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NEW BULGARIAN SOIL POLLUTION STANDARDS

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Abstract

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Recently in Bulgaria have been adopted new quality standards for soils polluted by arsenic, cadmium, copper, chromium, nickel, lead, mercury, zinc and cobalt, set on the base of three level system according to precautionary, maximum permissible (trigger) and intervention concentrations. The precautionary values are derived on the base of the background concentrations of the above mentioned inorganic substances into the soils. Maximum permissible (trigger) values are derived on the base of (eco) toxicity considerations for three pathways: soil-humans (direct intake); soil-food and fodder plants and soil-groundwater. The maximum permissible values are set for four land use types: arable lands, permanent grasslands, residential areas and for lands occupied by industrial/ commercial enterprises. These values are differentiated for three soil pH (H_2O) and for two soil textural classes: soil with coarse and medium texture and fine textured soils.

The intervention values are defined as 3 – 5 times of maximum permissible concentrations for three land-use types: agricultural lands (arable lands + grasslands), residential and industrial/commercial areas.

The purpose of the presentation is to describe the methods used for derivation the soil quality standards and to show the ways for their implementation.

Key words: soil quality standards, precautionary, maximum permissible (trigger) and intervention values, inorganic soil contaminants

Introduction

Soils, polluted by heavy metals and arsenic in Bulgaria are more or less well investigated and mapped. According to some estimations (Todorova, 2002) the total area of soils, polluted by different chemical substances is approx. 43 600 ha. They are located in vicinity of ferrous and non-ferrous metallurgical industrial enterprises, near highways and areas with chemical industry. In most cases the polluted soils contain a mixture of heavy metals. Between more widespread inorganic pollutants can be mentioned lead, copper, zinc, cadmium. Some soils are contaminated by arsenic.

Chemically polluted soils occupy comparatively small area of the country (only 0.2 % from the total territory), but the risks created by them on humans, animals, plants and ground waters is too high. Because of that it is important to develop criteria and set up standards which can be used for assessment the degree of the risk coming from contaminated soils.

The first standards for assessment the lead, copper and zinc polluted soils were set up in 1979. In 1994 the Ministry of Agriculture and Forestry (MAF)

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of Bulgaria has adopted new quality standards (still in force) for assessment the degree of pollution of the agricultural soils caused by heavy metals, oil products, radio nuclides, high salts content and affected by alkaline substances. For inorganic substances including arsenic, cadmium, copper, chromium, nickel, lead, mercury, zinc and selenium have been set two categories of quality standards: maximum permissible and intervention values, measured as concentration of each individual pollutant (mg/kg, total amount) in the upper soil horizon. The both were designed as generic numerical values, and the maximum permissible concentration values being differentiated for six pH (H_2O) of the soil. According to the concentration of each individual pollutant the soils are divided into three main categories: none polluted (level A), weakly, moderately and strongly polluted (level B) and extremely polluted (level C).

The 1994 soil quality standards are not effect-based and do not reflect other land use types besides agriculture. Some numerical values are not corrected on the base of the current research data. These and other disadvantages, analyzed by Sauerbeck (1996) made necessary development of new, third generation soil quality standards for polluted soils, now adopted officially by the Ministry of Environment and Water of Bulgaria.

This article present the methods used for derivation the new soil quality standards and their implementation for risk assessment the metal polluted soils.

Basic Concept

The Bulgarian Law of Environment Protection (2002) considers the soil as a limited, indispensable and non-renewable natural resource which has to be protected, used in a sustainable way and restored in order to protect human health and soil multifunctionality. One of the purposes of the soil protection is prevention or elimination of adverse changes of soil quality due to the processes of soil contamination. Like other European countries, the Bulgarian policy to contaminated lands is based on the recognitions of the pollution prevention, polluter pays principle, the precautionary principle and to use a procedure for risk assessment in order to identify the needs for remedial action. According to the Law, a special soil quality standard has to be developed as an instrument for appraisals the degree of pollution and risk assessment.

The updated soil quality standards are set on the base of the concept of three level system including precautionary, maximum permissible (trigger) and intervention concentrations. The three level system are widespread and are implemented in many European countries (Anonym, 1998, 1999; Fergusson, 1999). This system is accepted in the new Bulgarian Soil Protection Act /not yet adopted by the Parliament/ where definitions for “precautionary”, “maximum permissible” and “intervention” values are presented.

The precautionary levels of concentrations are defined as values which indicate that the soil is not contaminated but contains contaminants higher than background concentrations. This shows possible unfavorable soil changes in future which have to be avoided.

The maximum permissible (trigger) concentrations are perceived as values, which indicate that soil is contaminated but in the frame of acceptable risk. Investigations are needed in order to define the real risk related to current or intended lands use.

Intervention values are defined as a concentration of a contaminant in the upper soil horizon, which if exceeds, should be considered as a harmful and create an unacceptable risk for human under the specific soil use. Measures are required (interventions) to clean up affected soils or to change the land use type. According to this concept, precautionary, maximum permissible (trigger) and intervention values have been derived.

Derivation of Soil Quality Standards

The precautionary values are derived on the base of reference background values of the inorganic substances in the soil. During 1999 – 2002 a special investigation has been carried out (Atanassov at al., 1999, 2002) in order to summarize existing data on the concentration of As, Cd, Cu, Cr, Ni, Pb, Hg and Co in the soils, located in non contaminated or background territories of the country. The obtained background concentrations didn't vary significantly between different soils and because of that it was possible to establish generalized background values equal to all soils. The 90 percentiles values of the observed background concentrations have been accepted as *reference* background values for above mentioned substances. The soil reference background values are related to the top (A) horizons of the mineral soils and can be defined according LABO (1995) as values, which indicate the geogenic basic contents as well as the general anthropogenic additional pollution of the soils. For setting precautionary standards the calculated soil reference background values have been doubled (Table 1). The precautionary values have been designed principally for soils with pH > 6.0 and pH< 6.01 and for three soil textural classes: coarse, medium and fine textured soils. The values may be applied all over the country with exception the soils with extremely high natural (geogenic) metal content or metal polluted soils.

The maximum permissible (trigger) as well as the intervention values have been derived on the base of (eco) toxicity considerations, taking into account the impact of metal polluted soils on humans (direct intake), food and fodder plants and underground water. To derive maximum permissible (trigger) values for pathway: soil-human beings (direct intake) a calculation can be used proposed by Hammann and Gupta (1998):

$$TVsoil,\ mg/kg = \frac{bw\ ADI.e}{SI} \qquad (1)$$

where: TV – trigger values;
bw – body weight of a sensitive group of children = 20 kg;
ADI – acceptable daily intake of a pollutant from soil;
e - % of daily direct intake of a pollutant from soil;
SI accepted daily direct intake of soil (oral or through inhalation) from a member of a sensitive group of the population (g/daily).

The maximum permissible (trigger) values for the pathway: soil – food and fodder plants have been derived on the base of five step procedure used by W. Kцrdel at al (2003),and K. Terytze et.al. (2006) for derivation trigger values for soils polluted by persistent organic pollutants (POPs). The procedure includes

- Consideration of maximum residue (tolerable) level (MRL) in four group of plants: cereals, vegetables, fruits and fodder plants;
- Quantitative description of soil-plant uptake including calculation of transfer coefficients (Tc) and derivation of maximum permissible soil concentration (MPC) for each individual inorganic substance;
- Plausibility check, including expert judgment;
- Final stipulation of trigger values on the basis of Realistic Worst Case (RWC) scenario;
- Comparison with trigger values adopted in other countries for inorganic substances.

A key point of the procedure is obtaining data for maximum residue (tolerable) level. To calculate MRL values Atanassov (2004) have been carried out an investigation to summarize information from three sources: (1). Data from field, greenhouse and laboratory experiments with agricultural plants carried out on metal-polluted soils, on soils with added or known concentration of a pollutant in the soil and plant; (2). Data from field investigations of metal polluted soils and plants growing on these soils and (3). Calculated MRL according the method proposed by Kцrdel at al. (2003) in case of absence of reliable data.

The major disadvantages of this approach is lacking of sufficient data and knowledge concerning the thresholds and (eco) toxicity data for pathways soil-humans, soil-plants and soil-ground water. This is because the field and/or greenhouse experiments in many cases have been carried out for other purposes but not directly for establishment the relation between the concentration of the pollutants in the soil and impact on plant-water-other organisms.

To obtain numerical values from maximum permissible (trigger) concentrations in soil for inorganic substances an equation has been used, proposed by Kцrdel at al. (2003):

$$MPC\ soil = \frac{HF.MRLi\ (mg/kg)}{SF.\ Tc} \qquad (2)$$

where: MPC soil – maximum permissible concentration of metal in soil, mg/kg;

MRLi – maximum residual level for plant i ;

Tc – Transfer coefficient;

HF – hazard factor in order to relate the value to the precautionary aspect to hazard;

SF – Safety factor, used in case where not an optimal soil data are available.

The obtained maximum permissible (trigger) concentrations (Table2) are designed for four land use type: (a) Arable lands; (2) Permanent grasslands; (3) Residential areas, parks, and recreation site/facilities and (4) Lands occupied by industrial/commercial enterprises. These values in addition are designed for three soil pH (H_2O): (a) for soils with pH < 6.0; (b) soils with pH 6.0 – 7.4 and (c) soils with pH > 7.4. The maximum permissible (trigger) values are related to the soil texture. Approx. 80 % of the Bulgarian soils are medium, 9 % - coarse and 11 % - fine textured soils. The derived maximum permissible values are related to the medium and coarse textured soils. For fine textured soils (soils, containing in the upper soil layer particles smaller than 0.01 mm more than 60 %) the numerical values set for medium/coarse textured soils have to be multiplied by the empirically derived correction factors which vary between 1.2 up to 1.3 (Table 3). Other soil properties like organic matter content are not taken into account. The reason is that more soils of the country (more than 90 %) contain organic matter in the upper soil horizons between 1 and 3.5 % (average 2.2 %).

The intervention values have been designed for three land use types: for agricultural lands (arable lands + grasslands), for residential areas/parks and for industrial areas. For pathway: soil-food and fodder plants, the intervention values are defined as 3 – 5 times of maximum permissible concentrations, found according equation (2) and applying Best Case (BS) scenario. For the areas occupied by industrial/commercial enterprises the intervention values are based mainly on expert judgment and comparison with intervention values set in other countries. The established numerical intervention values are not corrected according soil properties. These values are equal for all soil under given land use type and include all relevant exposure pathways, e.g. soil ingestion, crops consumption, inhalation of soil contaminants, consumption of groundwater or dermal contact with contaminated soils.

Discussion

Soil quality standards are important instrument for implementation the soil protection policy. The quality standards can be applied as a decision-support tool in risk assessment of polluted soils and their impact on human health, water resources and other environmental compartments.

The assessment procedure is based on the measurement of the content of a particular substance in the soil and comparison the observed concentration with soil quality standards, expressed in table 1, 2 and 3. Generally, three levels of concentrations can be defined.

– The first, A-level, when the observed concentration of a particular substance (inorganic compound) in the soil is less than maximum permissible (trigger) value set for this substance or is closer to the reference background or precautionary values. The soil can be considered as multifunctional, without suspi-

Table 1
Reference background concentrations and Precaution values for As, Cd, Cu, Cr, Ni, Pb, Zn, Hg and Co in the soils of Bulgaria (in mg/kg dry soil, aqua regia extraction)

Soil	As	Cd	Cu	Cr	Ni	Pb	Zn	Hg	Co
Reference background concentration									
Standard soil	10	0.4	34	65	46	26	88	0.03	20
Precaution values									
Coarse textured soils	15	0.6	50	90	60	40	110	0.05	30
Medium textured soils	15	0.6	60	110	70	45	160	0.07	35
Fine textured soils	20	1	70	130	70	50	180	0.08	40
Soils with increased natural content	To be established on the base of local background concentrations								

Explanations: 1). Standard soils – soil with pH (H_2O) = 6.0

2). Coarse, medium and fine textured soils; with content of particles < 0,01 mm respectively up to < 20 %, 20-60 and > 60 %.

cion to be hazardous for public health or the environment.

– The second B- level, when the observed concentration of one or more substances in the soil is between maximum permissible and intervention values: the soil can be considered as contaminated, but the level of concentration does not create immediate risk for humans, environment or particular land use Further investigations are needed to ascertain whether the found level of concentration implies a danger.

– The third C-level, when the concentration of a particular substance in the soil is higher than the intervention value set for this pollutant: the soil can be considered as unacceptably polluted. The level of concentration of the particular substance implies a danger which has to be avoided through providing of remedial action (intervention) or changes of actual use of the land.

The application of soil quality standards for assessment the level of contamination needs obtaining reliable data for concentration of the pollutants into the soil. This can be made through field investigations, laboratory analyses and appropriate statistical treatment of the data obtained.

The procedure for investigation the contaminated soils include the following consecutive steps:

– Preliminary investigation of the suspected contaminated soil/sites and the polluted areas;

– Detailed investigation of the contaminated soil/sites and mapping;

– Relative risk rating to prioritize contaminated soils within each locality;

– Development of proposals for safety land use and/or projects for remediation of the damaged soils;

– Monitoring and management the area where remediation/reclamation activities have been carried out.

Soil sampling strategy includes preparing of mixed soil samples, each composed of nine individual samples equal in volume, taken in hexagonal grid of sampling pattern. The density of sampling points depends on the purposes of the investigation. The sampling depths are fixed to upper soil horizons: for arable lands-0-20 cm. and for non-cultivated soil- 0-10 cm. The laboratory methods used for analyzing the metal content in the soil include aqua regia extraction according ISO/DIN 11466(1997).These methods permit the determination of the fraction closely related to the total content of the metal in the soil which potentially can be released in the course of weathering processes

Table 2

Maximum permissible (trigger) and intervention values for As, Cd, Cu, Cr, Ni, Pb, Hg and Zn in agricultural lands and grasslands according to texture and pH of the soil (mg/kg dry soil, aqua regia extract)

Substances	pH (H_2O)	Trigger values		Correction coefficient, Cc	Intervention values for land used types in columns 3 and 4
		Agricultural lands	Grasslands		
1	2	3	4	5	6
Arsenic –As	-	25	30	1.2	90
	<6.0	1.5	2		
Cadmium – Cd	6.0 – 7.4	2	2.5	1.3	12
	>7.4	3	3.5		
	<6.0	80	80		
Copper - Cu	6.0 – 7.4	170	170	1.2	500
	>7.4	200	200		
Chromium – Cr	-	200	250	1.2	550
	<6.0	77	70		
Nickel - Ni	6.0 – 7.4	75	80	1.2	300
	>7.4	90	110		
	<6.0	60	90		
Lead – Pb	6.0 – 7.4	100	130	1.3	500
	>7.4	120	150		
Mercury - Hg		1	1	1.2	10
	<6.0	150	110		
Zinc - Zn	6.0 – 7.4	250	270	1.3	900
	>7.4	300	320		

Explanations:1). pH (H_2O); 2). Cc is applied when the content of particles smaller then 0.01 mm in upper soil layer is more 60 %

Table 3

Trigger and intervention values for As, Cd, Cu, Cr, Ni, Pb, Hg and Zn in soils for urban and industrial areas (in mg/kg dry soil, aqua regia extraction)

Substances	Residential areas, parks, sport facilities		Industrial/commercial areas	
	Trigger values	Intervention values	Trigger values	Intervention values
Arsenic - As	25	50	40	120
Cadmium - Cd	8	12	10	40
Copper - Cu	300	500	500	1000
Chromium - Cr	200	550	300	600
Nickel - Ni	100	300	250	700
Lead - Pb	200	500	500	1000
Mercury - Hg	8	10	10	40
Zinc - Zn	400	300	600	1500

and expresses the maximum hazard potential (Terytze, 2002).

Nevertheless, the procedure for investigation the contaminated soils/sites is still not yet thoroughly developed. The contaminated soil risk assessment is not adequately integrated with risk assessment of surface and underground water and biodiversity. In relation to contaminated land remediation practices there are no defined rules how to implement the intervention values as remediation targets. These and other problems have to be solved in the near future.

Conclusion

The soil quality standards set according to precautionary, maximum permissible (trigger) and intervention values are important tool for more realistic assessment the degree of contamination of soils polluted by inorganic substances. The precautionary values can be derived using background concentrations for arsenic, cadmium, copper, chromium, nickel, lead, mercury, zinc and cobalt in soils. For derivation the maximum permissible (trigger) and intervention values can be used (eco) toxicity data taking into account the impact of metal polluted soils on humans, food and fodder plants and underground water.

The obtained maximum permissible (trigger) concentrations are designed for four land use types, namely: arable .lands, permanent grasslands, residential areas and territories occupied by industrial/commercial enterprises. The values are differentiated according site specific characteristics like soil pH (H_2O) and soil textural class.

The intervention values have been designed as 3-5 times of maximum permissible concentrations found according equation (2) and applying Best Case (BC) scenario and corrected on the base of expert judgment.

The new soil quality standards can serve as an instrument for implementation the soil protection policy in the country. The intervention values can be used as soil clean-up objectives. Further improvements of the methods for soil risk assessment are needed through integration with risk assessment of water, air and biodiversity.

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