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Liming for Quality Protection

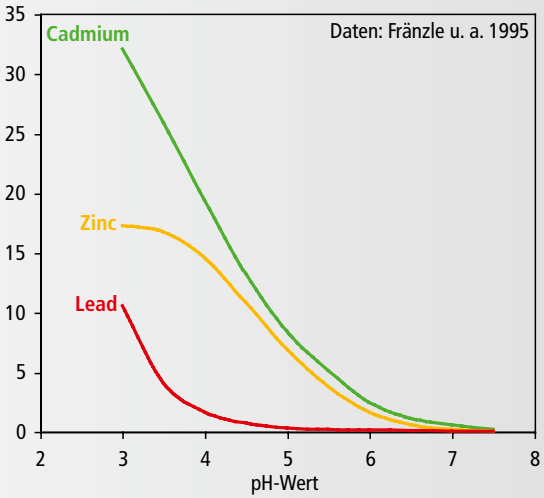
Specific Background

In foodstuffs and animal feed certain heavy metal maximum contents may not be exceeded when they are placed on the market or fed. The legal basis is regulated in the Foodstuffs and Animal Feed Law. The allowed maximum contents for lead and cadmium in vegetable foodstuffs and for arsenic, lead, cadmium and mercury in vegetable animal feed are laid down in national and in EU-regulations.

No legally binding maximum contents exist for other inorganic elements like copper, nickel, thallium and zinc. Instead suggested values for maximum heavy metals concentrations in animal feed are available, which aim at the protection of agricultural livestock.

Heavy metals in the soil are increasingly available for plants if the pH-value is low. Therefore, to assure a good plant quality and to observe the allowed maximum contents, a balanced lime supply of arable and grass land soils is recommended. This is the case even more if there are increased heavy metal contents in the soil.

Plant-available part (% of total content)



Prevention-, Test- and Measures-Limits of the German Soil Protection Law

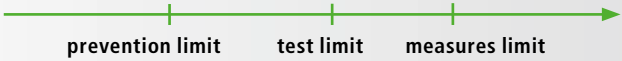
The Federal Soil Protection and Contamination Ordinance contains limit values for prevention, tests and measures.
If the harmful substances remain below the **prevention** values, and if good agricultural practices i.e. sufficient lime supplies are ensured, the plant quality is not expected to be endangered.

If the harmful substances in the soil exceed the **test** values, it has to be checked – taking into account the concrete conditions of the location - whether the plant quality (= exceeding the maximum values acc. to foodstuff legislation) and thus the crop are in danger. Should the values for **measures** be exceeded, this as a rule is due to harmful soil changes, meaning that there is an unacceptable risk of exceeding the maximum values for the respective undesired substances in foodstuffs or animal feed.

If the heavy metal contents lie in between the precaution and the test-/measure values, they remain below the risk area acc. to legal soil protection. However there is still an undesired risk that, under adverse conditions and with a low probability, the excess of maximum contents in the crop may occur. Such adverse conditions may be caused e.g. by acidified soils.

Difference between prevention and averting of a danger

Prevention		Averting of a danger	
damage imaginable, but unlikely	under continuous impact risk of damage	area of uncertainty	event of damage sufficiently probable
rest risk	undesired risk	check risk	unacceptable risk



Prevention-, Test- and Measures-Limits of the Federal Soil Protection and Contamination Ordinance (mg/kg soil)

Damaging Substance	Analytical method[1]	Arable Land/Grassland – Prevention limits acc. to soil types: Sand	Loam	Clay	Arable Land/Kitchen Garden (plant quality): Test Value	Measures value	Arable Land (growth interference): Test Value	Grassland (plant quality): Measures value
arsenic (As)	aqua regia	-	-	-	200/50 [2]	-	-	50
	AN	-	-	-	-	-	0,4	-
Lead (Pb)	aqua regia	40	70	100	-	-	-	1.200
	AN	-	-	-	0,1	-	-	-
Cadmium (Cd)	aqua regia	0,4	1	1,5	-	-	-	20
	AN	-	-	-	-	0,04/0,1 [3]	-	-
Copper (Cu)	aqua regia	20	40	60	-	-	-	1.300/200 [4]
	AN	-	-	-	-	-	1	-
Nickel (Ni)	aqua regia	15	50	70	-	-	-	1.900
	AN	-	-	-	-	-	1,5	-
Mercury (Hg)	aqua regia	0,1	0,5	1	5	-	-	2
	AN	-	-	-	-	-	-	-
Thallium (Tl)	aqua regia	-	-	-	-	-	-	15
	AN		-	-	0,1	-	-	-
Zinc (Zn)	aqua regia				-	-	-	-
	AN	60	150	200	-	-	2	-

1) = aqua regia (total content) / AN Ammonium Nitrate Extract (easily soluble part)
2) = For soils with temporarily reduced conditions (= ground water and water logging) the test limit is 50 mg/kg
3) = for areas with soft wheat crops or crops with cadmium-fortifying vegetables the measures value of 0,04 mg/kg is applicable, otherwise it is 0,1 mg/kg
4) = for grassland used by sheep the measures limit is 200 mg/kg

Note: The test- and measures values for heavy metals in soils were derived from analytical data in soils and plants. Only where the amount of data was sufficient, the test- and measures limits were included in the Federal Soil Protection and Contamination Ordinance.

For this reason measures reducing the harmful substances transfer from the soil to the plant become more important, the closer the heavy metal contents approach the test- and measure limits.

Harmful Substances Situation of Agriculturally Used Soils

Normally agriculturally used soils show unproblematic heavy metal contents. However, increased heavy metal contents may occur in regions with parent rock rich in heavy metals (geogenic part) or in regions with significant anthropogenic contamination. Considerable anthropogenic immissions of heavy metals can be found near mining and industrial centres. Thereby the damaging changes in soil are often caused by historical immissions of the iron ore smelting and the metal industry.
This is especially the case with wetland soils in mining and industrial regions; at high water marks contaminated suspended sediments are deposited on the meadows. Thanks to the air and water environmental policy the harmful substances immissions have decreased considerably in the last years.
Regions with partly clearly increased heavy metal contents can be found in all historic ore mining areas, like e.g. Erz Mountains, Harz Mountains, Sauerland, Black Forest or Stolberg near Aachen and in the wetlands of the rivers in these regions. The exact boundaries and contamination situation of regions with increased contents of harmful substances in the soil can be inquired at the responsible official administration offices.

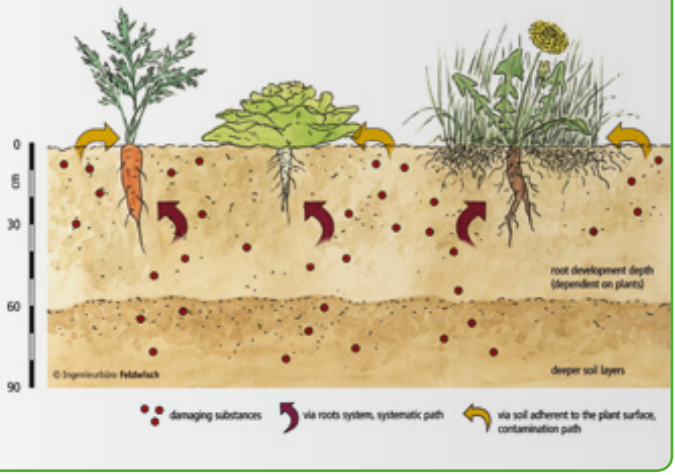
Plant Absorption of Heavy Metals

Heavy metals get into plants in two ways. Either dissolved heavy metals are absorbed by the roots with the soil water and thus arrive at the harvested crops. Or the contamination with soil on the plant surface is responsible for the heavy metal contents in the harvested crops.

The absorption via the root depends on the properties of the heavy metals as well as the pH value, i.e. on the lime condition of the soil. Simplified the following sequence of declining absorption rates via the roots is applicable:
Cd, Zn > Cu, Ni >> As, Cr, Hg, Pb, Tl

Due to specific binding forms these metals react differently to liming measures. The Cd- and Zn-uptake by the roots is very strongly influenced by the lime condition; below 6 pH these elements become increasingly plant-available. This is true also, but on a smaller scale, for Cu and Ni.

Transfer of damaging substances from soil to plant



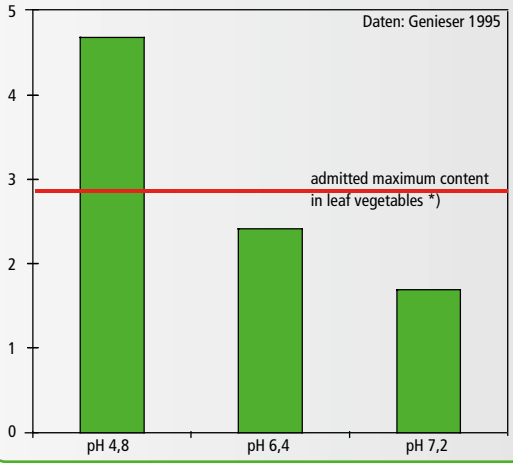
Pb becomes plant-available only in very acidified soils below 5 pH and can then increasingly be absorbed by the roots. Therefore an immobilisation of plant-available lead with liming measures is only effective on strongly acidified soils.

A connection between the lime condition and the root absorption does not exist for the other elements As, Cr, Hg and Tl. The content of these elements is mainly caused by contamination of the harvested crop with soil material.

Liming for Limitation of Heavy Metal Absorption via the Roots

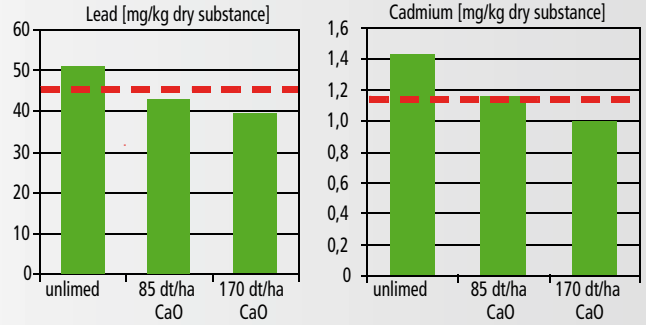
The plant availability of some heavy metals decreases with increasing pH values. This effect can be used to lower the heavy metal absorption of the plants, and thus to minimise the respective contents of undesired substances in plants.

Cadmium in spinach (mg/kg dry matter)



*) max. content of fresh weight of spinach (93% water or 7 % dry matter) is 0.2 mg/kg

In order to reduce the plant-available part of heavy metals in the soil, within the frame of good practice the pH/lime supply Class C should be maintained by regular preservation liming. Under these conditions as a rule the plant availability of harmful substances is clearly reduced. Spinach and grassland growth as examples of successful liming measures are illustrated below:



Heavy metal contents in grassland growth acc. to different liming intensities (acc. to Kowalewsky & Vetter 1982). Red, dashed lines: admitted maximum contents in dry matter.

Effectiveness of Liming

The contents for the heavy metals CD and Pb in foodstuffs, whose plant availability is influenced by the pH value, remain below maximum with great probability at pH levels above 6, if the following total contents in arable and horticultural land are not exceeded:

- Cadmium 2 mg/kg soil (analysis with aqua regia extract)
- Lead 250 mg/kg soil (analysis with aqua regia extract)

These threshold values for Cd and Pb in soil can e.g. be used for evaluation of soil analysis with respect to sewage sludge or bio waste application, because the relevant analytical results are gained by aqua regia extract. The test and measures values of the Federal Soil Protection and Contamination Ordinance for Cd and Pb are valid for the ammonium nitrate decomposition. Insofar the mentioned threshold values for Cd and Pb complement the legal

soil protection measures and/or analytical values and, as a rule, combine this with the estimation of a secure averting of a danger. To observe the maximum contents in animal feed the influence of the pH level is less relevant than it is the case with the cultivation of food stuffs. This is based on the fact that the heavy metal contents in animal feed are – apart from the absorption via the roots – mainly determined by contamination with soil at the plant surface. Cd is the exception: at low pH levels Cd is increasingly absorbed by the roots of the forage plants. Therefore it is recommendable to maintain a pH value of > 6.5 at cadmium contents of 5 – 20 mg/kg soil. At the same time measures for reduction of animal feed contamination with soil should be initiated (see below). A content of above 20 mg Cd/kg soil is critical with regard to the animal feed security (measures limit value acc. to Federal Soil Protection and Contamination Ordinance).

On all production locations with As or Hg pollution above the analytical and measures values as laid down by the Federal Soil Protection and Contamination Ordinance, it cannot be expected that a pH level optimisation excludes the risk of exceeding the allowed maximum values. Therefore apart from the preservation liming further measures should be taken (see below).

For the heavy metals copper, nickel, thallium and zinc without binding maximum values acc. to foodstuffs and animal feed legislation, only the analytical and measures values acc. to soil protection law are relevant. If the soil is contaminated with copper, nickel and zinc above these values, an absorption by the plant can be limited by a pH level optimisation. In the case of contamination with thallium liming is ineffective.

Further Measures for Quality Assurance

In the case of extremely high heavy metal contents in soils, which are multiply above the analytical and measures values acc. to the Federal Soil Protection and Contamination Ordinance, the plant

quality cannot be ensured solely with liming measures. In these cases particularly the following measure are to be considered:

- **Plant species and variety:** The heavy metal absorption differs from species/variety to species/variety, so that with a selection of species/varieties the foodstuff and animal feed quality can be influenced.
- **Harvesting and grazing methods with low contamination risk:** With regard to animal feed all means reducing contamination should be used, i.e. driving and grazing only on sward with high load bearing, plant care to obtain dens swards, reduction of stocking rate, reduction of the specific ground pressures when driving on the land, mower and haymaking machinery should not be too low (working height > 8 cm) etc.
- **Supply with humus:** A sufficient supply with humus contributes to the immobilisation of damaging substances.
- Detailed descriptions of further measures can be found in the literature as quoted below.

Further Advantages of a Balanced Lime Supply

A balanced lime supply does not only reduce the heavy metal absorption. Liming is also accompanied by an improved soil structure, so that the water and air balance in the soil are positively affected. The rain digestion increases, the danger of puddled soil surface and erosion decreases and the load bearing capacity is improved. Furthermore the soil organisms are activated. All effects contribute to safeguarding and improving the crop yield.

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