview

Given the Constitution, the Netherlands government has derived specific laws on soil protection and management; the year 2012 is the year of the 25th anniversary of the Soil Protection Act. Since major areas of the Netherlands are used for agriculture, there is an important link between

[2] Various examples of dose-effect relationships are presented in this Chapter. For example SSD's (Section 2.5.3) that are used to translate environmental concentrations ('dose') into ecological damage ('effects').

agriculture and soil. Amongst others, this concerns the use of fertilisers. Fertilisers may be of natural origin, or they may be artificial. Furthermore, fertilisers may contain many of the same substances that are regulated under the Soil Protection Act.

Some of these resources are – by law – characterized as ‘waste’ . By European regulations, waste is not a primary product, but: ‘*……"Waste" shall mean any substance or object …… which the holder discards or intends or is required to discard.*’ Though a farmer may have superfluous products (like corn plant remains), and though these materials are waste because it is not the primary product, such waste can be an appropriate fertiliser, as has been recognized for very long, as well as that it can be used to generate ‘green gas’, a more recent notion. While re-use of organic remains as fertiliser is ages old, the issue of risk assessment has come up in the last decades. Agricultural materials can contain remains of compounds like plant protection products or other chemicals. Due to this, regulations have been derived to operationalize the generic environmental protection target in the Constitution into soil protection regulations, waste regulations and fertiliser regulations and associated tools.

2.4.2 Soil policy overview

Upon the soil contamination case in the village of Lekkerkerk, in 1980, the Netherlands government published the Interim Soil Remediation Act in 1983. This act included the first generation of soil quality standards (SQSs, the A, B and C Values), based on background concentrations for soils known then and expert judgement. In 1987, the Soil Protection Act was introduced (Ministry of VROM, 2006). A main purpose of this act was to establish the accountability of individuals, which means that parties are fully liable for each case of soil contamination created since 1987. Going from broader principles to risk-based assessments, 1994 saw the first series of risk-based Soil and Groundwater Quality Standards and the methodology to determine the urgency of remediation (Ministerial Circular, 1994). The legislation was extended in subsequent years based on scientific evaluations. A major evaluation and update of the first series of SQSs was concluded in 2001 (Lijzen *et al.*, 2001; Otte *et al.*, 2001; Rikken *et al.*, 2001; Baars *et al.*, 2001; Verbruggen *et al.,* 2001).
SQSs are now operational for a suite of substances, and they pertain to various levels of protection or impact.

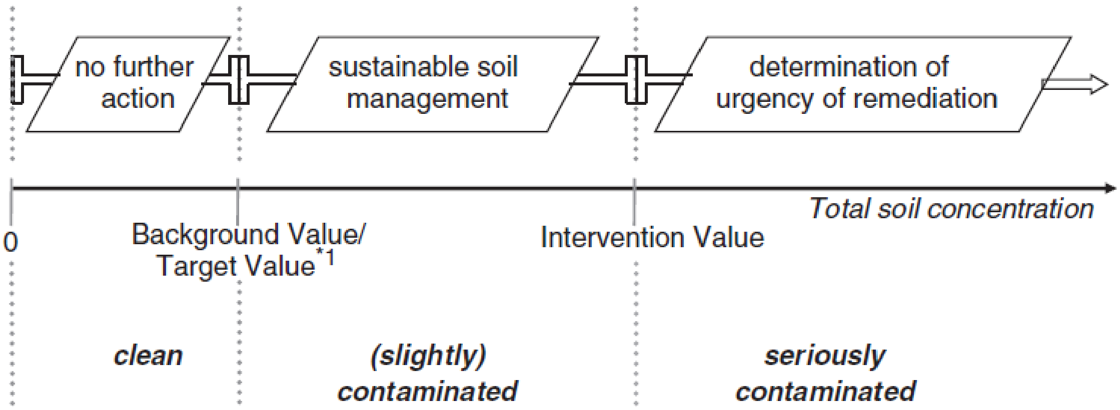


Figure 2.3. Maximum Values in soil management policy in the Netherlands

As a pragmatic lower bound, Background Values have been derived to define soil that is tagged ‘clean’. These Values were derived from compound concentrations measured a national inventory of sub soils, collected in natural and agriculturally used areas, with no known point sources of contamination in the vicinity. Considering risks (see also Section 2.5 and beyond), there is no signal that these pragmatic lower bounds imply a risk for man or the environment beyond the maximum tolerable risk level as defined. As upper bound, the Intervention Value was introduced as primary trigger to consider a soil as being 'highly contaminated'. That is: for at least one of the protection endpoints, there were risk-based signals of substantial hazard. The Intervention Value triggers further regulatory concerns and possible investigations, but far from always this is followed up by real remediation. This is a consequence of the fact that the value triggers potentials for concern and the need for (some) attention, but in many cases local conditions have appeared to preclude exposure of man or ecosystems. Risks are evidently highest when the source (the contaminant) is in a soil where it is highly available, and where exposure of e.g. man occurs widely due to an intensive use of the soil, e.g., as vegetable garden. In other cases man can be fully unexposed, e.g., due to the presence of pavement and an immobile compound, so that remediation is of lower urgency, An urgency evaluation system (Sanscrit) has been developed to evaluate cases of existing contamination (before 1987), while later contaminations have to be remediated by law.

In-between Background and Intervention Values, the soil is considered 'slightly contaminated'. Since soil use determines the level of local exposure, and since there are various major formats of soil use, a pragmatic classification system has been derived to combine risk-based protection of man and ecosystems and the needs imposed by activities with soil, like excavation and building. Soils may be transferred within their own soil quality class, or to a higher class, implying (at least) stand still (as stipulated in the Constitutional Article 21).

The scheme of Figure 2.3 provides a pragmatic and for the largest part risk-based contemporary background to judge amendments to soils, e.g. via fertilisers which may contain contaminant remains. The scheme has been also used as operationalization of the general soil protection target for evaluating whether sediments from rural ditches can be deposited on land. Policies for sediment deposition on land have thus been recently formulated considering predicted environmental concentrations as a consequence of multiple cases of spreading (each 5 years; see Figure 2.4), and validated (Harmsen *et al.*, 2012).

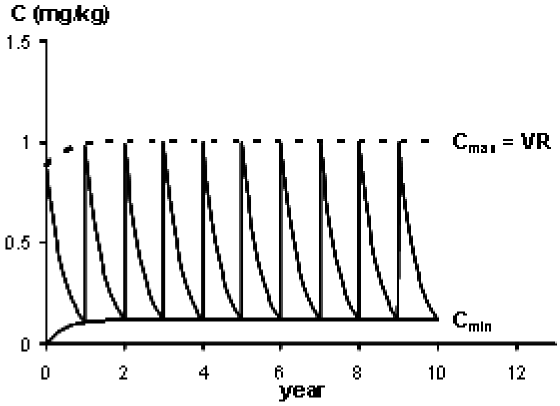


Figure 2.4. Example of results modelling Environmental Concentrations for repeated soil application

2.5 Background Values and Environmental Risk Limits

2.5.1 The role of Background Values and Environmental Risk Limits in deriving Environmental Quality Criteria

Early environmental standards were based on background concentrations and expert judgement (Swartjes *et al.,* 2012). As environmental policies developed, a more formalized framework for deriving Environmental Quality Standards was established based on scientifically derived background values and Environmental Risk Limits.

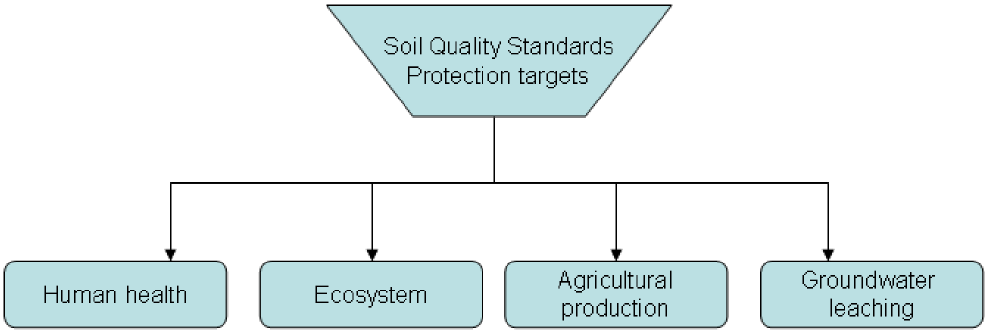


Figure 2.5. Protection targets soil (management and remediation) policy in the Netherlands

Background Values (BVs) and Environmental Risk Limits (ERLs) translate policy targets and/or protection targets into concrete concentrations of substances in environmental media Figure 2.5) . Some examples of policy and protection targets are:

- Concentrations (of soil, water, etc.) may not exceed those of relatively unpolluted areas;
- Concentrations may not affect more than 5% of the species in a certain ecosystem (assemblage of species), so that 95% of the species is fully protected;
- Lifelong exposure (to contaminants via soil, water, and air) may not give rise to more cancer incidences than 1 in every 100.000 persons in a civilian population.

Background values and environmental risk limits (ERL's) on the one hand and Environmental Quality Standards or -Criteria (EQS's and EQC's) on the other are often intermixed in speech and publications. However, it is important to realize, that ERL's and EQC's serve different purposes, and in practice, may or may not be numerically the same. ERL's represent concentrations in environmental media that correspond to certain predefined policy and/or protection targets (Figure 2.6). EQC's are ideally based on BV's or ERL's that were derived for the policy and/or protection targets that are pursued by setting the EQC's in the first place. However, in establishing a value for an EQS there may be reasons to adjust the value of the BV's and/or ERL's, or even adopt a completely different value. In this process the policy targets are weighed against other matters, such as socio-economic factors and the impact of ERL's on other policies.

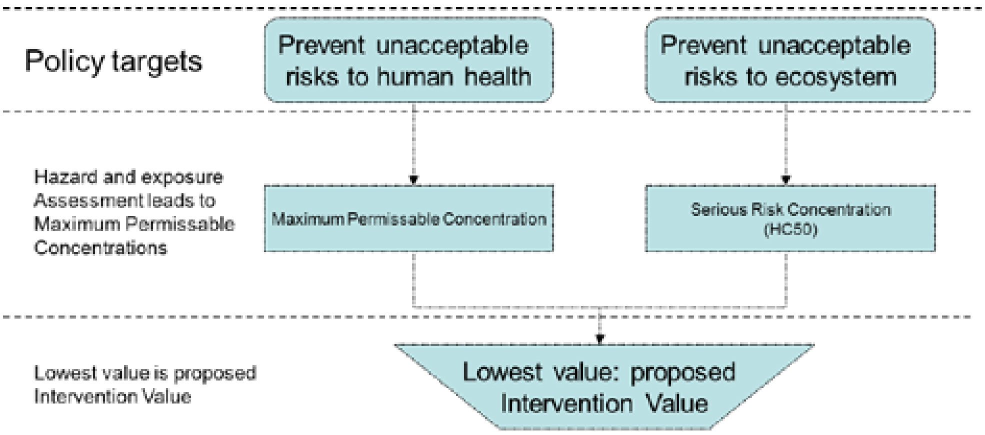


Figure 2.6. Example of application of Environmental Risk Limits (two science-based notions, middle) to derive a the regulatory Intervention Value for a compound. The latter is an SQS, a formal Standard used to judge soil quality

2.5.2 Background Values and Target Values

Background Values enable us to implement the policy target of the 'stand still principle': polluted areas should not be polluted further and clean areas must remain clean.

In 2008 the so called 'AW2000'-values (Lamé en Nieuwenhuis, 2007) were introduced in soil policy, as a replacement for the Target Values, which served as a reference for unpolluted soil up till that time. The reason for the replacement was that the risk-based Target Values were often lower than then natural background concentrations of compounds found in the field[3]. The measurements of the AW2000 project were collected in relatively unpolluted natural and rural (not agricultural) lands in the Netherlands. The monitoring was limited to upper soil, ground water and sediments were not measured. The 'AW2000' background value was derived by taking the P95 value[4] of the collected monitoring data in the upper 10cm of soil of a certain substance. Commonly, the AW value of a compound is (much) higher than the Target Values for that compound, which mainly relates to the safety margin used earlier in derivation of the TV.

Although the Target Values are in part replaced by Background Values in soil policy, they are still applied as standards for compost (BOOM, 1991) and as reference values for ground water and surface water.

The Target Values for groundwater are risk-based. They correspond to the 'Negligible Risk' level for aquatic ecosystems, whereby the aquatic ecosystem is considered representative for the groundwater ecosystem. This level is the so-called Maximal Permissible Risk Concentration (MPC) for aquatic ecosystems, which is defined as the concentration at which 5% of the aquatic species or processes may be affected beyond a No-Effect exposure (HC5, Section 2.3.3), divided by 100 (the safety margin). Subsequently, in the case of metals, the natural background concentration in groundwater is added to the risk limit, to obtain the value to be used in quality assessments (added risk approach, Section 2.3.3).

2.5.3 Ecological risk limits

The exposure assessment of ecosystems is complex, since each species explores its environment in different ways, resulting in different exposure pathways. Commonly, for practical risk assessment purposes, the ecological exposure assessment makes use of total concentrations of contaminant in soils when the assessment problem is a generic one, like e.g. the derivation of Soil Quality Standards.

Ecotoxicological risk limits can be derived using ecotoxicity data (usually the lowest, representing the most sensitive species known, commonly using No Observed Effect concentration data) in combination with a safety factor, or by using Species Sensitivity distributions (SSDs) (Posthuma *et al.*, 2002). SSDs are used to statistically derive a concentration that is sufficiently protective from all available ecotoxicity data for the multiple species tested. The SSD concept considers the fact that 'all animals are unequal'; in other words, different species in soils, such as mites, springtails, fungi, bacteria, nematodes, etc., show a different response to contaminant exposure. SSD modelling is currently used to derive ERL's in the Netherlands, and also in the USA and Canada, for example.

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3 This was due to the application of a more or less arbitrary assessment factor in the derivation of the Target Values

4 The P95 or 95th percentile is the concentration value of a contaminant below which 95% of the measured concentrations in the data set fall.

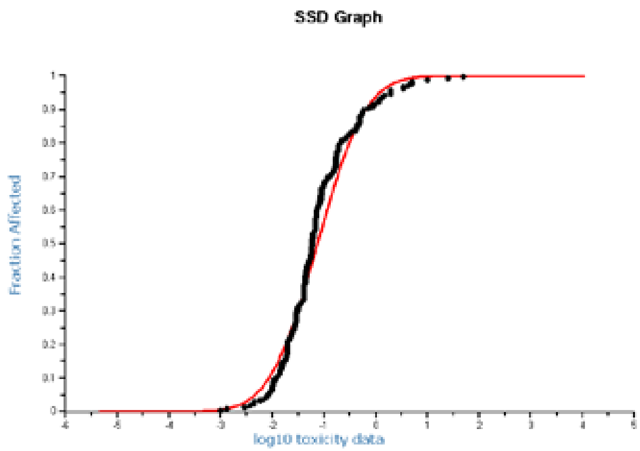

Figure 2.7. Example of a Species Sensitivity Distribution demonstrating the cumulative distribution of selected aquatic NOEC's of the substance chlordane. When the maximum permissible risk is set by policy choice to "5% of the species may at most be affected at their No Effect Concentration" which is at an Y-axis value of 0.05), then the associated environmental concentration (X) can be derived easily

Ecotoxicity data from laboratory tests with different species, for example NOECs (No Observed Effect Concentrations) or 50%-effect concentrations (EC50s), are collected from existing databases and plotted as a function of (total) soil concentration (see Figure 2.7, cumulative probability density function). The S-shaped curve is a statistical model fitted through those data, for example, as a cumulative log-positioned to the left of a less toxic contaminant. Posthuma *et al.* (2002) have provided a detailed overview of SSD theory and practices. In the Netherlands, effect data on functional test endpoints, like toxic effects on enzyme activities of the microbial communities of test soils, are also considered (FSD, Function Sensitivity Distribution). Protective, generic SQSs are based on the lowest value generated by an SSD and an FSD (when available). When the number of data is too low, the regulatory Quality Standard is derived from the lowest test endpoint, divided by a safety factor.

The ecotoxicologically based risk limit that underpins the Intervention Value has been defined as the HC50 (Hazardous Concentration for 50% of the tested species, i.e. 50% of potentially present organisms exposed at or above the No Observed Effect Concentration (NOEC)).

For metals, a so-called 'added risk approach' is applied in the derivation of ecotoxicologically based risk limits for soil. This means that the 'natural' background concentration in soils is added to the risk-based concentration (Crommentuijn *et al.*, 1997). This procedure implies that soil quality is assessed on the basis of the metal fraction that is attributed to the anthropogenic activity only.

The SSD approach offers the possibility to select risk limits from a continuous scale that suite the policy and/or protection target. Besides the HC50 protection level, in soil policy, the HC5 and HC20 concentrations are used as ecologically based risk limits for Environmental Standards.

Based on validation studies, there is – so far - no reason to believe that the currently-operational, protective soil quality standards, imply the presence of any known, measurable impact on ecosystems.

2.5.4 Risk limits based on agricultural production

In soil management, the quality standard for agricultural land is set equal to the Background Value (AW2000). For those cases where background quality is exceeded, a set of Risk Limits was derived for various forms of agriculture (ref LAC2006) that can be used to assess the impact on agricultural production or product quality.

The LAC2006 values give an indication of the risk of exceedance of product standards (for food and animal fodder) and/or economic damages (i.e. an impact on production of 10% or more due to phytotoxic effects and/or animal health effects). The LAC2006 values have no formal role in environmental policy, however, they are part of the higher-tiered methods of risk assessment of the 'Risk Toolbox' (Figure 2.8).

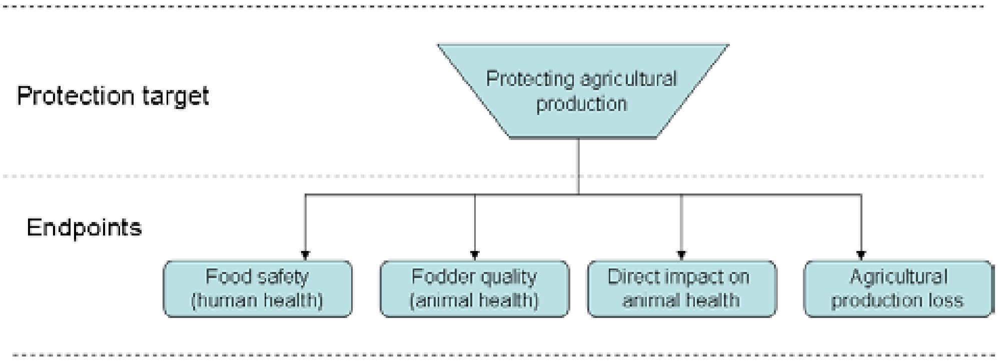

Figure 2.8. Endpoints used in deriving agricultural risk limits (LAC2006 values) for metals

2.5.5 Human health risk limits

Human health risk assessment with regard to contaminated sites includes again the two elements: exposure assessment and hazard assessment. The latter includes dose response assessment. Human exposure as the result of the exposure assessment is tested against the so-called Critical Exposure Value (CEV) leading to the risk characterisation, that is, the risk appraisal of the contaminated site.

The human health-based ERL is defined as the concentration of a contaminant in the environment which would result in an exposure according to an exposure scenario related to a residential site (potential exposure) equal to the CEV. In the Netherlands, the human health-based risk limits relate to lifelong exposure, except for lead, for which the child phase is the critical period. The exposure is based on a combination of Tendency Exposure (when sufficient information is available) and Reasonable Maximum Exposure (when insufficient information is available).

2.5.6 Recalculation of standards and risk limits to standard soil

Because metal concentrations in undisturbed soils differ per soil type and because it is not practical to set up different lists with soil type-specific Soil Quality Standards, a set of equations was developed to convert any soil contamination level (concentration) to a so-called standard soil with standard levels of organic matter (10%) and clay content (25%). These equations are called 'soil properties correction formulae' (Ministry of VROM, 2009). Given that the clay and organic matter contents are generally related to the bioavailable fraction, the 'soil properties correction' formulae are an indicative correction for bioavailability.

For organic substances, a basic method exists as well, to adjust for organic matter content in soil. Currently, the methods for adjusting EQC's en ERL's for soil characteristics are under revision (Spijker, 2012).

2.5.7 Leaching and groundwater contamination

With regard to contaminated site management, groundwater is an important protection target and a means of transport (pathway) for contaminants (Swartjes & Grima, 2011). Groundwater as protection target usually refers to the water in the water-saturated zone, which may be threatened by the leaching of contaminants from the unsaturated zone, certainly in the case of shallow groundwater bodies which are common for the Netherlands. The primary use for groundwater is as a source of drinking water. The water-saturated deeper soil layer is also a habitat for many organisms (e.g. Steube & Griebler, 2009). These organisms are specifically important for the degradation of organic contaminants (natural attenuation).

Protection targets for groundwater and surface water may pose additional demands on criteria for soil, sediments and fertilisers. In a truly inter-compartmental approach, criteria in all compartments would be harmonized. For instance, in the case of criteria for use specific Soil Quality management, research on the effects of leaching from slightly contaminated soils (Spijker, 2009) is still on-going. New insights into the consequences of soil management criteria for groundwater may lead to adjustment of the criteria for soil.

Leaching of contaminants into the unsaturated and saturated zone is considered for building materials and in higher tiered risk assessments of serious soil contaminations. For the latter, site specific leaching and groundwater dispersal models are applied to estimate the rate of groundwater contamination.

In the case of building materials, two types of Risk Limits are applied in soil policy. For inorganic substances, emission limits are derived. Up until now, nationally authorized leaching tests are only available for inorganic substances, therefore, for organic substances, maximal (composition) values in building materials are enforced.

2.6 Other concepts and criteria currently in use in fertiliser policies

2.6.1 Introduction

Section 2.5 discusses the fundamental building blocks of the risk based part of soil and fertiliser policies. These building blocks form the cornerstone of many of the risk based standards that are discussed in Chapter 3. Two more fundamental building blocks, that are not risk based, are discussed in this Section: the application of mass balance calculations in underpinning fertiliser criteria (Section 2.6.2) and the use of proxy criteria based on beneficial components in fertilisers (Section 2.6.3).

2.6.2 Mass balance approach

Limit values and limit application rates for fertiliser materials are often not (directly) based on environmental Risk Limits (see also Chapter 4). Instead, the criteria are based on mass balance equations, which aim to preserve an equilibrium ('stand still') between the supply of contaminants through the application of a type of fertiliser, and the removal by crops and/or degradation, preventing accumulation of contaminants in soil. In case a certain accumulation in the soil is allowed for, it may be evaluated by the application of Environmental Risk Limits. In a way, these mass balance calculations are long term exposure assessments.

Currently mass balance calculations are applied in fertiliser policy for heavy metals and for organic micro-contaminants in different types of fertilisers (see also Chapter 4). In the case of heavy metals, the flux of contaminants introduced by fertilisers must be offset by the removal of metals due to plant uptake. In the case of composts, the calculations take into account the re-use of plant material by application of the compost.

For organic micro-contaminants, the long term effects of repeated application combined with degradation is calculated using the methods described by Olde Venterink and Linders (1994). The methodology to establish standards for organic contaminants is based on the assumption that the long-term accumulation in soil may pose no risk for the terrestrial ecosystem (TCB, 1995). The principle used to derive the standards was that the accumulation level of contaminants in the soil in the long term may not exceed the negligible risk. The accumulation was calculated on the basis of an annual dosage and the decay of compounds in the soil.

The methods proposed by Olde Venterink and Linders (1994) are part of an environmental screening test to assess whether waste materials can be used as a fertiliser (Van Dijk *et al.*, 2008, see also Section 2.1). Currently a further development of the protocol is being prepared. The most important change in the new method is a provision for temporary higher concentrations after application of the material, coupled to a second – long term – risk level which should not be exceeded after repeated applications of the material (Figure 2.9).

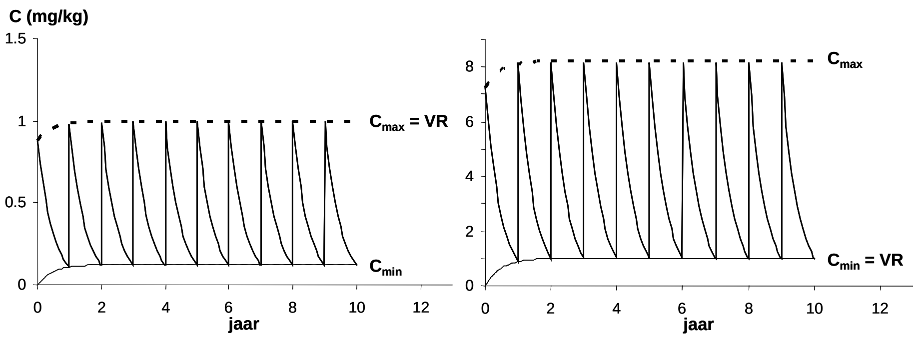

Figure 2.9. Left: the current protocol limits peak concentrations after application to the Target Value (TV). Right: the proposed protocol allows for temporary peak concentrations after application to a maximum of the Maximum Permissible Risk level (MPR). Long term concentrations after repeated application shall not exceed the TV

2.6.3 Limit values in relation to beneficial components

In some cases limit values are not given on the basis of the total mass of the fertiliser but on the basis of the mass of the beneficial components. Beneficial components are nutrients (nitrogen, phosphate, neutralizing value, organic matter, according to the Fertiliser Decree, Ub) and other components (magnesium, sulphur, sodium or calcium in gypsum, according to the Fertiliser Regulation, Ur). The rationale for choosing limit values on the basis of content per beneficial component is:

1. It is not necessary to have separate maximum application rates for these fertilisers as this category of fertilisers contains a large number of very different materials, often waste materials or residues. It was also assumed that control on the basis of dosages in the field is not possible, because these can only be checked by personal control at the site. Control is therefore necessary at an early stage, at the stage of trade or transport, by limiting the amount of

contaminants in the fertilisers (§3.3 of the explanatory note of the Decree of 2007, *Staatsblad* 251, 2007).

2. Limit values on the basis of content per mass of beneficial component reward the use of fertilisers with higher amounts of beneficial component, while limit values on the basis of mass of fertiliser do not make this discrimination (Janssen *et al.*, 1999). The amount of beneficial component in this class of fertilisers is important because it often concerns waste materials for which the use as a fertiliser in agriculture is preferred as it is the cheapest route.

3 Legislation of contaminants in fertilisers

- Countries have different categories of fertilisers
- Countries consider different contaminants
- Major groups of contaminants often considered are heavy metals and persistent organic contaminants (POPs), but precise sub-sets of these groups differ amongst fertiliser types and legislation
- As common grounds motivating the existence of the existing regulations, both the profitable aspects of fertilisers as well as potential threats have commonly been considered; a risk-based approach is common for the latter aspect, though operationalized in different formats

In the table 3.1 the main categories of fertilisers in the Netherlands are compared with similar categories in the surrounding countries. This is the result of our own research and consultation with experts from the Member States[5] themselves. It shows that countries have different categories which are comparable to a certain extent. The grey shaded categories are fertilisers or other materials for which contaminants are regulated. It is clear that in Germany most fertilisers have regulations for contaminants, followed by the Netherlands.

Table 3.1 Fertiliser categories in laws of the Netherlands and an approximate equivalent category in Belgium Flanders (BE-VLD), Germany (DE), Denmark (DK) and United Kingdom (UK). Grey: contaminants are regulated.

<table>
<tr><th>NL</th><th>BE-VLD</th><th>DE</th><th>DK</th><th>UK</th></tr>
<tr><td>EU fertilisers</td><td>EU fertilisers</td><td>EU fertilisers</td><td>EU fertilisers</td><td>EU fertilisers</td></tr>
<tr><td>Manure</td><td>Manure [3]</td><td>Manure</td><td>[5] Manure</td><td>[3,5] Manure</td></tr>
<tr><td>Sewage sludge</td><td rowspan="4">Organic soil improvers/ growing media.
If waste: Fertilisers and soil improvers</td><td>Sewage sludge</td><td>Sewage sludge</td><td>Sewage sludge</td></tr>
<tr><td rowspan="2">Compost</td><td rowspan="2">Bio waste</td><td>Composting preparations</td><td></td></tr>
<tr><td>Biodegradable wastes</td><td></td></tr>
<tr><td rowspan="5">Other (in)organic fertilisers [1,2]</td><td>- N, P and K fertilisers
- compound fertilisers
- Lime fertilisers
- micronutrients</td><td>(in)organic fertilisers and organo-mineral fertilisers</td><td rowspan="3">- Other straight fertilisers, groups [4] 1,2,3,5.
- Compound fertilisers
- Straight fertilisers, group 4</td></tr>
<tr><td rowspan="2">Other fertilisers, fertilisers of secondary elements, fertilisers of micronutrients, fertiliser for nutrients solutions</td><td>Wood ash</td><td>Bio-ash</td></tr>
<tr><td>Organic and organic-mineral fertilisers</td><td>Soil improvers</td></tr>
<tr><td>Growing media</td><td>Growing media</td><td>Growing media</td><td></td></tr>
<tr><td>Plant growth stimulants</td><td>Plant growth stimulants</td><td>Inoculum cultures</td><td></td></tr>
</table>

1 including lime.
2 also waste materials and residues.
3 is not part of fertiliser legislation concerned with trade.
4 section A: group 1 (nitrogen fertilisers), 2 (various phosphate fertilisers, 3 (various potassium fertilisers), 4 (dried blood, guano, bone meal meat meal etc.) and group 5 (liming products).
5 defined by EU animal by-products regulation (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:300:0001:0033:EN:PDF)

5 The study also involves regulation in Belgium Flanders, Denmark, Germany and the United Kingdom. Lise Kjærgaard Steffensen (Denmark), George Embert (Germany) and Alfred Generet (Belgium Flanders) were consulted. Text and standards were reviewed by these national experts.

3.1 The Netherlands

- Heavy metals are regulated in all fertilisers, except EC fertilisers and animal manure.
- Organic contaminants are regulated in organic waste materials and residues used as fertilisers.
- Limit values for contaminants in compost and sewage sludge are in mg per kg dry weight.
- Limit values in other regulated fertilisers are expressed in mg per kg beneficial component.

Categories of fertilisers

The Fertiliser Act (*Meststoffenwet*, MW) defines fertilisers. Fertilisers are products which:
1. are added to soil or growing media to make in suitable or more suitable for plant growth.
2. can be used as growing media.
3. are used a nutrients for plants.

The Fertiliser Act (MW) concerns the functionality of fertilisers, the trade of fertilisers and the protection of the soil. In normal circumstances a fertiliser does not harm the health of people, animals, plants or the environment (article 6 of Ub). Based upon the Fertiliser Act are rules about contaminants in fertilisers. These have been given in the Decree on the use of fertilisers (*Besluit Gebruik Meststoffen*, Bgm), The Fertiliser Decree (*Uitvoeringsbesluit Meststoffenwet*, Ub) and the Implementing Regulation (*Uitvoeringsregeling Meststoffenwet*, Ur). The regulation (EC) No 2003/2003 has been transposed in the Fertiliser Decree (Ub). Annex 1 provides an overview of names for regulations on fertilisers in the Netherlands and their English translation.

Article 7 of the Soil Protection Act states that the application of fertilisers can be regulated to protect the soil quality and structure. Based upon this are the rules about fertilisers in The Decree on the use of fertilisers (Bgm). The EC Sewage Sludge Directive has been transposed in The Decree on the use of fertilisers (Bgm) which regulates dosage and soil sampling and the Fertiliser Act (Ub) which regulates quality.

The categories of fertilisers in the fertiliser legislation are given in the table below.

Table 3.2 The various types of fertilisers in laws in the Netherlands (origin between brackets), short explanation and some examples.

Fertiliser type	Explanation	Examples
inorganic fertilisers:		
EU fertilisers (Ub)	Inorganic fertilisers according to Regulation (EC) No 2003/2003	Calcium ammonium nitrate (CAN)
Liming materials (Ub, Ur)	Inorganic or organic materials for decreasing soil acidity	Chalk, dolomite
Other inorganic fertilisers (Ub, Ur)	All inorganic fertilisers except EU fertilisers	Mixtures of inorganic fertilisers with lime and designated wastes that can be used as fertiliser: lime from drinking preparation, filter cakes of fertiliser production, processed egg shells.
Organic fertilisers:		
Animal manure (MW)		Cattle slurry, pigs slurry, chicken manure
Sewage sludge (Ub, Ur, Bgm)		Municipal sewage sludge, sewage sludge from feed processing plants
Compost (Ub , Ur)		VGF compost, green compost, spent mushroom compost
Other organic fertilisers (Ub, Ur)	All organic fertilisers except animal manure, sewage sludge and compost.	Peat, bark, digestate and designated wastes that can be used as fertiliser: sugar factory lime, concentrated juice of starch potato, hydrolysed and processed proteins of animal by-products (leather).

The inorganic fertilisers are defined by the Regulation (EC) No 2003/2003. All other inorganic fertilisers are called "other inorganic fertilisers". Examples of inorganic fertilisers are liming materials (Table 3.2). Wastes that are used as organic fertilisers are manure, sewage sludge's, digestate and compost. Manure is of these by far the most important. All other organic fertilisers are called "other organic fertilisers". Bio stimulants are not regulated as fertilisers.

Contaminants in fertiliser regulations

The Fertiliser Decree (Ub) and in the Implementing Regulation (Ur) have set limits values to contaminants: heavy metals and micro contaminants. The Fertiliser Decree (Ub) and in the Implementing Regulation (Ur) distinguishes five types of fertilisers for which heavy metals are regulated: liming materials, sewage sludge, compost, "other inorganic fertilisers", and "other organic fertilisers" (Table 3.3.). The regulations for contaminants do not apply for EU fertilisers. The regulations for organic micro contaminants only apply to "other organic fertilisers", and do not apply for sewage sludge or compost.

The permitted dosages of sewage sludge and the mandatory soil sampling every 10th year are regulated in the Decree on the use of fertilisers (Bgm). Dosage of all other fertilisers are regulated by application standards (*gebruiksnormen*) set by the Fertiliser Decree (Ub) for nitrogen and phosphorus.

Table 3.3 Reference to regulations for heavy metals and organic micro contaminants in fertilisers (or source materials) in the Fertilisers Decree (Ub) and Implementing Regulation (Ur). Dosages of all fertilisers are regulated by their nutrient in the Fertilisers Decree (Ub). Specific application limits and rules for sewage sludge are given in Decree on the use of fertilisers (Bgm).*

	Quality criteria				**Application rate**
	Heavy metals		**Organicmicro contaminants**		
	Ub	Ur	Ub	Ur	
Other inorganic fertilisers	Article 14	Article 8,10		Article9**	Ub
Liming materials	Article 14				
Other organic fertilisers	Article 14		Article 15		Ub
Sewage sludge	Article16				Ub, Bgm
Compost	Article 17				Ub

* Also rules for the use of compost and manure are given in the Decree on the use of fertilisers (Bgm), the application rate is however determined in the Fertiliser Decree by the nutrient content.

** This applies to "liming materials", and "other inorganic fertilisers" if these contain organic matter of animal or plant origin (article 15 lid 2 in UbMW en article 9 in Ur MW).

The contaminants regulated by the Fertiliser Decree and the Implementing Regulation are heavy metals and organic micro contaminants (Table 3.4). The list of organic micro contaminants is partly identical to the 12 POPs in the Stockholm Convention (except chlordane, heptachlor, mirex, and toxaphene).

Sewage sludge and compost are regulated on the basis of the content of heavy metals per kg dry weight. All other fertilisers (except EC fertilisers and animal manure) are regulated on the basis of the content of contaminants per beneficial component (see Chapter 4).

It should be noted that under the Regulation regarding Animal -By-products 5 stringent requirements apply regarding pathogens in compost from separately collected kitchen and garden waste (*GFT-compost*).

Table 3.4 Limit values for contaminants in fertilisers (mg kg^{-1}dm) (Fertiliser Decree, Ub). For a comparison the limit values for 'Other organic fertilisers' have been recalculated based on the maximum allowed dosage (i.e. 3 tons organic matter ha^{-1} yr^{-1})

Name		**Sewage sludge and other inorganic fertilisers (in mg kg^{-1} dm)**	**Compost (in mg kg^{-1} dm)**	**Other organic fertilisers (in g ha^{-1} yr^{-1})**
Permitted dosage (t dry matter ha^{-1} yr^{-1})		2 arable land, 1 grassland	No specific restriction*	No specific restriction*
Cd	Heavy metals	1.25	1	2.5
Cr	Heavy metals	75	50	150
Cu	Heavy metals	75	90	150
Hg	Heavy metals	0.75	0.3	1.5
Ni	Heavy metals	30	20	60
Pb	Heavy metals	100	100	200
Zn	Heavy metals	300	290	600
As	Heavy metals	15	15	30
Σ PCDD/PCDF				0.00152
α-HCH	HCHs			24.8
β-HCH	HCHs			0.96
γ-HCH (lindane)	HCHs			0.096
HCB				2.48
Aldrin	drins			0.56
Dieldrin	drins			0.56
Σ Aldrin/Dieldrin	drins			0.56
Endrin	drins			0.56
Isodrin	drins			0.56
Σ Endrin/Isodrin	drins			0.56
Σ DDT + DDD + DDE				1.84
PCB-28	PCBs			1.48
PCB-52	PCBs			1.48
PCB-101	PCBs			6
PCB-118	PCBs			6
PCB-138	PCBs			6
PCB-153	PCBs			6
PCB-180	PCBs			6
Σ 6-PCB (excl. PCB-118)	PCBs			30
Naftalene	PAHs			48
Phenanthrene	PAHs			60
Antracene	PAHs			48
Fluorantene	PAHs			14.8
Benzo(a)antracene	PAHs			18.4
Chrysene	PAHs			18.4
Benzo(k)fluorantene	PAHs			21.6
Benzo(a)pyrene	PAHs			23.2
Benzo(g,h,i)perylene	PAHs			16.8
Indeno(1,2,3-c,d)pyrene	PAHs			18.8
Σ 10-PAH	PAHs			920
Mineral oil				74800

*no specific restriction for this material, except the common applications standards for all fertilisers on the basis of N and P.

To use waste materials and residues as fertilisers some specific rules in the by the Fertiliser Decree (Ub) and the Implementing Regulation (Ur) apply. Only waste materials and residues that are efficient fertilisers and do not harm the man, animal, crop and environment can be applied as a fertiliser provided that these materials are listed in Annex Aa of the Implementing Regulation (Ur, website ministry, 2012). For this one has to submit a request to the ministry of Economic Affairs provided with information on their origin, nature, production process, analyses on beneficial components and contaminants. This information is judged according to a protocol (Van Dijk *et al.*, 2009). Other contaminants than listed in Table 3.4 can be part of this procedure if they form a risk for man, animal, crop or environment.

3.2 Belgium Flanders

- Heavy metals are regulated in all fertilisers, except EC fertilisers and animal manure.
- Organic contaminants are regulated in waste materials and residues used as fertilisers.
- Regulated in the content of contaminants in individual wastes and residues, and the total dose of contaminants in grams per hectare per year.

Categories of fertilisers

There is national Belgian legislation and legislation in Flanders for fertilisers and soil improvers. The royal decree concerning the marketing and use of fertilisers, soil conditioners and growing media (1998) (KB 7/1/1998) regulates trade. The national (federal) legislation defines fertiliser and soil improvers.

The Royal Decree (1998) defines the types of fertilisers, soil improvers and growing media in Annex I:

1. Fertilisers: EC-fertilisers, b. non-EC-fertilisers.
2.1. Fertilisers of secondary elements, EC-fertilisers: a. solid, b. fluid.
2.2. Fertilisers of secondary elements, non- EC-fertilisers: a. liming materials, b. others.
3. Soil improvers: a. organic, b. inorganic.
4. Growing media: a. organic, b. inorganic.
5. Fertilisers with micronutrients: a. EG-fertilisers, b. others.
6. Fertilisers for nutrient solutions.
7. Others.
8. Sewage sludge.

Contaminants in fertiliser regulations

Only products in Annex I of the Decree can be traded as fertilisers or soil improvers. Unprocessed animal manure is not part of this legislation. Materials such as digestate are not in the Annex I and need exemption from the national (federal) government (*FOD ontheffing*). This FOD-exemption contains a description of the raw materials and processes, a certificate (*Vlaco attest*), analysis on agronomic parameters and contaminants. Producers also need an exemption from the national government (*FAVV erkenning*). Sewage sludge is defined in the Royal Decree but the standards are regulated by the Flanders Region, Wallonia Region and Brussels-Capital Region.

*Table 3.5 Regulated contaminants in soil improvers and growing media (Royal Decree, 1998), and in waste and secondary materials used for fertilisers and soil improvers according to the Flemish regulation about sustainable management of materials and waste (Vlarema, 2012, from Annex 2.3.1) (unit: mg kg^{-1} dm) **

		Royal Decree, 1998		**Vlarema**
		Organic soil improvers	**Organic Growing media**	
Cd		2.5	1	6
Cr		100		250
Cu		375	50	375
Hg		2.5	1	5
Pb		500	50	300
Ni		50	10	50
Zn		750	100	900
Co		10		
As				150
Benzene	BTEXS			1.1
Ethyl benzene	BTEXS			1.1
Styrene	BTEXS			1.1
Toluene	BTEXS			1.1
Xylene	BTEXS			1.1
Benzo(a)anthracene	PAHs			0.68
Benzo(a)pyrene	PAHs			1.1
Benzo(ghi)perylene	PAHs			1.1
Benzo(b)fluoranthene	PAHs			2.3
Benzo(k)fluoranthene	PAHs			2.3
Chrysene	PAHs			1.7
Phenantrene	PAHs			0.9
Fluorantene	PAHs			2.3
Indeno(1,2,3cd)pyrene	PAHs			1.1
Naftalene	PAHs			2.3
Monochlorobenzene				0.23
Dichlorobenzene				0.23
Trichlorobenzene (4)				0.23
Tetrachlorobenzene (5)				0.23
Pentachlorobenzene				0.23
Hexachlorobenzene				0.23
1,2-dichloroethane				0.23
Dichloromethane				0.23
Trichloromethane (Chloroform)				0.23
Trichloroethene				0.23
Vinyl chloride				0.23
1,1,1-trichloroethane				0.23
1,1,2-trichloroethane				0.23
1,1-dichloroethane				0.23
Cis+trans-1,2-dichloorethane				0.23
Hexane				5.5
Heptane				5.5
Octane				5.5
Mineral oil C10-C20				560
Mineral oil C20-C40				5600
Polychlorobiphenyls (7 congeners)				0.8

*Until 1999 the standards for organic contaminants were not applicable for sewage sludge, and the dosage was limited to 4 tonnes sewage sludge per 2 years for arable crops and 2 tonnes per 2 years on grassland. After 1999 the dosages are regulated as given in g ha^{-1} $year^{-1}$.

The legislation for waste and secondary materials in Flanders is given in Flemish Regulation on Sustainable Management of Material Cycles and Waste Materials (*Vlaams reglement betreffende het duurzaam beheer van materiaalkringlopen en afvalstoffen: Vlarema* (2012), previously *Vlarea*). The *Vlarema* predescribes:

1. Quality standards for materials used for fertilisers and soil improvers. See table 3.5 for the regulated contaminants.
2. Use restrictions (the dosage of contaminants, specific rules for sewage sludge).
3. And a list of waste materials which can be used as secondary raw material (positive list, for example sugar factory lime). Vlarema (Article 2.3.1.1) states that all waste and secondary materials have to comply with the regulations, so Vlarema regulates the input and output.

The list of regulated contaminants in Vlarema (2012) for waste materials used as fertilisers and soil improvers is identical for waste materials used for other applications, such as assessment frameworks for soil quality. The list is given in Table 3.5. The list gives the limit values on the basis of the content of individual materials. Note that also the totals dosage of contaminants (sum of individual applications) is regulated. That limit dosage is equal to the given limit values times 2 tonnes dry matter per hectare per year.

Vlarema (2012). Annex 2.2 of Vlarema contains the list with waste materials that can be used as raw materials for fertilisers and soil improvers. Some of the materials, like sewage sludge, additionally need a specific report. Al waste materials which will be used as soil fertiliser or soil improver have to comply with the standards.

3.3 Denmark

- Heavy metals and organic contaminants are regulated in all fertilisers, except EC fertilisers and animal manure.
- Bio waste, bio-ash and sewage sludge have specific regulations.
- Cadmium is regulated in fertilisers containing more than 1% phosphorus, except animal manure
- Levels of selected organic contaminants (LAS, NPE, DEHP) are regulated in bio waste and sewage sludge.

Categories of fertilisers

The sales of fertilisers in Denmark are regulated by Act on fertilisers No. 417 of 3/05/2011, the Order on trade in fertilisers and soil improvers No. 664 of 15/12/1977, and the Notice of fertilisers and soil conditioners no. 862 of 27/08/2008, which also transposes the EC Regulation No 2003/2003.

The notice of fertilisers and soil conditioners no. 862 of 27/08/2008 defines:

1. Fertilisers (similar to EC Regulation No 2003/2003).
2. Other organic, organo-mineral, and inorganic fertilisers.,
3. Materials used for production of compost.
4. Soil improvers (liming products, peat products, compost, and other soil improvers).
5. Growing media.
6. Inoculum cultures.

According to the Act on fertiliser's No. 417 of 3/05/2011, fertilisers must have a demonstrable effect, be of good quality, and in normal use, should not have a detrimental effect on human, animal or plant health or the environment, and should not pose a risk to public safety.

In Denmark, the application of mineral fertilisers and manure are regulated by the nutritional need for nitrogen. Application of sewage sludge and other waste products are regulated for both nitrogen and phosphorous requirements. This means that waste products cannot be applied to agricultural areas if sufficient amounts of fertilisers already cover the plant nutritional need. The total application of mineral fertilisers, manure, sludge and waste products cannot be at a higher rate than the plant nutritional demand. This applies to each plant nutritional substance. If the nutritional need is limited by e.g. phosphorous, supplementary fertilisation is acceptable (Danish EPA, 2000).

Contaminants in fertiliser regulations

Cadmium is regulated in mineral fertilisers. According to the statutory order no. 223 from 1989, the maximum cadmium content is regulated for phosphorus-containing fertilisers, derived from phosphate rock, with a total phosphorus content of 1% or more. This order does not apply to manure, compost, sludge or similar waste products, unless these have added phosphorus, derived from phosphate rock.

The order does not include regulatory decisions on the maximum amount of P-fertiliser per hectare. However, in the guidance document, inorganic fertilisers are mentioned together with sludge, organic waste products etc., which indicates that the same maximum application rate referring to phosphorous, is in force.

The maximum cadmium content of mineral fertilisers is set to 48 mg Cd kg^{-1} P_2O_5 or 110 mg Cd kg^{-1} total P (Table 3.5).

Table 3.6 Limit values for heavy metals in fertilisers per kilogram phosphate (P_2O_5) and phosphorous (P).

Heavy metals	**Maximum value in mg/kg**	
	P_2O_5	P
Cd	48	110

The Ministry of Environment's Statutory Order nr. 223 of April 1989

The content of heavy metals in manure used for fertilising is not regulated. However, there are rules for where, when and how much manure is allowed to be spread for different crops (BEK nr 764 28/06/2012 - Order on professional livestock, manure, silage, etc. (Manure Order)). The rules of this Order apply to commercial livestock, including production, storage and use of manure.

Denmark largely relies on waste incineration. The general strategy is a ban on landfilling of waste that can be incinerated. The Statutory Order regarding the application of waste products for the agricultural purposes is No. 1650 (Sludge order, 2006). It regulates the agricultural use of the main types of biodegradable wastes (e.g. sewage sludge, compost, digestate) and provides limit values for content of heavy metals and organic contaminants. Compost from garden waste is not formally regarded as a product but is treated according to the general waste regulation for which the municipalities are responsible.

Two sorts of limiting values apply in the executive order for sludge: one is based on the amount of the single element on a dry matter basis (mg kg^{-1} dm), the other is based on the amount of the element compared to the total content of phosphorus (mg kg^{-1} P). In Tables 3.6 and 3.7 the limit values for heavy metals and organic micro contaminants in waste materials are shown.

The maximum permissible application of nutrition in the form of waste products is 30 kg total P ha-1 year-1, averaged over 3 years.

In addition, according to the Statutory Order BEK nr 49 of 20/01/2000, soil quality criteria are formulated for several heavy metals (see Annex 2). This means that areas applied with waste products must not exceed these soil quality criteria in the plough layer.

Table 3.7 Maximum values for heavy metals in sewage sludge, compost and digestate in Sludge Order (2006)

Heavy metals	**Limit value (mg kg^{-1} dm)**	**Limit value (mg kg^{-1} P-total)**
Cd	0.8	100
Cr	100	
Cu	1000	
Hg	0.8	200
Ni	30	2500
Pb	120	10000
Zn	4000	
As	25 (only private gardens)	

Table 3.8 Regulated organic micro contaminants for agricultural use of the main types of biodegradable wastes in Sludge Order (2006)

Organic micro contaminants	**Limit value (mg kg^{-1} dm)**
Linear alkylbenzene sulfonate (LAS)	1300
Nonylphenol Ethoxylates (NPE)	10
Bis(2-ethylhexyl) phthalate (DEHP)	50
Σ 11-PAH	3

In Danish agriculture, it is recommended to keep the soil pH above 6 by liming the soil (sandy soils pH 6-6.5, loamy soils pH 6.5-7.5). This means that in most soils in Denmark lime is added repeatedly to maintain optimal conditions for the crop. Mineral lime used in agriculture can contain cadmium as a contaminant. However, liming is not covered by any regulations in Denmark (Danish EPA 2000).

In Denmark there is national legislation on ash utilisation in forestry and agriculture (BEK nr 818 of 21/07/2008 - Order on the use of bio ash for agricultural purposes, Bio ash Order, 2008). Only ashes from wood and straw are allowed to be used. Wood ash is only to be used in forestry and straw ash only in agriculture. Mixtures can be used on both types of land. The ashes from straw incineration are usually applied to the agricultural soil from which they originate.

The same limits as for sludge were used for biomass ash until there came specific limit values in February 2000 (BEK nr 39 20/01/2000), and later in 2008 the Bio ash Order was implemented. Limit values for several heavy metals and organic micro contaminants were defined (Table 3.9).

There are separate limits for wood ash and straw ash. For cadmium, the limit is 20 mg Cd kg-1 dm wood ash and 5 mg Cd kg1 dm straw ash or a mixture of wood and straw ash. If the Loss on ignition, LOI, is over 5%, then the ΣPAH have to be analysed. The limit value for ΣPAH is 12 mg kg1 dry ash (Table 3.9).

Table 3.9 Maximum values for heavy metals in bio-ash (in mg kg^{-1} dm according to Bio ash Order, 2008)

Heavy metals	**Limit value**
Cd	5 (straw ash), 20 (wood ash), 5 (mixed)
Cr	100
Hg	0.8
Ni	60
Pb	120 (250 for wood ash in forestry)
Σ 11-PAH	12

3.4 Germany

· Heavy metals and organic contaminants are regulated in all fertilisers, except EC fertilisers.

Categories of fertilisers

Fertilisers and other related materials are defined in the fertiliser law (In German: *Düngegesetz*, DüngG). By this law:

1. Fertilisers are materials that supply nutrients to crops, or materials that maintain or improve soil fertility.
2. "Wirtschaftsdunger" are animal faeces or plant materials used in agriculture, or processed/generated mixtures.
3. Solid animal manure.
4. Fluid animal manure.
5. "Jauche (German), gier (Netherlands)", fluid mixture of animal manure, urine, feed and water.
6. Soil improvers (In German: Bodenhilfsstoffe): substances that mainly do not contain nutrients or microorganisms but improve biological, physical or chemical characteristics of a soil, or symbiotic nitrogen fixation.
7. Plant growth stimulants: substances that mainly do not contain nutrients, no plant protection agents that have a positive effect on plants.
8. Growing media.

Important is that the fertiliser law states that materials can only be applied according to Good Agricultural Practice, to support crops and soil fertility. A special aspect in the fertiliser law (DüngG) is a fund to pay for damages that might occur from the use of sewage sludge.

Contaminants in fertiliser regulations

From 2012 the main Ordinances that regulates contaminants in fertilisers, organic waste materials and sewage sludge is the Fertiliser Ordinance (*Düngemittelverordnung*, DüMV). The Biowaste Ordinance (*Bioabfallverordnung*, BioAbfV), and Sewage Sludge Ordinance (*Klärschlammverordnung*, AbfKlärV) are in force for biowaste and sewage sludge respectively if there is no rule in the Fertiliser Ordinance. The application of fertilisers and similar materials is regulated by several laws and ordinances. According to the Law for Promoting Closed Loop Management (*Kreislaufwirtschaftsgesetz*, KrWG) from 2012 organic wastes should be collected separately. The Bio waste Ordinance covers the processes and application of bio wastes and mixtures on agricultural land (BioAbfV). Suitable raw materials are listed in annex 1 of the Ordinance on Bio wastes (BioAbfV). The production processes and the application of sewage sludge are regulated by the Sewage Sludge Ordinance. The application of fertilisers is regulated by the Application of Fertilisers Ordinance (*Düngeverordnung*, DüV) which requires good agricultural practices of the fertilisers and prescribes rules especially about nitrogen and phosphorus use. The non-agricultural application of compost for landscaping and re-cultivation is covered by the Soil Protection law (BBodSchV).

The standards for contaminants are regulated mainly in the Fertiliser Ordinance (DüMV), but specifically for bio waste in the Bio waste Ordinance (BioAbfV), and specifically for sewage sludge in the Sewage Sludge Ordinance (AbfKlärV) (Table 3.10). Bio wastes and Sewage Sludge which are used in fertilisers should comply with the standards in the Ordinance of Fertilisers (DüMV) are used for all fertilisers and soil improvers, and also for sewage sludge and bio waste (see § 10-b 3 in DüMV; newssites,2, 3). The Ordinance of Fertilisers (DüMV) does also apply to animal manure (DüMV § 4, paragraph 3[6]). It does not apply to EC No 2003/2003 fertilisers (DüMV § 2).

[6] Only when concentrations of contaminants are expected to exceed the levels in column 2 of the DüMV the concentrations should be given on a label. Concentrations should not exceed the levels in column 3 of the DüMV.

Besides the criteria in the governmental legislation, and from the individual states, there are also voluntary quality assurance programmes for compost, digestates and for sewage sludge products. Certified compost (RAL GZ 251) and certified digestate products (RAL GZ 245) have additional criteria for various types of materials and processes. These voluntary quality assurance programmes use the same standards for heavy metals and organic micro contaminants as the governmental legislation. However, the certified sewage sludge compost (RAL GZ 258), and sewage sludge (RAL GZ 247) are relevant with respect to the standards for contaminants, because the government has agreed with the certifying organization that they will monitor certain contaminants for which at the moment it is believed that the pollution is decreasing and becoming less relevant. This is relevant for various organic contaminants organo-tin (TBT) and phthalates (DEHP).

Table 3.10 Standards for fertilisers, bio wastes (BioAbfv2012) and (concept) sewage sludge (AbKlarV2012), and fertilisers (DüMV2012). As of 2012 the standards for DüMV also apply for bio waste and sewage sludge. Until January 2015 the AbKlarV and BioAbfV can still be used for biowaste and sewage sludge respectively.

	Compost and digestates *BioAbfV*		**Sewage sludge** *AbKlarV*	**AbKlarV2012** *$<5\% P_2O_5$ ($>5\% P_2O_5$)*	**DüMV2012** *Anlage 2 Tabelle 1.4*
	Type 1	Type 2			
	mg kg^{-1} dm	mg kg^{-1} dm	mg kg^{-1} dm	mg kg^{-1} dm	mg kg^{-1} dm
Cd	1.5	1	10	2.5(3)	1.5 (2.5)*
Cr	100	70	900	100(120)	2 (=CrVI)
Cu	100	70	800	700(850)	900
Hg	1	0.7	8	1.6(2)	1
Ni	50	35	200	80(100)	80
Pb	150	100	900	120(150)	150
Zn	400	300	2500	1500(1800)	5000
As					40
Tl					1
AOX			500	400	
PCDD/Fs			100 ng kg^{-1} TCDD	30 ng kg^{-1} TCDD	30(5)** ng TEQ kg^{-1}
PCB			0.2#	0.1 #	
PAK				1 B(a)P	
PFC				0.1	0.1***
	BioAbfV2012				
	t dry matter ha^{-1} yr^{-1}				
Dosage	6.3	10	1.6		

* 2.5 mg Cd kg^{-1} for non-food crops. 50 mg Cd kg^{-1} P_2O_5 for fertilisers containing more than 5% P_2O_5.
** standard of 5 ng TEQ kg^{-1} for the applications on grassland.
***sum of PFOS and PFOA.
#each of the six PCBs.

3.5 United Kingdom

- Only statutory standards for contaminants in sewage sludge. Voluntary standards for compost and products from for digestate.

Categories of fertilisers

The sales of fertilisers are regulated by EC Regulation No 2003/2003 for the EC designated fertilisers, which is transposed in England and Wales by "The EC fertiliser Regulations 2006" (Defra, 2012). For fertiliser which is not EC designated sales are regulated by the 1991 UK Fertiliser Regulations (1991, 1998). These fertilisers do not have to be registered. The Fertiliser Regulations

1991 as amended specify the labelling according to type of fertilisers (straight fertilisers and liming products, or compound fertilisers), and covers the requirements to the labelling. The Department for Environment, Food & Rural Affairs (Defra, 2012) gives information about the legislation and about Good Agricultural Practices.

Contaminants in fertiliser regulations

The use of sewage sludge is regulated by the EU Sewage sludge Directive, and has been transposed in The Sludge (Use in Agriculture) Regulations 1989 (SI 1263). The policy for The Sludge Regulation was to protect against phyto-toxicity, with consideration to human and animal welfare (Hogg *et al*., 2002). This differs from policies in other countries, for example, it takes no account of the potential effects on micro-organisms, or a mass-balance approach. The Code of Practice for Agricultural Use of Sewage Sludge supports The Sludge Regulations (Defra, 2009).

Compost and digestate from anaerobic digestion made from approved bio-degradable wastes may be used without specific permission from the Environment Agency if the relevant Quality Protocols are followed. If compost and digestates complies with the requirements in these protocols, the Environmental Agency does not regulate these materials as waste. There is a Public Available Specification (PAS 100) for Compost, and for Digestates (PAS 110) ("Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials", WRAP, 2010). In practice for contaminants these specifications refer to the Code of Practice for Agricultural Use of Sewage Sludge (Defra, 2009). Other wastes and composts not produced according to the Quality Protocol may only be applied to land if Environmental Permitting Regulations are followed. These require prior notification to, or permitting by the Environment Agency. Raw materials used for the production of quality digestate are voluntarily regulated by the Quality Protocol Anaerobic digestate of the Environmental Agency (2010). Similarly raw materials for compost are regulated by the Quality Protocol Compost of the Environmental Agency (2012). For organic agriculture a specific standard was developed for composts in cooperation with Defra (UKROFS) but this has been outdated by the Council Regulation 2092/91/EC (with list of contaminants in compost in 1488/97/EC) on organic production of agricultural products (website defra).

In practice the rates at which sewage sludge and other organic waste can be applied, is determined by the nutrient contents according to Good Agricultural Practice (Defra, 2012) (page 32, nr 115 therein).

Table 3.11 Maximum dosage of heavy metals according to Sludge Regulation (1989), and voluntary Quality Assurance for compost (PAS 100, 2011) and digestates, liquor and fibre (PAS 110, 2010), and the use of sewage sludge on agricultural land (DoE, 1996).

Metall	**Sludge Regulation, 1989 sewage sludge**		**Voluntary Quality Assurance PAS 100 for compost**	**Voluntary Quality Assurance PAS 110; whole digestate, separated liquor and separated fibre**	**Code of Practice for use of sewage sludge on agricultural land[1]**
	mg kg^{-1} dm	kg $ha^{-1}year^{-1}$	mg kg^{-1} dm	mg kg^{-1} dm	kg ha^{-1} dm
Cd		0.15	1.5	1.5	0.15
Cr	25		100	100	15
Cu		7.5	200	200	7.5
Hg		0.1	1	1	0.1
Ni		3	50	50	3
Pb		15	200	200	15
Zn		15	400	400	15
Mo					0.2
Se					0.15
As					0.7
F					20

[1] http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf

The policy behind the Sludge Regulation is that the contents of heavy metals do not accumulate to elevated levels in soils and crops, and that risks of diseases to humans and livestock are minimised. Although the standards might not be protective enough it is assumed that in practice (Code of Good Agricultural Practices) the sludges do not contain all heavy metals at the level of the standards.

Specific codes of practice have been made for the use sewage sludge on agricultural land by the government (DoE, 1996) and industry (Adas, The Safe Sludge Matrix, 2001), for forestry (Forestry Commission, 2001) , and for industrial crops (Adas, 2001).

The soils where sludge is permitted, are limited to the soils in which the heavy metals contents are low or have a high pH. The table with limits is similar compared to the EC Sewage Sludge Directive (see Annex 2). The UK Sludge Regulations at present limit heavy metals, near the upper end of the range indicated in the EC Directive on Sludge (Hogg *et al.*, 2002).

Various types of waste materials which are exempted for use in agriculture by the Environmental Agency (2012). This limits the quantity of waste used per hectare. For compost and digestate the limits are 50 tonnes per hectare per year (EA, 2012). Compost that complies with the PAS100 standard is not regulated as waste.

3.6 Comparison of regulations on contaminants of selected member states

- Fertilisers and related materials are differently organised in the NL, VLG, UK, DE, and DK.
- Contaminants are regulated in sewage sludge, compost and digestate, in most countries. In the Germany and the Netherlands contaminants are also regulated in other fertilisers. Only Germany has limit values for animal manure [7].
- There are limit values for content of contaminant per (dry) mass of fertiliser or per beneficial component, and there are limit values for the dosage of contaminants per hectare per year, and there are limit values for contaminants in soil above which no fertiliser (sewage sludge or compost) can be used.
- Only Denmark has limits for LAS, NPE, DEHP
- Only Germany has limits for PFCs, Tl
- Only Flanders has limits for BTEXS, and a range of chloroethanes, –ethenes, and –benzenes.
- Only the Netherlands has limits for DDT, DDD, DDE , HCH, drins
- Maximum limit values for heavy metals are the lowest in NL
- Maximum limit values for common organic contaminants (PAHs, PCBs) are lowest in VLG.

3.6.1 Contaminants

The comparison of regulations for fertilisers in various countries is complicated due to differences in the type of fertilisers. Of course all aforementioned countries meet requirements of the EC Regulation No 2003/2003. However they all differ in regulation of fertilisers that do not meet these requirements. Differences starts with the definition of fertiliser. In Germany all fertilisers and similar materials are called fertilisers by law but all categories with types have separate definitions. Also the Netherlands only fertilisers are regulated but distinguishes compared to Germany only categories for which definitions are given. In Belgium a distinction is made between fertilisers, soil improvers, and other materials for which types with definition are given. Denmark distinguishes more categories and the UK follows EC Regulation No 2003/2003 only.

[7] Animal manure that is traded.

EC fertilisers according to EC Regulation No 2003/2003, compost and sewage sludges are treated as separate materials in all countries. In Flanders and Germany the regulation for compost are similar as for digested materials. In Flanders the regulations for sewage sludge, compost and other organic fertilisers or soil improvers has been harmonized.

From the table (3.12) below it is clear that heavy metals are regulated in all countries and materials. Most countries regulated dioxins, PCBs and PAHs in organic fertilisers. While the Netherlands regulates the persistent organic contaminants (POP), Flanders regulates a long list of organic hydrocarbons. Different from the other countries, Denmark regulates Linear Alkylbenzene Sulfonate (LAS), Nonylphenol Ethoxylates (NPE), and Bis (2-ethylhexyl) phthalate (DEHP), and Germany regulates the sum of PerFluoroOctane Sulfonate (PFOS) and PerFluoroOctanoic Acid (PFOA) (perfluorinated chemicals: PFCs).

Table 3.12 Overview of contaminants mentioned in fertiliser statutory (s), if not statutory, voluntary (v) regulations (for references, see chapters above).

Country	Regulation	Statutory (s) or voluntary	Cd, Hg, Ni, Pb	Cu, Zn	Tl	As	Σ PCDD/ PCDF	Σ PAHs	ΣPCBs	DDT DDD DDE , HCHs,	AOX	Mineral oil	BTEXS	Hydrocarbons *	LAS, NPE, DEHP	PFC
Compost																
NL	Fert. Decree and Fert. Regulation	s	x	x		x										
BE	Royal decree 07.01. 1998	s	x	x												
BE-VLG	(Flanders) Vlarema	s	x	x				x	x		x	x	x	x		
DE	Ordinance on Biowastes (BioAbfv)	s	x	x												
DK	Statutory order nr. 1650 13/12/2006	s	x	x		x		x							x	
UK	PAS 100	v	#													
Digestate																
NL	Fert. Decree and Fert. Regulation	s	x	x		x	x	x	x	x						
BE-VLG	(Flanders) Vlarema	s	x	x		x	x	x	x		x	x	x	x		
DE	Ordinance on Biowastes (BioAbfv)	s	x	x												
DK	Statutory order nr. 1650 13/12/2006[1]	s	x	x		x		x							x	
UK	PAS 110	v	#													
Fertilisers																
NL**	Fert. Decree and Fert. Regulation	s	x	x		x	x	x	x	x		x				
DE ***	DuMV	s	x	x	x	x	x	x	x							x
DK ****	statutory order no. 223 1989 P-fertilisers	s	&													
Sewage sludge																
NL	Fert. Decree and Fert. Regulation	s	x	x		x										
BE-VLG	(Flanders) Vlarema	s	x	x		x		x	x		x	x	x	x		
DE	sludge ordinance (AbfKlärV)	s	x	x			x	x			x					x
DK	Statutory order nr. 1650 13/12/2006	s	x	x		x		x							x	
UK	Sludge Regulation 1989 (SI 1263)	s	x	x												

* 25 monocyclic aromatic hydrocarbons

**all fertilisers except: EC fertilisers and animal manure, compost and sewage sludge

*** all fertilisers except EC fertilisers. All fertilisers: including animal manure, soil improvers, substrates and plant stimulants. For sewage sludge (AbfKlarV) and biowaste (BioAbfV) the specific regulations can be used.

**** Only Cd in P fertilisers

^hydrocarbons

only CrVI

Besides differences in quality standards and permitted dosages there are significant differences between the countries in the way they permit input materials for products as compost and digestates, which materials they permits as fertilisers (or soil improvers), and how standards are used: for the input materials or only for the product (Table 3.13).

Table 3.13 Qualitative statutory (s) standards for contaminant control in fertilisers.

Country	Standards for input or product (output)	Positive list compost	Positive list for other fertilisers or raw material (or secondary raw materials) for fertiliser production
UK (v)	No standards	Not applicable	Not applicable
VLG (s)	Input and output	waste materials for fertilisers and soil improvers (Annex 2.2.Vlarema)	
NL (s)	Output	Source separated "VFG" or green waste, no animal manure	Other inorganic fertilisers, other organic fertilisers, and List of waste and residues permitted to be used as fertilisers.
	Input	Substrates, by-products and waste permitted for anaerobic digestion	List of waste and residues permitted to be uses for anaerobic digestion
DE (s)	Input and output	1. List of residues without approval 2. List of residues with approval according to § 9a. 3. 3. list of raw materials	
DK (s)	output	1. List of six categories of waste materials (Annex 1 of BEK nr 1650, 2006)	

Some materials are not regulated for example bio waste in the UK only has voluntary regulations for compost and digestate, and in the Netherlands there are no regulation for specific regulations for bio stimulants.

3.6.2 Sewage sludge

The UK uses the maximum dosage permitted by the EU sewage sludge directive. Denmark uses the maximum dosage for Cu and Zn, for the other heavy metals Denmark and the Netherlands have the lowest permitted dosages (Table 3.14). The differences between countries are currently very large. In practice Flanders, the Netherlands, several states Germany sewage sludge from urban waste water treatment plants is hardly used in agriculture.[8] On the other hand, in Denmark, and United Kingdom the majority of sewage sludge is used in agriculture[9].

Besides quality standards, and limited dosages, the Sewage Sludge directive also demands soil standards above which sewage sludge cannot be used. A comparison between the Netherlands and surrounding countries is given in Annex 2. Also in this case there are large differences between countries. While Flanders, the Netherlands use the upper boundary of background soil concentrations as a limit value, the United Kingdom uses the higher concentrations which also depend on the soil pH. Taking the soil pH into account shows that the UK uses a risk approach as a basis for the limit values.

[8] The same counts for Austria and Switzerland. However in France
[9] Also in France the most sewage sludge find a re-use in agriculture.

Table 3.14 Comparison of standards for sewage sludge in Denmark (DK), Belgium Flanders (VLG), Germany (DE), the Netherlands (NL) and current standards for Sewage sludge by the EU (86/278). For comparison some values have been calculated [d] (between brackets). Parameters that cannot be compared are omitted [e].

Contaminant	DK [e]	VLG [e]	DE [e]	NL	UK	EU
Maximum dosage of sewage sludge in tonnes dry matter per hectare per year						
	7		1.6	2 [c]		
Maximum dosage of contaminants in kg $ha^{-1}yr^{-1}$						
Cd	(0.0056)	0.012	(0.016)	(0.0025)	0.15	0.15
Cr	(0.7)	0.500	(1.5)	(0.15)		
Cu	(7)	0.750	(1.3)	(0.15)	7.5	12
Hg	(0.0056)	0.010	(0.013)	(0.0015)	0.1	0.1
Ni	(0.21)	0.100	(0.3)	(0.06)	3	3
Pb	(0.84)	0.600	(1.5)	(0.2)	15	15
Zn	(28)	1.8	(4.1)	(0.6)	15	30
As	(0.175)	0.3		(0.03)		
PAH	(0.021)	0.00136 - 0.0046 [b]				
PCB		Σ 0.0016 [c]	0.0008 [a]			
limit values for contaminants in mg kg^{-1} dm						
Cd	0.8	6	10	1.25		20 – 40
Cr	100	250	900	75	25	
Cu	1000	375	800	75		1000 – 1750
Hg	0.8	5	8	0.75		16 – 25
Ni	30	50	200	30		300 – 400
Pb	120	300	900	100		750 – 1200
Zn	4000	900	2500	300		2500 – 4000
As	25	150		15		
PAH	3	0.68 – 2.3 [b]				
PCB		Σ 0.8 [c]	0.2 [a]			

[a] given per congener or as a sum of congeners (Σ) in ng/kg.
[b] the range of limit values for different PAHs.
[c] grassland (1 tonnes ha^{-1} yr^{-1}) and arable land (2 tonnes dry matter ha^{-1} yr^{-1}). Here 2 tons dry matter ha^{-1} yr^{-1} are applied.
[d] calculated on the basis of a maximum dosage of sewage sludge and the limit values.
[e] not all parameters are given, as no comparison can be made, for: Denmark (LAS, DEHP, NPE), Germany (AOX, PCB, PCDD/F) and Flanders (table 2.4).

3.6.3 Compost and other fertilisers

Maximum limits to contaminants in compost are given in Table 3.15. Large differences are found for Cu and Zn. Arsenic is not taken into account by DE and UK.

In practice only a fraction of the compost in Germany[10] (Amlinger *et al.*, 2004) can comply with the standard for Eco-label compost. The proposal for the EoW criteria (JRC/IPTS, 2011) are based upon the Eco-label compost standard with higher standards for Cd (factor 3/2), Pb (6/5) and Zn (4/3) compared to the Eco label compost standards (JRC/IPTS, 2011, annex 12; see Annex 3) . The rationale for the proposed standards is a compromise between the wish to recycle materials and the accumulation of contaminants in soil. A study of Orbit/ECN (2008) states that application of compost with contents similar to the Eco-label standards would not lead to an unacceptable accumulation of metals in soil within 100 years.

[10] Also Austria

Table 3.15 Limit values for contaminants in compost and other fertilisers (mg kg^{-1} dm) in various countries. When a country does not have standards, the voluntary standards are given (see annex 4). For a comparison the values for the Netherlands have been recalculated to mg kg^{-1} dm.

Contaminant	**Waste and residues used as fertilisers and soil improvers**						**Compost**	**Fertilisers**	**EoW[c]**
	DK [g]	VLG [g]	DE [g] type1	DE [g] type2	NL [h, g]	UK	NL	DE	EU, Jrc
	s	s	s	s	s	v	s	s	
Cd	0.8	6	1.5	1	1.25	1.5	1	1.5(2.5)	1.5
Cr	100	250	100	70	75	100	50		100
Cu	1000	375	100	70	75	200	90	900	100
Hg	0.8	5	1	0.7	0.75	1	0.3	1	1
Ni	30	50	50	35	30	50	20	80	50
Pb	120	300	150	100	100	200	100	150	120
Zn	4000	900	400	300	300	400	290	5000	400
As	25 [f]	150			15		15	40	
PCB		0.8 [d]			0.74 -3				
PAH	Σ3 [e]	0.68 – 2.3			Σ20 [e]				
Σ PCDD/PCDF					760	[a]		30(5) [a,b]	
Mineral oil		560 – 5600 [i]			37400				
Dosage									
t ha^{-1} yr^{-1}	7		6.9	10	j				

[a] Units for dioxins, in German DüMV ng TEQ kg^{-1}); in the NL in ng kg^{-1}.
[b] Lower value for grassland
[c] For comparison purposes: the EoW criteria
[d] Per congener
[e] DK: Σ11-PAK, NL: Σ10-PAK
[f] Only private gardens
[g] Not all parameters are given, as no comparison can be made, for: the Netherlands (see table 2.3), Denmark (LAS, DEHP, NPE), Germany (Tl, PFC) and Flanders (table 2.4).
[h] Organic contaminants only in organic fertilisers.
[i] For C10-C20: 560 mg kg^{-1}, and for C20-C40: 5600 mg kg^{-1}.
j Compost use is regulated in the Netherlands by phosphate use standards.

3.6.4 EC fertilisers

The current EU Regulation No 2003/2003 has no limits for contaminants. A few countries have a derogation for the EU Regulation No 2003/2003 to set a limit on the cadmium content in phosphate fertilisers. Sweden, Finland and Austria already had standards before entering the EU (Table 3.16). Sweden (20 mg Cd kg^{-1} P_2O_5), Finland (22 mg Cd kg^{-1} P_2O_5), Austria (75 mg Cd kg^{-1} P_2O_5) (website DG Enterprise and Industry, about derogations).

Table 3.16 Regulated organic micro contaminants for agricultural use of the main types of biodegradable wastes

Country	**Limit value (mg Cd kg^{-1} P_2O_5)**	**Remark**
Austria	75	Derogation EC, 2012
Sweden	20	Derogation EC, 2012
Finland	22	Derogation EC, 2012
Denmark	48	No derogation has been asked
Average in Europe	36	Nziguheba and Smolders, 2008

According to a study of phosphate fertilisers in European countries (Nziguheba and Smolders, 2008) the average cadmium content is 36 mg Cd kg^{-1} P_2O_5, while the 10, 50 and 90 percentile are 2.8, 38 and 73 mg Cd kg^{-1} P_2O_5 respectively, thus showing a large variation. The Danish phosphorus-related threshold of 48 mg Cd/kg P_2O_5 was exceeded in a significant number of the analysed phosphorous fertilisers in Denmark (Petersen *et al.*, 2009).

In Flanders, the federal authorities and the phosphate producing industry agreed on a maximum content of Cd in phosphate fertilisers of 90 mg/kg P_2O_5.

Various risk assessment studies have been made on cadmium in fertilisers by nine member states (AU, BE, CZ, DK, Fi, FR, DE, GR, IR, SW, UK) (website DG Enterprise and Industry, about cadmium in fertilisers). On the basis of these extended risk assessments some countries (see table above) have introduced a limit value for cadmium in phosphate fertilisers, while the others have not done so. The risk assessments calculate at which limit value accumulation of cadmium in soil can be prevented (ERM, 2001). Limit values for Cd in phosphate fertilisers can be achieved by mandatory or voluntary requirement for phosphate fertilisers[11]. The Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE, 2002)(according to article 15 in Regulation (EC) No 2003/2003) is of the opinion that a limit for Cd in phosphate fertilisers should be based on a risk assessment approach considering all cadmium sources. In an opinion about a recent request of Sweden to extend the limit on Cd in phosphate fertilisers, the CSTEE (2012) stated that there is no proof that the risk of cadmium in fertilisers in Sweden is different from that in other European countries. For other contaminants in fertilisers the CSTEE has not expressed an opinion.

3.7 Comparison of standards with measured levels of contaminants in fertilisers

Comparison

To obtain insight in the loads of contaminants to soils in the Netherlands with the application of organic and mineral fertilisers a review has been made on the volumes and concentrations. The information gathered was focussed on the heavy metals and organic micro contaminants that are regulated the Fertilisers Act and its Decree (Ub) and the Implementing Regulation (Ur). For the loads of heavy metals and arsenic, an approximate overview could be made. Information on the volumes of most main fertiliser categories is available. For some categories, production volumes are monitored (manures, VFG compost, main inorganic fertiliser types). For some categories only estimates are available (green compost). Recent, i.e. less than 5 years old, information on concentrations of heavy metals is, for most fertiliser categories, scarce and available information is limited to few sources. However, an approximate overview could be made. Some calculations are based on few data.

On one category of fertilisers no information was available, the so-called “other (in)organic fertilisers”. These products have to comply with the regulations on contaminants from the Fertiliser legislation. For one product information was available and has been used, i.e. sugar factory lime, which is nowadays the main liming material used in the Netherland.

For the organic micro contaminants, only one source of information is available (Driessen and Roos, 1996). These measurements are outdated, as fluxes of these contaminants have changed considerably because of regulations on emissions and usage, and overall changing production processes. Therefore, these published data were not used.

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11 There is a large variation of cadmium concentrations in phosphate rocks, and production processes have a large influence on the cadmium concentrations in the fertilisers (Van Kauwenbergh, http://www.fertilizer.org/ifa/HomePage/LIBRARY/Publication-database.html/Cadmium-Content-of-Phosphate-Rock-and-Fertilizers.html).

In table 3.17 we compare the average contents of contaminants of fertilisers in the Netherlands with proposed quality standards for various product groups of fertilisers in the EU and current standards for sludge and other organic and other inorganic fertilisers in the Netherlands. Comparison of the average contents with the minimum of all standards shows that in general fertilisers meet the most critical standards. Exceptions are triplesuperphosphate (TSP), Thomasslag (basic slag), animal manure, lime cake and the thick fraction of pig manure. The listed contents for TSP, which are within the ranges of the contents reported by Smolders and Nziguheba (2008), exceed the maximum permissible contents for chromium, nickel and zinc. It should be noted, however, that TSP meets the criteria for inorganic fertilisers because nickel is below this standard and there are no standards for chromium and zinc. Sugar factory lime exceeds the standard for cadmium. Copper and zinc contents in manure and the thick fraction of pig manure exceed standards for organic fertilisers with a factor 2-4. Also municipal sewage sludge does not meet the criteria especially because of its high contents of copper and zinc.

In table 3.18 we compare the theoretical maximum average loads of metals to the soil based on the basis of the beneficial value of the fertilisers (N, K_2O, P_2O_5). Maximum inputs of nutrients were set to 150, 100 and 80 kg ha^{-1} for K_2O, N and P_2O_5 respectively. Generally the comparison of loads gives the same picture as the comparison based on maximum contents. Exceptions are spent mushroom compost, green- and VGF compost of which the metal contents meet the criteria whereas the loads exceed the maximum loads for several metals. This is due to the low nutritional value of the composts of which large amounts are needed to obtain the desired P_2O_5 supply. Table 3.19 contains the actual load using the average metal and nutrient content of fertilisers as used under normal conditions. These data are calculated from source data as listed in Appendix 7. The data in table 3.19 are expressed in ton per year but are converted to gram per hectare for comparison purposes with data in 3.18. The conversion is done by dividing the annual load by the total surface area for agriculture (i.e. $2\ 10^6$ ha including both grassland and arable land). The relative contribution of each group of fertilisers to the total load is given in table 3.20 and illustrated in figure 3.1.

Table 3.17 Average values of metal contents in various fertilisers and wastes in the Netherlands in comparison with proposed standards (mg.kg^{-1}dm) based on data provided in Annex 7. Numbers in bold/red exceed minimum of listed standards, numbers are in bold when maximum value of range exceeds minimum standard

	n[1]	**Cd** **< 5% P_2O_5**	**Cd** **>5% P_2O_5**	**Cr VI**	**Cr tot**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**
Standards											
Inorganic Fertilisers		3	60(40/20)	2			2	120	150		60
Micronutrient Fertilisers		200	200				100	2000	600		1000
Organic Fertilisers		1.5			100		1	50	120		30-60
EoW		1.5			100	100	1	50	120	400	
Fertilisers (NL)		1.25			75	75	0.75	30	100	300	15
Minimum of standards		1.25	60	2	75	75	0.75	30	100	300	15
Average metal contents in products											
KCl (KCl40 and KCl60)	6	0.24			0.47	0.23		1.77	3.26	10.2	1.80
Kainite (Patentkali)	2	0.02			0.32	0.20		0.78	0.72	0.20	0.78
TSP	7		32.4		**174**	49.3		**56.3**	3.88	**617**	0.14
NPK 15+15+15	1		0.9		9.00	5.85		1.95	3.42	15.5	**103**
NP 26+14	1		1.20		25.9	9.52		6.86	6.51	37.5	2.90
Basic slag (Thomasslag or Thomasmeel)	1		0.42		**1988**	28.1		11.4	30.7	92.3	3.26
Calcium ammonium nitrate (CAN)	3	0.10			0.81	2.03	0.06	7.19	7.85	5.43	**56.9**
Magnesammon	1				1.98	0.99		1.98	34.8		
Magnesium ammonium sulphate (MAS)	1	0.40				2.55	0.00	2.33	1.30	86.7	
Spent mushroom compost	3	0.30			12.3	31.3	0.02	23.0	8.93	138	2.00
Green compost	3	0.45			20.2	31.5	0.12	10.2	35.1	143	4.70
VGF compost	4	0.5			17.7	33.9	0.11	8.80	69.6	166	3.80
Cattle slurry	4	0.23			7.25	**88.5**	0.04	11.9	11.7	177	0.79
Pig slurry	3	0.36			11.7	**416**	0.03	17.1	11.2	**792**	0.97
Chicken manure	5	0.20			6.72	**80.5**	0.03	11.7	14.2	**324**	0.67
Ground limestone	2	0.45			1.91	16.2	0.01	4.05	3.25	35.8	
Magnesium limestone	2	0.83			2.20	9.55	0.01	7.45	27.6	133	
Sugar factory lime	2	**1.58**			30.3	42.5	0.02	5.10	10.2	171	5.9
Industrial sewage sludge[1]	7	0.86			20.4	31.7	0.06	18.4	12.2	145	3.23
Municipal sewage sludge[2]	10	**1.45**			42.6	**394**	**1.00**	29.6	**133**	**993**	9.27
Mineral concentrate from pigs slurry	1					1.34				6.97	
Mineral concentrate from cattle slurry[5]	1					0.03				0.46	
Thick fraction pig slurry	1					**132**				**403**	
Thick fraction dairy cattle slurry	1					17.5				0.01	

[1] number of studies / years
[2] average 2000-2006
[3] average 2000-2009
[4] Standards for (in)organic fertilisers (except EC No 2003/2003 fertilisers) in the Netherlands. [5] Data for mineral concentrates and thick fraction manure (Ehlert and Hoeksma, 2011).
[5] mineral concentrate from cattle manure.

Table 3.18 Theoretical maximum load of metals ($g.ha^{-1}yr^{-1}$) when fertiliser is used according to the maximum regulatory beneficial supply in the Netherlands (150 $kg.ha^{-1}$ K_2O; 100 $kg.ha^{-1}$ N; 80 $kg.ha^{-1}$ P_2O_5) and the average metal contents of specified fertilisers. Maximum loads of compost, sludge and manure are based on their average P_2O_5 content and the maximum P_2O_5 supply.

	n[1]	Cd	Cr tot	Cu	Hg	Ni	Pb	Zn	As	Regulatory beneficial component
Maximum permissible load[2] load (g ha^{-1})		2.5	150	150	1.5	60	200	600	30	
KCl (KCl40 and KCl60)	6	0.1	0.4	0.1	0.0	0.7	1.5	5.4	0.7	K_2O
Kainite (Patentkali)	2	0.0	0.1	0.0	0.0	0.2	1.0	1.8	0.0	K_2O
TSP	7	**5.7**	17	7.4	0.0	8.5	0.5	92.8	0.0	P_2O_5
NPK 15+15+15	1	0.5	4.8	3.1	0.0	1.0	1.8	8.2	0.0	P_2O_5
NP 26+14	1	0.7	15	5.4	0.0	3.9	3.7	21	1.7	P_2O_5
Basic slag (Thomasslag or Thomasmeel)	1	0.3	**1223**	18	0.0	7.0	19	57	2.0	P_2O_5
Calcium Ammonium Nitrate (CAN)	3	0.0	0.5	0.8	0.0	2.8	3.0	2.1	7.3	N
Magnesammon	1	0.0	0.9	0.5	0.0	0.9	16	0.0	0.0	N
Magnesium ammonium sulphate (MAS)	1	0.2	0.0	1.2	0.0	1.1	0.6	40	0.0	N
Spent mushroom compost [3]	3	1.7	62	**216**	0.2	**269**	47	**908**	13	P_2O_5
Green compost [3]	3	0.0	**262**	**543**	**1.6**	**134**	**551**	**2433**	**62**	P_2O_5
VGF compost [3]	4	**7.4**	**260**	**501**	**1.6**	**132**	**1056**	**2372**	**50**	P_2O_5
Cattle slurry	4	0.9	28	**397**	0.1	44.5	44	**735**	3.2	P_2O_5
Pigs slurry	3	0.6	18	**707**	0.1	29.5	22	**1331**	1.5	P_2O_5
Chicken manure	5	0.5	16	**208**	0.1	23.8	29	**799**	1.7	P_2O_5
Industrial sewage sludge	7	0.9	21	32	0.1	17.9	12	147	3.2	P_2O_5
Municipal sewage sludge	9	2.2	63	**580**	1.5	43.9	197	**1464**	14	P_2O_5
Mineral concentrate pigs slurry	1			19				100		N
Mineral concentrate cattle slurry	1			0.3				4.2		N
Thick fraction pigs slurry	1			**679**				**2072**		P_2O_5
Thick fraction cattle slurry	1			130				0.1		P_2O_5

[1] number of studies or years of monitoring.

[2] the maximum permissible load is based on the maximum annual allowed application rate of 2 tons dry matter of sewage sludge and other inorganic fertilisers on arable land according to the Netherlands Fertiliser decree (Ub).

[3] Spent mushroom compost, green compost and VGF compost are not used as organic fertiliser in NL but as soil improver. Soil in compost is not taken into account when applying phosphate use standards. Effectively calculated loads are therefore 50% lower.

Table 3.19 Actual annual load of nutrients (kton yr-1) and heavy metals and arsenic (ton yr-1) with mineral fertilisers, liming materials, animal manure, compost (incl. spent mushroom compost and industrial sewage sludge to soils in the Netherlands for 2010/2011.

Category	**N**	**P_2O_5**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**
	10^6kg	10^6kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
N	200		0.09	6.7	1	0.05	15.6	0.7	4	0.4
P_2O_5	20	31	1.45	6.0	3	0.01	1.8	0.9	15	0.6
K_2O			0.01	0.0	0	0.00	0.1	0.2	0	0.1
Liming materials			0.11	1.5	3	0.00	0.6	1.3	13	0.3
Compost	13	6	0.38	18.2	32	0.09	8.9	42.9	139	3.7
Cattle slurry	205	74	1.03	27.1	502	0.46	23.3	24.4	736	6.3
Pig slurry	72	42	0.32	8.5	357	0.09	11.6	7.4	780	1.1
Chicken manure	4	2	0.01	0.5	5	0.00	0.5	0.8	26	0.1
Sludge*	1	3	0.01	0.6	1	0.00	0.4	0.8	4	0.1
Total (kton or ton)	515	158	3.42	69,2	903	0.69	62.9	79.4	1718	12.7
Total	257.5	79	1.71	34.6	452	0.35	31.5	39.7	859	6.4
	(kg ha^{-1})	(kg ha^{-1})	(g ha-1)	(g ha^{-1})	(g ha^{-1})	(g ha^{-1})	(g ha^{-1})	(g ha^{-1})	(g ha^{-1})	(g ha^{-1})

*mostly sewage sludge from food and paper industry, no municipal sewage sludge's.

Table 3.20 Relative contribution to the loads of heavy metals and arsenic with mineral fertilisers, liming materials, animal manure, compost (incl. spent mushroom compost) and industrial sewage sludge to soils in the Netherlands for 2010/2011. Contributions in excess of 50% of the total load are marked red.

Category	**N**	**P_2O_5**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**
	%	%	%	%	%	%	%	%	%	%
N	39	0	3	10	0	7	25	1	0	3
P_2O_5	4	19	42	9	0	1	3	1	1	4
K_2O	0	0	0	0	0	0	0	0	0	1
Liming materials	0	0	3	2	0	0	1	2	1	2
Compost	3	4	11	26	4	13	14	**54**	8	30
Cattle slurry	40	47	30	39	**56**	**67**	37	31	43	49
Pig slurry	14	26	9	12	40	12	18	9	45	9
Chicken manure	1	1	0	1	1	0	1	1	1	0
Sludge*	0	2	0	1	0	0	1	1	0	1
Total	100	100	100	100	100	100	100	100	100	100

*mostly sewage sludge from food and paper industry, no municipal sewage sludge's.

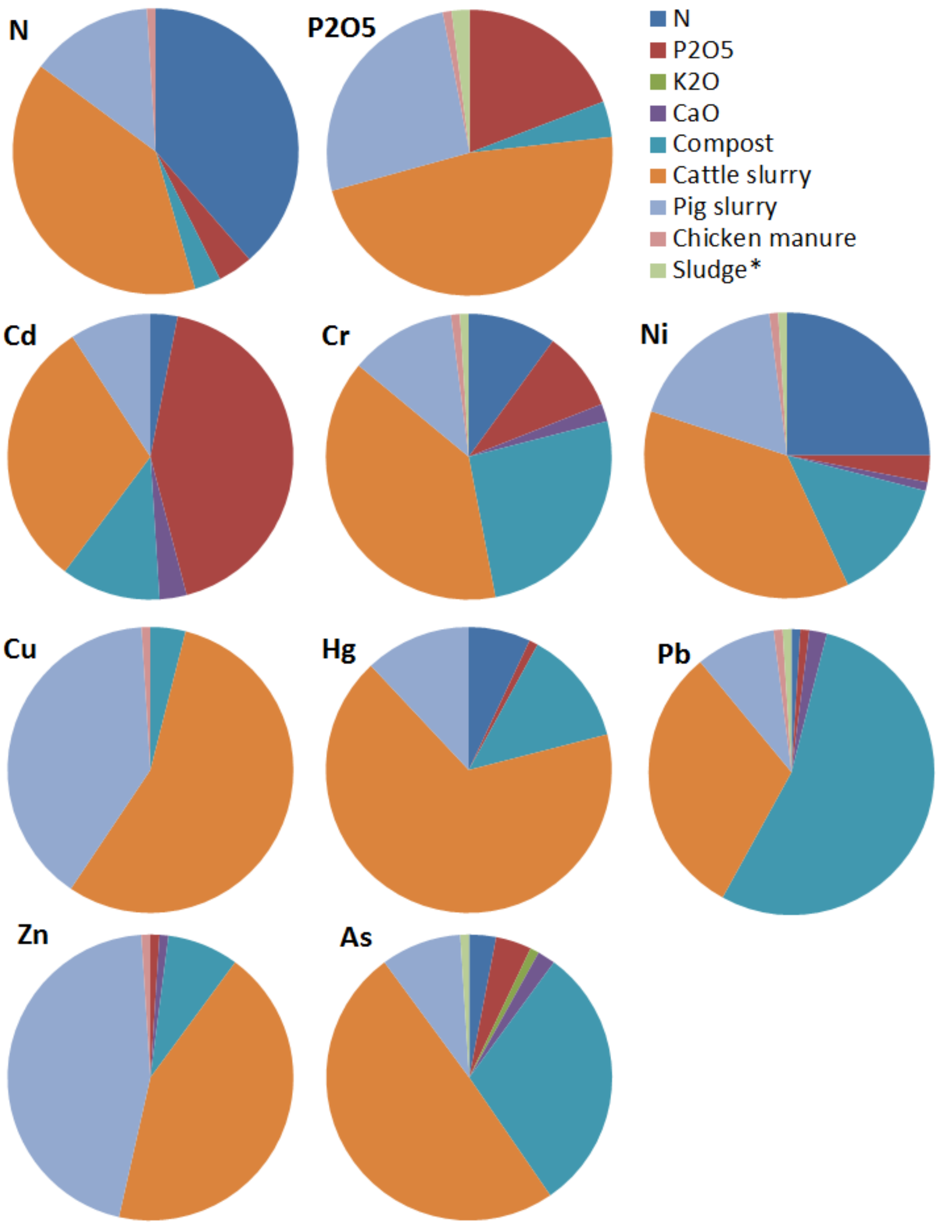

Figure 3.1 Relative contribution of mineral fertilisers (N, P_2O_5, K), liming materials, compost (incl. spent mushroom compost, animal slurry or manure (cattle, pig, chicken), and industrial sludge to the loads of heavy metals and arsenic to soils in 2010/2011

Synthesis

- In 2010, the calculated amount of N and P applied to soil in the Netherlands by fertilisers, manure and compost was 515 mln kg (N) and 158 mln kg (P_2O_5) respectively. From these product categories animal manure is the main source of nitrogen and phosphorus on agricultural soils in the Netherlands.
- Apart from nutrients and organic matter, both inorganic and organic fertilisers contain other elements, amongst others heavy metals and arsenic.

- The information gathered allows for a general comparison between various classes of fertilisers, but it should be kept in mind that the underlying data on concentrations of heavy metals and arsenic in fertilisers are limited and in some cases older than 10 years.
- From all organic waste materials reviewed, animal manure is the main source of copper, zinc, mercury, nickel, chromium and arsenic. Zinc and copper mainly originate from additives in feed but copper also stems from hoof disinfection solutions mixed with manure.
- Compost is the dominant source of lead when comparing various (in)organic fertilisers, and also contributes significantly to the total load of arsenic, chromium, nickel, mercury and zinc.
- The share of compost in view of the heavy metal load to soils is relative large compared to the contribution of N and P. The main aim of adding compost to soil however is the addition of organic matter rather than nutrients.
- Mineral fertilisers are the main source of cadmium (P fertilisers), and also contribute to the nickel, chromium, arsenic and mercury load to soils.
- No information is available on volumes and concentrations of the so-called “other (an)organic fertilisers”.
- No recent information is available on loads and concentrations of organic micro contaminants in the product reviewed here.

4 Origin of legislation of contaminants

4.1 Introduction

This report highlights the backgrounds of existing legislation related to fertilisers in a limited number of member states of the European Union. In view of the upcoming EU-regulatory changes in the field of fertiliser trade it is imperative to consider the aims and (potential) shortcomings of current legislative frameworks in order to find the balance between benefits and potential risks of trade and application of (organic) fertilisers. Here we summarize major findings which have to be addressed when revising policy related to trade and (re)use of fertilisers. This results in a series of recommendations (research issues) which eventually can lead to a new framework regarding the quality assessment (or guidelines) for fertilisers.

4.2 Development of fertiliser regulation in the Netherlands

Regulation of fertilisers in the Netherlands has a long history. The main goal that has triggered legislation of fertilisers was the protection of the farmer against poor quality and fraud with fertilisers, soil amendments and liming materials. From 1889 onwards, the quality of agricultural commodities - amongst which fertilisers - was regulated by law. The quality check solely focused on nutrients, acid neutralising value and organic matter. Due to experience and evolutions in the field of agronomy, the basics of the system as we know now were laid and published in 1950. In that year, a novel decree came into force, again focused on the quality control of fertilisers, soil amendments (inorganic and organic soil improvers) and liming materials. Contemporary analytical methods and quality criteria for nutrients, acid neutralising value and organic matter were summarized by this decree. From then onwards this decree was adapted on a regular basis due to national and international (EEG and BENELUX) developments in fertiliser technology, new fertiliser types and analytical procedures as well as the desire to reduce trade barriers between nations.

Initiating appraisal of potential threats by contaminants

For a long time, environmental risk assessment of fertilisers was in the Netherlands not an issue. This perception changed due repeated observations of serious contaminant impacts on human and environmental health and integrity, animal welfare, and agricultural production and product quality. Contamination of soils, water bodies and air, and the outbreak of animal diseases, triggered several laws to protect human and environmental health and agriculture. Such effects however were related to the observed impact in local cases (Lekkerkerk) and not so much in view of impact of fertiliser use in agriculture. This increased awareness of the impact of soil contamination on human health triggered legislation regarding organic fertilisers initially related only to the quality of sludge and specific types of compost.

Laws and regulations that appeared afterwards (including plant protection, animal health) were largely sectorial, linking neither e.g. water and soil, nor contaminants and pathogens to fertilisers. Developments within the scope of the fertiliser decree were rather independent of those of the environmental laws.

Basics of European initiatives linking waste, fertiliser and the environment

The first fertiliser product the use of which was restricted based on environmental concerns via defining a maximum acceptable contamination level and dosage, was sewage sludge. This development had already an European dimension as the EU6 worked together towards formulating an European directive for sewage sludge. The developments in the context of sewage sludge provided a framework for another commodity: compost. Still, regulations of sewage sludge and compost, although these commodities could be used as an organic soil amendment (organic soil improver) in the Netherlands, the fertiliser act did not regulate contaminants, only criteria for the production process, definition and organic matter were given.

The instalment of criteria for maximum allowable contamination of sewage sludge and compost however triggered in the Netherlands the development of contamination standards for fertilisers, soil amendments and liming materials in general. The development of these environmental standards started in de late eighties and early nineties of the last century and have led to the establishment of the first environmental test for waste products that were intended to be used in the Netherlands as a fertiliser or a soil amendment in 1998. In 2007 this environmental test came into force for all fertilisers not being a formally defined EG-fertiliser or animal manure.

European proliferations of waste and fertiliser appraisal regulations
The awareness of risks related to application of sludge and compost to soils and the subsequent criteria resulting from this, provided a pitfall for practice: setting national standards for additional EG-fertilisers could cause a trade barrier, especially when all countries are free to develop their own criteria. In practice, although derogation is possible, only some EU member states have therefore used this tool to define European-wide appraisal criteria. In fact, risk-based quality criteria have been proposed so far for cadmium only, and only part of the member states adhere to this European criterion, the Netherlands not being one of them.

4.3 State of art in fertiliser quality appraisal

Specific regulations in the Netherlands
The concerns of the past period, on both fertilising as well as risk aspects, has led to the definition of various categories of commodities that were regulated in relation to waste, (re-)use as fertiliser, and potential risks. Animal manure is amongst the products that is most heavily regulated in the Netherlands. Regulations are in place for use, dosage, application standards, application methods and trade which partly triggered the decision not to include environmental concerns related to contaminants. Even more so since it presumably would lead to too many administrative costs without a clear prospect on effective contribution to Good Agricultural Practice. Moreover, the focus of regulations appeared to change.

Dual focus: profits and risks
The change that occurred in 2007 was the final introduction of the dual focus in the regulations. Till 2008 the focus was on the protection of the farmer against poor quality and fraud. Since 2007 it was expanded to a more risk-orientated fertiliser decree. The consideration was that, after 120 years of protection on fertiliser quality, the modern farmer is a well-educated and experienced entrepreneur with adequate knowledge of fertilisers, soil amendments and liming materials. The modern farmer is technically supported by the fertiliser industry and agricultural advisory services and certification schemes are into force. Due to this, the need for regulations on profits of fertiliser and quality control received lower priority for further innovation than regulation on possible risks coming from contaminants in fertilisers. This led to a reduction of regulation on fertilisers, soil amendments and liming materials. In this process, the number of categories of fertilisers was reduced.

For categories of fertilisers in the Netherlands, the profitable (fertilising) characteristics were regulated via relatively low minimum requirements for nutrients, acid neutralising values and organic matter. Furthermore only one definition of fertiliser became into force. The previously used concepts of soil amendments (inorganic of organic) and liming materials were abandoned. The definition of fertiliser was focused on all uses of only nutrients, acid neutralising value and organic matter.

In 2007 requirements related to maximum acceptable annual load of heavy metals and persistent organic micronutrients in the fertilisers were installed. These requirements were based on average use of nutrients (load per hectare), acid neutralising value and organic matter. These values, when linked with limit values that were set for soil protection, lead to maximum acceptable loads of heavy metals and POP's in the fertilisers themselves. It should be noted however that in the Netherlands initial soil protection limits used to set the maximum load were not based on a specific environmental effect, i.e. not risk-based, but merely related to target levels (*Achtergrondwaarden*) derived from screening of non-polluted soils. Obviously acceptable contaminant loads aimed to protect soils at such levels can be considered implicitly protective for all risk categories including risks for ecosystem, groundwater quality or product quality.

In essence, now, the fertiliser act changed from a commodity protection measure to a control measure including risk assessment of fertilisers in view of soil quality, and – henceforth – agricultural products and product quality, as well as health protection for man and ecosystems.

4.4 Current EU legislation and cross-cutting themes in view of contaminants

The aforementioned change in legislative focus from risks to (trade)profits, or stated differently, from waste to re-use, is not solely a process of the Netherlands. At present, existing EU directives are still mainly aimed at risk prevention. Within the EU27, a large number of activities address the risk and risk control with the final aim to protect human health, environment, agricultural productivity and product quality. These activities result in a constantly changing legislative environment, with direct or indirect links to the fertiliser context as illustrated by the following list of directives and regulations.

By regulating the maximum contents, a limited number of regulations have a direct impact on the content of contaminants in fertilisers,
- Sewage Sludge Directive, 86/278/EEC, on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture.
- Regulation (EC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs.

Other regulations have a strong influence on the content of contaminants in fertilisers, for example by determining the maximum contents of nutrients in animal feed (e.g. Cu, Zn), or by determining the materials that can or cannot be used for the production of fertilisers.
- Regulation (EC) 1831/2003, on additives for use in animal nutrition (specifically already authorised feed additives in Directive 70/524/EEC, website EU).
- Regulation (EC) No 396/2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin
- Directive 2008/98/EC on waste (Waste Framework Directive, including End of Waste criteria)
- Regulation (EC) No 1069/2009 (Animal by-products Regulation)
- Regulation (EC) No 1107/2009 concerning the placing of plant protection products on the market

The target of regulating contaminants in fertilisers is to protect the soil, and by doing so, protecting the animal, plants and humans. To reach this goal many other regulations are relevant, setting the targets.

- Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs, and Council Regulation (EEC) No 315/1993 laying down Community procedures for contaminants in food.
- Directive 2002/32/EC on the undesirable substances in animal feed
- Water Framework Directive, Directive 2000/60/EC establishing a framework for community action in the field of water policy.
- Nitrate Directive, 91/676/EEC, concerning protection of waters against pollution caused by nitrates from agricultural sources

Many contaminants in sewage sludge are governed by the products used in every day live which partly end up in sewage sludge. Also relevant are other sources of contaminants, such as air pollution, which is also regulated on EU level.

- Regulation (EC) No 1907/2006 (concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, REACH)

In each of these regulations and contexts, regulatory issues may directly or indirectly influence trade and appraisal of fertilisers. It is beyond the scope of this report to enumerate all cross-cutting themes and issues. However, as can be seen, a suite of regulations, each originating from different concerns and triggers, and each with specific aims, might relate to the appraisal, trade and use of fertilisers. Via a multitude of factual links that exist in practice, fertilisers relate to all these aspects, for example via quality of goods used as raw material (end product may be loaded with contaminants present in the raw material). It is evident that the factual importance of such links varies.

Although the procedure (process of implementation) of regulation within the EU27 had given guidelines by the European Commission[12], risk assessment for consumer goods is rather sector orientated activity. One can use similar concepts for risk control but there is no common shared policy yet.

Also in the risk assessment in the Netherlands is rather sector orientated; an integrated approach on risk assessment for consumer goods (among which fertilisers) cannot be recognised yet although work is in progress.

4.5 Origin of standards in the Netherlands

- Standards for heavy metals are based on a balance between input and output by crop Export, and a very limited accumulation in soil.
- Regulated organic contaminants are limited to POP (persistent organic contaminants). Standards are based on a limited accumulation in soil and degradation.
- Standards for loads of heavy metals are equal for sewage sludge and all other fertilisers, except EC fertilisers animal manure and compost.
- Standards for compost are based on sewage sludge except that fraction of soil in compost is taken into account.

4.5.1 General

In this chapter the origin and the basic considerations for the standards for contaminants in fertilisers are recollected. After a short history, the policies for limiting contaminants in a certain fertiliser are described, secondly the limit values, and thirdly the dosage. A distinction is made between types of fertilisers, and the type of contaminants (heavy metals, organic contaminants).

[12] 2011/0351 (COD) new legislative framework (nlf) alignment package, implementation of the goods package

In the Netherlands the regulation of contaminants in fertilisers started in 1980 by a guideline of the Water boards in which the dosage and content of heavy metals in sewage sludge were regulated (*Unie van Waterschappen*, 1980). See graph 4.1. below. In 1986 the Sewage sludge Directive (86/278/EEC) also published rules for the dosage and content of heavy metals. In 1991 the BOOM was published (came into in force from 1993 onwards) which regulated sewage sludge, compost, and soil like material made from compost (*zwarte grond*), in the Netherlands. New fertilisers or waste use intended to be used as fertiliser, soil amendment or growing medium, not mentioned in the List of fertilisers of the former Fertiliser Decree 1977 (*Lijst van Meststoffen van de Meststoffen-beschikking 1977*), needed an exemption to be traded as fertiliser (*Ontheffingsbeschikking verbodsbepaling meststoffen*). A screening test on quality and agronomic effectiveness assessed if the materials were truly fertilisers. The screening test for this exemption was extended with an environmental screening, informally at the start of the BOOM legislation in 1993 but later in 1999 this environmental screening (*Milieutoets*) was formalised (Janssen *et al.,* 1999). The BOOM and the environmental screening test have been incorporated and simplified in the fertiliser legislation (Fertiliser Decree, Fertiliser Directive and the Decree on the use of fertilisers) in 2007. Currently, waste materials, other than animal manure, sewage sludge and compost, cannot be used as a fertiliser (article 5, Ub) except when allowed by a specific regulation by the minister. The environmental screening test is still operational for waste materials to be used as a fertiliser (Van Dijk *et al.,* 2008). A large number of wastes are currently allowed as fertiliser or materials that can be used for fertiliser production by the minister (article 4 in Ur) and can be found in Annex Aa of the Implementing Regulation (Ur). Materials that can be used for fertiliser production also includes wastes that are used by biogas plants.

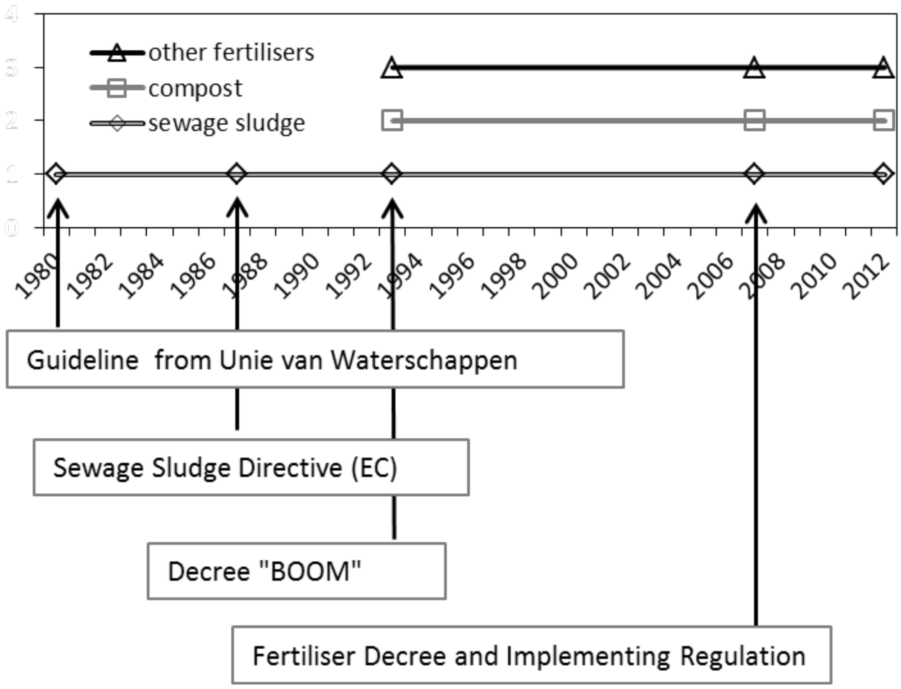

Figure 4.1 Historical timeline of standards for contaminants in fertilisers except EU fertilisers and animal manure. After 2007 the application rate of sewage sludge is regulated by the Decree on the use of fertilisers (Bgm) which is based upon the Soil Protection Act. The application rate of compost and other fertilisers are regulated by the Fertiliser Decree (Ub) and the Implementing Regulation (Ur)

There are limit values for heavy metals for all fertilisers in the Netherlands except for EU fertilisers and animal manure (TCB, 2012). See table 4.1. below. For EU fertilisers, animal manure, sewage sludge and compost there are also no limit values for organic contaminants. For all other types of organic fertilisers (called “other organic fertilisers”) organic contaminants are regulated. These standards for organic micro-pollutants are given in the Fertiliser Decree (Ub), Annex II therein) and the Implementing Regulation (Ur Annex Ab, therein). See table below. The origin of the standards in the four references (table 1 to 4) is different, and is therefore discussed in paragraph 4.5.5. The starting points are also different, except that the standards for heavy metals in Table 1 of the Annex II in the Fertiliser Decree (Ub), and Table 1 of the Implementing Regulation (Ur) are based on the standard for sewage sludge in table 3 of the Fertiliser Decree (Ub).

Table 4.1 Reference to limit values for heavy metals and organic micro contaminants in fertilisers according to the Fertiliser Decree (Ub) and Fertiliser Regulation (Ur). The table numbers and annexes are from given regulations.

Type of fertiliser	**Heavy metals**		**Organic micro contaminants**	
	Annex II of Ub	Annex Ab of Ur	Annex II of Ub	Annex Ab of Ur
Other inorganic fertilisers	table 1	table 1**		table 2*
Liming materials	table 1			
Other organic fertilisers	table 1		table 4*	
Sewage sludge	table 2			
Compost	table 3			

* This is also required for liming materials (*kalkmeststoffen*) and Other inorganic fertilisers (*overige anorganische meststoffen*) that contain organic material from animal or plant origin.

** Copper- and zinc fertilisers are regulated by EC No 2003/2003 (article 10).

The current standards (content and dosage) for maximum acceptable load of heavy metals all originate from repealed legislation: “Decree on the quality and use of other organic fertilisers” (*Besluit Overige Organische Meststoffen* (BOOM), 20-11-1991). This former decree is nowadays part of the Fertiliser Decree (Ub). Some standards from BOOM have been adapted to the fertiliser use standards. The origin of these standards have been discussed in chapter 2.

Organic micro contaminants are regulated in organic fertilisers and fertilisers of which Ca, Mg, Na and/or S are beneficiary components but organic matter from plant or animal origins is also present. Organic micro contaminants are not regulated for strict inorganic fertilisers. At present, compost, sewage sludge and animal manure are exempted. The Netherlands decided against setting limits for organic contaminants in compost, as levels were considered too low to be of concern (TCB, 1995, 2004). The explanatory note of the Fertiliser Decree (2007) indicates an evaluation on the need of setting limits to organic micro contaminants for compost. However, this evaluation has not yet been carried out. Recently, the TCB (2012) also has given the advice to reconsider the decision on the regulation of organic micro contaminants in compost, and other fertilisers.

Use of waste as fertiliser

Waste can be used as fertiliser if it is included in Annex Aa of the Implementing Regulation (Ur). The minister decides if a waste can be used as fertiliser. The decision in based on a risk assessment according to a protocol. The risk assessment treats inorganic and organic contaminants (Van Dijk *et al,* 2009). Pathogens, plant propagules and other physical impurities however can be addressed if needed. The protocol is used to assess the quality of waste that is designated for use as fertiliser, of raw material (or secondary raw material) for the production of fertilisers or as substrate for biogas production resulting in a digestate that used as fertiliser. Part of this protocol still links fertiliser and soil quality regulations using concepts of soil protection from the earlier days of soil policies. In view of recent scientific insights in the relation between dose and effects, the risk evaluation scheme has recently been adapted for organic micro contaminants (Ehlert *et al.,* 2013).

The science-based and policy-adopted text of the innovated protocol-version of 2013 uses the contemporary insights of risk control and risk evaluation, as well current policy principles for soil protection. Aside from science and policy driven issues the context of the fertiliser dossier is changing. The current incentives to recycle waste ('circular economy'), and the modes of cascading waste (first re-use waste for its valuable components, then for energy and lastly for use of nutrients), leads and will stimulate the re-use of residues. Hence residues are often no longer considered as wastes, but valued by-products, again with profit aspects for agricultural use (fertiliser function) and other profits (circular economy, limiting resource depletion, green gas, et cetera) but also including a risk aspect (potential load of contaminants). This urges the need to clearly define and quantify benefits and (soil) threats of residues in order to set-up a balanced set of quality criteria.

4.5.2 Heavy metals in sewage sludge

Policies for heavy metals in Sewage Sludge

The legal basis for the application restrictions for sewage sludge on agricultural land are based on the Sewage Sludge Directive from 1986. The goal of the Directive 86/278/EEC on Sewage Sludge is to promote the correct use of sewage sludge on land and to ensure that humans, animals and the environment are full safeguarded against harmful effects.

In the Netherlands, from 1980, previous to the Sewage Sludge Directive, there was already a guideline from the Union of Waterboards (*Unie van Waterschappen*; UvW, 1980) to restrict the use of sewage sludge, and to set quality criteria for sewage sludge. Later, when planning the BOOM legislation for sewage sludge, compost and soil like material made from compost in 1989 the target was to reach an equilibrium between supply of heavy metals by sewage sludge and the removal by crops after 1995 (explanatory note of concept BOOM, TCB, 1991). Therefore only the limit values for the content of heavy metals, and application rate of sewage sludge as planned for the period after 1995, are thus relevant for the origin of the current limit values. The limit values for sewage sludge in the Netherlands are actually based on a compromise between two targets (Janssen *et al.,* 1999), similar to the European Directive:

1. A balance between the input by sewage sludge and the removal by arable crops, and:
2. Opportunity to use sewage sludge in agriculture.

When planning the limit values for the period after 1991 (in 1989) it was already clear that sewage sludge needed to be treated outside agriculture (concept BOOM in TCB, 1991). The gradual stricter standards made it possible for water boards to find enough capacity for treatment, mainly by incineration.

The limit values and the limit application rates have not been derived from assessment of ecotoxicological risks of soil pollution. This is because there is no relation between a flux, as are the current limits, and a state, as are the ecotoxicological risks (TCB, 1997). The policy to have an equilibrium between the supply of heavy metals by sewage sludge, and the removal by crops, results in no accumulation of heavy metals in soil. If a certain accumulation in the soil was allowed for, it might be evaluated on an ecotoxicological basis.

Quality standards for heavy metals in sludge

The quality standards for sewage sludge in the current Fertiliser Decree are identical to the standards in BOOM (1995). These standards were already planned in 1989 (concept BOOM in TCB, 1991). In the first phase, from 1987 until 1990, it was planned that the guideline from the UvW would not be adapted (UvW, 1980). In a second phase from 1990 until 1994 the standards were stricter, and in a third phase, after 1995, the standards would be even stricter (see Table 4.2 below). It was expected that the stricter standards would lead to a restricted use of municipal sewage sludge in agriculture (TCB, 1991) but would stimulate the use of relative clean sewage sludges from for instance food industry. It pointed out that in the period between 1990 and 2000 the heavy metal contents in sewage sludge showed a strong decrease (CBS, statline).

Table 4.2 Origin of quality standards for heavy metals in sewage sludge in Fertiliser Decree and Sewage Sludge Directive (standard and dosage). For comparison also the expected export by crop and the accepted accumulation according to the Building Materials Decree (Bouwstoffenbesluit, Bsb) are given.*

	Sewage sludge Directive 1986	**Richtlijn UvW 1980 (1984)**	**BOOM 1995 before 1995**	**BOOM 1995 after 1995**	**Ub 2007***	**Export by crop according to BOOM (1990)**	**Building decree Bsb**
mg kg dm^{-1}							
Cd	20 to 40	10 (5)	3.5	1.25	1.25		
Cr	-	500	350	75	75		
Cu	1000 to 1750	600	425	75	75		
Hg	1 to 1.5	10 (5)	3.5	0.75	0.75		
Ni	300 to 400	100	70	30	30		
Pb	750 to 1200	500	300	100	100		
Zn	2500 to 4000	2000	1400	300	300		
As	-	10	25	15**	15		
g ha^{-1} yr^{-1}							
Cd	150			2.5	2.5	1.4	1.2
Cr				150	150	2	150
Cu	12000			150	150	40	54
Hg	100			1.5	1.5	0.2	0.45
Ni	3000			60	60	2.3	52.5
Pb	15000			200	200	1.5	127.5
Zn	30000			600	600	250	210
As				30	30		43.5

* calculated on the basis of maximum dosage and limit values. ** increased after advice of TCB (1991)

The standards, and the dosage norms from the UvW (1980) originate from a proposal from a Scientific Committee working under the responsibility of the Commission of Experts of the (repealed) Fertiliser Act 1947. For lead, however, a stricter limit was used in 1980. This Committee stated that on vulnerable soils even after 80 or 100 years no problems would occur due to accumulation of heavy metals (UvW, 1980). The input of heavy metals from other sources was not taken into account in this argument. The dosage for arable land exceeds that for grassland because of the larger soil depth considered (UvW, 1980). The maximum standard for Cd and Hg have been lowered in 1984 (UvW, 1985) because of new scientific insight. The change in quality standards after 1995 is not well documented. In paragraph 2 of the explanatory note (concept BOOM 1990) it says for example that the standards after 1995 are based on 'the current knowledge' (that is 1990). The target after 2000 in BOOM was an equilibrium (balance) between crop offtake (i.e. export by agricultural products) and input by sewage sludge. Representative data for heavy metal uptake by crops at that time were taken from Breimer and Smilde (1986) and is quoted in the explanatory note of the concept BOOM (1990). The values used for crop export are listed in table 4.2. The low crop offtake (export) for metals like Cr and Pb relative to the maximum allowed input levels indicate that for these metals a certain degree of accumulation was unavoidable.

Although not stated in the explanatory memorandum of BOOM (1990) it is clear that the chosen limit values would result in accumulation of some contaminants in the soil, also after 1995. In the Building Materials Decree (Bsb) the policy was to accept 1% increase of the target values within a period of 100 years over a soil layer of 1m depth. This legislation was developed, in the same period as BOOM, to regulate the use of soil and mineral materials on soil.

Limit values for the dosage of sewage sludge

The current limit for the dosage of sewage sludge is given in the “Decree on the use of fertilisers” (Bgm). Previously the limit for the dosage of sewage sludge was defined by a guideline from the water boards (*Unie van Waterschappen*, 1980), in 1993 these limit values have been formalized to quality standards in legislation (Table 4.3). The BOOM legislation was published on 3 December 1991 and entered into force on 1 January 1993. The limit values have not changed since 1980 for arable land and grassland.

Table 4.3 Maximum annual dosage of sewage sludge (t dry matter ha^{-1} yr^{-1})*

	UvW1980	**BOOM, 1993**	**Bgm**
Arable land	2	2	2
Grassland	1	1	1
Other land		0	
Nature		0	
Nature, other land that is grassland		0	

*or twice the amount per 2 years.

Next to maximum annual dosage of sewage sludge, also the nitrogen and phosphate use standards apply. For sewage sludge in general the phosphorus content regulates its use. Regulation is set by the Fertiliser Decree (Ub). Phosphate use standards strive towards maintenance fertilisation i.e. export of phosphorus by crops is compensated by fertilisation. Phosphate use standards depend on the phosphate status of the soil. At a high status the phosphate use standard is lower than the export by the crop, at low phosphate soil status, the use standard is – slightly – higher (Table 4.4).

Table 4.4 Maximum dosage of phosphorus kg P_2O_5 (ha^{-1} yr^{-1}) and nitrogen including other fertilisers

Land use	**BOOM, 1993**		**Ub***
Arable land	125**		55-85
Grassland	175**		85-100
Other land			85
Nature			20
Nature, other land that is grassland			70**

*application standards in 2012, limit depends on the phosphorus availability of the soil.

** as planned for period after 1995

The Sewage Sludge Directive, and implemented in the Netherlands by the Decree on the use of fertilisers (Article 1c in Bgdm 1998) mandates that soils receiving Sewage Sludge should be analysed. Soils should comply with the limit values in Decree on the use of fertilisers (*Besluit gebruik meststoffen*, Bgm). The soil limit values are identical to the “target values” from the Streef- en Interventiewaarden in the Soil legislation. The legislation for protection of soil has changed, and in the current Soil Quality Decree (Besluit Bodemkwaliteit; Bb) “target values” are not used any more, and have been superseded by background values.

4.5.3 Heavy metals in compost

Policies for heavy metals in compost

The current standards and application restrictions for compost are given in the Fertiliser Decree and the Implementing Regulation (2007). Compost has been regulated since 1993. This coincides with the strong increase of the production of separately collected waste from vegetables, fruit and gardens by municipalities between 1990 and 1995 which to a large extent is utilised for compost (*GFT-compost*). In this relative short period the successive policies for developing standards for heavy metals in compost have been outlined in the explanatory notes of concept BOOM (TCB, 1991), BOOM (1991) (became into action 1993, 1995) and the combination of the Fertilisers Act 1947 and BOOM (2007) into the new Fertiliser Decree (Ub).

The policies have been commented by the Netherlands technical committee on soil protection (TCB) which has given advice on most adaptations of the legislation (TCB, 1989, 1991, 2003).

The starting point of the BOOM (TCB, 1991) legislation was to go, in phases, towards an equilibrium between the input of heavy metals by compost and the removal of heavy metals (mass balance approach), and secondly ensuring the use of compost in agriculture. This policy has received a numerical elaboration in the explanatory memorandum to a concept of BOOM (TCB, 1991) and has been reviewed by the TCB (1991). This derivation will be discussed in the next paragraph.

Standards for heavy metals in compost

The standards for heavy metals in compost in the current Fertiliser Decree (in: Annex II, table 3) are identical to the standards in the previous BOOM legislation (1995), except for copper and zinc (Table 4.5). The standards for copper (from 60 to 90 mg kg^{-1}) and zinc (from 200 to 290 mg kg^{-1} ds) were raised by a factor 1.43, which according to the explanatory note, are equal to the margin which is used when enforcing the law. This was described in "Control sampling and analysis other organic fertilisers (1998): a batch of compost is only rejected when it is a factor 1.43 above the standard. The TCB (TCB, 2004) advised not to use this factor as it is difficult to discriminate it from a structural increase of the standard for copper and zinc. Compared to the concept BOOM (1990) the BOOM (1993) increased the standard for nickel from 10 to 20 mg kg^{-1} ds on the basis of the advice from the TCB (1991).

Table 4.5 Origin of standards for heavy metals in compost in the Fertiliser Decree (Ub). For comparison the European standards for eco-label soil improvers are given (between brackets the standard in 1994).

	BOOM, 1990-1995			**Ub, 2007**		**Eco label 98/488/EC(94/923/EC)**
	'Clean compost'	'Very clean compost'		Compost		Soil Improvers
	mg/kg dm	mg/kg dm		mg/kg dm		mg/kg dm
Cd	1	0.7		1		1(1.5)
Cr	50	50		50		100 (140)
Cu	60	25		90*		100(75)
Hg	0.3	0.2		0.3		1
Ni	10 (20)	10		20**		50
Pb	100	65		100		100(140)
Zn	200	75		290*		300
As	5(15)	5		15**		

* Factor 1.43
** Enhancement, advice TCB (1991)

As previously mentioned, the standards for compost (concept BOOM, TCB, 1991) are roughly based on the mass balance approach (TCB, 1991) and the content of soil in the compost (*basisvracht*). In the explanatory notes in BOOM legislation the derivation of the chosen standards is given but not the exact numerical derivation. The numerical elaboration was difficult as the scientific knowledge about the removal of heavy metals by crops in arable agriculture (at that time from Breimer and Smilde, 1986) were scarce, or when available, highly variable (TCB, 1991). The TCB (1991) attempted to recalculate the chosen standards. Incorporated in the mass balance approach were two other concepts:

i. the assumption of a generic value of 70% of soil in compost (TCB, 1991), and
ii. the assumption that the green mass is decomposed to stable organic matter in compost with a ratio 7.21 to 1 (TCB, 1991).

The contribution of soil in compost was important for the derivation of the standards for compost on the basis soil target values. The standards for "very clean compost" were therefore based on the soil target values and the assumption of 70% of soil in compost, although, as the TCB (1991) concluded, the slightly higher values in the concept BOOM could not be recalculated (Annex 6). The difference between the standards for "clean compost" and "very clean compost" could be explained to a large extent by the contribution of crops grown on uncontaminated soils. The TCB (1991) analyses showed that the recalculation resulted in logical values without large differences for the "clean compost", except for Cu, Pb, and Hg, for which the recalculated values were lower. As mentioned in the Table above, the recalculation for As and Ni gave higher values. The suggested higher standard values of the TCB (1991) have been adopted in the BOOM legislation from 1993.

The current standard for heavy metals in compost in the Netherlands (Table 3.5) are lower or equal to the requirements for the European Community eco-label to growing media (1994 , 2007). These EU standards were set in 1994, and only changed slightly in 1998, and as such have been relevant for the derivation of quality standards in the United Kingdom. The precise relation between the development of the Netherlands standard and this EU standard remains unclear but the values they are rather similar for Cd, Cu, Pb and Zn.

Limit values for the dosage of compost

Currently the application use standards (*gebruiksnormen*) are used for the total amount of phosphorus and nitrogen used for all fertilisers including compost. A comparison with the old legislation, for which the standard values for heavy metals were derived, is possible when the dosage is recalculated. Assuming an average P content of 6 g P_2O_5 kg^{-1} dm, the application use standard for phosphorus (as phosphate) in 2013 range from 50 to 100 kg P_2O_5 (ha^{-1} yr^{-1}) depending on land use (arable land or grassland) and soil phosphorus status. On land used as nature 20 kg P_2O_5 ha^{-1} yr^{-1} is allowed. Application use standards are given by the Fertiliser Decree (Ub) (see tables below), result in a maximum dosage of 3to 17 t DM ha^{-1} yr^{-1} respectively. In the Table 4.6 these dosages are given between brackets.

There is only a small difference between the current and the old legislation for "very clean compost". However, there is a large change between the original concept BOOM (1990), the maximum amount of compost in BOOM (1995), and the current legislation, for "clean compost".

Table 4.6 Maximum dosage of compost (t DM ha^{-1} yr^{-1}) and between brackets the calculated maximum dosage on the basis of the application standards (app. st). for phosphate.

Land use	**Concept BOOM, 1990**			**BOOM, 1995**			**Bgm***
	Clean compost	Very clean compost		clean compost	very clean compost		compost
Arable land	3	appl. st.		6	(18) app. st.		(9-14) app. st.
Grassland	0	appl. st.		3	(25) app. st.		(14-17) app. st.
Other land	3	appl. st.		6	(12) app. st.		(3) app. st.
Nature	0	0		0	-		(3) app. st.
Nature, other land that is grassland				0	-		(12) app. st.

*a single application of compost of 200 t ha^{-1} yr^{-1} is possible.

Table 4.7 Maximum dosage of phosphorus kg P_2O_5 (ha^{-1} yr^{-1}) including other fertilisers.*

Land use	Concept BOOM, 1990		BOOM, 1995		Ub
Arable land	125 (250 maize)		110		55-85
Grassland	0		150		85-100
Other land	70		70		20
Nature	0		-		20
Nature, other land that is grassland	-		-		70

*The application use standard for nitrogen is not included in this table because in practice the phosphorus content in compost will determine the maximum dosage.

** The application use standard for N and P have been decreased in the years between 2007 to 2013, and they depend on soil type and land use. Application standard for N depends also on fertiliser type, application use standard depends on soil P status.

As mentioned previously, in the mass balance approach two other concepts were incorporated: the assumption of a generic value of 70% of soil in compost (TCB, 1991; Ehlert *et al.,* 2005), and the assumption that the green mass is decomposed to stable organic matter in compost with a ratio 7.21 to 1 (TCB, 1991). Such a mass balance approach results in a simple calculation, if removal by crop is on average 6.5 t ha^{-1} yr^{-1} dm, then the input by a similar amount of conservative elements by compost (only organic mass) is reached using 0.9 t ha^{-1} yr^{-1} dm. Assuming that compost consists of 30% organic mass and 70% of soil (caused by contribution of soil from gardens in waste) the mass balance approach results in 0.9 + 2.1 = 3 t ha^{-1} yr^{-1} dm compost. If the crop removal is higher, for example 13 t ha^{-1} yr^{-1} dm, this mass balance approach results in 6 t ha^{-1} yr^{-1}. These dosages are the same range as in past BOOM (1995) legislation for "clean compost".

As can be seen in table 4.7, based upon the current application use standard the Fertilser Decree permits a higher dosage of compost than previously was permitted in the BOOM legislation for "clean compost", and therefore results in a much higher input of heavy metals. An annual application of compost as large as regulated by the application use standard is only expected locally (page 49, 2007) and is not expected to be negative (page 5 of TCB, 2006) also because the most used alternative fertiliser, animal manure, also contains a relatively high amount of Cu and Zn.

It should also be noted that the current "target values" for a good soil quality (Bb, 2008) are slightly lower than the "target values" (TCB, 1991) which were used to explain the heavy metals contents in "very clean compost" on the basis of 70% clean soil in compost (*basisvracht*) for Cd, Cr, Hg, Pb and As.

4.5.4 Heavy metals in Other organic fertilisers, Other inorganic fertilisers, and liming materials

Policies for heavy metals Other organic fertilisers, Other inorganic fertilisers, and liming materials

The limit values are not given on the basis of the total mass of the fertiliser but on the basis of the mass of the beneficial components. Beneficial components are nutrients (nitrogen, phosphate, neutralizing value, organic matter, according to the Fertiliser Decree (Ub) and other components (magnesium, sulphur, sodium or calcium in gypsum, according to the Implementing Regulation (Ur). The rationale for choosing limit values on the basis of content per beneficial component is:

1. It is not necessary to have separate maximum application rates for these fertilisers as this category of fertilisers contains a large number of very different materials, often waste materials or residues. It was also assumed that control on the basis of dosages in the field is not possible, because these can only be checked by personal control at the site. Control is therefore necessary at an early stage, at the stage of trade or transport, by limiting the amount of contaminants in the fertilisers (§3.3 of the explanatory note of the Decree of 2007, Staatsblad 251, 2007).

2. Limit values on the basis of content per mass of beneficial component reward the use of fertilisers with higher amounts of beneficial component, while limit values on the basis of mass of fertiliser do not make this discrimination (Janssen *et al.,* 1999). The amount of beneficial component in this class of fertilisers is important because it often concerns waste materials for which the use as a fertiliser in agriculture is preferred as it is the cheapest route.

In practice almost all the Other organic fertilisers are wastes or residues with an exempt by the minister according to article 5 of the Fertiliser decree. Currently the exempt is given when a type of material has been judged by the minister as an effective fertiliser, and complies with the environmental standards. This type of material is then listed in the Implementing Regulation (Ur, Annex Aa). Previous to the Fertiliser Decree and Implementing Regulation these materials were individually regulated (§3 and §6.2 explanatory note, of the Decree of 2007, Staatsblad 251, 2007). Individual fertilisers were evaluated on the basis of the positive effects as a fertiliser and their environmental impacts (*milieutoets*). This environmental screening test has been in practice since the BOOM legislation in 1993 and was formalized later (§6.1 explanatory note of the Decree in 2007, Janssen *et al,* 1999), and has become a part of the current legislation (Ub, Ur).

Standards for heavy metals in Other organic fertilisers, Other inorganic fertilisers and liming materials.

The limit values for heavy metals are given on the basis of the mass of the beneficial components. The limit values for the amount of heavy metals per unit of area and unit of time are based on the maximum acceptable soil pollution as is accepted for sewage sludge. This is also explained in paragraph 3.3 of the explanatory note of the Decree of 2007 (Staatsblad 251, 2007) where the Fertiliser Act 1947 and BOOM have been integrated in the current Fertiliser Act.

The quality standards for heavy metals for the “Other organic fertilisers”, “Other inorganic fertilisers” and liming materials are given in Table 1 of Annex II of the Fertiliser Decree. The standards have been derived from the standards for sewage sludge, times the maximum dosage of sewage sludge on arable land (BOOM, 1995), as given below.

At the maximum dosage of beneficial components this results in a maximum dosage of heavy metals as given in the table 4.8 which is identical to the maximum dosage of heavy metals by sewage sludge.

Table 4.8 Calculated maximum dosage of heavy metals resulting from quality standards for fertilisers and for sewage sludge.

	Calculated dosage using: -Fertiliser Decree,Table 1 from Annex II or Annex	**Calculated dosage using: - Fertiliser Decree, Annex II table 2**	**Fertiliser Decree, Annex II table 2**
	-At a maximal dosage of one beneficial component*	At maximal dosage of sewage sludge on arable land: 2 t ha^{-1} yr^{-1}	Standards for sewage sludge
	g ha^{-1} yr^{-1}	g ha^{-1} yr^{-1}	mg kg^{-1}
Cd	2.5	2.5	1.25
Cr	150	150	75
Cu	150	150	75
Hg	1.5	1.5	0.75
Ni	60	60	30
Pb	200	200	100
Zn	600	600	300
As	30	30	15

* Per ha, this is 80 kg P_2O_5, 100 kg N, 150 kg K_2O, 400 kg neutralising value, 3000 kg organic material, 75 kg MgO, 75 kg SO_3 of 60 kg Na_2O.

Three policy levels to choose these limit values were evaluated when developing the environmental screening test (Janssen *et al.,* 1999):

1. High ambition: Ideally the input of contaminants is smaller or in balance with the removal by crops. For this arable crops are chosen because here these fertilisers are used, while on grassland animal manure is mostly used in the Netherlands. As heavy metal contents in crops, and leaching from soil, both vary strongly this ambition necessitates limit values that at least depend on land use.
2. Medium ambition: The same input as for other regulated fertilisers such as sewage sludge
3. Low ambition: the target values for good soil quality are never exceeded.

The current legislation chose a medium ambition. At this ambition some fertilisers might increase the heavy metals content in soil. However, Janssen *et al* (1999) assumed that the fertilisers only have one or two components with a relatively high content of heavy metals. Using a combination of fertilisers in practice will probably result in a dosage of heavy metals that is lower than the maximum calculated dosage on the basis of the standard and the user norm. Choosing a higher ambition would probably lead to problems with current waste and other residues that are used as fertiliser in agriculture. The current legislation however allows the use of various fertilisers, for example a fertiliser for P, a fertiliser for Mg, a fertiliser for N, a fertiliser for organic matter, and a lime which all can have a maximum content of for example Cd. In that case the dosage is five times the calculated dose in the table above. Janssen *et al* (1999) (§3.4 therein) however judged that it is very unlikely that so many different fertilisers are used and that all these would have high contents in one heavy metals, in this example Cd.

4.5.5 Organic micro contaminants in Other organic fertilisers

Policies for organic micro contaminants

Similar to the heavy metals in “Other organic fertilisers” (chapter 4.1.3) the organic micro contaminants are given on the basis of the mass of the beneficial components, and not on the basis of the total mass of the fertiliser (Ub , Annex II, table 4). This is for the same reasons as outlined in the previous chapter, firstly, it enables control which is otherwise not possible, and secondly, it promotes fertilisers with relatively high contents of beneficial components. The micro contaminants were selected (RIVM-selectie, without explanation) because of their persistent character in soil (Olde Venterink and Linders (1994): dioxin, PAH, PCB and some persistent pesticides for which the application has been forbidden in agriculture.

The methodology to establish standards for organic contaminants is based on the assumption that the long-term accumulation in soil may pose no risk for the terrestrial ecosystem (TCB, 1995). The values are based on calculations in Olde Venterink and Linders (1994). The principle used to derive the standards was that the accumulation level of contaminants in the soil in the long term may not exceed the negligible risk. The accumulation was calculated on the basis of an annual dosage and the decay of compounds in the soil. The TCB (1995) states that the approach of Olde Venterink and Linders (1994) ignores the mass-balance approach or “stand-still” principal. It was necessary to assume a certain accumulation of organic micro contaminants. This means that the standards are a compromise between soil protection and the disposal of organic residues in agriculture. For policy reasons the calculated maximum values for organic contaminants were increased by a factor of 4. Janssen *et al* (1999) addressed this as a “low ambition” policy.

Recently (2012) the TCB gave the advice to maintain the standards for organic micro contaminants in “Other organic fertilisers”.

Standards for Organic micro contaminants

The standards have been derived by Olde Venterink and Linders (1994) by numerical procedure using (1) half-life values (values between 125 and 5100 days from literature), (2) the target value, and (3) accumulation till the target value in a soil layer of 20 cm depth and a soil density of 1.4 kg L^{-1}. If the target values were not available (PCDD/Fs) a negligible risk concentration was calculated from the maximum permissible concentration divided by 100. It should be noted that the target values used by Olde Venterink and Linders (1994) have been replaced in the Soil Quality Regulation by background values, and the negligible risk values (VR) have been updated. The background values for persistent organic micro contaminants are higher than the target values used by Olde Venterink and Linders (1994), which were based on an ecotoxicological approach. For a range of persistent organic micro contaminants, the current soil background values in the Netherlands exceed the old target values (Lame *et al.,* 2004). This explains why materials that contain soil, such as compost, also contain this range of persistent organic micro contaminants.

4.6 Belgium Flanders

- Standards for heavy metals and organic contaminants are based on limited accumulation in soil within 100 years.

In Belgium the Royal Decree of October 1977 on the use of fertilisers and soil improvers already stated that they had to be free of any harmful or toxic substances etc. which are likely to harm flora and human and animal health. At the implementation of the European Sewage Sludge Directive of 1986, Flanders, Brussels and Wallonia did choose different limit values for sludge.

The limit values in Vlarema 2012 have been taken from Vlarea 1997. The limit values for heavy metals in Vlarea were based on a decree for sewage sludge which was introduced in 1992 to comply with the European sewage sludge directive from 1986 ("7 januari 1992. - Besluit van de Vlaamse Executieve houdende vaststelling van het Vlaams reglement inzake milieuvoorwaarden voor hinderlijke inrichtingen"). Most standards in Vlarea are a factor 2 lower (Cd, Cr, Cu, Hg, Ni, Pb) except for As, and Zn (Table 4.9). The permitted dosage however in Vlarea is identical to the decree from 1992, except for Zn for which a lower value was chosen. It is not clear how the limit values in the Decree of 1992 were derived. Some values, the limit values for Hg and Zn in soil were not in accordance, with the EU Sewage Sludge Directive (to high). This is relevant for the standards for sewage sludge because these have probably been based on soil standards.

A comparison of the limit values with sewage sludge analyses according to Huybrechts and Dijkmans (2001) showed that in 1998-1999 only 5% of the sewage sludge complies with the Vlarea (1997) standards. Therefore the Mira-Council (2003) advised to change Vlarea to have a standard of 400 mg kg^{-1} for Cu and 1400 mg kg^{-1} for zinc because this would make 75% of the sewage sludge comply with Vlarea.

According to Broos and Quaghebeur (2011) the basis for the current limit values in Vlarema is the principle of "marginal soil loads". A marginal soil load was defined as the enrichment of the average soil metal concentration (50-percentile) to the target soil quality (90-percentile) for an annual dose of 2 tonnes dry matter of soil conditioner during a period of 100 years. For some heavy metals, the maximum allowable dose was even limited further to only an annual dose, calculated on 1% of the average value of the soil concentrations. However, on the basis of the soil target values this derivation of the actual limit values does not seem so simple and therefore OVAM (Luc Debhaene) was asked for information. This could not be given on short notice.

Table 4.9 Origin of limit values for heavy metals in sludge. (Com (1997) 23 final).

	Decree of 1992	**Vlarea 1997**	**Vlarema 2012**		**86/278/EC**
mg kg^{-1} dm					
Cd	12	6	6		20-40
Cr	500	250	250		
Cu	750*	125 (375**)	375		1000-1750
Hg	10	5	5		16 -25
Ni	100*	50	50		300 - 400
Pb	600	300	300		750 - 1200
Zn	2500*	300 (900**)	900		2500 - 4000
As		150	150		
	g ha^{-1} yr^{-1}				
Cd	12	12	12		150
Cr	500	500 (2500)	500		
Cu	750	250 (750)	750		12000
Hg	10	10	10		100
Ni	100	100	100		3000
Pb	600	600	600		15000
Zn	2500	600 (1800)	1800		30000
As	300	300	300		
	tonnes ha^{-1} yr^{-1}				
dosage	2/3arable 1/3 grass	4 /2 arable 2/2 grass			

* higher standards for Cu 750, Ni 100 and Zn 2500 until 1999. In period 1991-1994 it is reported that Flanders allowed twice as high dosages (in g ha^{-1} yr^{-1}) on arable crops. ** until 1997 higher levels of Cu and Zn are permitted.

A proposal has been written to (Broos and Quaghebeur, 2011) to adept the contaminant list in Vlarema (18 parameters less), and to adjust the values, on the basis of a risk assessment, to protect soil and water. The report contains much information on the actual contaminant concentration of wastes used as fertilisers and soil improvers.

4.7 Denmark

- Standards for heavy metals and organic contaminants are based on a risk assessment. End-points of the risk-assessment are human, soil biological health, animal health and crop quality.

The Danish standards are partly based on studies with a risk based approach and to some extend they are policy based (Pers. comm. John Jensen, Aarhus University; Tørsløv *et al.,* 1997). Plant uptake rate and leaching to groundwater are both taken into account. Danish standards are mainly based on No Observed Effect Concentrations (NOEC). In the current legislative/regulatory framework, the use of fertilisers in Danish agricultural production is administered by the by the Danish AgriFish Agency. The legislative principles are described in the Law on Fertilisers (*Consolidation act no.415 at 3 May 2011*). The law gives information on the requirements for registration of primary producers (farms) and the use of fertilisers. Depending on the crop types produced, each farm has a maximum of Nitrogen they can use on the fields. If they have more livestock than their fields can carry, they have to make agreements with other farms to receive the surplus fertilisers. In organic farming, the rules mentioned above are the same, and there are additional rules for organic farming.

Mineral fertiliser

The limit value for the Cadmium content in mineral fertiliser has been reduced twice since 1990 (BEK 223/1989). It started with a maximum of 200 mg Cd / kg P. In 1995 it was reduced to 150 mg Cd / kg P, and in 1998 it became 110 mg Cd / kg P, what it is today.

After 1 July 1990: 200 mg Cd / Kg P
After 1 July 1995: 150 mg Cd / Kg P
After 1 July 1998: 110 mg Cd / Kg P

On farms with pigs, the maximum amount of manure applied to soil is 140 kg N/ha, whereas on farms with cattle, sheep and goats the maximum is 170 kg N/ha. The Danish derogation from the Nitrates Directive makes it possible to apply up to 230 kg N/ha on farms with at least 2/3 cattle when certain conditions are met (order no. 764/2012). The amount of fertiliser allowed, manure and mineral, depends on the type of crop and soil (consolidation act no. 415/2011).

Waste materials (Sewage sludge, compost, digestate)

The limit values for material to be distributed in agriculture and forestry were reduced in 1995, 1997 and in 2000 (Table 4.10).

Table 4.10 Limit values for cadmium in sludge applied to soil.

Date	mg Cd/kg dm	mg Cd/kg total P	Reference
After 01.07.1995	1.2	320	BEK 823/1996
After 01.07.1997	0.8	200	BEK 823/1996
After 01.07.2000	0.8	100	BEK 49/2000
After 13.12.2006	0.8	100	BEK 1650/2006

The total application of nutrition in the form of phosphorous from waste materials must not be more than 30 kg total P/ha/year, averaged over 3 years, i.e. a maximum of 90 kg P/ha every third year. Also, the total amount of waste products applied to the soil must not exceed 7 tonnes dm/ha/year, averaged over 10 years (BEK 1650/2006).

Waste products containing more than 75% manure calculated as dry matter are treated as manure and are recalculated to animal units, i.e. one animal unit equals a maximum of 100 kg total N.

Biomass ash

Application of ashes from incineration of straw and wood, bark, and shredded wood on agricultural soil is regulated by Statutory Order no. 818/2008. The maximum application rate is calculated as average over 5 years (Table 4.11). For ashes from straw and mixed straw/wood the maximum applied amount to agricultural soil is 5 ton dm/ha/5 years. The total amount of phosphorous must be 90 kg P/ha/3 years at maximum. For wood ashes the maximum applied amount to forest soil is 1-3 ton dm/ha/10 years.

Table 4.11 Maximum amount of cadmium reaching agricultural soil from Biomass ash based on the Danish regulation.

Source	Max Cd content	Max application rate	Max amount Cd
Straw ash	5 mg/Kg dm	5 ton dm/ha/5 yr	0.8 g/ha/yr
Wood ash	20 mg/Kg dm	1-3 ton dm/ha/10 yr	60 g/ha/75 yr
Mixture straw/wood	5 mg/Kg dm	5 ton dm/ha/5 yr	0.8 g/ha/yr

In Summary

For Cadmium, the maximum dosage has been calculated for several types of fertiliser, used in Denmark (Table 4.12). It shows that the maximum dosage varies between 0.8 and 5.6 g/ha/yr.

Table 4.12 Calculated maximum dosage of Cadmium resulting from standards for fertilisers.

Source	**Max concentration**	**Max appl. Rate**	**Max amount Cd g/ha/year**
Mineral P-fertiliser	110 mg Cd/kg P	-	-
Waste materials	0.8 mg Cd/kg dm or 100 mg Cd/kg P	30 kg/ha/year	3
Manure	-	1,7 animal units/ha	-
Straw ashes (farmland)	5 mg Cd/dm	1000 kg dm/ha/yr	0.8
Wood ashes (forestry)	20 mg Cd/kg dm	100-3000 kg dm/ha/yr	60 g/ha/75 years

The Green growth agreement in Denmark (2009-2015) is constructed to modernise the Danish agriculture industry and to strengthen the industry as a supplier of green energy. The goal is that up to 50% of livestock manure in Denmark can be used for green energy in 2020. Also, the intention is to abolish the obligation for the maximum number of livestock units per hectare a farmer may have and to abolish the limit for the number of hectares a farmer may own.

4.8 Germany

- Standards for heavy metals are based on a limited accumulation in soil, and are based upon an EU proposal from 2000 and current concentrations.
- Standards for organic contaminants are based on risk, or on the basis of as low reasonably possible.

Origin of standards in the Germany

The sewage sludge ordinance (AbfKlärV), originally from 1982, has been adapted in 1992 (BMU, 1992). Concepts for a new sewage sludge ordinance have been discussed in the last 10 years. The latest concept, dated in 2010 (BMU, 2010) stems from proposal in 2007 (“arbeitsentwurf”). A new concept is expected in the end of 2012 (website BMU) according to the state secretary of the Ministry BMU.

The Ordinance on Biowaste (BioAbf) originally from 1998 has been strongly adapted on 23 April 2012 (BMU, 2012) although standards for contaminants remained the same; various controls have been added to prevent the use of contaminated biowaste on agricultural land. The fertiliser legislation (DüMV), originally from 1962, has been recently adapted in November 2012 (DüMV, 2012). The proposed standards in the concept sewage sludge ordinance (AbfKlärV) were harmonised with the fertiliser ordinance (DüMV, 2012), of which the current DüMV is the most actual. The origin of all the concept-standards in the concept-AbfKlärV2010 is briefly discussed in the explanatory note of the amendment, and also the origin of the new standards in the fertiliser ordinance (DüMV, 2012) are briefly eluded in the regulation. This discussions and the derivations will be given below per category of substances.

Other relevant developments are End-of-Waste policy (BMU, 2012) which has been implemented in the Kreislaufwirtschaftsgesetz (KrWG, 2012). A target in development is to use the phosphate from the sewage sludge (UBA, 2012).

Similar to other countries the sewage sludge quality in Germany has greatly improved between 1990 and 2000 (UBA, 2012). In line with this the standards the German government has adapted the standards for sewage sludge (see table 4.13). The first legislation in 1982 permitted much higher heavy metal contents in sludge than the current amended sewage sludge ordinance (AbfKlärV, 2012). Sewage sludges used in fertilisers should comply with the DüMV2012.

Table 4.13 Origin of standards for contaminants (mg kg^{-1} dm) for sewage sludge (AbfKlärV, 1992, concept 2010).

	from 1982 until 1992	From 1992	Concept 2010**	DüMV2012	Explanation in text
Cd	20	10 (5)*	2.5(3)	1.5 (2.5&)	(2)
Cr	1200	900	100(120)	2 (=CrVI)	(2)
Cu	1200	800	700(850)	900	(2)
Hg	25	8	1.6(2)	1	(2)
Ni	200	200	80(100)	80	(2)
Pb	1200	900	120(150)	150	(2)
Zn	3000	2500(2000*)	1500(1800)	5000	(2)
As				40	X
Tl				1	x
PCB		0.2	0.1		(1)
PCDD/F		100 **	30#	30##	(1)
B(a)P			1		(2)
AOX			400		(xx)
PFT			0.1		(2)
dosage	5 t ha per 3 years				

*sensitive soils
** between brackets the standards for sludges with more than 5% P2O5
#in ng TCDD-toxicity equivalents ## in I-TE dioxine and dioxin-like PCBs
& for tree-bark, and fertilisers on non-food crops

Policy per group of contaminants

Category 1. Persistent Organic Pollutants (POP) with decreasing contents in sewage sludge (dioxin/furanes and PCBs).

-dioxin. In DuMV (2012, page 89 explanatory note to table 1.4) the origin of the limit of dioxin is explained. The limit of dioxin in green fodder (0.75 ng I-TE dioxins kg^{-1} dm), as regulated by “futtermittel” animal feed stuff legislation limit is sometimes exceeded (guideline 2006/13/EC). Therefore a stricter standard for dioxin on grassland is used. As the background value in grassland is 0.2 ng I-TE dioxins kg^{-1} dm, and at 10% soil contamination of the forage with soil and fertiliser results for Fertilisers a maximum concentration value of: 10 x 0.55 ng I-TE dioxins kg^{-1} = 5.5 ng I-TE dioxins kg^{-1} dm.

Category 2. Persistent Organic Pollutants (POP) and heavy metals with currently relatively high contents in sewage sludge.

-B(a)P: a new limit for benzo(a) pyrene as an indicator of PAH. This limit is based on an advice from 2000, and is identical to the trigger value for B(a)P in agricultural soil in the Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV).

-PFT: a new limit of sum of PFOS and PFOA, perfluoroctanesulfate and perfluoroctaneacid. Different from other organic contaminants these substances can be translocated from the soil into in plants. The limit value for the sum of PFOS+PFOA is based on the detection limit for these substances in most laboratories. A preliminary value of 0.1 mg kg^{-1} has been used since 2006 in some states, after an incident with a soil conditioner in Germany, which showed that when a pollution event occurs, the population is exposed to higher environmental concentrations leading to elevated PFC levels found in blood samples (Hölzer *et al.*, 2008).

-the limits for heavy metals in the concept AbfKlärV have been based on the concept EU Sewage Sludge directive (EC, 2000) in 2000 with target values for 2025 (see Annex 7 of this report), and by taking the improved quality of sewage sludge into account. In the concept of the sewage sludge ordinance (AbfKlärV2010) the heavy metals limits have been differentiated on the basis of the phosphate content to improve the recycling of phosphate. It is however unclear on which the EU draft proposals (EC, 2000) were based. As a gradual decrease of contaminants in sewage sludge was planned by reducing the amount of materials that end up in sewage sludge. It is therefore based on the principle that the concentrations of contaminants should be as low as achievable.

Category 3. Persistent Organic Pollutants (POP) which decreasing contents in sewage sludge due to various policies. These are organotin compounds, phthalates and musk compounds.

By having an agreement with the organisations for voluntary Quality Assurance to check on these substances, and with the current decreases in sewage sludge, standards for these substances are not necessary.

Category 4. Compounds for which no standards or monitoring is necessary.

These are, linear alkylbenzene sulfonate (LAS), nonylphenol (NP), and nonylphenolethoxylates (NPe), and nanoparticles, which are less relevant due to fast decay or low toxicological relevance (UBA, 2012).

The current standards for heavy metals and organic contaminants in sewage sludge are decreased to protect the soil and taking into account already improved quality of sewage sludge.

The permitted heavy metal load by the sewage sludge ordinance (1992) and the EU sewage sludge directive have been judged not protective enough by the BMU. These standards have been discussed intensively during the last 10 years (Bannick *et al.*, 2002; BMU, 2007). Various concepts to obtain threshold values for fertiliser, sewage sludge, compost and other (organic) fertilisers in Germany have been discussed (Amlinger *et al.* 2004). These have resulted in the new amended and harmonised concept of the sewage sludge ordinance (AbfKlärV, 2010).

Compost and other biowaste are regulated by the “Bioabfallverordnung” from 1998 as amended in 2012. The standards for contaminants, only heavy metals, have not changed. The current standards of the sewage sludge ordinance (1992) are slightly higher than those (a factor 1 to 2), permitted by the current biowaste ordinance (BioAbf).

Table 4.14 Calculated permitted dosages according to the sewage sludge ordinance (AbfKlärV, 1992) and biowaste ordinance of 1998 (BMU, 2012).

	BioAbf Class 1 g ha^{-1} yr^{-1}	**BioAbf Class 2 g ha^{-1} yr^{-1}**	**AbfKlärV All soils g ha^{-1} yr^{-1}**	**Concept EU Sewage Sludge Directive**
Cd	10	10	16.7 (8.3)**	15 (6)
Cr	667	700	1500	2400 (1800)
Cu	667	700	1330	2400 (1800)
Hg	6.7	7	13.3	15 (6)
Ni	333	350	333	600 (300)
Pb	1000	1000	1500	1500 (600)
Zn	2670	3000	4170 (3330)**	6000 (4500)
PCB			0.3	
PCDD/F			167	
AOX			833	

* concept for limit in 2015 (limit in 2025 between brackets)

** Sandy soil or pH<6

4.9 United Kingdom

- The policy for proposing standards is based on extended risk assessments. The end-points to be protected are human and animal health, product quality, and soil biological health.
- Only sewage sludge is regulated. There are voluntary standards for compost and digested materials based on Good-Agricultural-Practice. These standards are based upon proposals made in the EU in 2000, which are based on limited accumulation of contaminants in soil.
- There is concern that the soil quality standards for Cd and Pb are not protective enough for food quality, and in case of Zn for soil health.

The UK Government and the Environment Agency believe that the recycling of sewage sludge on land is the Best Practicable Environmental Option in most circumstances (Defra, 2007). The permissible heavy metals rates in the UK when using sewage sludge in agriculture (1989) are identical to the EC sewage sludge directive, except that the limit value for Cu and Zn are a factor 2 lower. The policy is directed at preventing to high levels of contaminants in soils. Soil analysis are needed according the EC sewage sludge directive.

Relatively high heavy metal contents are allowed in soil with a high pH because the uptake of some heavy metals by crops depends on soil pH. It shows that the policy of the United Kingdom is on minimizing the negative effects on crops and soil organism, and not, for example, on a balance between input and output of heavy metals.

The Environmental Agency states that soil analysis for heavy metals should also be carried out before the first application of compost and again when any predicted soil heavy metal concentration becomes equal to or greater than 75 percent of its corresponding limit value set out in the Sludge Code (Environmental Agency, 2012).

Although amendments have been discussed often (Defra, 2006), the standards for sewage sludge have remained unchanged. However, because it's widespread use in the UK, there has been much research on the effects of sewage sludge (Defra, 2006; Defra, 2007). Problems with the current permissible standards have been identified. The limit for Cd of 3 mg kg^{-1} in soil is not protective (Chaudri *et al*, 2007) enough to prevent exceeding the maximum permissible Cd content in grains according to the (EC, 2001). There is also the risk of exceeding the Cd and Pb permissible contents in meat products (kidney of sheep) due high heavy metal contents of soil after sewage sludge amendments (Hillman *et al.*, 2003). Also, repeated applications of sludge to pasture land can result in the accumulation of organic contaminants which are of potential concern in the long term. Effects on microbial communities and clover rhizobia have recently been assessed on long term experiments with sewage sludge (Defra, 2007). According to Defra (e-mail Dr Hart 15 nov 2012) a revision of the UK regulations has been stopped and efforts are now put in the new EC Regulation.

Compost and digestate
The standard for compost have been developed in 1999 by The Composting Association (Hogg *et al*, 2002): except that the proposal was: Cu 100, Pb 150. According to Hogg *et al.* (2002) the standards were proposed when the 90th percentile of compost was more or less in line with the German RAL standards (RAL, 2007) and similar EU eco-label criteria for soil improvers and growing media (2007/64/EC) which were already developed in 1994 (94/923/EC, 1994). These limits were much lower than those set in earlier OWCA proposals (Organic Waste Composting Association OWCA, the predecessor of the Compost Association, currently: Association for Organics Recycling AfOR). Note that for Cd, Cr, Hg, Ni and Zn the British standards are identical to the EoW criteria developed by JRC IPTS (2012).

4.10 General observations

The limits for the contaminants in fertilisers and the permitted dosages differ strongly between countries. This suggests that the loading of soils can be very different. However, in the case of sewage sludge the limit values for soil are very similar between countries and are mainly determined by the upper range in the background contents in soil. The permitted dosages by bio waste (compost, digestate) still differ very much between countries.

The standards for various fertilisers in the Netherlands and surrounding countries have historically been developed from those for sewage sludge. These standards, as can be seen in the figure above, have been used in various ways in the countries.

The principles to derive limit values are common between the countries.
1. Limit values derived from ‘Practice’
   In the case of sewage sludge the limit values have been adapted between 1980 and 1990 and are largely related to commonly observed levels of contaminant concentrations in sludge. For compost various limit values have been influenced strongly by the ALARA principle. In Germany and the Netherlands two different standards have been used for some time (clean and very clean), with different application rates, to stimulate the production of very clean compost.
2. Limit values based on Soil protection guidelines
   The Netherlands, Flanders and Germany have used concepts from soil protection (precaution, background values) in the limit values for compost, bio waste and sewage sludge. The basic concept was to avoid accumulation or allow an ‘acceptable’ amount of accumulation.
3. Limit values based on risks for specified receptors
   Denmark has used a risk approach for cadmium, and organic contaminants in fertilisers. Germany has followed a risk approach for some organic contaminants (dioxin, PFC).

5 Appraising fertiliser quality: risk assessment

- Close study of the existing regulations for fertilisers and soil protection suggests the presence of a limited set of fundamental principles for managing the risks (risk reduction strategies)
- Regarding the potential risk of contaminants, the four principles are: (1) best practices, often based on experience, potential product quality or processing, (2) acceptance of a specific degree of (acceptable) accumulation, (3) Stand Still, i.e. no net accumulation, and (4) receptor-specific (crop, health, et cetera) risk-based evaluations
- Different fertilisers classes have been addressed differently, partly related to differences in the product life cycle, from its origin to its use; practicable management and appraisal approaches have been fitted to these life cycles

5.1 General introduction: background of current limits

In this chapter we compare the concepts of the regulations for fertilisers which are used in various countries, specifically the underlying principles to come to a certain standard or regulation. The regulation of fertilisers and soil amendments –ideally- should be aimed at achieving a balance between merits related to the beneficial use i.e. (i) inputs of nutrients and organic matter to soils and (ii) recycling of (organic) waste materials on one hand and the limitation of potentially unwanted effects on the other. Potentially unwanted effects include for example levels in food crops in excess of food quality standards or impact on the soil ecosystem. This will be elaborated upon later on. Here we distinguish four basic principles underlying the regulation of fertilisers/soil amendments to limit the inputs of contaminants in soils (see Figure 5.1):

1. (Best) practice i.e. reasonable lowest achievable levels depending on the quality of raw materials (e.g. compost) and processing.
2. No net accumulation of contaminants in soil or "stand still" of present levels: inputs of contaminants are balanced by outputs (plant uptake, leaching and erosion).
3. Acceptable accumulation of contaminants in soil (not risk based) e.g. in terms of percentage of present contaminant levels in soil.
4. Risk based regulations aiming at the protection of one or more specified receptors or protection targets: human health, ecosystem, agricultural production (including the quality of agricultural products in view of human- and animal health) and ground- and surface water.

The principles listed above can be ordered with respect to their ambition level going from high to low. Both stand still and the risk based principles represent a high ambition level. The stand still principle is the most stringent aiming to safeguard soils against future impacts and preserving the possibility of different uses of soils. Risk based concepts allow some possible accumulation of contaminants, but below risk levels. Best practice can be classified as a medium ambition level whereas the non-risk based acceptable accumulation represents the lowest ambition level. From these basic concepts several options, including hybrid systems have been elaborated (Amlinger et. al, 2004) which will be discussed in the forthcoming sections. Aside from these measures to minimize environmental impacts many other practical considerations and goals (e.g. sustainability and the wish to recycle materials) influence the regulation of fertilisers and soil amendments. Furthermore juridical aspects such as the principle of equality of status may apply. Within a certain concept several options may be available to achieve the objective. For example when using the stand still principle or risk based approaches the inputs of contaminants are to be regulated. This implies the definition of a maximum load which is the result from the concentration of the contaminant in the product and the dosage of that product. Concentrations may be defined as concentrations per mass of the product or by a concentration of the beneficial component (e.g. phosphorus or organic matter) Here we discuss first the variations of the basic concepts and thereafter the options for their practical implementation.

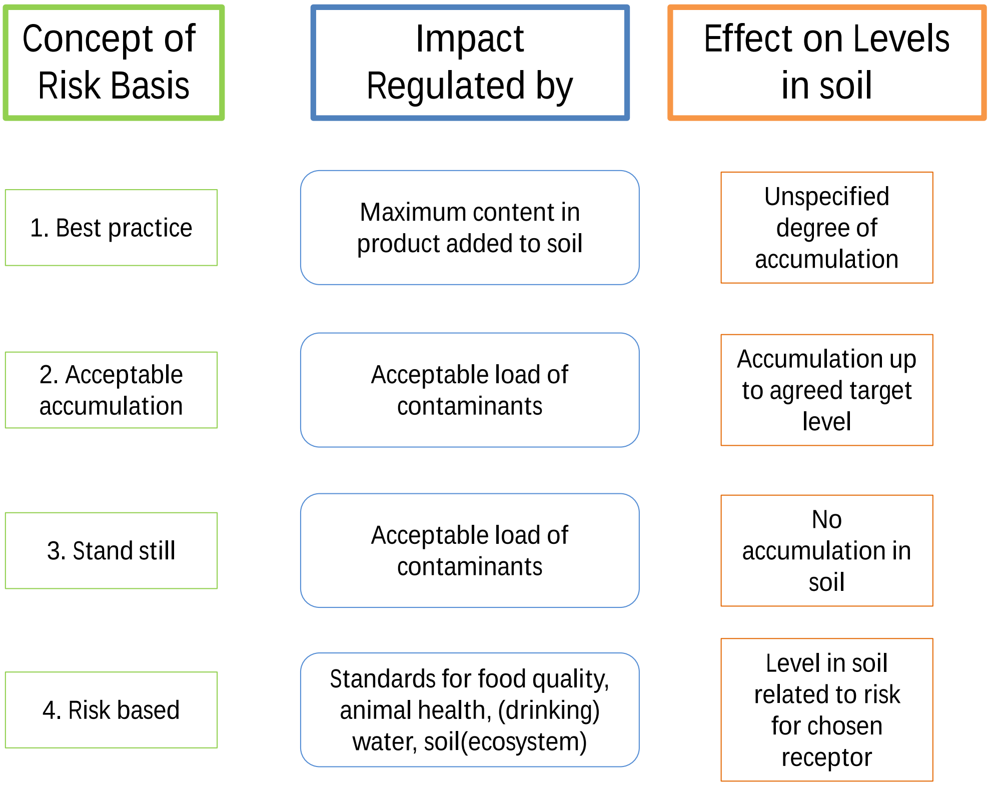

Figure 5.1 Concepts and principles used in the derivation of standards for fertilisers and soil amendments

Mass balance model

The derivation of regulations based on acceptable accumulation (2), stand-still (3), risk based principles (4) all require the use of some kind of mass balance model for contaminant behaviour in soil. To achieve stand still the inputs of contaminants should be balanced by the outputs i.e. plant uptake, leaching and erosion. An acceptable accumulation can be defined as an increase in terms of percentage of a certain soil content (e.g. present contents) or as a maximum soil content. In the latter case also a time frame has to be chosen in which soils may reach this maximum level. In the risk based approach inputs of contaminants to soil should not lead to concentrations in soil (or soil solution) above a certain level aimed at the protection of the distinguished receptors. Mass balance models vary with respect to the balance terms incorporated in the model and with respect to the detail of the mass balance terms. The removal of contaminants by plant uptake depends both on soil usage (type of crops grown) and soil type (Römkens *et al.,* 2008). Removal of contaminants by leaching depends on the contaminant concentration and soil properties (e.g. soil organic matter content, pH) depending on the substance and the precipitation surplus (Groenenberg *et al.,* 2006; Groenenberg, 2011). Besides the inputs by fertilisers also other pathways, e.g. atmospheric deposition, contribute to the contaminants inputs to soil.

It should be noted that there is a potential conflict between model detail and the aimed generality of the regulations. Most regulations are presently based upon rather simple mass balance approaches e.g. only taking into account a representative uptake flux by crops.

5.1.1 Best practice

In case of the best practice principle the primary principle is the ability to use a certain product. e.g. because of agricultural benefits, despite the fact that its usage may lead to accumulation of contaminants which are unavoidably present in the product because they are naturally existing components in the raw materials. It should be kept in mind though that for many contaminants naturally present in raw materials (for example Cu, Zn) or intentionally added (including antibiotics) this 'best practice' level by definition leads to a certain load to soils. In fact various examples exist of current standards based on best practice production processes. This is the case for example for compost in the Netherlands where current standards are derived from, or at least adapted based on natural levels of metals like Cu and Zn in raw fodder materials. Whether or not such levels are acceptable in view of a risk based approach is an entirely different discussion.

To limit unwanted effects the quality of the product has to meet quality standards which can be met according to best technological means or best practice.

When a certain product meets certain quality standards it can be used either without any limitations or according to good agricultural practice.

5.1.2 Acceptable accumulation of contaminants in soil

At present several countries have maximum tolerable loads of heavy metals to soils, although these are generally non-science based and often rather arbitrary settings. The concept allows for a certain degree of accumulation of contaminants in soils. The accepted accumulation is not by definition risk-based, i.e. based on source-pathway-receptor calculations but to some extend the accepted accumulation is linked to target levels in soil to avoid harmful effects. Such a limit can be expressed as a maximum soil limit based for example on the 90 percentile of present contaminant concentrations in soils. In Flanders such a concept is used in which one allows loading of the soil from the 50th percentile to the 90th percentile during a period of 100 years. Another possibility is to express acceptable accumulation as a percentage of present concentrations as is done in the Netherlands decree on building materials, which allows for an accumulation of 1% of present soil contents in 100 years.
The principle enables the user to restrict further accumulation in those soils which are already at for example the 90-percentile level by withdrawing or withholding the permission to use or receive certain fertilisers/soil amendments which would lead to accumulation in excess of this level.

5.1.3 No Net Accumulation or stand still approach.

The no net accumulation or stand still approach aims at balancing input and output fluxes of contaminants in soils. This approach is also often referred to as the mass-balance approach (e.g. Amlinger *et al.* 2004), however this may be confusing as other approaches also include mass-balance models to come to maximum input fluxes corresponding with the desired protection level (e.g. in the risk based approach). Therefore we avoid the use of the term mass balance when referring to the stand still approach. The main subject of protection in the mass balance approach is the *level of contaminants* in the soil itself. According to Amlinger *et al*. (2004) such precautionary limit values are to safeguard soils against future impacts and long term protection is aimed at preserving the possibility of different uses of soils. Several options of the stand still approach are described below:

a. A limitation of acceptable concentrations of contaminants in fertilisers and soil amendments at the same level of soil background concentrations ("same to same" or "similar to similar"). A major practical consequence of this approach is a zero tolerance level for non-natural compounds (e.g. PCB's, herbicides/pesticides).

b. A limitation of the load of heavy metals and organic contaminants so that it matches the amount of tolerable exports from soil via harvested crops, leaching and erosion (import=export). In case of organic contaminants also decomposition of the contaminant can be accounted for. Loads from other sources (deposition, use of herbicides/pesticides etc.) should be included.

5.1.4 Risk based assessment

As presented in Chapter 4 for the Netherlands, inputs to the environment can be regulated so as to prevent unwanted effects on various receptors. The basic concept of a risk-based approach is the source-pathway-receptor principle. In this principle, the quality of various receptors is warranted using specific quality standards. Examples of relevant receptors or protection targets in view of agriculture include:

- *Agricultural production criteria* : including crop quality criteria, animal health, phytotoxicity, or reduced crop yield due to the effect of a specific compound or mixture of compounds and product quality in view of human- and animal health.
- *Human health*: effects related to human health either due to consumption of arable crops, animal products or direct ingestion of soil by children (US))
- *Ground- and surface water quality* either related to intake by human beings (drinking water) or ecological standards (e.g. Water Framework Directive)
- *Ecosystem health* including effects on the below- and above ground ecosystem (ecotoxicological limits soil organisms and effects on the food chain e.g. mammals and birds)

Regulations for fertilisers and soil amendments can be based on the most critical of the selected pathways.

A key aspect of the risk based approach is that it only can be applied if there is a quantifiable relationship (transfer model) between a level in the acceptor side (plant, animal, human being) and the level in soil as illustrated in figure 5.2. Ultimately this requires a mass balance approach as well to relate the current level in a specific soil to the maximum load that can be applied so as to avoid levels in soil exceeding the acceptable level.

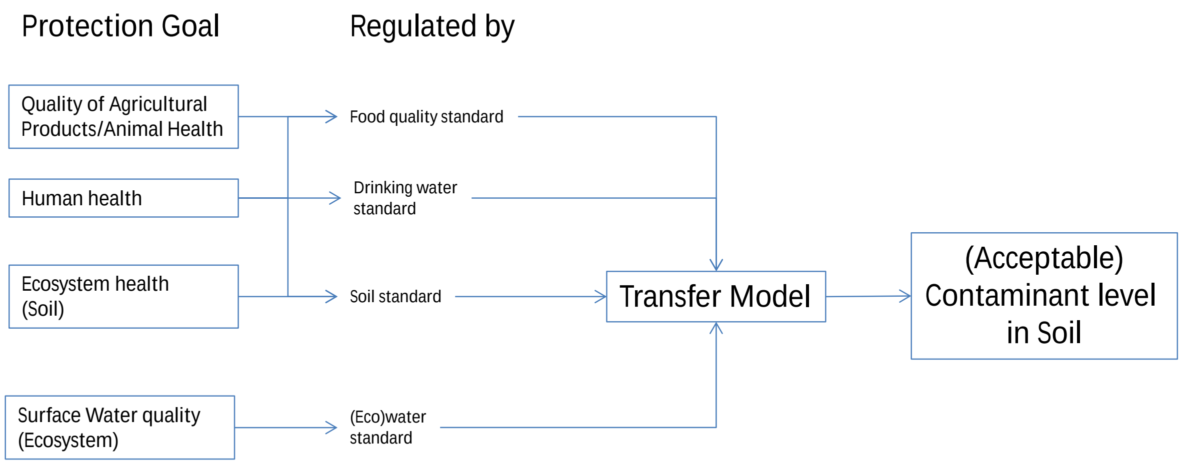

Figure 5.2. Relation between acceptors (left) and soil (right). The standards in the middle section refer to protection levels not to be exceeded in order to avoid an effect (i.e. intake of soil, crops, water or exposure to soil or water in case of ecosystem health)

5.2 Comparison of approaches in different countries

Table 5.1 gives an overview of the underlying concepts of the regulations for the different products in the considered countries.

Table 5.1 Overview of principles for managing risks related to contaminants in fertilisers and soil amendments in six Member States. Numbers refer to the following principles: 1= Best practice, 2= Acceptable accumulation, 3= Stand still, 4 = Risk-based.

Country	Compost	Digestate	Sewage sludge	Fertilisers*
EU	-[a]	-	2	-
NL	3,1	3	3	3,4[b]
VLG	2	2	2	2
DK	4	4	4	4
DE	3	3	2	4,1
UK	-	-	2	-

*Other fertilisers, i.e., fertilisers not regulated by EC Regulation No 2003/2003
[a] not regulated yet
[b] Protocol version 3.1 for waste and 'reststoffen'

The origin of the standards and the permissible dosages of fertilisers show that sewage sludge, compost and other fertilisers have been treated in very different ways although attempts have been made to make a common approach for all fertilisers (Flanders, Denmark) except the EU fertilisers. A risk-based approach can result in very different standards, depending on the system that is described in the scenario. When aiming to exclude ecological effects this usually leads to rather strict standards. If on the other hand a risk-based approach is aimed to prevent soil concentrations that might have effects on human health, then it results in very high permissible dosages such as in the UK and even much higher in the US (Hogg *et al.,* 2002).

In most European countries another approach has been followed, especially for compost. In some countries the standards have been set a low as practically possible (the Netherlands, Austria, Luxemburg) in such a way compost is now threated as a product rather than as waste. In many countries compost is sold to the public, only in the Netherlands the agriculture is the largest compost user (Amlinger *et al.,* 2004). In the Netherlands the perception of a clean product has been so strong that the specific dose restrictions for compost on arable land and for grassland have been released. Dose is now restricted to the permissible N and P use norms similar to other fertilisers.

The policy around sewage sludge has been influenced strongly by a wish to practically ban sewage sludge in agriculture like in the Netherlands, Switzerland, and some German states. This has become the situation in countries where farmers and public are not keen on using this material. In that case the policy (Flanders, Germany) has been to strive to strict rules similar to compost to regain trust.

Products from digestate might also be sensitive for public discussion. Currently the regulation or the voluntary quality assurance in Flanders, the UK, and Germany have similar standards for contaminants in digests as for composts.

6 Concluding remarks

The aims of this study are twofold:

1. To describe the concepts of the risk-basis (*risico-basis*) that have been used to derive quality standards for contaminants of the current Fertiliser Act of the Netherlands, and
2. To provide a technical description of the history and background of current legislation of fertilisers in the Netherlands and neighbouring countries.

Chapters 3 and 4 provide insight on current legislation of contaminants in the Netherlands, Belgium Flanders, Denmark, Germany and United Kingdom and addresses with a bird's eyes view their origin. Each country has developed their own system to safeguard men, animals, crops and the environment against contaminants in fertilisers and through resourcing reused wastes and by-products. But the regulatory systems differ per country in number and nature of contaminants, maximum permissible contents and underlying criteria.

The concept of a 'risk-basis' and the criterion that is risk-based have been discussed in chapter 5. For clarity, descriptions of risk-basis and risk-based are recalled here.

Risk-basis: the ***concept*** applied to derive a standard for soil or soil amendments (including fertiliser). An example of a risk-basis is the principle of stand-still. In chapter 5 different concepts of the risk-basis are described.

Risk-based: in order for a standard in soil or fertiliser to meet the ***criterion*** of 'risk-based' there needs to be a quantifiable link between the acceptable level and an effect in soil, crop or water which is usually related to a quality criterion in each of these compartments (e.g. food quality standard or water standard).

Regulations on contaminants in fertilisers composts and wastes in the Netherlands:

- The current risk basis in the Netherlands is related to an defined (accepted) degree of accumulation of heavy metals and organic micro pollutants.
- The regulation of inorganic contaminants (metals and arsenic) follows scientific and policy ideas from the nineteen seventies and eighties of the last century.
- The accepted degree of accumulation of heavy metals and arsenic is not quantitatively related to current day multiple risk indicators in use to protect human health, animal welfare, product quality or ecosystem functioning.
- For organic micro pollutants the accepted degree of accumulation does take into account a more system-oriented assessment, following recent adjustments and the inclusion of new scientific insights.
- As loads of contaminants have been tuned to requirements for nutrients, liming materials and organic matter in agriculture, risks on an unacceptable increase of contamination level are controlled.
- Currently the quality of fertilisers used in the Netherlands as well as organic wastes used as fertiliser including industrial sewage sludge and compost meet quality standards on contaminants imposed by the Fertiliser Act and are also in line with proposed criteria for the re-use of organic waste are being developed in the EoW Directive.
- The only exception to this are levels of Cu and Zn in animal manure and a general non-compliance of (municipal) sewage sludge with either existing regulation or EU proposed legislation within the framework of the EoW Directive and proposals of the revision of the EU Regulation No 2003/2003.

- The introduction of quality standards for Cu and Zn for fertilisers, and animal manure, will impose application limitations for manure in the Netherlands when using EoW criteria.

Final concluding remarks

- The current European and national regulations have different definitions of fertilisers and fertiliser appraisal approaches, due to historical reasons but also due to differences in intensity of agricultural practices. This makes harmonisation of legislation difficult.
- Substantial differences exist in numerical values for standards of contaminants between the Netherlands, Flanders, Denmark and Germany. With exemption of sewage sludge, the United Kingdom has no legal standards yet for contaminants in fertilisers.
- Differences originate from different target levels for soil on one hand and acceptable loading rates on the other. This results in a large range of criteria for various fertilisers or organic wastes. Probably this is due to differences in the acceptance of contaminant loading rates, differences in nutrient requirements depending on soil type, climate etcetera as well as intensity of the agricultural production system.
- Member States have developed their own concepts and approaches of risk basis to obtain national guidelines for contaminants in fertilisers (for concepts see annex 8). This has led to notable differences in the regulatory basis, which is most visible in advisory values for sludge in different member states. Different definitions and appraisal criteria limit trade across Europe, while they do not earmark responsible application rates.
- Member States have Developed their own concepts and approaches of risk basis to obtain national guidelines for contaminants in fertilisers. This has led to notable differences in the regulatory basis, which is most visible in advisory values for sludge in different member states. Different definitions and appraisal criteria limit trade across Europe, while they do not earmark responsible application rates.
- The basis of fertiliser appraisal methods was laid long ago. Progressing scientific insights and data can, via scenario studies, elucidate whether protection targets can be reached under proposed changes of regulations, like EU Regulation No 2003/2003. In many cases the scientific basis of the risk-basis chosen by Member States is based on views and concepts from the 1980's. Although this implies that the approach as such can be improved by considering, for example, a broader and improved risk-based 'systems approach', this does not necessarily imply that current advisory levels are not protective. To assess whether or not current or proposed legal limits are in line with multiple environmental targets, i.e. water quality, ecosystem quality, product quality et. cetera, an analysis of the impact of the use and application of fertilisers and other (organic) waste materials should be performed. This obviously requires an appropriate set of tools that are able to quantify the environmental impact of various products in a time frame of 10 to 100 years. Such tools have been developed in the member states (i.e., Denmark, Belgium Flanders, Germany and the Netherlands) which allows for a quantitative evaluation.
- It is advisable to seek a harmonised basis for risk assessment of contaminants in fertilisers. By handling, the same risk basis increases the understanding and dialogue between Member States. The use of a single risk basis does not necessarily lead to a single EU-wide numerical standard value since difference in land use (e.g. crop type), intensity of agriculture, soil fertilisation and climate can result in ranges of standard values across the EU or in different member states.
- The use of fertilisers is considered commonly for specific combinations of soils, crops and land use, implying the need to define minimum and maximum criteria between which a material can be considered a fertiliser, but also use prescriptions for local application. This can pertain to maximum (macro- and micro)nutrient applications for the situation, as well as specific loads, which can be region- or nation-specific. The aforementioned analysis can result in a flexible system based on either quality criteria of products or allowed annual loads of products which are in line with set protection targets. Considering differences in soil, land use and climate, such quality criteria or loads can be region or nation-specific.

- Beyond the fertilisers themselves, there are major external drivers that imply a need to consider aspects beyond profitable and adverse aspects of fertilisers. Major drivers in the legislation regarding waste, soil and water are:
    - o System oriented legislative frameworks (WFD, STT) versus sectorial regulation may result in mis-fits: A desire to obtain a more integral protection of the environment including soil, water and ecosystems rather than a sector-oriented approach dealing with specific sectorial protection issues. This is a reply to facts: soil contamination can be a threat to water bodies, the latter being regulated at the European level. Such effects are the main driving force behind e.g. the WFD and Thematic Strategy for Soil protection
    - o Sustainable development asks for broadening of scope to e.g. avoiding resource depletion: There is a general need or desire to more effectively re-use valuable and non-endless resources, including nutrients and organic matter, in view of a more sustainable land-use. This aspect is relevant for the proposed End of Waste Directive and revisions of the Sludge Directive and Waste Directive.
- Fertiliser quality management and regulations can take various shapes. The actual or desired quality of fertilisers or organic soil amendments can be regulated by various principles:
    - o Process control, relevant for organic soil amendments like compost. This then requires less quality control of the product itself provided the process control is sufficient to maintain the desired quality of products.
    - o Direct legislative frameworks for product quality or product load based on a risk-based assessment of the environmental impact; at present this can be linked to e.g. the proposed EoW criteria or the (revision of the) Sludge Directive.
    - o Indirect legislative frameworks that control the quality of source materials for specific end-products. This is especially relevant for Cu and Zn which are regulated through additives in animal food which ultimately controls levels in manure. Obviously this also requires a system approach that links accepted levels of Cu and Zn in feed additives to levels of Cu and Zn in soil and (surface) waters.
- Benefits and risks aspects both tend to ask for a broader evaluation. The current practical and regulatory drivers make that any revision of the fertiliser regulations have to be seen in view of both benefits – and there: not only crop yield, but a wider evaluation of sustainability issues – of fertilisers as well as potential adverse effects, direct to the soil, or elsewhere. At present this link between benefits and compliance with multiple environmental targets has not been incorporated in current legislative frameworks. This implies that valuable assets of fertilisers and waste materials at present go unnoticed.

Acknowledgement

The study also involves regulation in Belgium Flanders, Denmark, Germany and the United Kingdom. We thank Lise Kjærgaard Steffensen, George Embert and Alfred Generet respectively of Denmark, Germany and Belgium for their willingness to review concepts on national regulations.

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Annex 1 Translation of references to law

Table A.1.1 English translation of references

Name in the Netherlands in references	English name in this report	Abbreviation in this report
Meststoffenwet http://wetten.overheid.nl/BWBR0004054/	Fertiliser Act	MW
Uitvoeringsbesluit Meststoffenwet http://wetten.overheid.nl/BWBR0019031/	Fertiliser Decree	Ub
Uitvoeringsregeling Meststoffenwet http://wetten.overheid.nl/BWBR0018989/	Implementing regulation	Ur
Besluit Bodemkwaliteit http://wetten.overheid.nl/BWBR0022929	Soil Protection Decree	BB
Besluit kwaliteit en gebruik overige organische meststoffen * http://wetten.overheid.nl/BWBR0009360/	Decree on the quality and use of other organic fertilisers	BOOM
Besluit Gebruik dierlijke meststoffen http://wetten.overheid.nl/BWBR0009066/	Decree on the use of fertilisers	Bgm
Bouwstoffenbesluit bodem- en oppervlaktewaterenbescherming*	Building Materials Decree	Bsb

*this decree no longer applies.

Annex 2 Limits for contaminants in soil when using sewage sludge or compost

According to the sewage sludge directive, sludge is only permitted on soils that comply with the soil standards in the sewage sludge directive or stricter rules set in the member states.

Important, some countries also use this rule for the application of compost and biowaste. This is the case for biowaste according to the German legislation for compost and digestates (BioAbfV, § 9) for uncertified producers (BioAbfV, § 11) , and for compost according to the voluntary PAS100.

Table A.2.1 Standards for heavy metals in soil (mg kg $^{-1}$ dm)

	86/278/EEC	**United Kingdom**				**Denmark**	**Germany**	**The Netherlands**	**Flanders**
	6<pH<7	5<pH<5.5	5.5<pH<6	6<pH<7	pH>7	*	**	***	****
Cd	1-3	3				0.5	1.5 (1)	0.79	1.2
Cr						30	100	100	91
Cu	50-140	80	100	135	200	40	60	36	72
Hg	1 -1.5	1				0.5	1	0.3	1.5
Ni	30 -75	50	60	75	110	15	50	35	56
Pb	50-300	300				40	100	85	120
Zn	150-300	200	250	300		100	200 (150)	140	200
As								29	35

*Denmark: https://www.retsinformation.dk/Forms/R0710.aspx?id=12278. These values are equal to the soil quality standards in Denmark to protect the most sensitive humans.

**Germany: AbfKlärV. Lower values for Cd and Zn in sandy soils (< 5% lutum), and soils with 5<pH<6. No sewage sludge on soil with a pH <5. These values are almost identical to the precautionary (“vorsorgewerte”) values in the Soil protection Ordinance (BBodSchV) for clay soil or loamy soils. For sandy soils the precautionary (“vorsorgewerte”) are lower, but, as mentioned earlier, on these soils sewage sludge is prohibited if the pH <5.

***The Netherlands: Bgm, soil specific: standard soil in the Netherlands is at 25% lutum and 10% organic matter.

****Flanders: Vlarema (2012), soil specific: standard soil in Flanders is at 10 % lutum and 2% organic matter.

Annex 3 Limits for contaminants in EU Eco-label and organic agriculture

The European standard for eco-label compost has been used as a basis for the proposal of the EoW criteria for fertilisers from bio-waste. The choices has been extensively explained in Annex 11 of JRC Ipts (2012). However, the origin of the eco-label criteria is not known to the authors (the origin of the criteria in 1994, and the origin of the amendment in 1998 of the Cd, Cr, Cu, Pb criteria cannot be traced by the authors). The criteria are close to the criteria in Austria, and the Netherlands, countries with advanced source separation and composting systems. The eco-label is a voluntary instrument intended to selectively improve products that improve the environment. The limit values are valid unless national legislation is more strict, as is the case in the Netherlands. It is not often used for soil improvers and growing media. In the Netherlands there are nine products in the category growing media which have an eco-label (*Milieukeur*) but no soil improvers with an eco-label. In Belgium one soil improvers has an eco-label. Denmark, Germany and the United Kingdom have no eco-label producers for soil improvers or growing media.

The European standard the use of composted or fermented household waste in organic agriculture is stricter. The origin of the regulation is 2092/91 and the limit values were given in regulation no. 1488/97/EC. The origin of these limit values are not known to the authors.

Table A.3.1 European Standards for heavy metals in eco-label soil improvers (799/2006) and growing media (64/2007) and compost from separately collected biowaste for organic agriculture (1488/97/EC) in mg kg^{-1}.

	Eco-label	**Eco-label**			**Organic production**	
	Old**	Latest**				
year	1994	1998-2006			1997	
Cd	1.5	1			0.7	
Cr	140	100			70#	
Cu	75	100			70	
Hg	1	1			0.4	
Ni	50	50			25	
Pb	140	100			45	
Zn	300	300			200	
As *	7	10				
Mo *	2	2				
Se *	1.5	1.5				
F *	200	200				

* only for products containing materials from industrial processes
** COM Decision (EC) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:325:0028:0034:EN:PDF ecolabel to soil improvers, and 64/2007 eco-label on growing media.
***EU regulation on organic agriculture 2092/91, 1488/97/EC.
permitted CrVI is set on 0 (detection limit).

Annex 4 Regulated contaminants in fertilisers

Table A.4.1 Regulated contaminants in fertilisers (mg kg^{-1}, except for dioxins which are given in ng TEQ kg^{-1}). To enable a comparison between regulated contaminants all standards have been recalculated to mg per kg^{-1} by assuming a certain dosage (see footnotes).

		Fertilisers and soil improvers	**Compost**	**Other in(or)ganic fertilisers (see footnote)**	**Fertilisers DuMV**	**Compost and digestates BioAbfV**	**Sewage sludge AbKlarV**	**Sludge order**	**Bio-ash**	**Sludge (see footnote)**
		Flanders	NL	NL	DE	DE	DE	DK	DK	UK
	Tonnes dry matter/ha/yr	2	-	2	-	6.3	1.6			
Heavy metals	Cd	6		1.25	1.5	1.5	10	0.8	5/20/5	75
	Cr	250		75	2	100	900	100	100	25
	Cu	375		75	900	100	800	1000		3250
	Hg	5		0.75	1	1	8	0.8	0.8	50
	Pb	300		30	80	50	200	120	120/250	750
	Ni	50		100	150	150	900	30	60	1500
	Zn	900		300	5000	400	2500	4000		7500
	Co									
	As	150		15						
	Tl				1					
	Σ PCDD/PCDF			0.00076	30 (5)		100			
	AOX						500			
PAHs	Antracene			24						
	Benzo(a)anthracene	0.68		9.2						
	Benzo(a)pyrene	1.1		11.6						
	Benzo(b)fluoranthene	2.3								
	Benzo(ghi)perylene	1.1		8.4						
	Benzo(k)fluoranthene	2.3		10.8						
	Chrysene	1.7		9.2						
	Fluorantene	2.3		7.4						
	Indeno(1,2,3cd)pyrene	1.1		9.4						
	Naftalene	2.3		24						
	phenantrene	0.9		30						
	Σ 10-PAH			20				3		
MAHs	Monochlorobenzene	0.23								
	Dichlorobenzene	0.23								
	Trichlorobenzene (4)	0.23								
	Tetrachlorobenzene (5)	0.23								
	Pentachlorobenzene	0.23								
	Hexachlorobenzene	0.23								
	1,2-dichloroethane	0.23								
	Dichloromethane	0.23								
	Trichloromethane (Chloroform)	0.23								
	Trichloroethene	0.23								
	Vinyl chloride	0.23								
	1,1,1-trichloroethane	0.23								
	1,1,2-trichloroethane	0.23								
	1,1-dichloroethane	0.23								

Continuation of table 1

		fertilisers and soil	compost	other in(or)ganic fertilisers	fertilisers DuMV	compost and digestates BioAbfV	sewage sludge	Sludge order	Bio-ash	Sludge (see footnote)
		Vld	NL	NL	DE	DE	DE	DK	DK	UK
	Cis+trans-1,2-dichloorethane	0.23								
	Hexane	5.5								
	Heptane	5.5								
	Octane	5.5								
	Mineral oil C10-C20	560		37400						
	Mineral oil C20-C40	5600								
HCHs	α-HCH			12.4						
	β-HCH			0.48						
	γ-HCH (lindane)			0.048						
	HCB			1.24						
BTEXS	Benzene	1.1								
	Ethyl benzene	1.1								
	Styrene	1.1								
	Toluene	1.1								
	Xylene	1.1								
drins	Aldrin			0.28						
	Dieldrin			0.28						
	Σ aldrin/dieldrin			0.28						
	Endrin			0.28						
	Isodrin			0.28						
	S endrin/isodrin			0.28						
	S DDT + DDD + DDE			0.92						
	PCB-28	0.8		0.74			0.2			
	PCB-52	0.8		0.74			0.2			
	PCB-101	0.8		3			0.2			
	PCB-118	0.8		3						
	PCB-138	0.8		3			0.2			
	PCB-153	0.8		3			0.2			
	PCB-180	0.8		3			0.2			
	Σ 6-PCB (excl. PCB-118)			15						
	PFC				0.1					
	Linear alkylbenzene sulfonate (LAS)							1300		
	Nonylphenol Ethoxylates (NPE)							10		
	Bis(2-ethylhexyl) phthalate (DEHP)							50		

Notes per column:

3.Only for comparison purpose the limit values are given in mg per kg, assuming a dosage of 2 tons ha^{-1} yr^{-1}. In the legislation the limit values are given per kg beneficial component for "Other in(or)ganic fertilisers". Limit value per beneficial component x amount of beneficial component divided by the total dosage of 2 tons per year per hectare gives a content on the basis of dry weight.

3.Only heavy metals for inorganic fertilisers.

9. Only for comparison the limit values for sludge in the UK have been recalculated to mg kg^{-1} by assuming a dosage of 2 tonnes ha^{-1} yr^{-1}. Regulated are the heavy metals by amounts per hectare per year.

Annex 5 Annual load of fertilisers in the Netherlands

Manure

Volumes of manure produced

Animal manure is the main source of mineral nutrients to agricultural soils in the Netherlands (source: CBS Statline) (Table A.5.1). In 2010, it accounted for 53% of the nitrogen and 79% of phosphate applied. Because of regulations on the amount of manure that can be applied per hectare, and the high animal to soil ratio on most animal farms, many animal farms have a surplus of animal manure that they are not allowed to apply on their own fields. This has led to the creation of a manure market, in which manure is negatively priced. Animal manure can therefore strongly compete with mineral fertilisers.

Figure A.5.1 shows the total production of animal manure in the Netherlands from 1990 to 2011 (source: CBS Statline). Cattle manure constitutes the biggest part, followed by pig manure. Chicken manure only constitutes a small part. However, it should be noted that the data are on a fresh product basis. Chicken manure is mainly solid, whereas cattle and pig manure are mostly slurries. The category “others” includes amongst others horse, goat, sheep.

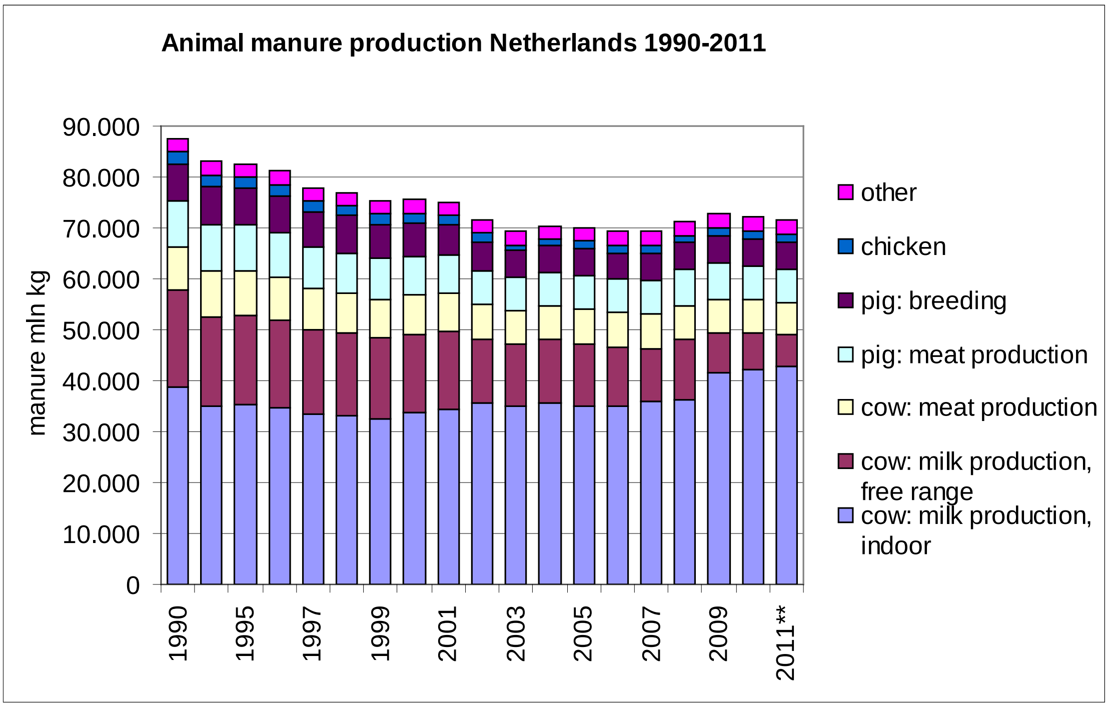

*Figure A.5.1 Total amount of manure produced in the Netherlands between 1990 and 2011, expressed as 10^6 kg fresh manure (Source, CBS, Statline). ** data for 2011 not confirmed yet*

Part of the animal manure is exported or incinerated. Of the total amount of cattle and pig manure produced, only 75% is used in agriculture, and of the total amount of chicken manure only 10% is used in Netherlands agriculture. Chicken manure is mainly exported or incinerated (Leusink *et al.* 2011).

Concentration of heavy metals in manure

The application rate of animal manure is regulated by the N and P contents. There are no regulations on the concentrations of heavy metals in manures or the amount that is applied with these manures.

Heavy metal contents of animal manures are not commonly measured. The heavy metals in the animal manure mainly result from the feed stuffs. Apart from the heavy metals that these feed stuffs contain originally, several metals are added such as copper and zinc. In addition, materials used in the stables such as bedding material and cleaning products end up within the manure. Moreover, the cupper used in “food baths” for cattle is also spoiled into the manure. The use of Cu in food baths has increased and is considered an important source for the Cu in manures (Römkens and Rietra, 2008).

Data on heavy metal contents were measured in 1996 by Driessen and Roos for the most common categories of manure. Distinctions were made between animals, type of production (meat, milk, eggs, breeding), and type of manure (slurry or solid). For cattle slurry from cows held for milk production, a distinction was further made for ration (with or without maize) (Table A5.1).

In 2008, Römkens and Rietra measured the heavy metals of 3 main categories of manure: cattle slurry from cows held for milk production, pig slurry for pigs held for meat production, and chicken slurry from chickens held for meat production (Table A5.1).

A major discrepancy in the data collected in 1996 and 2008, is the increase in concentrations of Cu in cattle slurry which partly can be explained by the addition hoof disinfection solutions to manure. Copper levels in chicken manure decreased during the same period. Concentrations of Zn increased in both cattle and pig slurry. Concentrations of As increased in all three categories, whereas concentrations of Ni and Cr have decreased.

Table A.5.1. Concentrations of nutrients and heavy metals are given below. Expressed on dry matter basis.

Type	**N**	**P_2O_5**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**	**Source**
	g kg^{-1}	**g kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	
cattle slurry (milk)	49.5	17.3	0.25	6.4	135	<0.12	4.5	4.8	198	1.6	1
cattle slurry (milk)	49.6	22.5	0,24	8,4		0,047	10	8	156	0,53	2
cattle slurry (milk)	55.3	19.9	0.19	6.2	42.0	0.038	17.0	18.0		0.28	2
cattle slurry (meat)	50.7	24.1	0.25	8.0		0.034	16	16		0.75	2
pig slurry (meat)	89.4	50.2	0.35	8.1	404	<0.14	9.2	5.6	952	1.9	1
pig slurry (meat)	74.8	43.5	0.30	14	397	0.027	21	14	564	0.56	2
pig slurry (breeding)	76.7	47.8	0.43	13	446	0.038	21	14	859	0.44	2
chicken slurry	72.7	48.5	0.26	8.0		0.033	18	17.0		0.75	2
chicken manure (egg)	57.0	32.9	0.19	9.4	52	0.026	8	12	386	0.49	2
chicken manure (breeding)	34.9	43.3	0.19	5.7	54	0.023	13	18	335	0.62	2
chicken manure (meat)	48.2	25.1	0.2	3.9	78	0.04	3.3		266	1.1	1
chicken manure (meat)	58.0	31.0	0.18	6.6	138	<0.02	16	10	307	0.37	2

1) Römkens and Rietra, 2008; 2) Driessen and Roos 1996

Loads of heavy metals from manure

With the data on volumes and concentrations, the total production of N, P_2O_5 and heavy metals in animal manure have been calculated (Table A5.2). The calculations give an underestimation of the total amount produced, as only the main types of animal manure are included. The manures categorized as “others” in figure A.5.1 are not included. As these only constitute a small part of the total manure, it is assumed that their contribution to the total amount of heavy metals and arsenic is (very) small.

Table A.5.2. Calculated production of nutrients and heavy metals in manure in the Netherlands in 2011. Calculated with data from CBS Statline (amounts), Römkens and Rietra 2008 (heavy metal concentrations of cattle slurry, pig slurry meat production, chicken manure meat production), and Driessen and Roos 1996 (%DM, heavy metal concentrations not measured by Römkens and Rietra).

Type	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^6 kg	10^6 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
cattle slurry (milk)[1]	245	86	1.2	32	669	0.60	22.3	23.8	981	7.9
cattle slurry (meat)	28	13	0.14	4.4		0.02	8.8	8.8		0.41
pig slurry (meat)[1]	63	36	0.25	6.0	286	0.10	6.5	4.0	674	1.3
pig slurry (breeding)[2]	33	20	0.18	5.5	190	0.02	8.9	6.0	366	0.19
chicken slurry[2]	0	0	<0.01	0.02	n.d.	<0.01	0.04	0.03	n.d.	<0.01
chicken manure (egg)[2]	23	13	0.08	3.9	21.3	0.01	3.4	4.9	158	0.20
chicken manure (breeding)[2]	3	3	0.01	0.41	3.9	<0.01	0.94	1.3	24	0.05
chicken manure (meat)[1]	16	8	0.07	1.30	26.0	0.01	1.1	2.1	89	0.37

[1] Römkens and Rietra, 2008; [2] Driessen and Roos 1996

From the data on total production in table A5.2, corrected for export and incineration (25% for cattle and pig slurry, 90% for chicken manure) the total load of N , P_2O_5 and heavy metals to soils in the Netherlands has been calculated (table A5.3).

Cattle slurry contributes most to the heavy metal load with manures, which is in line with the contribution to the amount of slurry. Only for zinc, total load from pig slurry is higher than from cattle manure.

Table A.5.3. Calculated loads of nutrients and heavy metals with application of manure in agriculture in the Netherlands in 2011. Calculated with data from CBS 2012 (amounts), Leusink et al. 2011 (% used in agriculture), Römkens and Rietra, 2008 (contents) and Driessen and Roos 1996 (contents)

Type	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^6 kg	10^6 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
cattle slurry	205	74	1.03	27.1	502	0.46	23.3	24.4	736	6.3
pig slurry	72	42	0.32	8.5	357	0.09	11.6	7.4	780	1.1
chicken manure	4	2	0.01	0.5	5	<0.01	0.5	0.8	26	0.1

Compost and Spent mushroom compost

Volumes

In the Netherlands compost is categorised based on origin. The main categories are VGF-compost and green compost.

The VGF compost (from vegetables, garden and fruit waste, in the Netherlands GFT), is produced from organic waste from the separate collection of the municipal solid waste (Verhoef 2010). The total amount of VGF-compost produced is monitored on a yearly basis by Agentschap NL. The total amount varies between 600-700 mln kg compost per year (Table 4) (Agentschap NL, 2012).

Green compost is produced from yard trimmings, clippings and the organic residues from gardens, road sides, parks and other public spaces, as a result of separate collection by communities, landscapers and governmental organisations. The total amount of green compost is not monitored, but an amount of 700 mln kg is mentioned by BVOR-AV (2012). About 2,5 mln tonnes of green waste is processed yearly, of which 62% is composted in open air (Verhoef 2010). Assuming a conversion factor for green waste to compost of 0,5 this would result in 775 mln kg green compost (Table 4).

A different category is Spent mushroom compost, which consists of a composted mixture of horse dung, mixed with straw, chicken manure and gypsum, which has been used as a growth medium for mushrooms (champignon). Spent mushroom compost is not officially recognised as compost as it is derived from manure. Of the total amount of Spent mushroom compost produced, 78% is exported (Leusink *et al*. 2011) (Table A5.4).

Table A.5.4. Total volume of compost and Spent mushroom compost in the Netherland.

type compost	year	Volume (10^6 kg fresh product)	source
VGF compost	2000	309	1
	2007	695	2
	2008	595	2
	2009	631	2
	2010	639	2
	2011	680	2
Green compost	2011	700	3
	2009	775	5
Spent mushroom compost	2000	600	1
	2010	793 (of which 620 exported)[a]	4

1) Delahaye *et al.* 2003; 2) Agentschap NL 2012; 3) BVOR-VA 2012; 4) Leusink *et al*. 2011 ; 5) calculated from Verhoef 2010 assuming conversion factor of 50%

<u>Concentrations of nutrients and contaminants</u>

Information on the concentration of heavy metals in compost and Spent mushroom compost is given by various sources (Table 5). In most cases, the data has been supplied by the producers. Delahaye *et al*. 2003 have used data from other sources which are not specified. Only Den Boer *et al*. 2012 give information directly derived from measurements.

Table A.5.5a. The concentrations of nutrients, heavy metals and arsenic in VGF compost, all contents expressed on dry matter basis

dm	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	source
(%)	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	
70	13.6	5.3	0.7		35.7			101.4	166		1
			0.4	14.1	27.3	0.1	6.6	52.8	148		2
69	13.3	7	0.5	18.8	35.7	0.14	9.8	65.3	175	3.8	3
70	13.6	5.3	0.4	20.2	36.8	0.1	10.0	59.0	173	3.8	4
70	18.4	9.1									5

1) Bokhorst and Ter Berg 2001; 2) Delahaye *et al*. 2003; 3) Heeres *et al.* 2005; 4) Bos 2010 ; 5) Den Boer *et al.* 2012

Table A.5.5b. The concentrations of nutrients, heavy metals and arsenic in Green compost, all contents expressed on dry matter basis

dm	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	source
(%)	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	
60	6.3	3.5	0.5		38.2			24.9	163		1
60	14.3	12.8	0.4	20.5	27.0	0.1	10.0	38.0	127	4.6	3
59	9.2	4.0	0.45	19.8	29.4	0.13	10.3	42.3	139	4.8	4
60	8.3	3.7									5

1) Bokhorst and Ter Berg 2001; 3) Heeres *et al.* 2005; 4) Bos *et al.* 5) Den Boer *et al.* 2012

Table A.5.5c. The concentrations of nutrients, heavy metals and arsenic in Spent mushroom compost, all contents expressed on dry matter basis

dm	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	source
(%)	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	
33	17.3	10.7	0.2		26.0			4.2	115		1
			0.4	14.5	30.0	0.0	2.9	12.6	145		2
59	21.4	12.8	0.29	10	38	0.03	43	10	153	2	3
33	23.3	13.3									5

1) Bokhorst and Ter Berg 2001; 2) Delahaye *et al.* 2003; 3) Heeres *et al.* 2005; 5) Den Boer *et al.* 2012

<u>Loads of heavy metals</u>

With the data on volumes and concentrations the loads of N, P_2O_5 and heavy metals have been calculated (Table A5.6). The loads have been calculated using the most recent data.

Table A.5.6. The calculated loads of nutrients and heavy metals applied to the soil in the Netherlands in 2010 with use of compost or Spent mushroom compost.

	N	P_2O_5	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^6 kg	10^6 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
VGF compost	8.7	4.3	0.2	9.6	17.5	0.04	4.8	28.1	82.3	1.8
Green compost	3.5	1.5	0.2	8.6	11.3	0.04	4.2	16.0	53.3	1.9
Spent mushroom compost	1.3	0.8	0.02	0.6	3.9	<0.01	0.2	0.6	8.7	0.1
Total	13.0	6.3	0.4	18.2	31.7	0.09	8.9	42.9	139.5	3.7

Calculated with the data from Agentschap NL(2012), BVOR-VA (2012), Leusink *et al.* (2011) for volumes; Den Boer *et al*, (2012) for %DM, N and P_2O_5; and Bos (2010) and Heeres *et al.* (2005) for contents of heavy metals and arsenic.

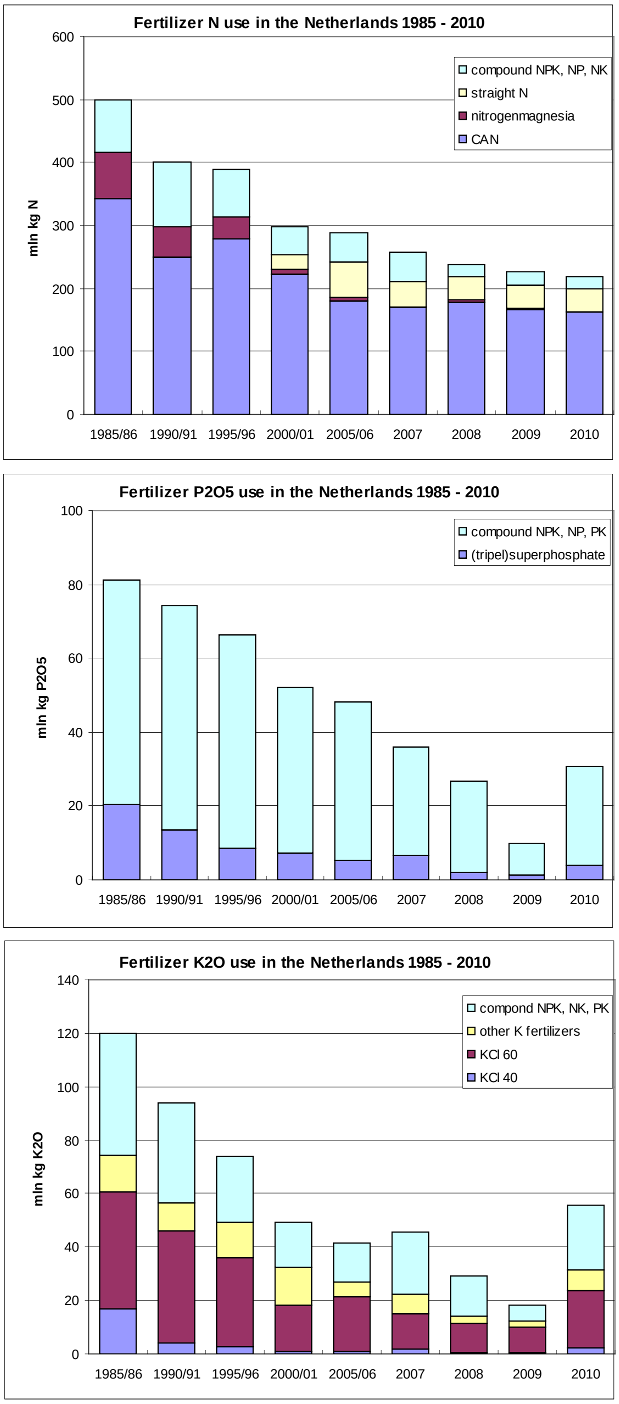

Figure A.5.2. Total fertiliser use in the Netherlands between 1985 and 2010 (LEI/CBS 2012)

Mineral fertilisers

Volumes

The use of inorganic fertilisers in the Netherlands has decreased considerably during the last decades (LEI/CBS, 2012) (Figure A5.2). Between 1985 and 2010, the total amount of N and P fertilisers applied has decreased with more than 50%, while the use of K fertilisers has decreased with 90%. This is the result of the implementation of regulations on the amount of N, P_2O_5 and animal manure that is allowed per hectare yearly. In 2010, mineral fertilisers contributed 39% of the N and 19% of the P_2O_5 total loads from fertilisers, manures and composts to soils in the Netherlands.

Concentrations of nutrients and contaminants

Information on the concentrations of heavy metals in mineral fertilisers is limited and in most cases old. Also, the concentrations given can deviate considerable between the different sources.

Contamination with heavy metals in N and K fertilisers is generally considered to be low in comparison to the contents in P fertilisers. In a recent screening of contaminants in fertilisers in Denmark (Petersen *et al*. 2009) it was concluded that the level of heavy metals in straight K and compound NS fertilisers was very low, so that it would be safe to exclude them from control screening programmes.

In the Netherlands, the main N fertilisers are ammonium nitrate limestone (CAN: calcareous ammonium nitrate) and ammonium magnesium (MAS, magnesammon or stikstofmagnesia). The magnesammon fertilisers are blended with dolomite limestone, which can contain varying concentrations of contaminants. Also CAN is commonly blended with dolomite, but may also be blended with calciumcarbonate. In a review study (EPA 1999), highly diverging concentrations in dolomite are given for lead (Pb: 0,7-49 mg kg dolomite) and zinc (Zn: 8-224 mg kg dolomite), (Cr: <2,5-32 mg kg dolomite) and nickel (Ni: <5-33 mg kg dolomite). This could provide one explanation for the diverging figures found in literature for N fertilisers.

Data from Smilde (1984) were based on actual measurements, but are old and might be outdated. The data from Van Erp and Meeuwissen (1996) were based on literature review, including both Netherlands and international data. Especially the concentration of arsenic as given by Van Erp and Meeuwissen is very high. Internal information of the MMF (Minerale Meststoffen Federatie) shows that the concentrations of arsenic by producers in the Netherlands are considerably lower.

Table A.5.7a. The concentrations of N, heavy metals and arsenic in N fertilisers, in mg kg^{1} N

Type	**N**	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**	**Source**
	%	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	**mg kg^{-1} N**	
CAN	26	0.37	5.6	1.7	0.370	39.8	2.7	6.8		1
CAN									*<<10*	4
CAN	26	0.37	3.7	8.3	0.370	39.8	85.2	25.9	*219*	2
CAN	26	0.37		13.4	0.002	3.4	2.7	30.0		3
Magnesia nitrogen		0.90	7.3	3.4	0.000	7.3	5.9	13.6		1
Magnesia nitrogen									<5	4
Magnesia nitrogen	22		9	4.5		9	158			2
Magnesia nitrogen	22	1.80		11.6	0.015	10.6	5.9	*394.0*		3
Straight N fertilisers		0.90	159.9	3.4	0.410	331.5	5.9	13.6		1

1) Delahaye *et al*. 2003; 2) Van Erp and Meeuwissen (1994); 3) Smilde 1986; 4) confidential information MMF

Only for the phosphatic fertilisers recent measurements on some representative fertilisers in the Netherlands are available (Smolders and Nziguheba, 2007). In 1996, concentrations of heavy metals in some common phosphatic fertilisers have been measured (Hotsma *et al*.1996; Driessen en Roos, 1996). Concentrations given by Delahaye *et al.* (2003) and Van Erp and Meeuwissen (1994) were based on existing literature. Data by Smilde (1984) were based on measurements but are probably outdated as production processes have changed since then.

For P containing fertilisers, both the origin and the processing of the phosphate ore seem to affect the final concentration in the fertilisers (Petersen *et al*. 2009). In general, Petersen *et al*. (2009) found that the concentrations of Cd, Zn and As in P fertilisers in Denmark were linearly related with the concentration of P. For the compound NPK fertilisers the concentrations of Cr and Ni were linearly related to the concentration of iron in the fertiliser.

The compound NP(K) fertilisers are most commonly used in the Netherlands. According to Westhoek *et al*. 1996, the composition is diverse, but the concentration of contaminants will vary between that of NP26+14 and TSP. Thomasslag has been used in ecological agriculture as a P-fertiliser but is mostly abandoned nowadays because of the high contents of heavy metals, especially Cr, Cu and Zn.

Table A.5.7b. The concentrations P_2O_5, heavy metals and arsenic in P fertilisers, in mg kg^{-1} P_2O_5

Type	P_2O_5 %	Cd mg kg^{-1} P_2O_5	Cr mg kg^{-1} P_2O_5	Cu mg kg^{-1} P_2O_5	Hg mg kg^{-1} P_2O_5	Ni mg kg^{-1} P_2O_5	Pb mg kg^{-1} P_2O_5	Zn mg kg^{-1} P_2O_5	As mg kg^{-1} P_2O_5	Source
TSP	46	64.0	326	84		123	5.4	1387		4
TSP	45	58.1	490	66	0.047	90	11.7	1216		1
TSP	45	59.8	490	66	<0.047	90	11.7	1216	0.3	5
TSP	46	62.3	229	70		112		1434		2
TSP	46	95.6		248	0.152	223	9.6	1965		2
TSP	46	78.3								2
TSP	45	80.0		114	0.065	102	4.4	904.		3
NPK 15+15+15	15	5.9	60	39		13	22.8	103		4
compound P		24.20	271.0	54.0	0.424	64.0	46.5	471.0		1
compound P		82.0		135	0.110	90	15.0	720		3
NP 26+14	14	8.60	185.0	68.0	<0.137	49.0	46.5	268.0	20.7	
DAP		0.0	9	31		5	4.8	19		4
DAP		15.10	263.0	52.0	<0.47	48.0	5.5	311.0	18.3	5
Thomasslag	13	3.20	15290.0	216.0	<0.153	88.0	236.5	710.0	25.1	5

1) Delahaye *et al*. 2003; 2) Van Erp and Meeuwissen 1994; 3) Smilde1986; 4) Smolders and Nziguheba 2007; 5) Hotsma *et al*. 1996

Table A.5.7c. The concentrations K_2O, heavy metals and arsenic in K_2O fertilisers, in mg kg^{-1} K_2O

Type	K_2O %	Cd mg kg^{-1} K_2O	Cr mg kg^{-1} K_2O	Cu mg kg^{-1} K_2O	Hg mg kg^{-1} K_2O	Ni mg kg^{-1} K_2O	Pb mg kg^{-1} K_2O	Zn mg kg^{-1} K_2O	As mg kg^{-1} K_2O	Source
Potash salts		0.45	5.9	0.3	0.000	0.0	20.0	28.5		1
KCl 40	40	0.40	3.7	0.3	0.000	7.4	11.0	60.0		1
KCl 40	40	2.5					5.0			2
KCl 40	40	0.4					11	60		3
KCl 60	60	0.13	0.1	0.3	0.000	3.9	1.2	8.4		1
KCl 60	60	0.4	0.3	0.8		3.3	10.8	23.3	4.7	2
KCl 60	60	0.43					11	23.3		3
Patentkali	30	0.03	0.5	0.3	0.000	1.2	1.8	0.3		1
patentkali	30	0.1	1.6	1.0		4.0	3.0	1.0	2.6	
other potasium fertilisers		0.13	7.4	0.3	0.810	45.2	1.2	8.4		1

1) Delahaye 2003; 2) Van Erp and Meeuwissen; 3) Smilde 1986

Data on concentrations of contaminants in K fertilisers are scarce. According to Petersen *et al*. (2009) the straight K fertilisers have very low concentrations of contaminants compared to the phosphatic fertilisers. Also application of potassium in the Netherlands has decreased significant in the last decades, due to the increased use of animal manure for crop production.

Loads of heavy metals

From the data on the application of mineral fertilisers and concentration of heavy metals therein, an approximate load of heavy metals with addition of mineral fertilisers has been be calculated (Table A5.8). For every fertiliser type, the load has been calculated using the lowest and highest figure on heavy metal concentration found. Only the data on concentrations by Van Erp and Meeuwissen (1994) have been excluded. According to Hotsma *et al*. 1996, these data are not realistic for the Netherlands as they are based on old information and partly from other countries, where the parent materials and production processes may differ from those used in the Netherlands.

Table A.5.8a. Calculated loads of heavy metals applied with use of N fertilisers in the Netherlands for the year 2010. Calculated using the minimal and maximal contents of metal as found in literature (Table 7a, but excl. Van Erp and Meeuwissen 1994).

Type	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
CAN (min)	0.060	0.901	0.275	0.000	0.551	0.437	1.102	0.000
CAN (max)	0.060	0.901	2.164	0.060	6.449	0.437	4.860	0.810
MAS (min)	0.001	0.008	0.004	0.000	0.008	0.006	0.015	0.000
MAS (max)	0.002	0.008	0.013	0.000	0.012	0.006	0.432	0.000
straight N	0.033	5.824	0.124	0.015	12.078	0.215	0.496	0.000
total min	0.094	6.733	0.403	0.015	12.637	0.659	1.612	0.000
total max	0.095	6.733	2.301	0.075	18.539	0.659	5.788	0.810

Table A.5.8b. Calculated loads of heavy metals applied with use of P_2O_5 fertilisers in the Netherlands for the year 2010. Calculated using the minimal and maximal contents of metal as found in literature (Table 7b, but excl. Van Erp and Meeuwissen 1994).

Type	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
TSP min	0.225	1.262	0.255	0.000	0.348	0.017	3.497	0.001
TSP max	0.309	1.895	0.441	0.000	0.476	0.045	5.367	0.001
compound (N)P(K) min	0.158	1.617	1.035	0.003	0.355	0.402	2.760	0.555
compound (N)P(K) max	2.200	7.271	3.622	0.011	2.415	1.248	19.319	0.555
total min	0.382	2.879	1.290	0.003	0.703	0.419	6.257	0.557
total max	2.510	9.167	4.063	0.012	2.891	1.293	24.686	0.557

Table A.5.8c. Calculated loads of heavy metals applied with use of K_2O fertilisers in the Netherlands for the year 2010. Calculated using the minimal and maximal contents of metal as found in literature (Table 7c,but excl. Van Erp and Meeuwissen 1994).

Type	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
KCl 40 min	0.000	0.001	0.000	0.000	0.002	0.002	0.001	0.000
KCl 40 max	0.000	0.001	0.000	0.000	0.002	0.002	0.013	0.000
KCl 60 min	0.000	0.000	0.001	0.000	0.007	0.003	0.019	0.010
KCl 60 max	0.001	0.001	0.002	0.000	0.009	0.025	0.052	0.010
Total min	0.000	0.001	0.001	0.000	0.009	0.005	0.020	0.010
Total max	0.001	0.002	0.002	0.000	0.010	0.027	0.065	0.010

Calcareous fertilisers

The application of calcareous fertilisers in the Netherlands has decreased with 60% between 1985 and 2010 (LEI/CBS, 2012). The main source of CaO is sugar factory lime or lime cake (schuimaarde) which is an organic fertiliser resulting from the sugar beet refinery.

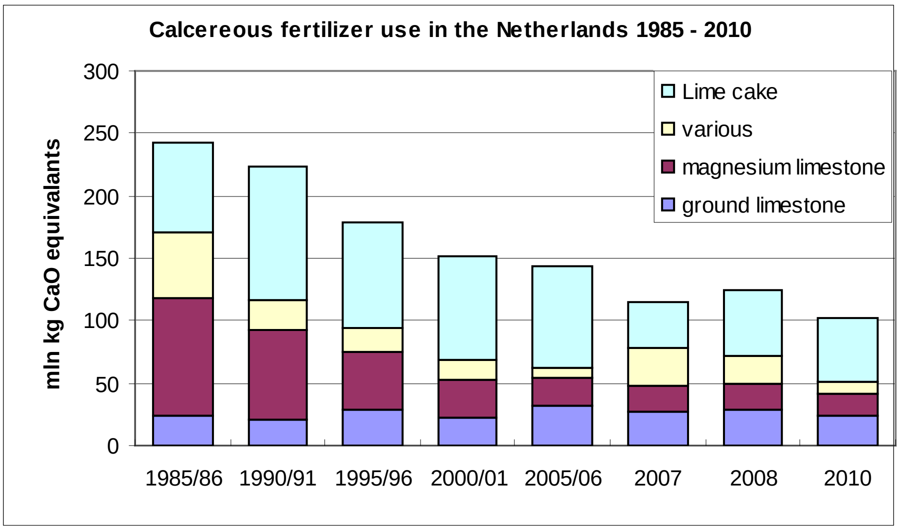

Figure A.5.3. Calcareous fertiliser use in the Netherland between 1985-2010 (LEI/CBS, 2012)

<u>Concentrations of heavy metals</u>

The concentrations of heavy metals in calcareous fertilisers are given by Hotsma *et al.* (1996) (partly recalculated to CaO equivalents by Westhoek *et al*. 1996) and by Delahaye *et al.* (2003).

Table A.5.9. The concentrations of heavy metals in calcareous fertilisers, all in mg kg^{-1} CaO eq.

Type	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Source
ground limestone	0.19	0.8	6.8	0.005	1.7	1.4	15.0		1
ground limestone	0.7	3.02	25.7	0.019	6.4	5.1	56.6		5
magnesium limestone	0.36	1.0	4.1	0.005	3.2	11.9	57.3		1
magnesium limestone	1.3	3.4	15.0	0.018	11.7	43.2	208.2		5
lime cake	1.65	32.5	45.0	0.015	5.0	11.3	179.0		1
lime cake	1.5	28	40	0.02	5.2	9	162	5.9	5

1) Delahaye *et al*,.2003; 5) Hotsma *et al*. 1996 and Westhoek *et al.* 1997

<u>Loads of heavy metal</u>

From the data on total volumes and concentration the loads of heavy metals with the main calcareous fertilisers have been calculated (Table A5.10)..

Table A.5.10. The load of heavy metals and arsenic with to soils in the Netherlands with application of calcareous fertilisers in 2010.

Type	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
ground limestone	0.017	0.073	0.624	0.000	0.156	0.124	1.375	
magenesium limestone	0.022	0.060	0.260	0.000	0.203	0.747	3.602	
lime cake	0.075	1.403	2.004	0.001	0.261	0.451	8.116	0.296
Total	0.114	1.536	2.887	0.002	0.619	1.322	13.093	0.296

Calculated using data from LEI/CBS, 2012 (volumes); and Hotsma *et al*. 1996 (concentrations).

Other (an)organic fertilisers

Information on the volumes and concentrations of heavy metals and arsenic in the so called “other inorganic and organic fertilisers” in the Netherlands is not available.

Sludges

Sewage sludge is not applied to agricultural fields in the Netherlands. All sewage sludge is disposed of to be incinerated; in special sewage sludge incinerators (60%), in cement industry (20%) or in power plants (20%) (CBS, 2012).

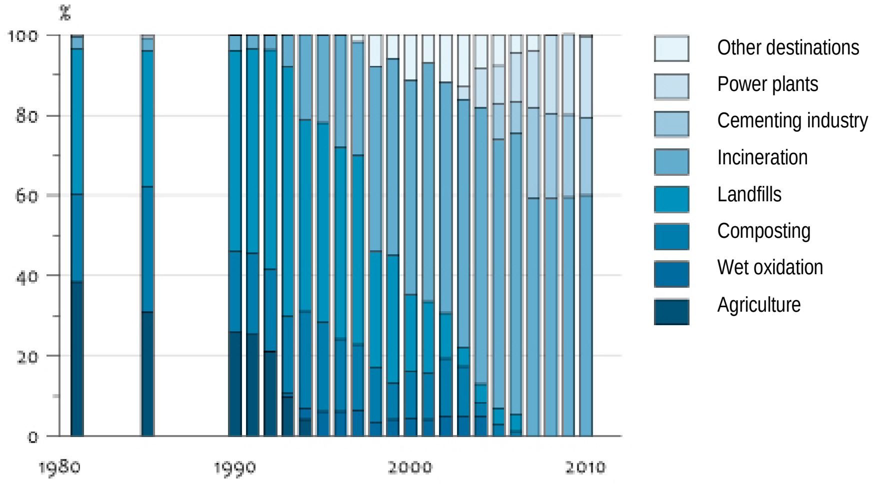

Figure A.5.4 The destination of sewage sludge in the Netherlands between 1980 and 2010 (CBS, 2012)

Sludges from other industries are partly applied to agricultural fields. These are mostly sludges from the agro-food or paper industries.

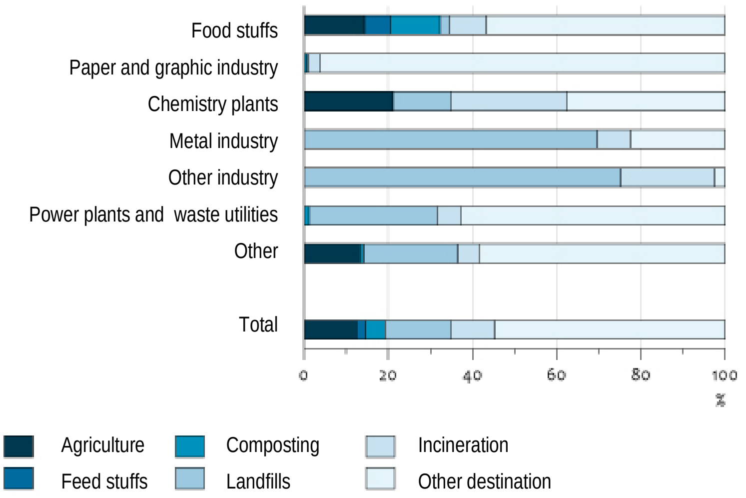

Figure A.5.5. Destination of industrial sludges in 2010 in The Netherlands (CBS, 2012)

The loads of nitrogen, phosphate and heavy metals with the application of sludges to agricultural fields has been monitored from 1980 till 2006. Till 1995, sewage sludge was still applied to agricultural fields. From 1995 on, only industrial sludges were applied, mainly derived from the agro-food and paper industry. In 2006, the monitoring of loads of nutrients and heavy metals was stopped because the applications became too low to be considered relevant.

Table A.5.11. Volume of sludges (sewage or industrial) applied to agricultural soils in the Netherland and the loads of nitrogen, phosphate, heavy metals and arsenic with these sludges (source: CBS Statline 2012)

year	Sewage sludge	Industrial sludge	N	P_2O_5	Cd	Cr	Cu	Hg	Pb	Ni	Zn	As
	10^6 kg DM	10^6 kg DM	10^6 kg	10^6 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg	10^3 kg
1981	69.1	21.0	3.6	8.7	0.4	10	34	0.2	23	2.9	106	0.4
1990	81.6	65.0	4.6	10.1	0.2	4	31	0.1	14	2	74	0.5
1995 [1)]	0.0	29.7	1.5	2.3	0.02	0.5	1.4	0	0.4	0.3	4	0.1
1999 [1)]	0.0	25.6	0.9	1.6	0.06	0.5	1.1	0	0.3	0.2	4	0.1
2000 [1)]	0.0	36.1	1.5	3.0	0.02	0.6	1.3	0	0.4	0.3	5	0.1
2003 [1)]	0.0	34.4	1.6	2.3	0.02	0.9	1.1	0	0.5	0.5	6	0.1
2004 [1)]	0.0	27.7	1.1	2.1	0.02	0.5	0.8	0	0.4	0.3	3	0.1
2005 [1)]	0.0	33.7	1.2	2.5	0.07	0.6	0.9	0.01	0.7	0.4	5	0.1
2006 [1)]	0.0	25.7	1.1	2.7	0.01	0.6	0.9	0	0.8	0.4	4	0.1
2007	0.0	20.5										
2008	0.0	19.9										
2009	0.0	17.2										
2010	0.0	24.0										

[1)]loads of nutrients and metals from industrial sludges only

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Annex 6 Comment on NL standards for compost

The standards for compost cannot be recalculated accurately. Janssen *et al.* (1999) suggested that the dosage of heavy metals resulting from application of compost exceed those from sewage sludge due to the contribution of soil in compost. They suggested that the standards for “clean compost” are explained by the dosage of heavy metals by the standards for sewage sludge plus the contribution from the soil present in compost. They concluded from this that the standards for compost are (partly) derived from those of sewage sludge.

Table A.6.1 Evaluation of the standards for compost in the BOOM .

	Clean compost 6 t ha yr		**“Basisvracht” 70% of soil in compost**		**Sewage sludge 2 t ha yr**	
Cd	6.0	>	1.8	+	2.5	
Cr	300	≈	252	+	150	
Cu	360	>	76	+	150	
Hg	1.8	>	0.9	+	1.5	
Ni	120	>	63	+	60	
Pb	600	>	231	+	200	
Zn	1200	>>	273	+	600	
As	90	≈	71	+	30	

Annex 7 New and old proposals for EU limits for contaminants in fertilisers

The regulations in the report can be compared to various very recent and older proposals. Below, the latest proposal presented in WG3 in a powerpoint presentation in given, and the proposal in the End-of-waste report (JRC IPTS, (2012). Also some of the older EU proposals are given as they have influenced the national legislation of some countries.

Table A.7.1 Various proposals for standards for contaminants in organic fertilisers.

			Working document on sludge 3rd draft [c]					**Proposal EU 2001for Biowaste [d]**		
	EoW [a] 2012	**WG3 [b] 2012**	**proposal**	**Medium term (about 2015)**		**Long term (about 2025)**		**Class 1**	**Class 2**	**Stabilised biowaste**
	mg kg^{-1}		mg kg^{-1}	mg kg^{-1}	g ha^{-1}	mg kg^{-1}	g ha^{-1}	mg kg^{-1}		
Cd	1.5	1.5	10	5	15	2	6	0.7	1.5	5
Cr	100	CrVI	1000	800	2400	600	1800	100	150	600
Cu	100		1000	800	2400	600	1800	100	150	600
Hg	1	1	10	5	15	2	6	0.5	1	5
Ni	50	50	300	200	600	100	300	50	75	150
Pb	120	120	750	500	1500	200	600	100	150	500
Zn	400		2500	2000	6000	1500	4500	200	400	1500
As		30-60								
AOX			500							
PCB		0.2	0.8							0.4
PAH		Σ 6	Σ 6							3
PCD/Fs*		30	100							
DEHP			100							
NPE			50							
LAS			2600							
PFC		0.1								

[a] Technical report for End-of-waste criteria on Biodegradable waste subject to biological treatment Third Working Document August 2012

[b] Organic fertilisers – Max. limit values for non-nutrient metals. Results of the technical working groups for the revision of the Fertilisers Regulation. Fertilisers Working Group meeting. 19th November 2012.

[c] working document on sludge 3rd draft, 2000, http://ec.europa.eu/environment/waste/sludge/pdf/sludge_en.pdf

[d] EU Biowaste directive working document 2nd draft 2001

* ng I-TEQ/kg

Annex 8 Available tools to model the source-receptor pathway

Tools

Various tools are available which can be used in developing fertiliser standards based on the stand still principle and risk based approaches as discussed in the previous chapter. These models/tools can be used to assess the various terms of the mass balance such as , transfer fluxes from soil to plants and leaching fluxes to ground- and surface waters. The same tools have been used to derive agricultural soil limits. The concepts to derive critical soil concentrations aiming at the protection of food quality (human health) and animal health are described by Römkens *et al*. (2008) and have been used to derive the LAC-2006 advisory limits of the Netherlands soil decree. Furthermore these concepts have been implemented in the Risk Toolbox (http://www.risicotoolboxbodem.nl/). Here we give a brief description of the available tools to calculate mass balances of contaminants in soils.

Soil to plant transfer models

Simple models are available which link the concentration of a certain contaminant in the harvestable parts of agricultural crops with the concentration of the contaminant in soil and soil properties e.g. organic matter content and pH. Such relations can be used both to derive critical concentrations in soils and to calculate the uptake flux of contaminants by crops. Such relations have been developed for heavy metals (Römkens *et al*., 2008) and organic micro-contaminants like PFOS and DDT. At present a complete set of soil plant transfer functions for metals and organic micro pollutants has been implemented in the Netherlands model used for site specific risk assessment (CSOIL).
The uptake flux is calculated by multiplying the yield of the product with the concentration of the contaminant in the crop.

Mass balance models

A simple mass balance model is pictured in figure 1. The soil is represented by one layer of soil of a certain thickness usually corresponding to the thickness of the root zone or plough layer. Input fluxes include the load of contaminants due to the application of fertilisers and (when relevant) other inputs e.g. atmospheric deposition. The output fluxes are (1) uptake of contaminants by plants and (2) leaching of the contaminant to deeper layers. Uptake can be calculated using soil to plant transfer models. To calculate the leaching flux one has to calculate the concentration of the contaminant in the soil water phase. Again relations are available which relate the concentration in solution depending on the concentration in soil and soil properties. Such relations have been derived for heavy metals (Römkens *et al*., 2004; Groenenberg *et al*., 2012) and organic micro-contaminants. The leaching flux is calculated as the product of the precipitation surplus and the concentration in solution. For organic micro-contaminants also decomposition of the material has to be considered.

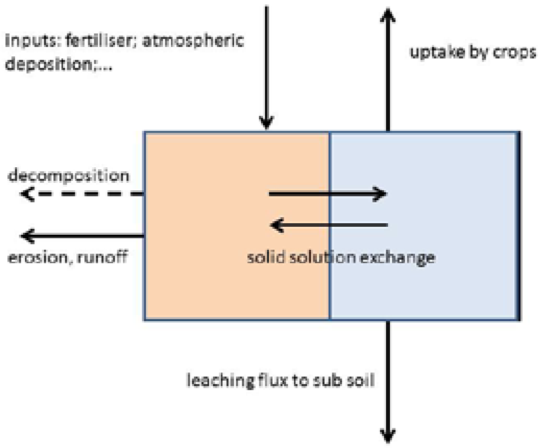

Figure A.8.1 Schematic presentation of the mass balance of contaminants

These one layer models can be used to derive maximum inputs aiming at: (i) stand still of soil concentrations (Chapter 5 concept 1:stand still); (ii) concentration levels in soil aiming at the protection of specified receptors (Chapter 5 concept 2: risk based) and to calculate the maximum input flux related to an acceptable accumulation in soil (Chapter 5, concept 4). Another possibility is to use these models in a geographic context at regional or national scales for scenario analysis to evaluate the effects of certain measures on the long term development of contaminant concentrations in soils. National scale models are available at Alterra for heavy metals (Groenenberg e al., 2006) and at RIVM for organic micro-contaminants (pesticides). The required soil data are available in databases at the national scale and can be extended to the European scale.

To be able to calculate mass fluxes of contaminants to ground- and surface waters the transport of contaminants has to be calculated over a larger depth. Usually a soil column of several meters depth is considered divided over multiple layers of various thickness. For each layer inputs and outputs are calculated according to the same principles as described for the one layer model. Leaching to surface waters is calculated as lateral fluxes from soil layers to ditches and canals. The necessary hydrology (water fluxes) and soil properties are available at national scale within the model framework STONE which was developed by Alterra, RIVM and Deltares to calculate nitrogen and phosphorus fluxes to ground- and surface water. Present contents of heavy metals (for various depths) were mapped by Alterra. National scale models have been used to evaluate heavy metal accumulation and leaching to ground- and surface waters for various scenarios of present and reduced heavy metal inputs due to inputs with fertilisers and manure (Groenenberg, 2011). An example of such an approach is illustrated in Figure A6.1 which gives present metal contents in soil and future metal contents in year 2100 when fertilisers are applied in present amounts and present quality (Groenenberg, 2011).

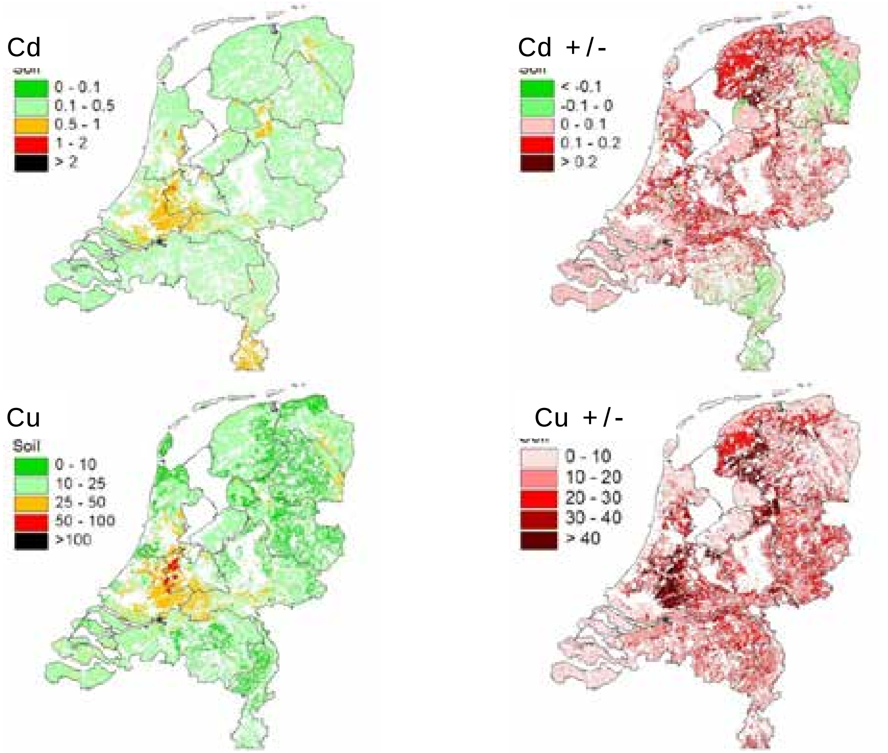

Figure A.8.2 Cd and Cu concentrations in soil (mg.kg^{-1}) in 2000 (left) and changes in soil metal concentration (in mg kg^{-1}) in 2100 (right) in case of a continuation of the current land use and manure application rates

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Thema Agromilieu
Wettelijke Onderzoekstaken
Natuur & Milieu
Postbus 47
6700 AA Wageningen
T (0317) 48 54 71
E info.wnm@wur.nl

www.wageningenUR.nl/
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