

National Inventory of Potential Sources of Soil Contamination in Cyprus

Part 2

Risk-Based Approach to Assessment of Cypriot Contaminated Sites

Eleonora Wcislo and Marek Korcz

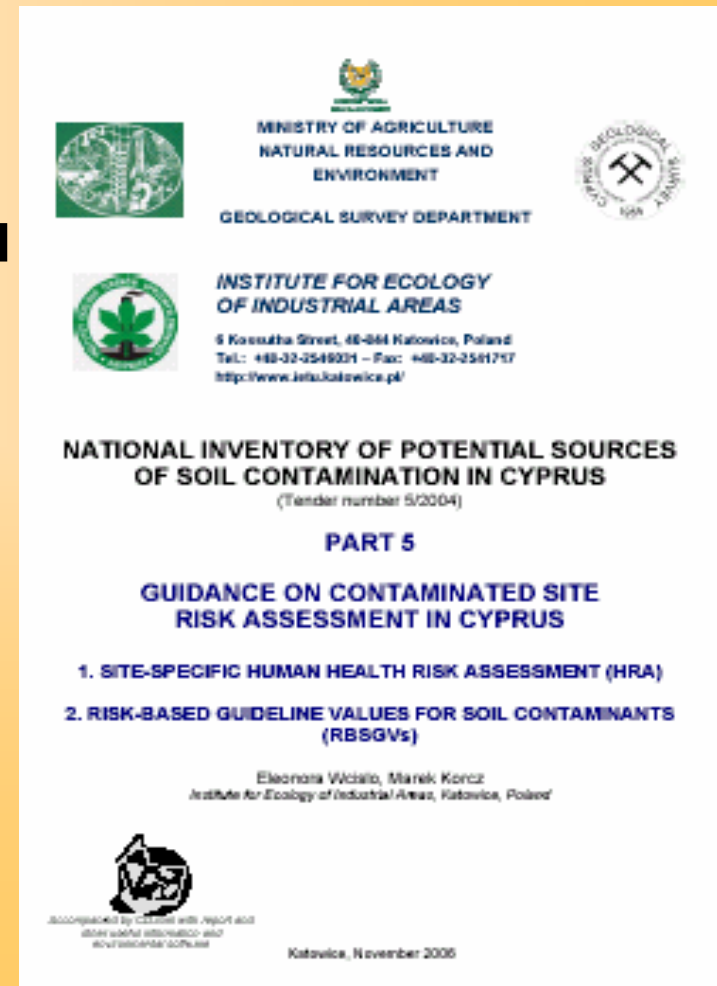
Institute for Ecology of Industrial Areas, Katowice, Poland

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Guidance on Contaminated Site Risk Assessment in Cyprus

- risk-based approach to assessment of Cypriot contaminated sites
- methodology for developing risk-based soil guideline values (RBSGVs)
- RBSGVs for Cypriot soil contaminants under different land use patterns
- chemical-specific data
- methodology for site-specific human health risk assessment (HRA)



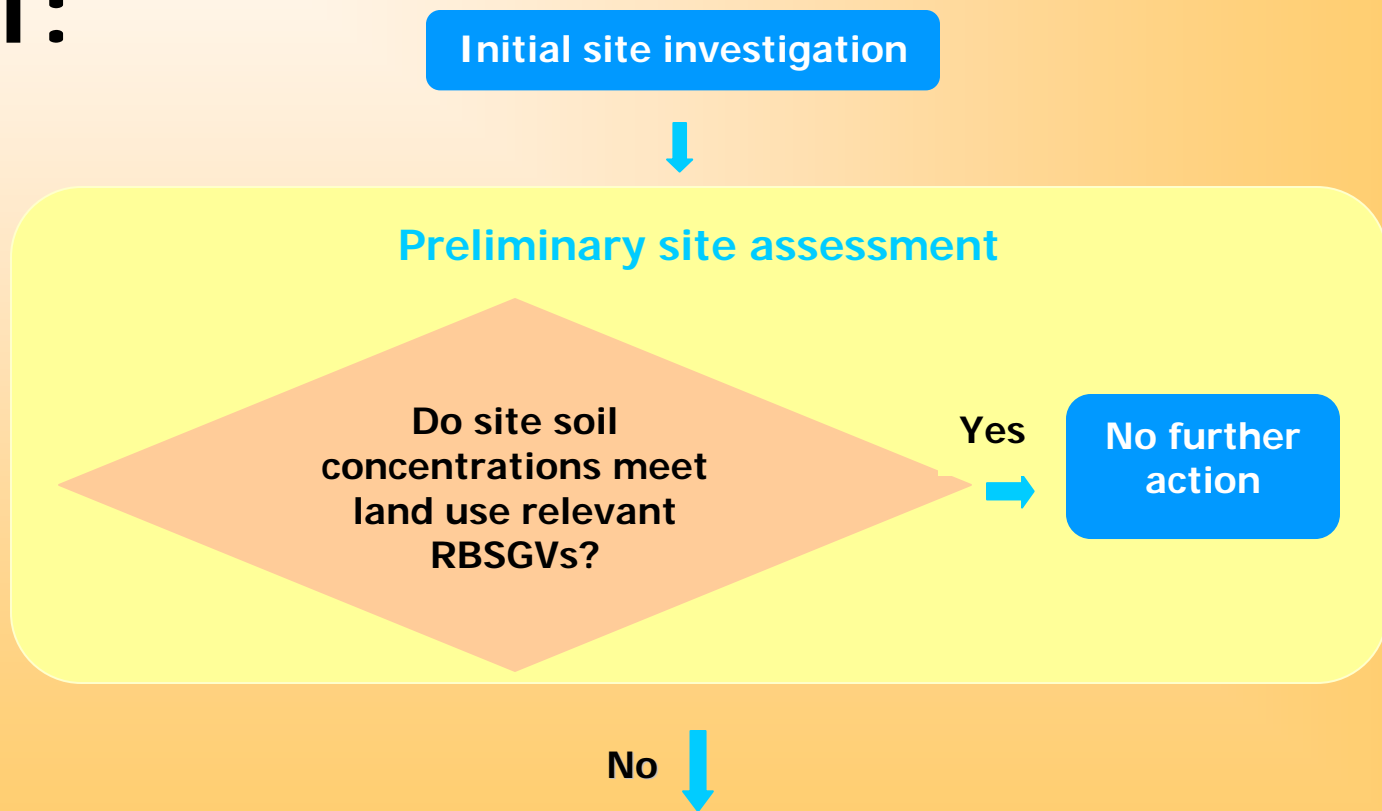
Risk-based approach characteristics

- two-step assessment process
- refers to human receptors
- considers three land use patterns – industrial, residential and recreational
- refers to current and/or future land use patterns
- adopted the recent US EPA risk assessment procedures (US EPA 1996, 2000, 2001, 2002)

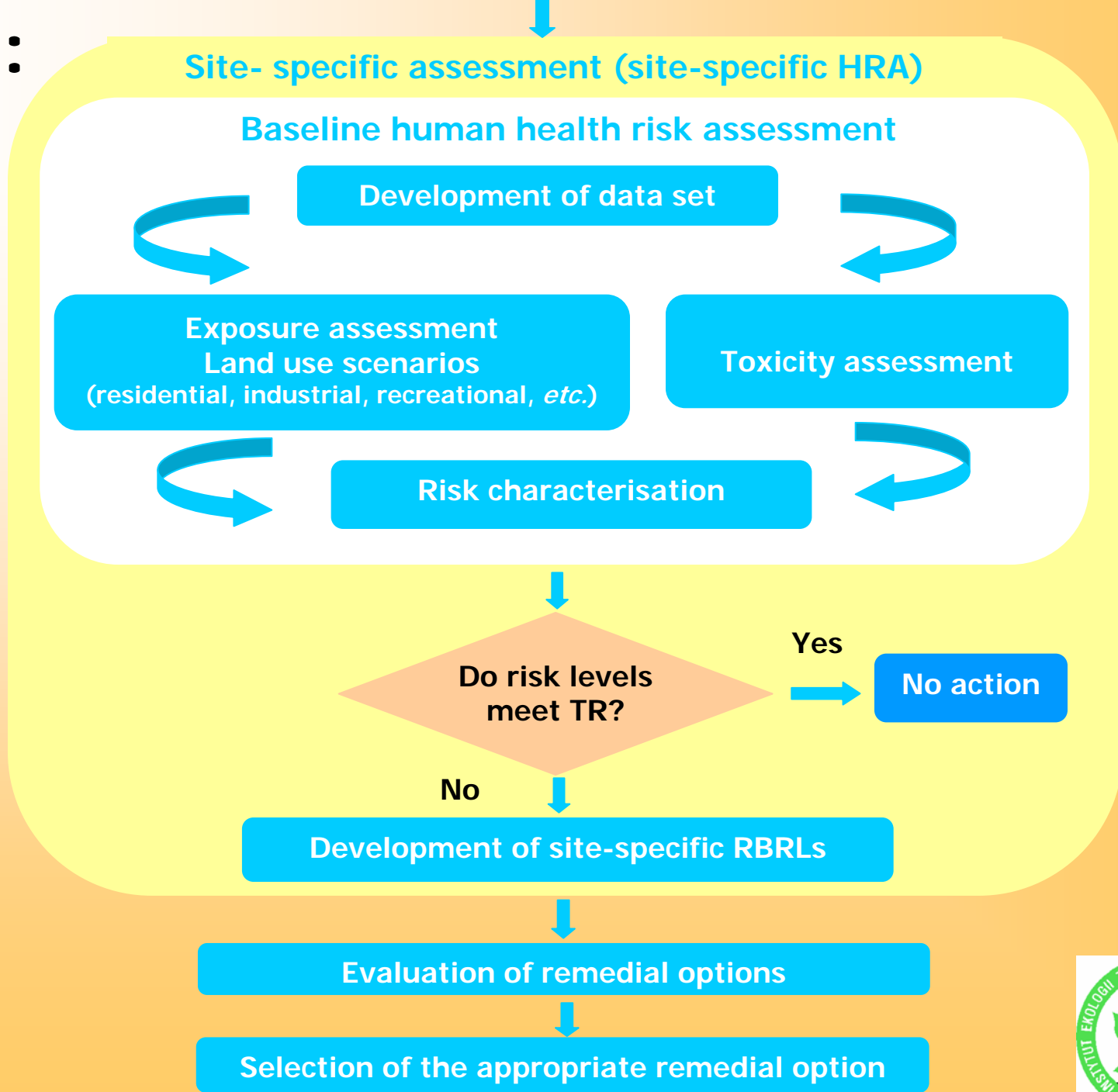


Two-step contaminated site assessment process

Step 1:



Step 2:



Risk-based soil guideline values - RBSGVs

concentration levels for individual chemicals at or below which no appreciable chronic human health risk is expected



RBSGVs

- **intended for the protection of human health**
- **developed for 102 potential soil contaminants, selected according to soil polluting activities in Cyprus**



RBSGVs

- developed under three basic exposure scenarios
 1. industrial
 2. residential
 3. recreational
- derived from standardised sets of equations and default values



RBSGVs - Receptors

- **industrial land use**
 - **outdoor worker**
- **residential and recreational land uses**
 - **child receptor for non-cancer effects**
 - **aggregate residential/recreational user for cancer effects**



RBSGVs

Default exposure parameters

Symbol	Description	Unit	Residential scenario		Industrial/Commercial	Recreational scenario	
			Child	Adult	scenario (Adult)	Child	Adult
EF	Exposure Frequency	days/yr	350	350	225	214	214
ED	Exposure Duration	years	6	24	25	6	24
FC	Soil Fraction Contacted	unitless	1	1	1	0.08	0.08
BW	Body Weight	kg	15	70	70	15	70
IR _o	Ingestion Rate for soil	mg/day	200	100	100	200	100
IR _i	Inhalation Rate for soil	m ³ /day	10	20	20	10	20
SA	Skin Surface Area - soil contact	cm ²	2800	5700	3300	2800	5700
AF	Soil-to-skin Adherence Factor	(mg/cm ² /day)	0.2	0.07	0.2	0.2	0.07
AT (non-carcinogens)	Averaging Time AT=ED*365d/yr	days	2 190	8 760	9 125	2 190	8 760
AT (carcinogens)	Averaging Time	days	25 550	25 550	25 550	25 550	25 550

RBSGVs

Default target risk levels

Target Hazard Quotient (HQ) = 1

Target Cancer Risk = 1E-06



RBSGVs – Methodology (1)

Calculated types of RBSGVs

- combined oral/dermal RBSGVs
- inhalation RBSGVs (fugitive dust or volatiles)
- cancer and non-cancer RBSGVs
- soil saturation limit (C_{sat}) – for volatiles, liquid at typical soil temperatures



RBSGVs – Methodology (2)

- compared all types of RBSGVs
- the lowest value (as the most conservative) selected as the final RBSGV under a given land use pattern



RBSGVs

Groups of substances (1)

- inorganics (*e.g.*, As, Cd, Cr, Hg, Ni, Zn)
- aromatic hydrocarbons (*e.g.*, benzene, ethylbenzene, toluene, xylene)
- PAHs (*e.g.*, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene)



RBSGVs

Groups of substances (2)

- chlorinated aliphatic hydrocarbons
(*e.g.*, chloromethane, 1,1-dichloroethane, 1,1-dichloroethene, trichloroethene, tetrachloroethene)
- chlorobenzenes
- phenols and chlorophenols



RBSGVs

Groups of substances (3)

- pesticides (*e.g.*, aldrin, DDT)
- dioxins and dioxin like PCBs
- other substances
(*e.g.*, dibutylphthalate, ethylene glycol, methyl-tert butyl ether)



RBSGVs - Recommendation

- **revise and regularly update the derived RBSGVs (*e.g.*, in 5 years)**



Site-specific HRA process steps

- **perform baseline HRA**
 - develop data set
 - assess exposure
 - assess toxicity
 - characterise risk
- **develop site-specific risk-based remedial levels (RBRLs)**
(if risk estimates exceed target risks)



Development of data set

- preliminary identification of potential human exposure, according to the defined land use patterns
- collection and evaluation of existing site data
- identification of data gaps (*a check list of necessary data provided*)
- contribution to the development of sample collection strategies (if required)
- identification of analytical needs



Development of data set

- collection and evaluation of new site data
- sorting soil concentrations by appropriate depths of sampling relevant to land uses and types of chemicals
- division of a site into sub-areas and sorting site data by sub-areas (if required)
- collection of updated chemical-specific data for site contaminants
- development of unified data set for each chemical (statistical calculation)



Exposure assessment

- identification of potential receptors (children, adults) and their types of activities
- identification of soil exposure pathways
 - incidental soil and dust ingestion
 - dermal contact with soil
 - inhalation of fugitive dust
 - inhalation of volatiles outdoors
- estimation of pathway-specific chemical intakes (*relevant equations provided*)



Toxicity assessment

- collection of information on toxicity of evaluated contaminants
- identification of important toxicity measures (RfD_s , CSF_s , ABS_d , ABS_{GI})
- identification of carcinogen classes and target effects/target organs



Risk characterisation (1)

Non-cancer risk

- quantification of hazard quotients (HQs) for each non-carcinogen/exposure route by receptors (child, adult)

$$HQ = CDI / RfD$$

- calculation of total hazard index (HI) by receptors (child, adult) (summing HQs calculated for all exposure routes/pathways and all non-carcinogens)



Risk characterisation (2)

Non-cancer risk

- comparison of total HI with non-cancer target risk ($HI = 1$)
- summing the HQs according to the target organs/effects, if $HI > 1$



Risk characterisation (3)

Cancer risk

- quantification of cancer risks (CRs) for each carcinogen/exposure route by receptors (child, adult)

$$CR = CDI \times CSF$$

- calculation of total CR by receptors (summing the CRs calculated for all exposure routes/pathways and all carcinogens)



Risk characterisation (4)

Cancer risk

- calculation of aggregate risk under residential and recreational exposure scenarios
- comparison of total CR with cancer target risk (CTR=1E-06)



Risk characterisation (5)

- **presentation of baseline risk assessment results**
- **characterisation and presentation of uncertainties**



Site-specific RBRLs

concentration levels for individual chemicals, also termed risk-based concentrations, which correspond to target risk (TR), *i.e.*, a specific cancer risk level (*e.g.*, $1E-06$), or hazard quotient (HQ), or hazard index (HI) (*e.g.*, less than or equal to 1)



Development of site-specific RBRLs (1)

- calculation of soil oral/dermal and inhalation RBCs under the relevant exposure scenario

$$\text{RBC} = C \times \text{TR} / \text{Calculated Risk}$$

- C – chemical concentration in soil
- TR – target risk (cancer or non-cancer)
- RBC – risk-based concentration (oral/dermal or inhalation)



Development of site-specific RBRLs (2)

- calculation of adjusted RBCs for non-carcinogens, if more than one chemical affects the same target organ or organ system

$$\text{ARBC} = \text{RBC}/n$$

ARBC – adjusted risk-based concentration

RBC – risk-based concentration (oral/dermal or inhalation)

n – number of contaminants with the same target organs/effects



Development of site-specific RBRLs (3)

- calculation of C_{sat} for volatile contaminants, liquid in typical soil temperatures
- establishment of volatile inhalation RBC as equal to C_{sat} , if the calculated volatile inhalation RBC $> C_{sat}$

Development of site-specific RBRLs (4)

- comparison of all types of RBCs, developed for a given contaminant
- selection of the lowest RBC value as a preliminary remedial level
- comparison of the lowest RBC with the background concentration (BC)
- establishment of RBRL as equal to BC, if the lowest RBC < BC



Risk-based approach role in decision-making (1)

- determine the needs for reducing risk and the needs for remedial/corrective actions
- set up remedial/corrective options
- select a remediation option or a corrective action, appropriate for site-specific conditions



Risk-based approach role in decision-making (2)

- design and conduct site remedial action to protect human health
- facilitate other risk management decisions (*e.g.* changing the land use pattern)



Thank you for your attention !!!



**Institute for Ecology of Industrial Areas
6 Kossutha Street
40 - 844 KATOWICE**

<http://www.ietu.katowice.pl/>

