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Chemical Time Bombs – Proposed Method for the Map Presentation

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Abstract

The presented paper is a proposal for the method of map presentation of chemical time bombs (CTB), which has been designed for a model region with an area of 1000 sqkm, in the central part of Slovak Republic. The CTB map has been compiled on the basis of a re-evaluation of present state of stream sediments, surface- and groundwaters contamination as well as of the inventary and evaluation of principal sources of polution - waste deposits directly or potentially affecting the environment. The presented method of CTB map represents a model of map presentation of areal and hot-spot CTB with categorisation of their toxicity level and the possibility (probability) of environmental polution.

Key words: stream sediments, surface water, groundwater, waste deposits, chemical time bombs

4 Figs

Introduction

The contamination of the environment with chemicals of various origin and varying composition is at present a very important environmental problem, which has to be dealt with by all economically developed countries. A great danger is the accumulation of chemicals, the so-called chemical time bombs, with possible time-delayed, but sudden effects of long-time accumulate pollutants, due to an accident, natural disaster or slow and permanent changens in the environment, e.g. acid deposition, global climate changes, drainage regime etc.

Within the complex environmental-geochemical research in the Slovak Republic, the project "Long-term environmental risks for soils, sediments and waters in the Danube river basin" has been launched in the year 1991 within the National Environmental Care Program. This project is a part of the international program "Chemical Time Bombs – CTB" , which has been initiated by the Foundation for Ecodevelopment, Mondial Alternatief - VROM NL.

As a part of this project in the Slovak Republic, the Dionýz Štúr Institute of Geology has been given the task of elaborating a method for compiling survey maps of CTB and compiling a model CTB map on the scale 1:50 000 of an area of approximately 1000 sqkm.

As model territory, where the method for CTB map compilation has been elaborated, was selected the area of Žilina and Martin basins, approximately the half of which consists of mountaineous regions (maximum height 1700 m above sea level) and other half of intermontane basins, with intesive economic activiteis and considerable level of antropogenic polution. The natural conditions - the character of rocks and hydrogeological characterization of the territory - are evident in the legend to the map presented on Fig. 1 and 2.

For the compilation of a survey map, criteria for determination and evaluation of potential places of chemical bomb occurrences (hot spots) have been elaborated, as well as their categorisation according to the level of danger to the water component of the environment.

For the compilation of the survey map itself, the following input data have been processed and evaluated according to the elaborated criteria:

- present state of the chemical composition of active stream sediments and their relationship to existing natural and antropogenic sources of contamination
- present state of qualitative properties of underground and surface waters and their relationship to sources of polution
- evaluation of hydrogeological conditions of the studied territory and their classification from the viewpoint of CTB
- inventory of principal sources of polution - waste deposits, with direct or potential evironmental impact.

The proposed method of a survey CTB map represents a compilation of the above input information in a map of areal and spot potential occurrences of chemical time bombs, which may gradually or suddenly decrease the qualitative characteristics of natural water. All input data from chemical analyses represent toxic anorgaic elements and components. Neither soils, nor organic substances have been evaluated, since no complete databases synthesising the studied territory as a whole are hitherto available.

Criteria for potential CTB

The following basic conditions have to be taken into consideration when solving the problem of potential CTB criteria (STIGLIANI et al., 1991):

- gravity of the effects
- non-synchronality of the polution and manifestations of negative effects
- suddeness of the manifestations of negative effects
- discontinuous and non-linear character of the effects

Chemical time bombs represent a time delay (slow, immediate) between the accumulation of toxic matter and its harmful effect (it is not necesarily immediate) after release.

Environmental conditions always have dominant effects. The identification of critical CTB places is represented by high input of toxic components into environment, due to geographic conditions, initiated by sudden change of environmental conditions. In case when the toxic matter is of natural origin, the "hot spots" are relatively difficult to identify.

The following criteria have been determined for the "Survey Map of CTB":

a) toxic element contents in active stream sediment, the concentrations of which in the model region exceed the value of x + 3s, or they exceed the "B" value according to Netherland Standards. These anomalies represent on one hand an areal source of the contaminant, and, on the other hand, from the geographic position of anomalies in natural conditions and the presence or absence of antropogenic polution sources may indicate a primary or secondary source of toxic matter.

b) selected groups of components in ground- and surface water, the contents of which exceed the criteria of STN 75 7111 (Slovak Technical Standard - Drinking water) in the case of groundwater and STN 75 7221 (Classification of surface water quality) in the case of surface water. The distinguished anomalies of contaminated collectors are considered to be an areal CTB, from which gradually, or suddenly, after a change of natural conditions, e.g. a flood wave, change of the infiltration function of the surface flow into drainage and vice versa, the CTB may "explode".

c) hydrogeological characterization of the rock environment:

- type of aquifer permeability
- grade of aquification
- flow direction of groundwater, represents a very important criterion, by which the possibility and velocity of the spread of polutants after a CTB explosion may be evaluated

d) inventory and evaluation of antropogenic polutions sources - waste deposits. At this criterion we were guided by the condition, that CTB is represented by a solid waste accumulation, its toxicity level and the possiblity of contamination. Of course, it is a certain simplification, liquid and gaseous contamination sources were not taken into consideration, however, their impact so far cannot be expressed on a map of this scale, as well as changes of hydrological regime, the effect of which may be a contact of groundwater level with the bottom of the deposit. This may be expressed in the future e.g. by the weight balance method, critical loads etc. This criterion was applied in the identification of hot spots as a numeric code, which was the result of a sum of weighted numeric codes for solid waste deposits in the studied region.

Characterization of evaluated input information

The following input data were available from the studied model region:

1. Map of toxic elements in stream sediments (KANDERA, 1993)
sampling density: 1 sample/1 sqkm
analysed fraction: 0.125 mm
analysed association: 37 elements

The anomalies represent the x + 3s value of element concentration, or exceeding of the "B" value of "Netherland Standards" (BODIŠ, 1993).

2. Natural water quality map (RAPANT, 1993)
sampling density: 1sample of groudwater/3 sqkm
1 sample of surface water/2 sqkm
analysed association: 35 elements and components
sampling object: groundwater: spring, drillhole, gallery, well (first aquiferous horizon)
surface water: brook, river, water reservoir

On the basis of grouped quality indicators, 8 quality classes of underground water (classes A-H) and 5 classes of surface water (I.-V.) have been defined.

3. Basic hydrogeological characterization of the region

The following parameters of hydrogeological characterization of the rock environment have been applied:

– type of aquifer permeability
– grade of aquification
– areas of surface water inlet (possible sources of contamination) into aquified collectors

The characterization of rock environment and the most important hydrogeological chacteristics of the territory are evident from figures 1 and 2, the legend to the CTB map.

4. Spot sources of pollution

Potential sources of pollution were identified with the help of a database (register) of waste deposits in the studied region. The following data on waste deposits were used for the CTB map construction: localization, type of waste, its quantity, toxicity and possibility of contamination spread.

Methods and legend of CTB map

The philosophy of distinguishing critical CTB places (hot spots) in the model region was based on available information on the abiotic component of the environment and the definition of the term "Chemical Time Bomb". The survey map shows the areal and spot critical places, as well as the grade of danger from the viewpoint of polutant contents and the time factor of contaminating matter spread after "CTB explosion". It is necessary to note that from the viewpoint of the endangerment of biotop and man, there are at present no real data on the speciation of pollutants, i.e. the form of their occurrence in various media. In any case, there has been analysed the total sum of an element or component in natural water and stream sediments.

The compilation of chemical time bombs map was based on the following parameters and data types:

The used data types may be divided into:

a) tables related to points (characteristics of spot anomalies and waste deposits)
b) graphic (anomalous contents of contaminants, hydrogeological characterization)

There are two types of critical CTB locations, areal and spot (Fig. 3).

I. AREAL CRITICAL CTB SITES are identified on the basis of criteria in anomalously increased element or component contents in underground and surface water, active stream sediments and the hydrogeological characteristics of the rock environment. They represent an accumulation of toxic matter in water collector or in stream sediment. In case when above the critical place (anomaly) or in river sediments there is an anomaly in the chemical composition of natural water in the drainage area, where in the whole drainage area above the anomaly or inside it there is no secondary pollution source, these anomalies may be considered as geogenic.

The position of critical places of contaminated water or sediments may be various, e.g. in drainage areas, in the direction of waterflow, the first critical CTB place is the sediment, then the water or vice versa, or they may overlap.

From abovesaid the following combinations result for the identification of potential CTB source:

a) contaminated water
b) contaminated sediment
c) contaminated water as well as sediment

According to contamination grade of natural water and river sediments, areal CTB anomalies have been divided into three categories - low, medium and high.

Areal critical CTB places are thus constructed from "layers" of graphic data on the quality of underground and surface water, the quality of river sediments, in relation to the basic hydrogeological characteristics.

DATA	PARAMETERS	DATA TYPES
hydrogeochemical data	analysis of ground- and surface water	areal anomalies, isolines, spot data
stream sediments	analysis of sediments	areal anomalies, isolines, spot data
hydrogeological data	grade of aquificaton, character of collectors, flow direction	areal and spot data, linear data
land	river network, inhabitated areas, waste deposits	areal data, spot data, linear data

Categorisation of areal CTB

	sediment	ground water	surface water
low	1-element anomaly	quality class C-D	quality class III.
medium	2-element anomaly	quality class E-F	quality class IV.
high	3- and more element anomaly	quality class G-H	quality class V.

II. SPOT CRITICAL CTB SITES – they can be defined as places with an occurrence of waste deposit, characterized by weighted numerical code and the type of rock environment, which may potentially or immediately endanger the environment.

The numerical code includes the following parameters:

– toxicity of deposited waster matter is evaluated according to the origin and charater of the waste in 4 classes:

0 – non-toxic
1 – low-toxic
2 – medium-toxic
3 – high-toxic

– the quantity of waste (in m^3)

1 – up to 1000 m^3
2 – 1000 –10 000 m^3
3 – over 10 000 m^3

– contamination possibility (technical state of the deposit), the evaluation is based on 4 grades:

0 – no
1 – possibly
2 – probably
3 – yes

– the waste deposit is situated in an area of toxic element anomaly in stream sediment:

0 – no anomaly occurrence
1 – one element anomalous
2 – intersection of two element anomalies
3 – intersection of anomalies of 3 and more elements

– the waste deposit is situated in an area of anomaly occurrence in ground water:

0 – no anomaly occurrence
1 – class C-D
2 – class E-F
3 – class G-H

– the waste deposit is situated in an area of anomaly occurrence in surface water:

0 – no anomaly occurrence
1 – class III.
2 – class IV
3 – class V.

The sum of resulting weighted values of numerical codes reached 1-18 and it takes into account practically the categorisation of CTB according to toxicity grade:

1–3 no CTB
4–7 low CTB
8 –10 medium CTB
11–18 high CTB

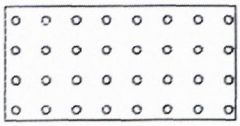
The results of the summing for various waste deposits are shown in the list of selected waste deposits presented in the Appendix. In the map, the criterion is shown as the size of the quadrangle and the numbers shows the localisation of the deposit with a detailed characterization in the database (Appendix).

The categorisation of critical CTB spots according to contamination possibility takes into account also the time factor of contaminated matter spread at slow or immediate release (explosion). This factor is shown by the intensity of colour inside the quadrangles. The categorisation (low, medium , high) has been made according to the aquification grade of the territory (transmissivity coefficient for collectors with inter-granular permeability, specific run-off for other collectors).

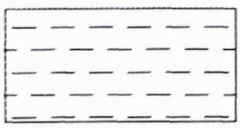
categorisation of spot CTB according to contamination possibility	aquification grade
high medium low	very high, high medium low

DESCRIPTION OF ROCK ENVIRONMENT

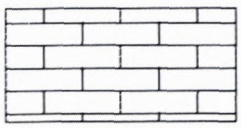
I. Type of permeability of aquifers



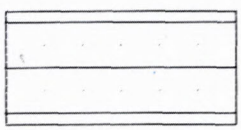
Intergranulal permeability (Q – sands, gravels; N – sands, gravels).



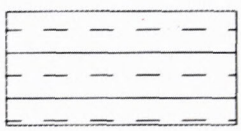
Fissure permeability (granitoids, crystalline schists, dolomites, quartzites, sandstones).



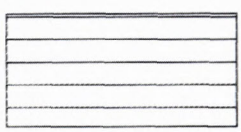
Karstic–Fissure permeability (limestones, dol. limestones, alternating limestones and dolomites).



Irregular alternation of aquicludes and intergranular aquifers (N – alternation of clay, sands, alternation of marls with sands).



Irregular alternation of aquicludes and fissure aquifers (Fg, N, Mz – alternation of sandstones with claystones).



Aquiclude area impermeable as a whole (N – clays, marls, Pg – claystones, claystones predominating over sandstones, K – marls, marly limestones, T – Carpath. keuper, Lunzs beds, shales, shales predominating over sandstones).

II. Degree of water–bearing in aquifers (expressed by a number next to age symbol of aquifer)

WATER–BEARING		Aquifers with intergranular permeability, T ($m^2.s^{-1}$)	Other aquifers Q ($l \cdot s^{-1}.km^{-2}$)
1	very high	$> 1.10^{-3}$	> 13
2	high	$1.10^{-4} - 1.10^{-3}$	9 – 13
3	medium	$1.10^{-5} - 1.10^{-4}$	3 – 9
4	low	$< 1.10^{-5}$	< 3
5	area without aquifers		

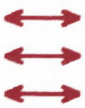
III. Age of aquifers

Q Quaternary
N Neogene
Pg Paleogene
Mz Mesozoic (generally)
K Cretaceous
T Triassic
γ crystalline rocks (generally)

IV. Other symbols

Aquifer boundaries

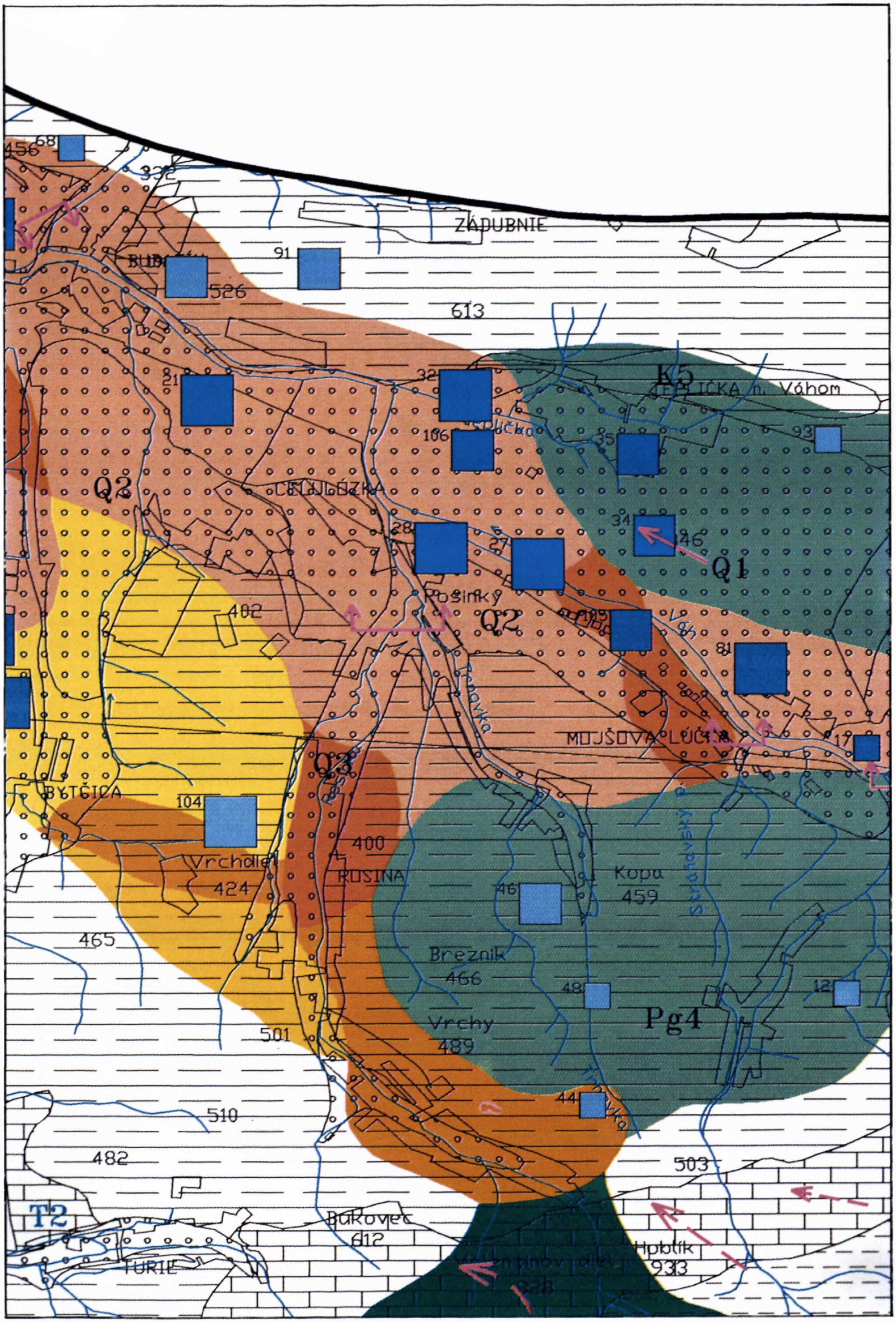
Direction of grounwater flow (observed, presumed), possible direction of contamination spreading



Section of surface stream with possible entry of contaminated waters

Entries of surface streams into areas of significant aquifers

Significant local losses of surface streams to aquifers



ZÁDUBNIE
613
K5
Q2
Q1
Q3
Pg4
T2
CELULÓZKA
Pošinky
MOJŠOVA LÚČKA
BYTČICA
Vrchdiel
424
400
RUSINA
Kopa
459
Breznik
466
Vrchy
489
465
501
510
482
503
Bukovec
612
Hoblík
933
TURIE
526

CRITICAL CTB SITES

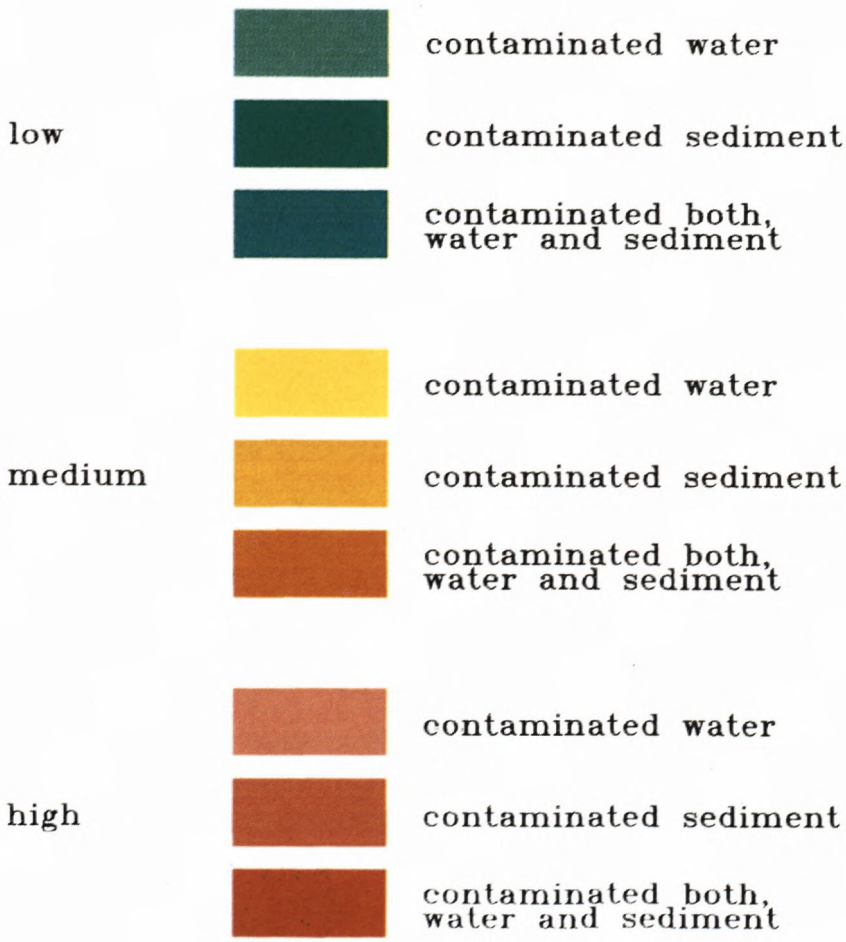
A. Local

CTB classification according to degree of toxicity

CTB classification according to contamination potentiality

B. Areal

CTB classification Potential CTB source



Conclusion

The proposed method of CTB survey map compilation represents a possibility for showing CTB "hot spots" on a map, i.e. the accumulation of chemical matter with possible delayed manifestations of the accumulated pollutants due to an accident, catastrophy or due to slow and long-term changes in the environment. On the basis of the accepted philosophy, areal and spot CTB sources are distinguished, which are the evaluated and categorised on the basis of the character and origin of contaminants, their toxicity and the probability of contamination spread into natural environment.

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