

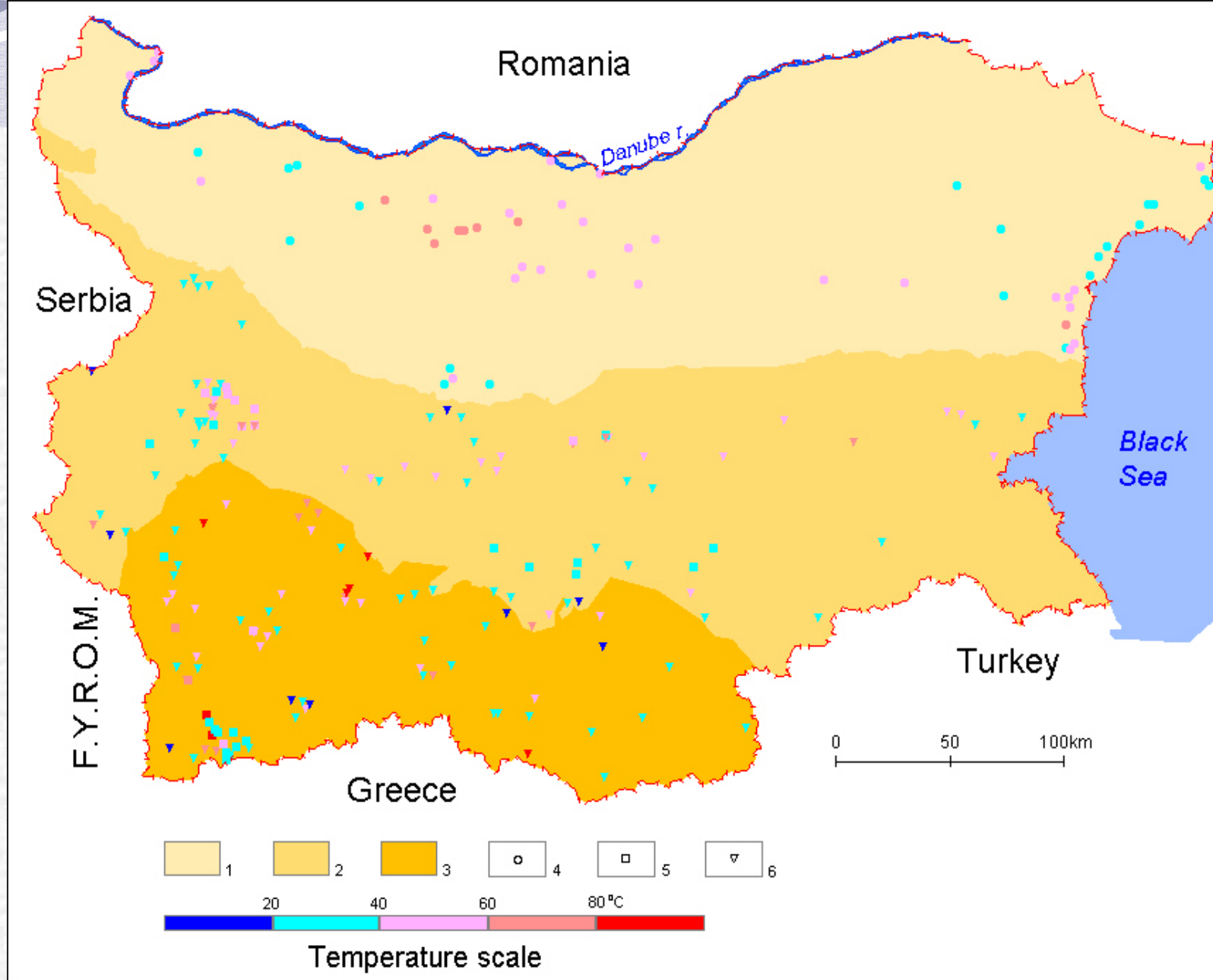
**NEW METHODS AND COMPUTER  
MODELS FOR PROTECTION OF  
THERMOMINERAL WATERS,  
ACCORDING TO THE RESPECTIVE  
LEGISLATION IN BULGARIA**

**Elka N. Pentcheva,  
Aleksy D. Benderev**

**Bulgarian Academy of Sciences, Sofia**

# INTRODUCTION

Bulgarian territory is very rich in thermal waters (more than 1000 sources and boreholes) of temperature in the range of 20°C-100°C. About 72% of the total discovered flow rate has temperature up to 52°C.



1. Moesian plate (stratified reservoirs) 2. Sredna gora, incl. Balkan zone (secondary stratified reservoirs, fractured reservoirs) 3. Rila-Rhodopes massif (predominantly fractured reservoirs) 4. Major wells and groups of wells discovering stratified reservoirs in a plate region.

The data basis for recent resource reassessment is taken from about 160 hydrothermal fields located all over the country, which 102 are state-owned. The total dynamic flow rate of sub thermal and thermal waters run up to 4600 l/s, of which 3000 l/s is the flow rate of the revealed thermal waters of  $T > 25^{\circ}\text{C}$ . About 43% of the total flow rate are waters of temperature between  $40^{\circ}\text{C}$ - $60^{\circ}\text{C}$ .

Established chemical water content (TDS) varies respectively, in:

- Southern Bulgaria - from 0.1g/l up to 1.0 g/l (only for a few sites it is between 1 g/l to 15g/l)
- Northern Bulgaria - from 0.1g/l up to (100g/l - 150g/l).

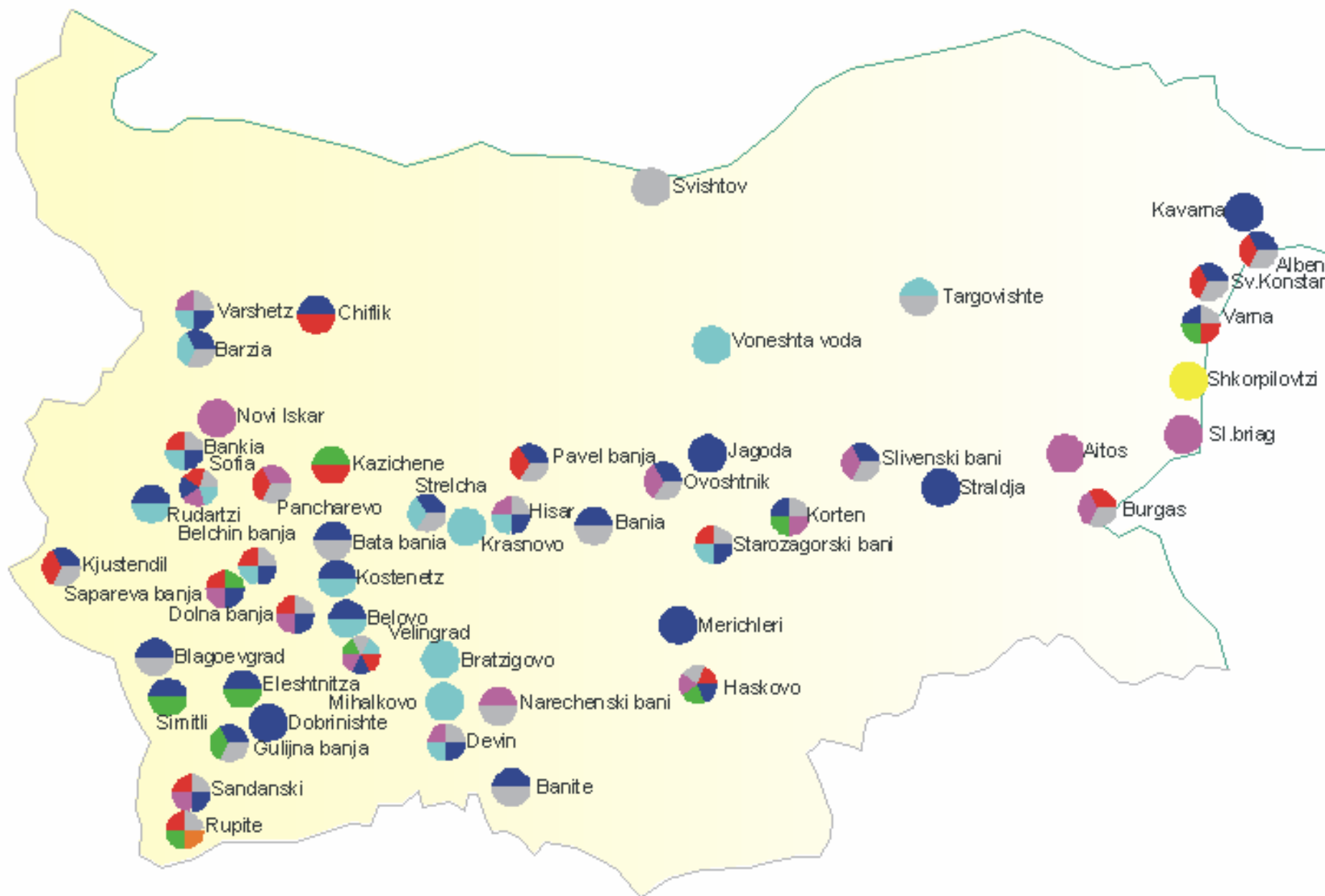
About 70% of the thermal waters are slightly mineralized (<1g/l) with fluoride concentration ranging from 0.1 to 25mg/l, various metasilicic acid concentrations (up to 230mg/l) and of mostly high alkalinity.

In comparison to most of the European mineral waters, the Bulgarian ones have a lot of advantages: **low TDS** (close to the optimal one typical for potable water), **a remarkable richness and variety of oligoelements and microcompounds**, **high purity level** (especially in terms of anthropological pollution, microbiological purity and interesting scale of water types).

## State-of-art

During ancient times thermal waters had been utilised mainly for healing, disease prevention, washing and bathing. But as early as Roman times waters were used on a large scale for under floor heating in Public baths (hypocausts).

Currently thermal water application is mainly in balneology, space heating and domestic hot water supply, greenhouses, swimming pools, bottling of potable water, aquaculture (microalgae) and extraction of chemical derivatives.



- |   |  |
|---|--|
|  space heating                       |  treatment and rehabilitation |
|  prevention and public mineral baths |  greenhouses                  |
|  swimming pools                      |  chemical derivatives         |
|  bottling                            |  aquaculture                  |



A number of large spa resorts had developed in places of old Thracian or Roman residential areas on the territory of the country. Bulgarian spa resorts nowadays (66 official registered) offer accommodation in 3 to 5 stars hotels and a built up structure of health centers controlled by the Ministry of Health. Experienced specialists working in spas offer treatment of a wide range of diseases.

Currently operating health centers using thermal water sources (state-owned and municipal) amount to about 60. Mineral baths and swimming pools are common in them. Thermal waters in most of the spas also flow out of taps. This allows a free-of-charge and massive water use for drinking and disease prevention. Geothermal energy is currently used for space heating of buildings only in 12 spas as in 4 of them air-conditioning is providing in addition.

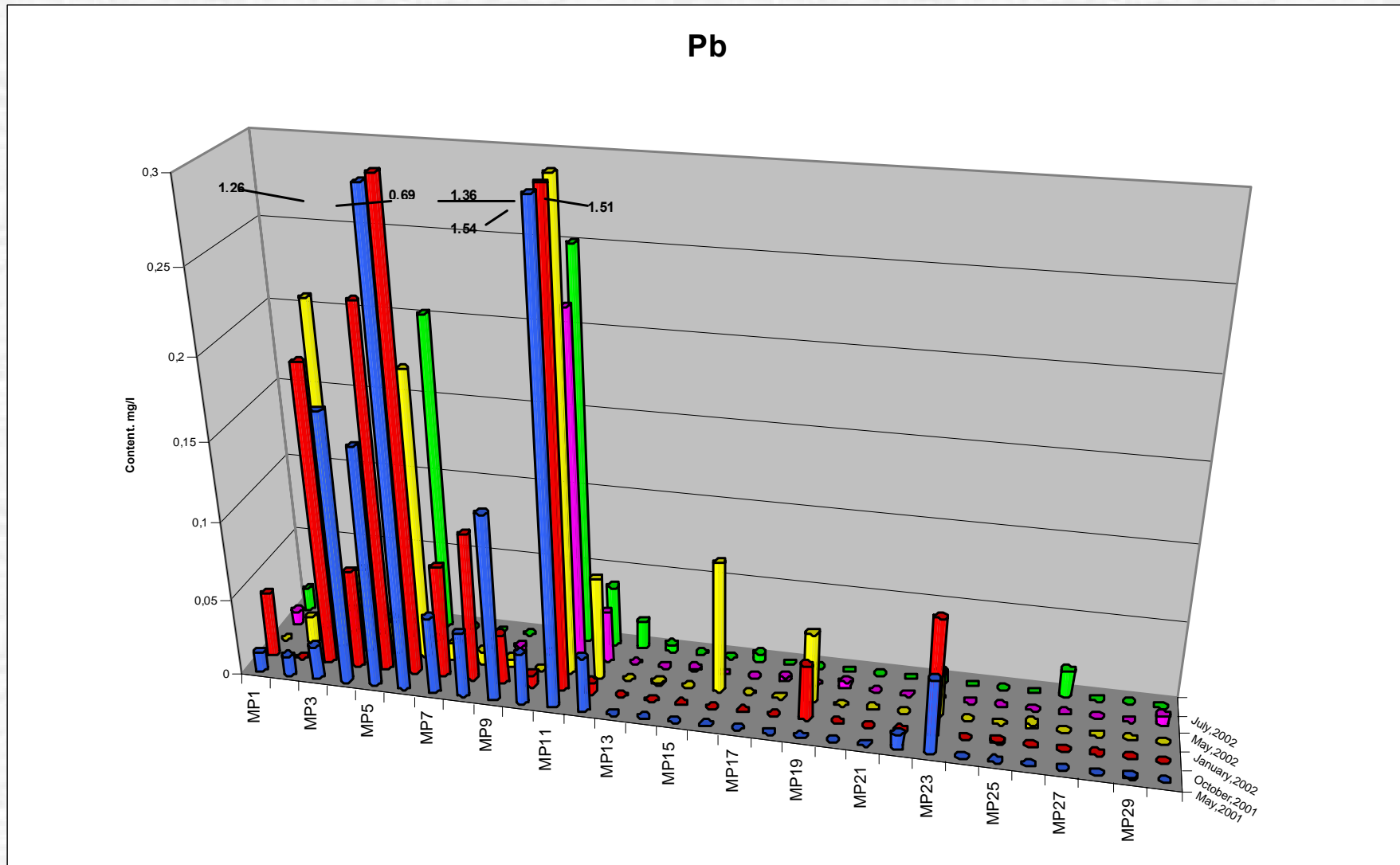
The number of bottling companies has increased during the last 10 years from 3 state-owned (before 1990) to 41 private enterprises nowadays. Their production meets mainly the demand of the local market. Several major reasons for high development rate of bottling exist due to the: - predominant thermal waters of low TDS (<1 g/l);- and big variety of water chemical content that provides opportunity for bottling of potable water as well as of mineral water for drinking in prescribed doses. This activity is very profitable also because the water cost is low and amounts to 2.5 USD/m<sup>3</sup>.

# Results and discussion

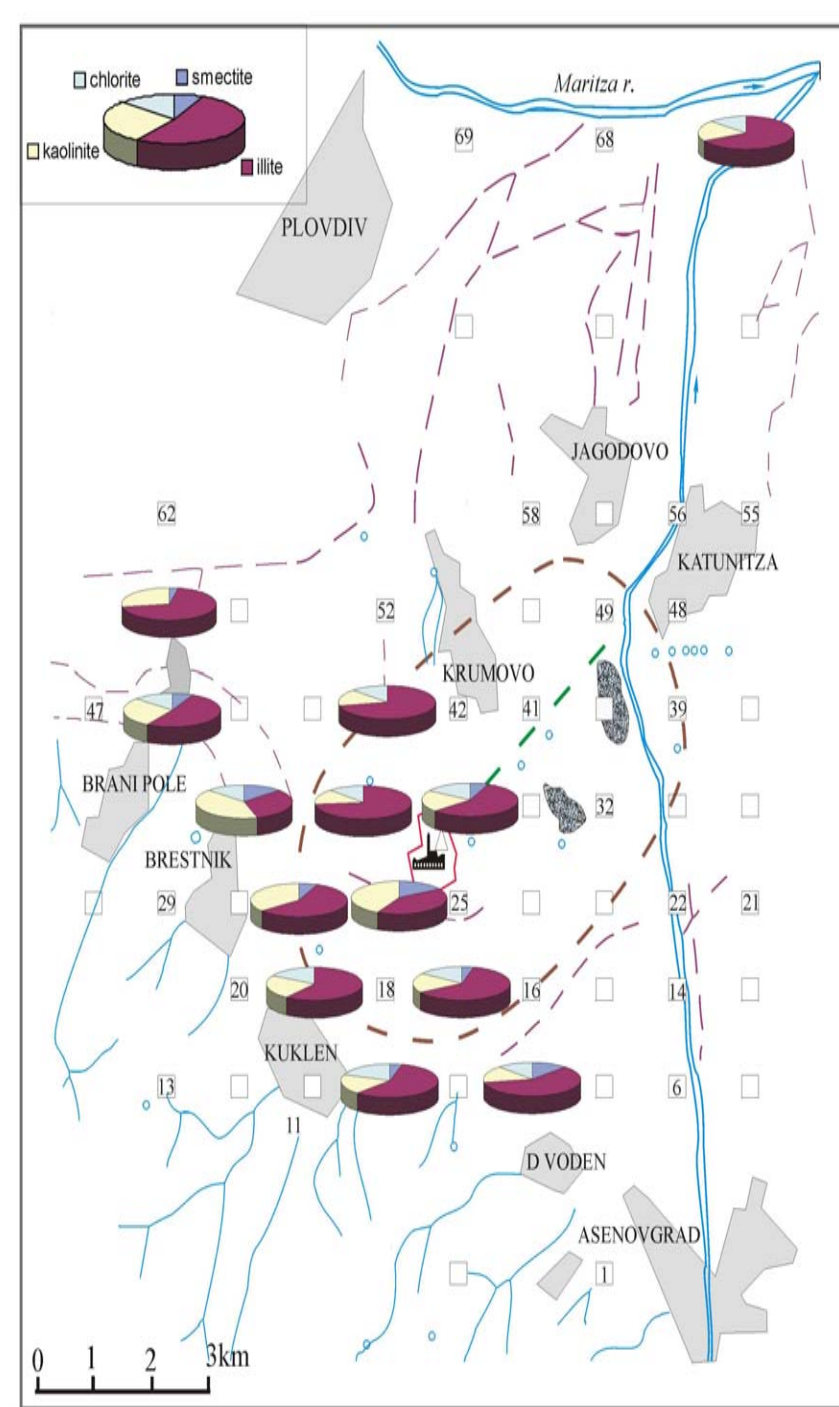
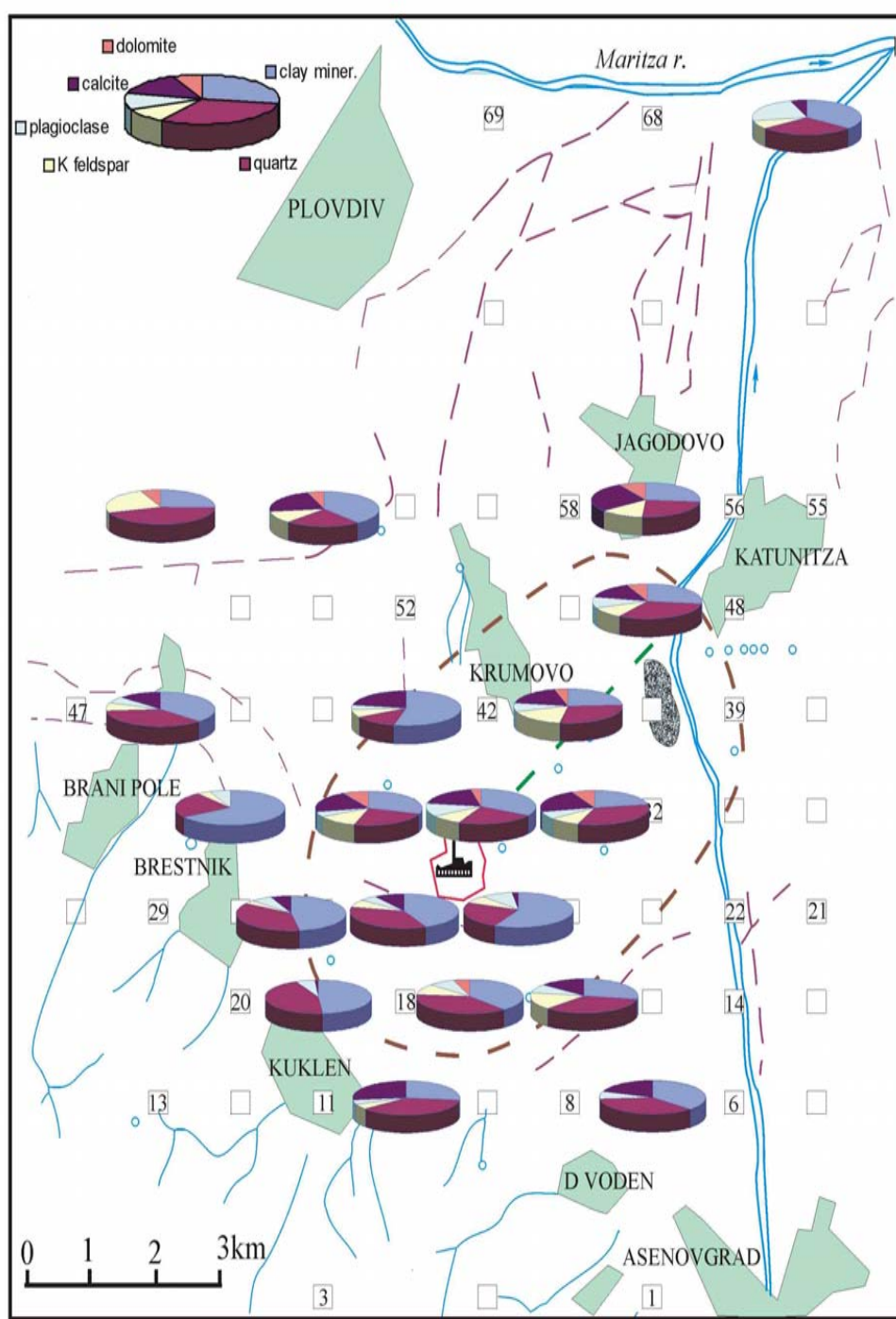
## **I. New methods and computer models**

In the aim of mastering the protection and the risk assessment of thermomineral waters in the regions, endangered by industrial and mining activities (organized at the best Bulgarian resort area in the frames of the Former COMECON), we accorded very important attention during the last 5 years to the creation of original models and tools for the prevention of our hydrothermal systems (the weakest point of the Bulgarian thermalist policy!).

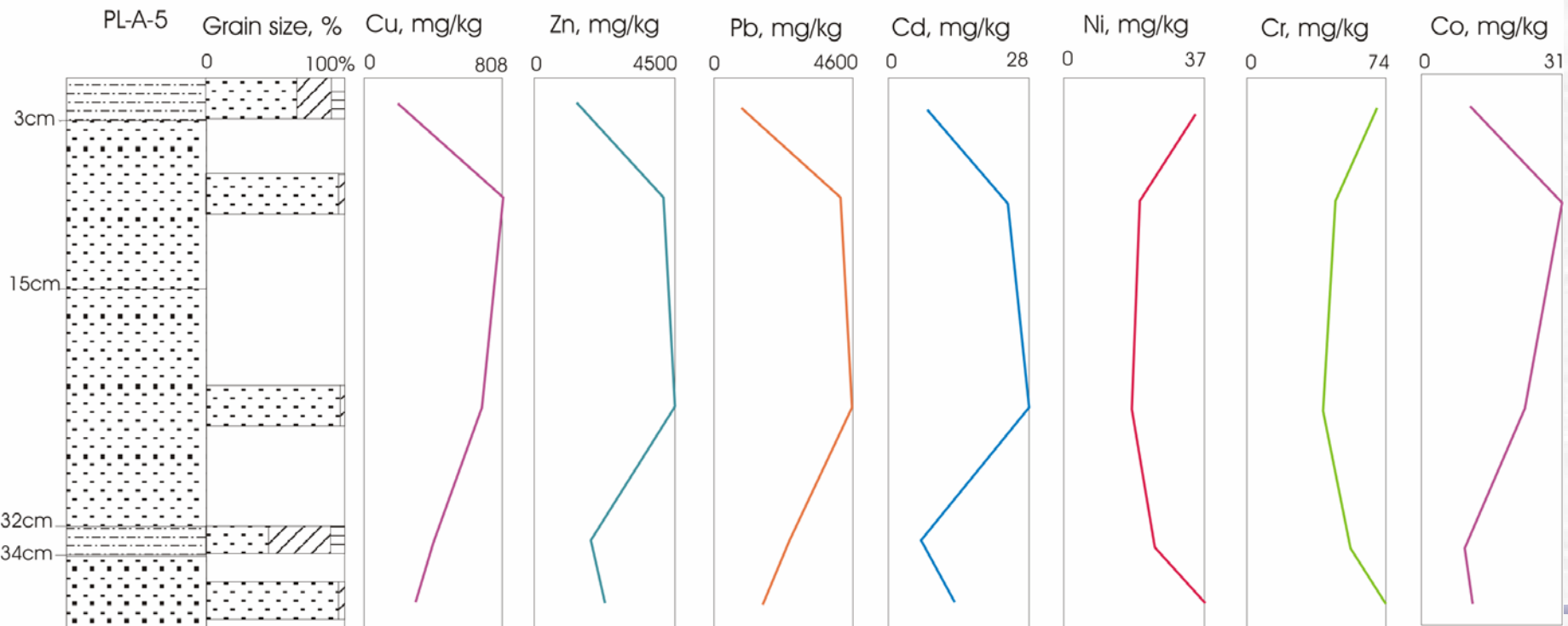
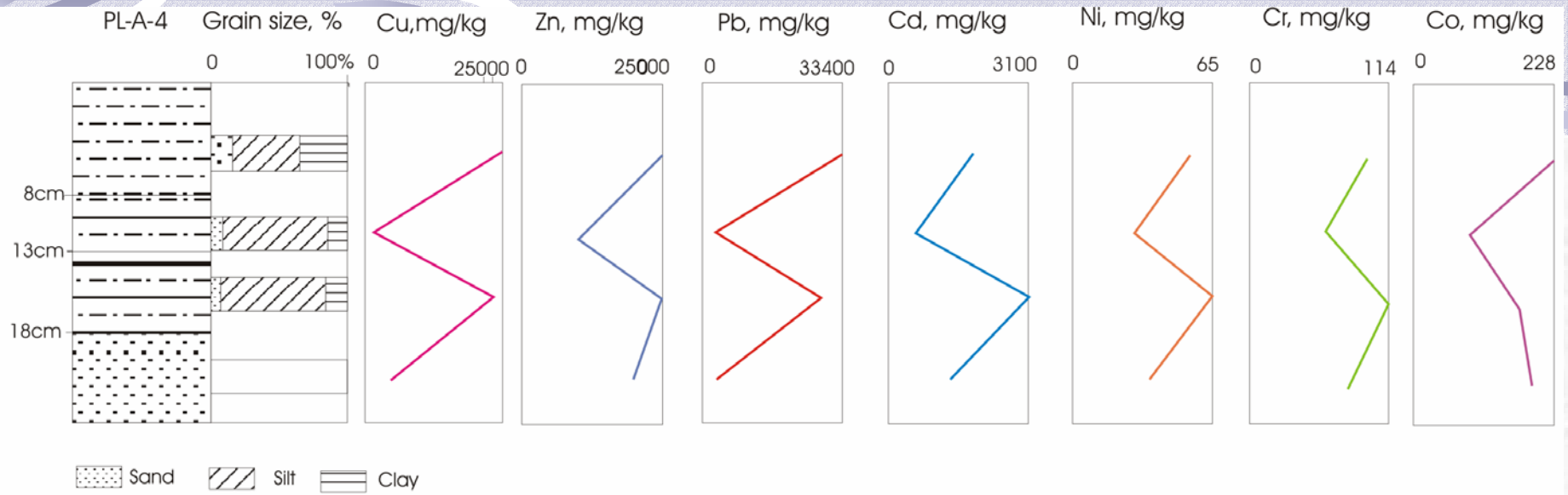
With the financial support of NATO SfP Programme, in collaboration with BRGM (France) our team created a GIS integration model for the risk assessment and the most important a coupled hydrochemical – hydrodynamical model for prediction studying and control of the eventual metal and arsenic contamination of thermomineral systems. We worked in a metal polluted zone (200 km<sup>2</sup>) of the Plovdiv region. A powerful database system is created, containing all the data, related to the different compartments of the environment :waters, soils, sediments, vegetables, wastes, etc.



Pb seasonal monitoring (waters)



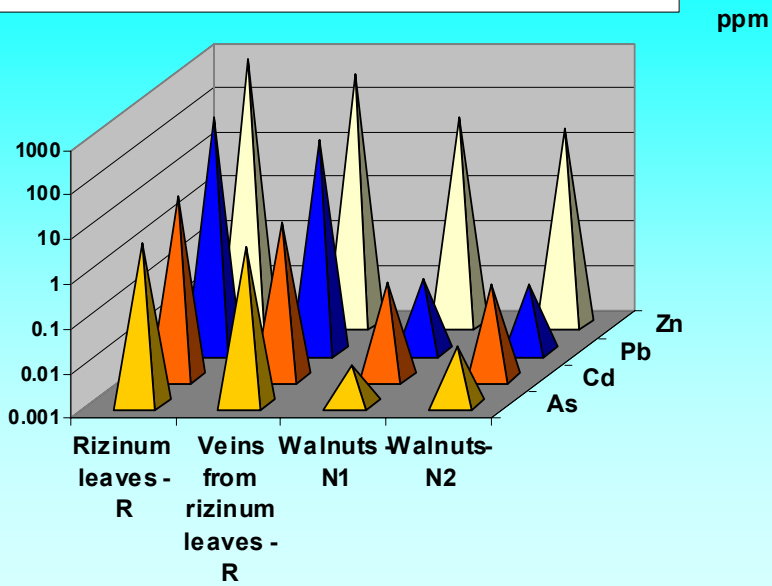
**Mineralogical composition of soils and distribution of clay minerals**



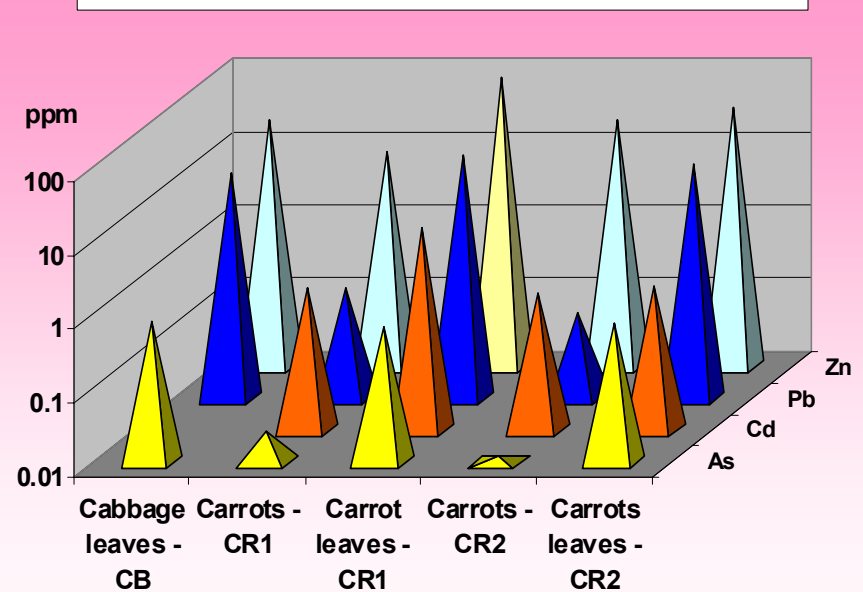
**Distribution of heavy metal concentration in sediment profiles**



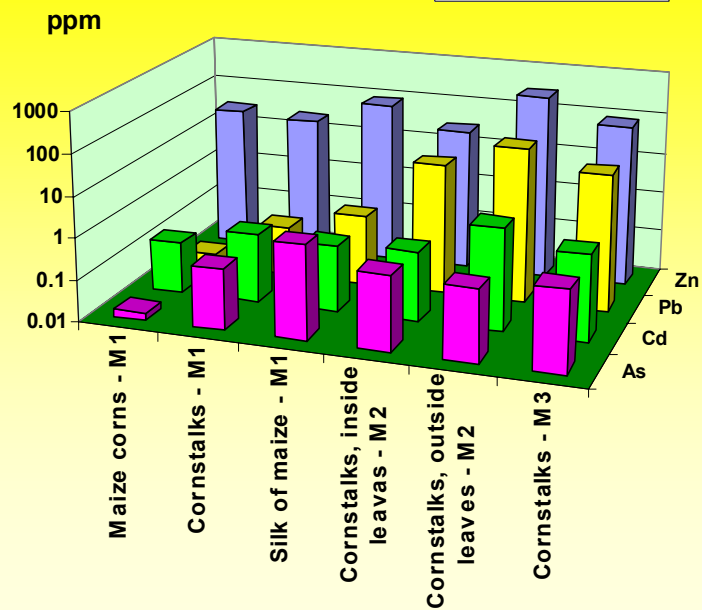
Walnut kernels MPL As, Cd=0.05; Pb=0.1



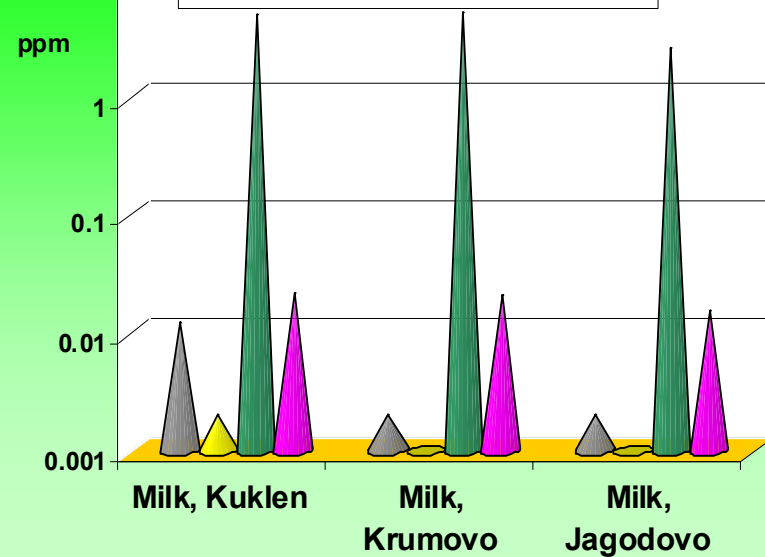
Carrots&Cabbage MPL As=0.2; Cd=0.1; Pb=0.1; Zn=50.0



MPL Cd =0.1; Pb=0.2



Pb, MPL=0.02 Cd, MPL=0.01 Zn, MPL=5.0 As, MPL=0.05



# Pollutant concentrations in vegetable and milk samples



Gas exhalation and physico-chemical parameters of the waste dump

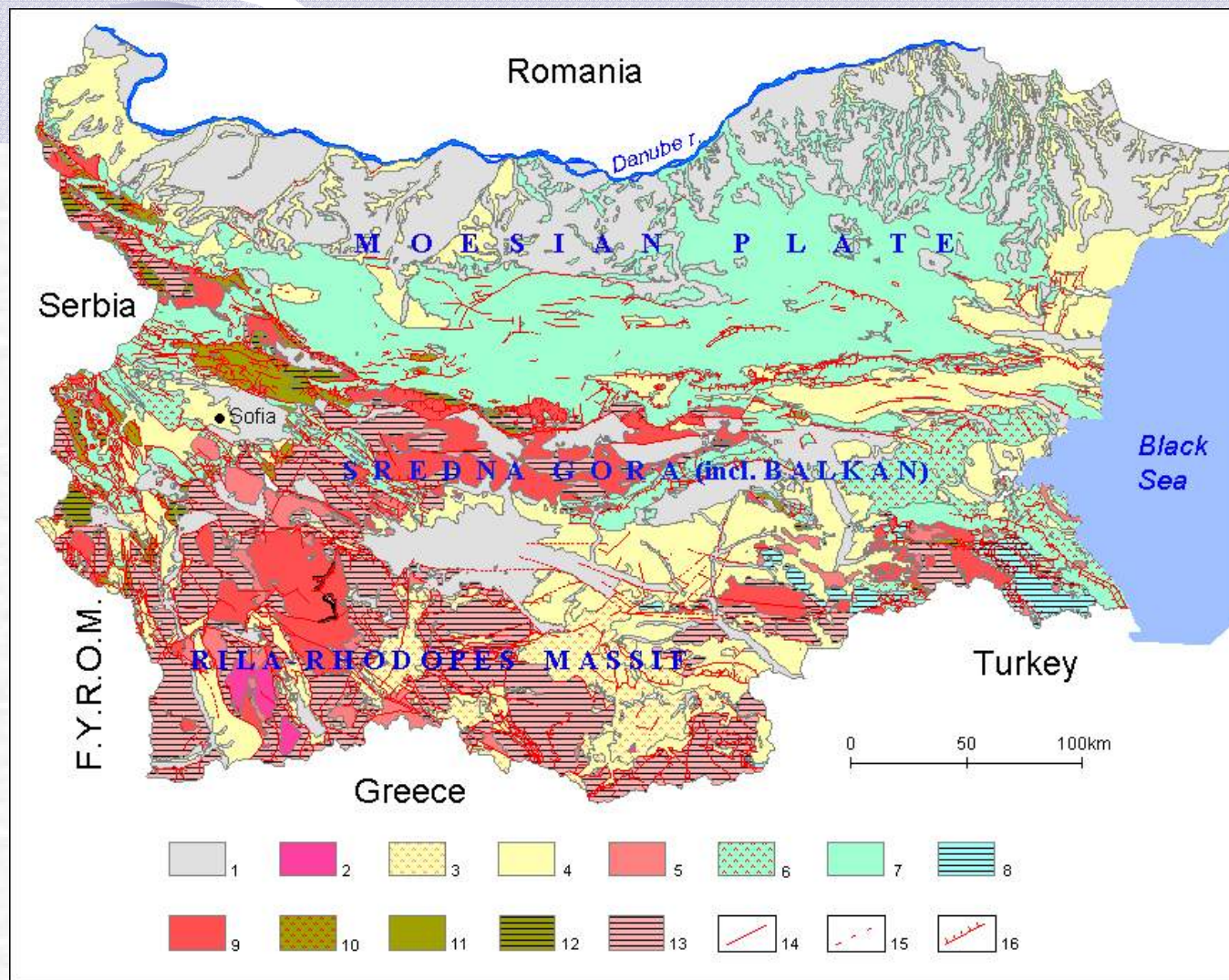


The data:

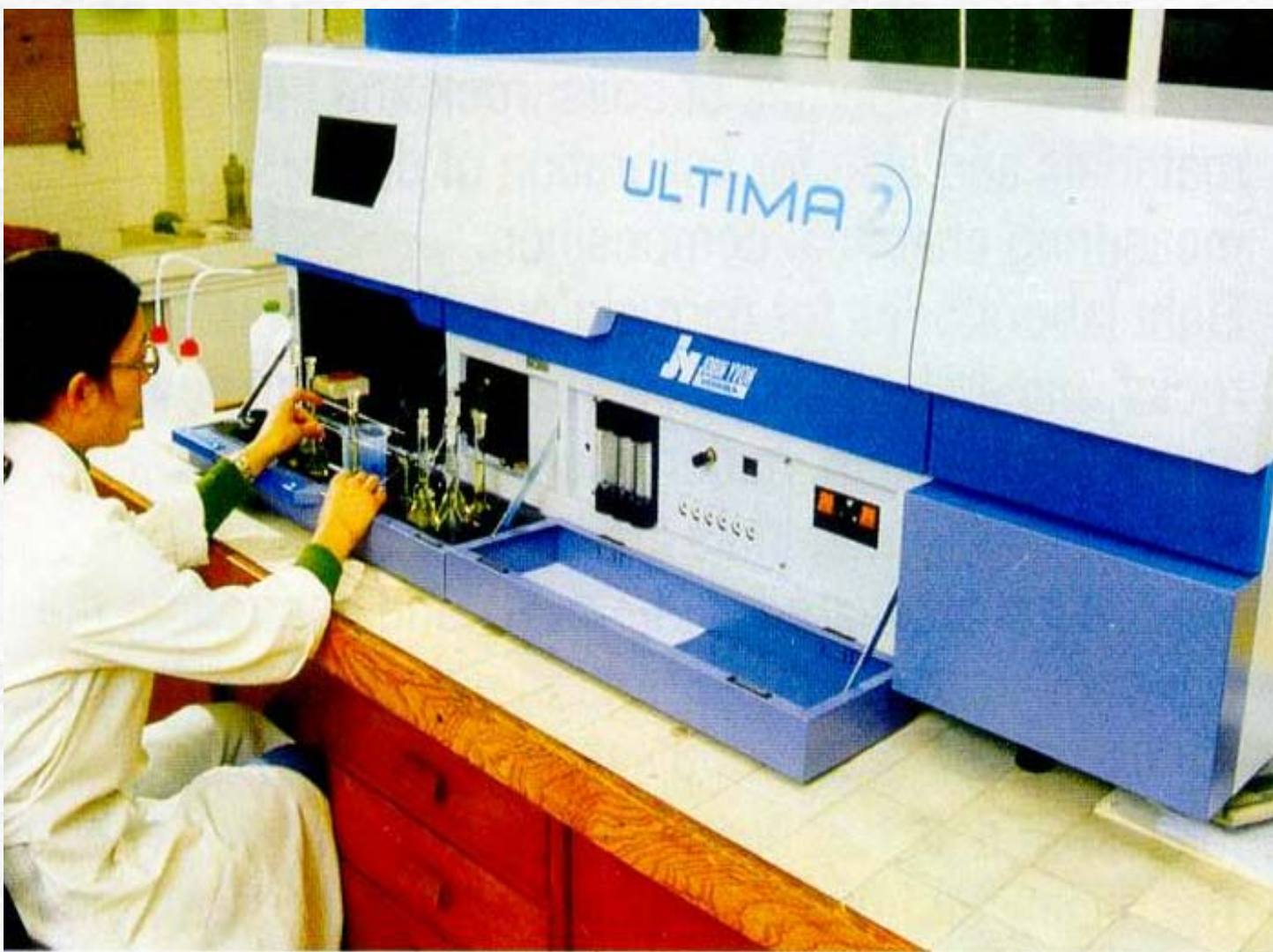
- physical geographic,
- geological,
- geochemical,
- hydrogeological,
- hydrochemical

are analyzed and integrated into modern  
GIS tool.

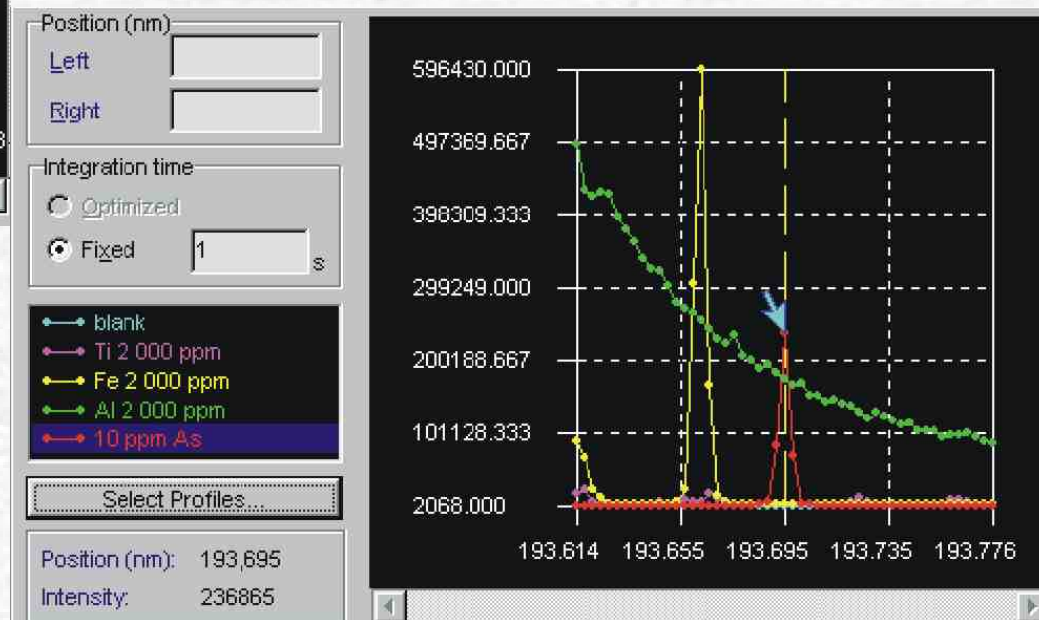
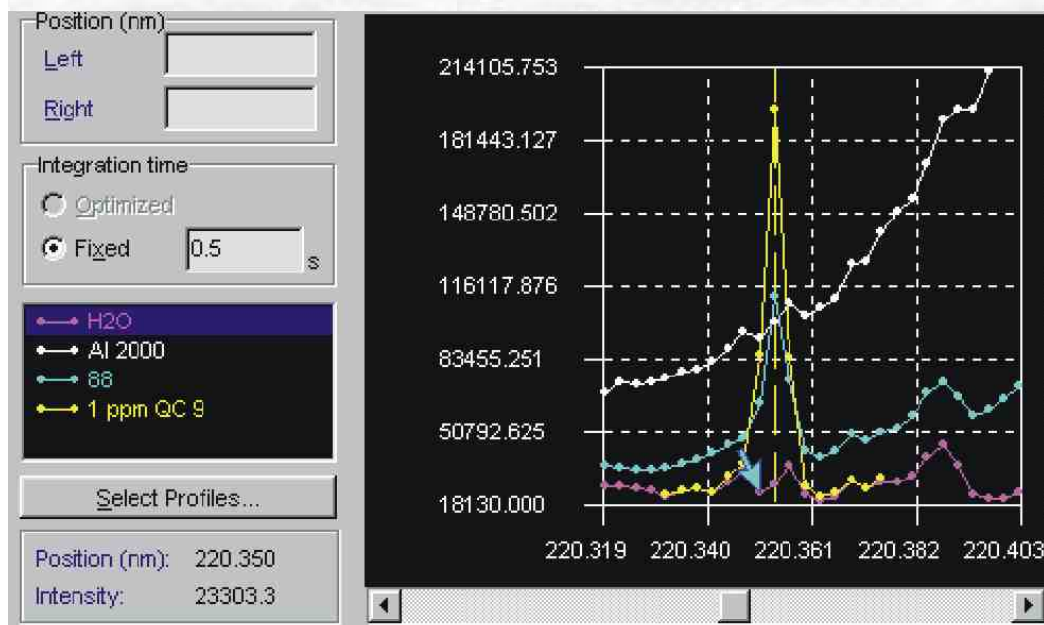




1. Quaternary unconsolidated deposits    2. Neozoic intrusive rocks    3. Neozoic volcanic and volcano-sediment rocks    4. Neozoic sediment rocks    5. Mesozoic intrusive rocks    6. Mesozoic volcanic and volcano-sediment rocks    7. Mesozoic sediment rocks    8. Mesozoic metamorphic rocks    9. Paleozoic intrusive rocks    10. Paleozoic volcanic and volcano-sediment rocks    11. Paleozoic sediment rocks    12. Paleozoic metamorphic rocks    13. Prepaleozoic metamorphic rocks    14. Faults    15. Assumed faults    16. Line of overthrust

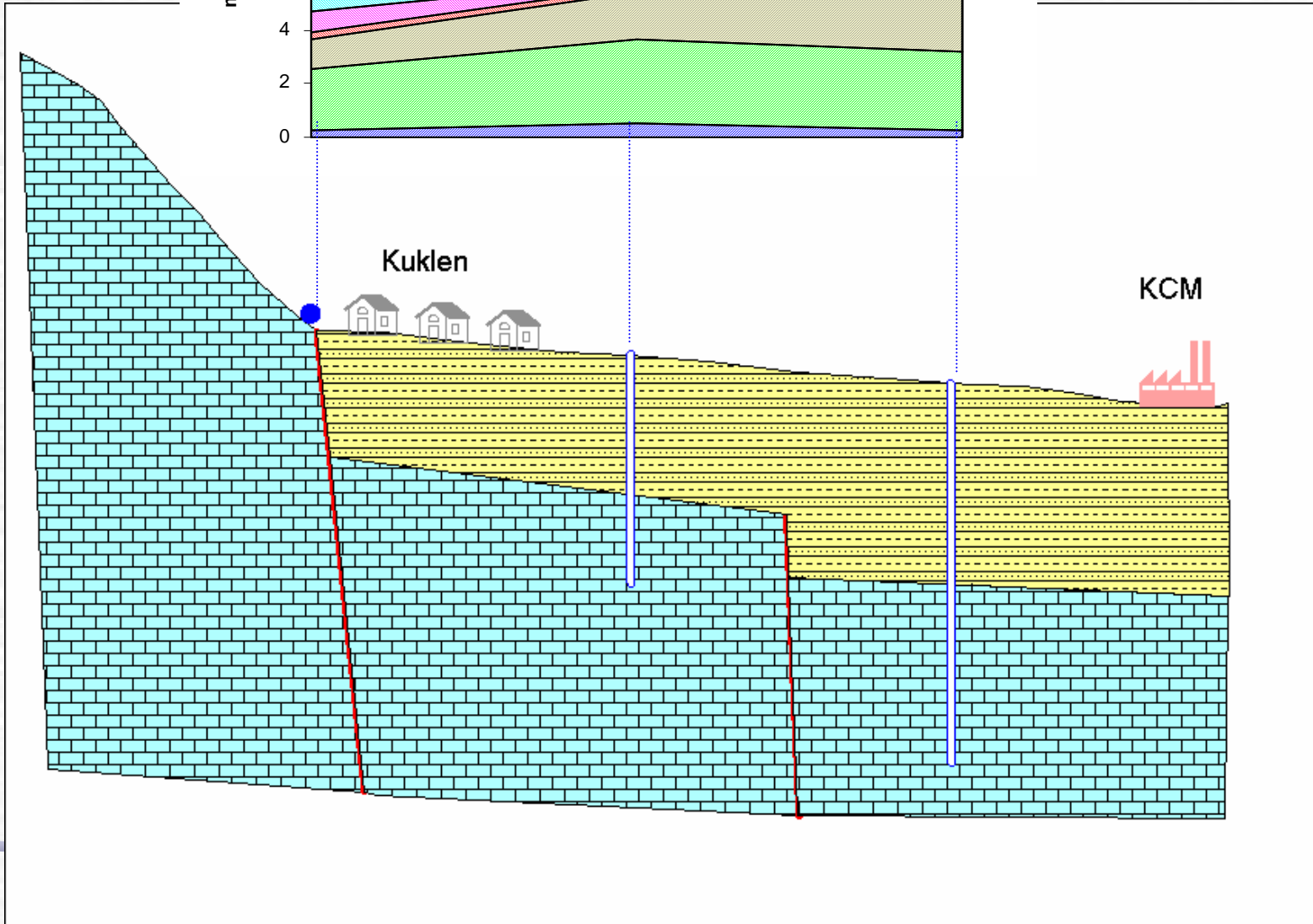
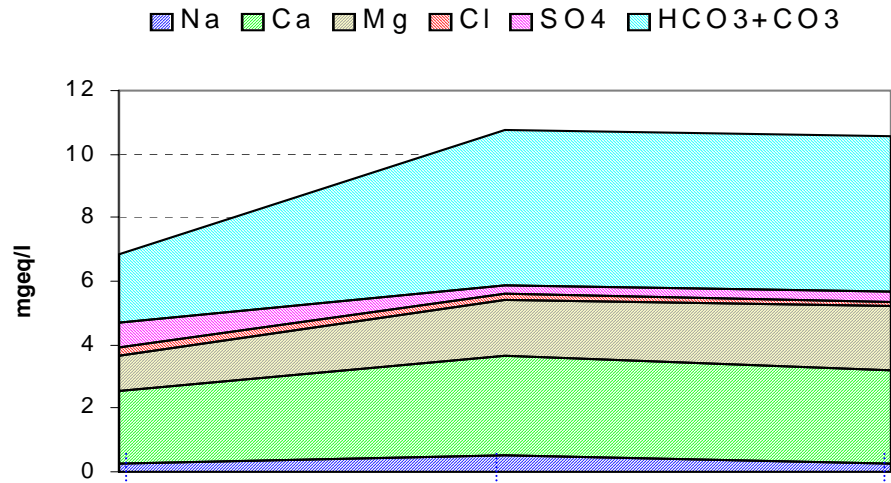


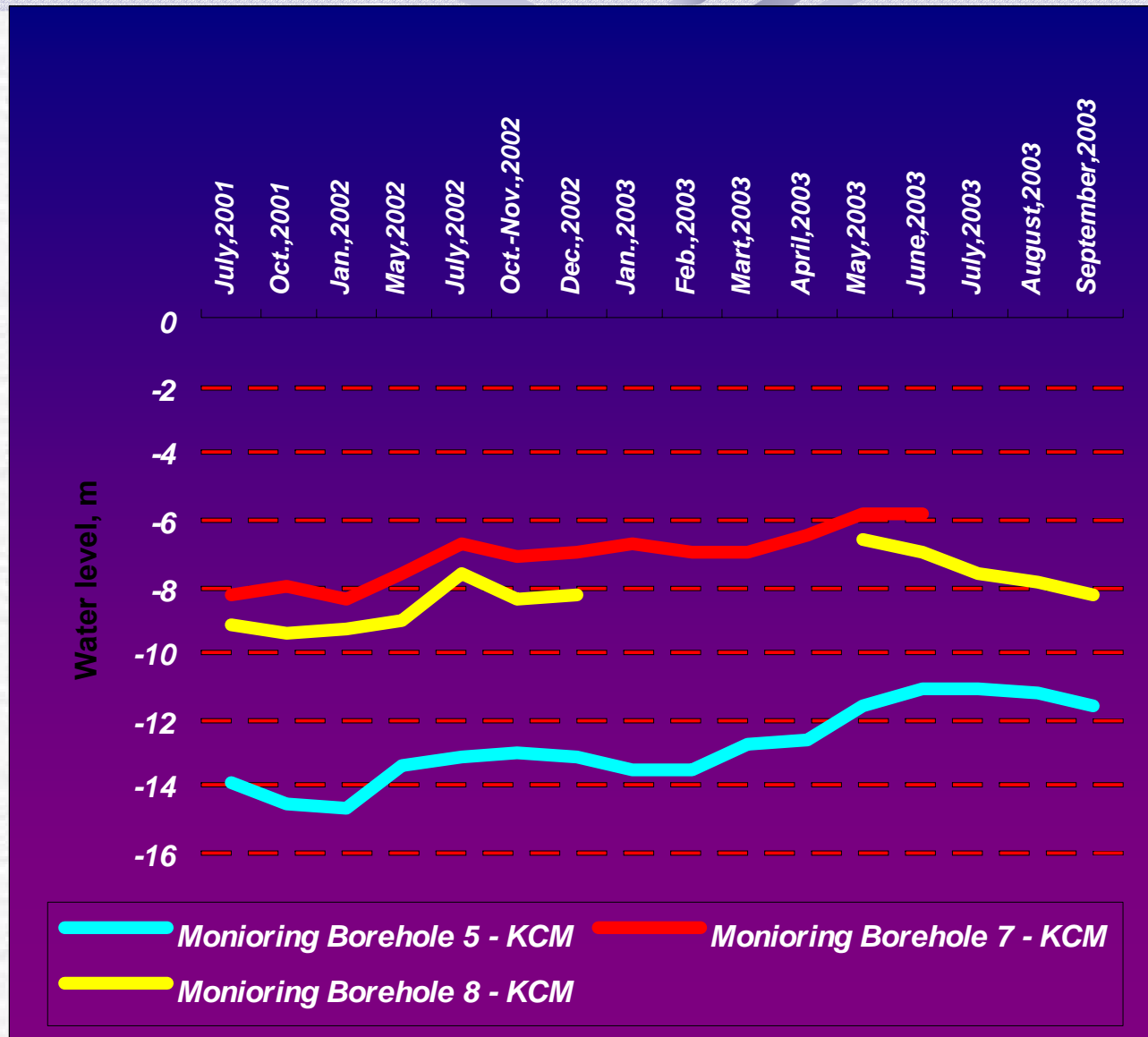
Jobin Yvon ULTIMA 2 High Resolution ICP-AES



Scans over the spectral region around the analysis line of Pb.

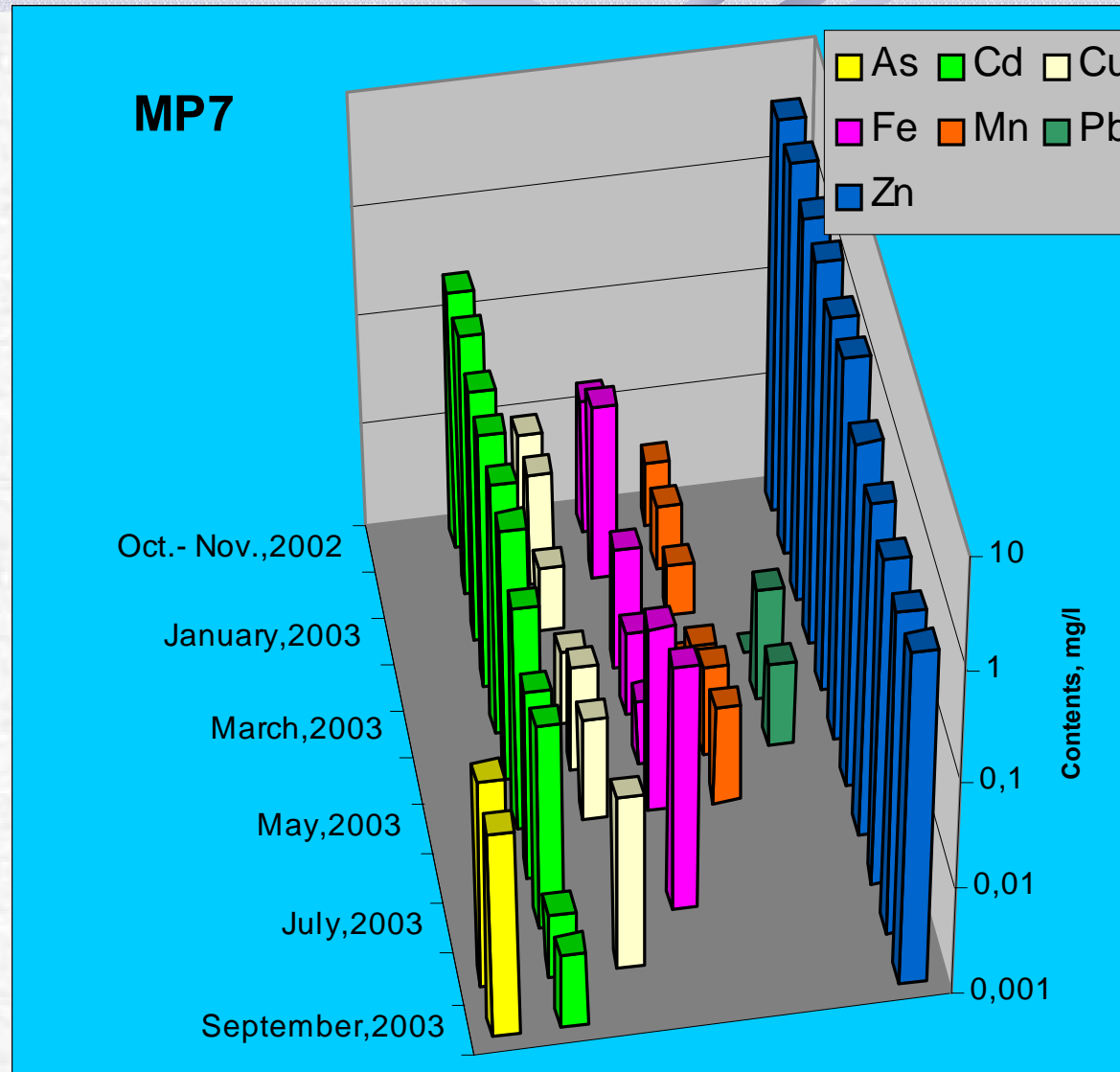
# Macrocomposition of the mineral waters, juxtaposed to the geological situation





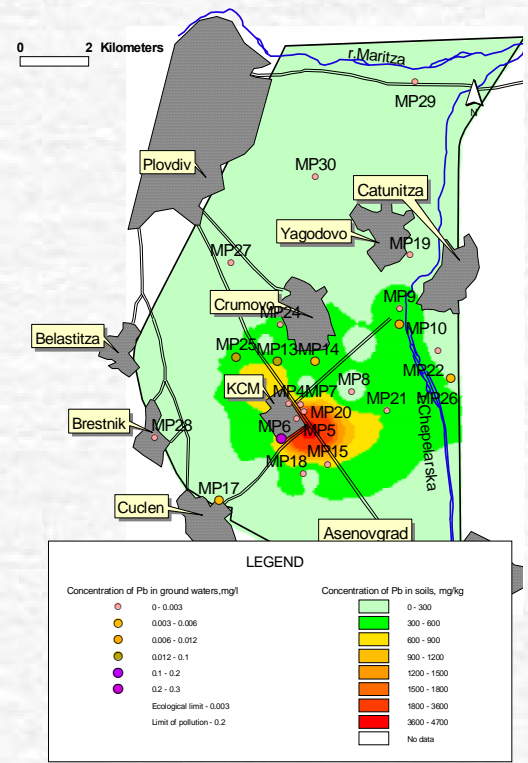
Groundwater level fluctuations in some monitoring points



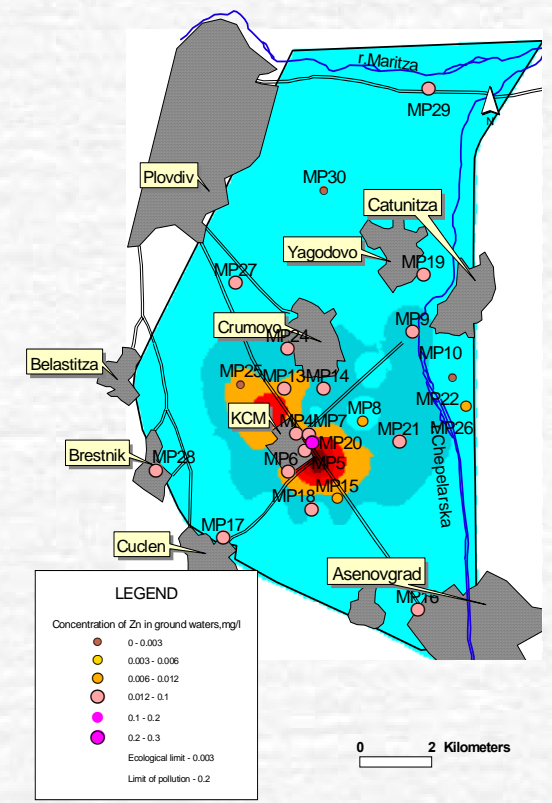


Monthly pollutant changes

Pb



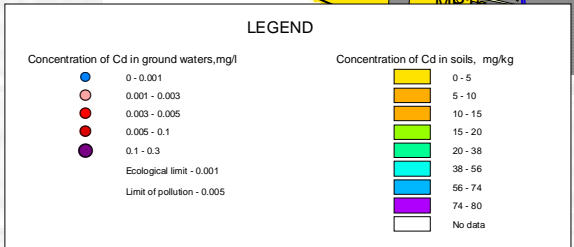
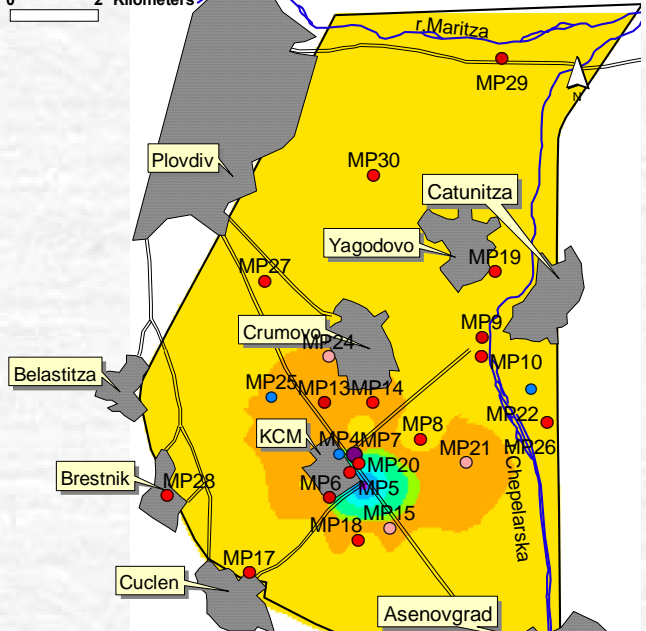
Zn



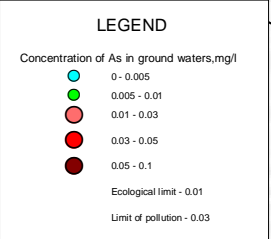
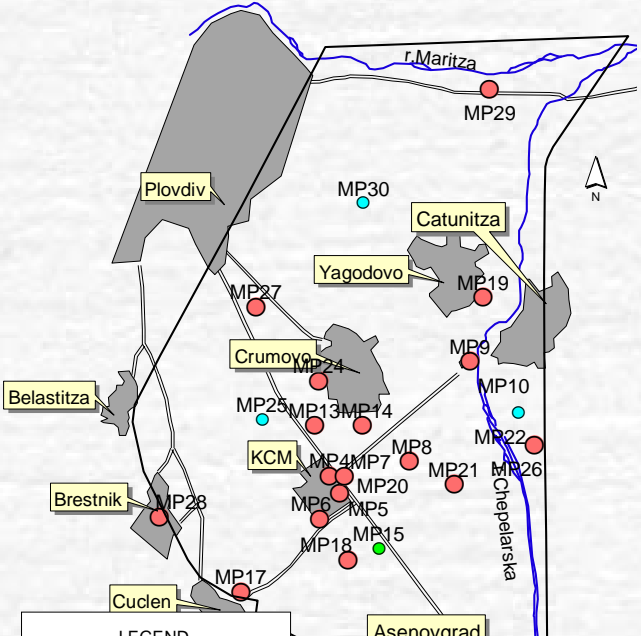
GIS integrated maps of the Pb and Zn contamination

# Cd

0 2 Kilometers

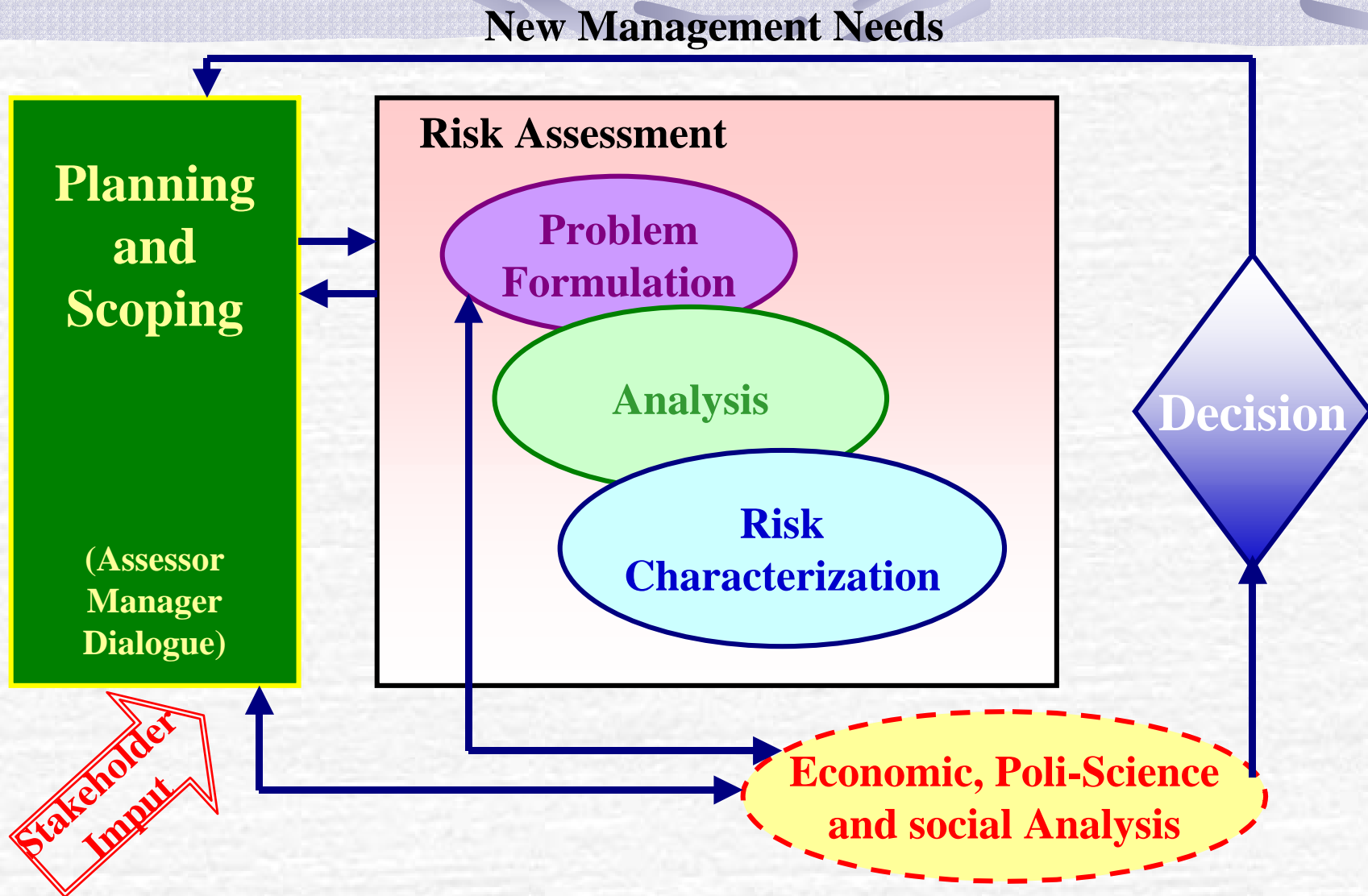


# As



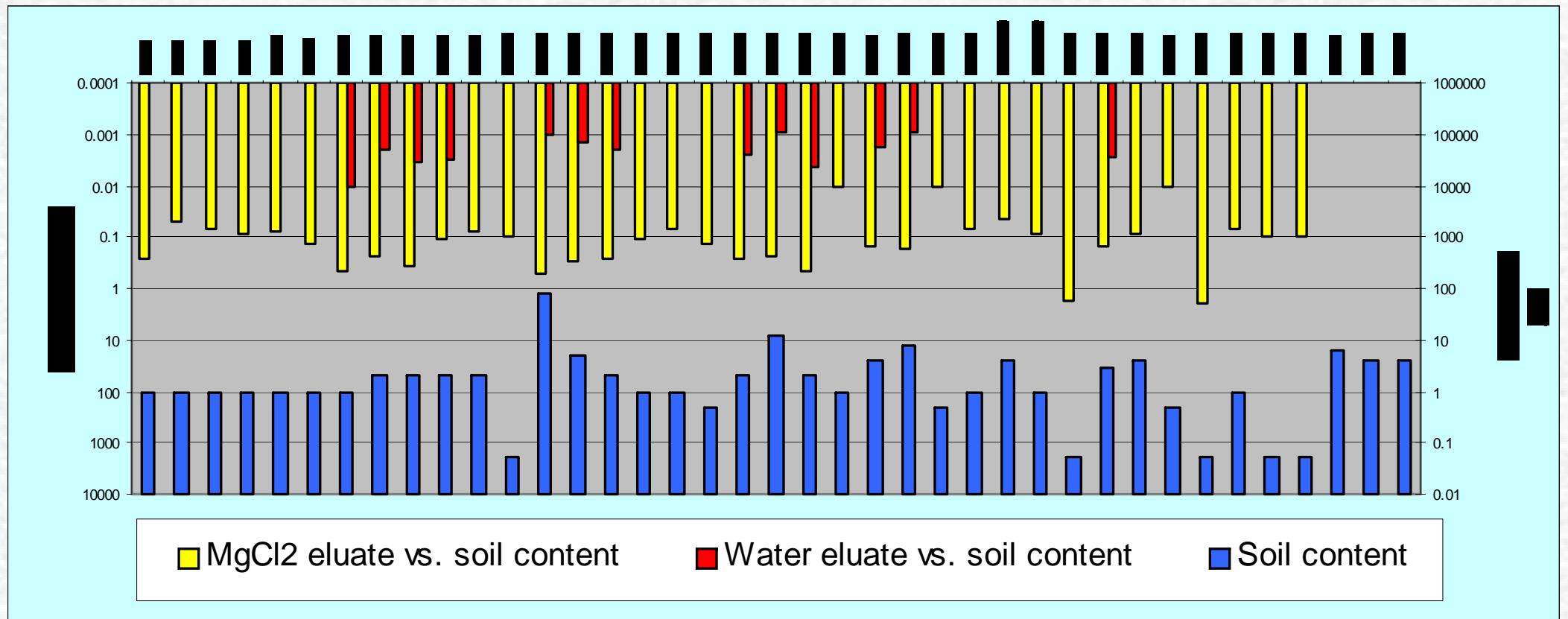
0 2 Kilometers

## GIS integrated maps of the Cd and As contamination

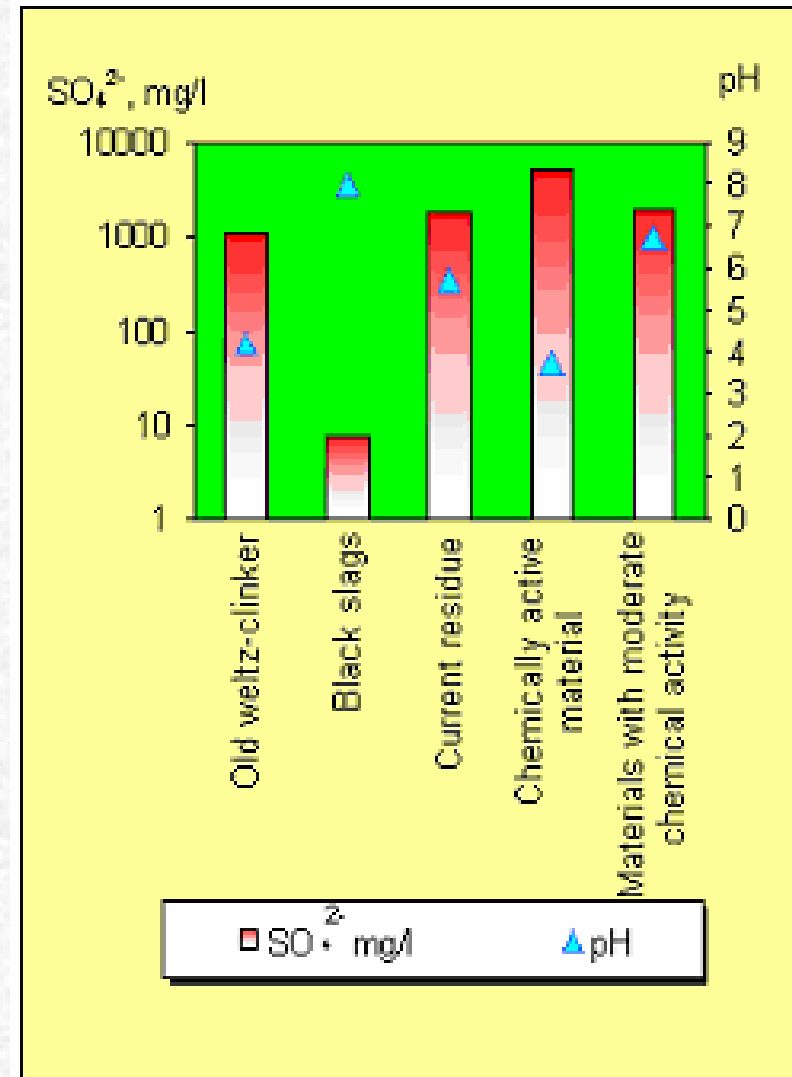
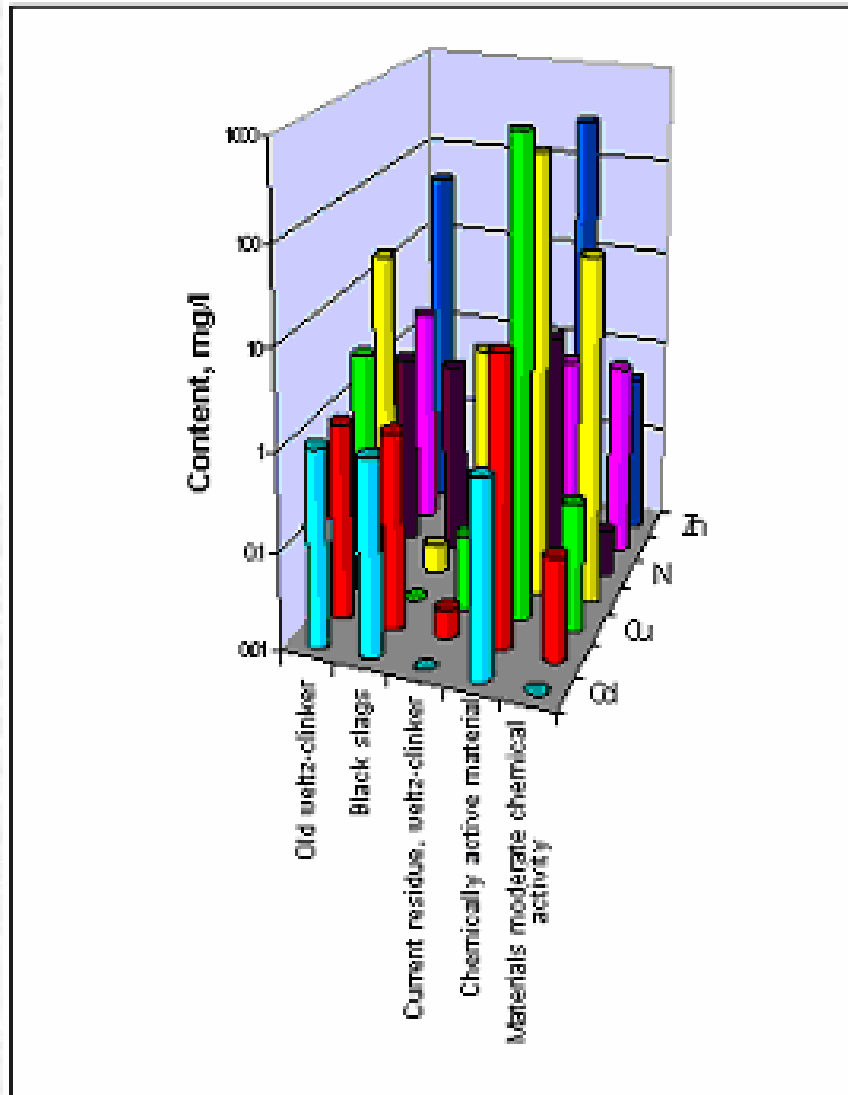


The GIS offers a graphic use easily manipulated and provides a possibility to interactively update the database, to analyse different data set and for risk assessment.

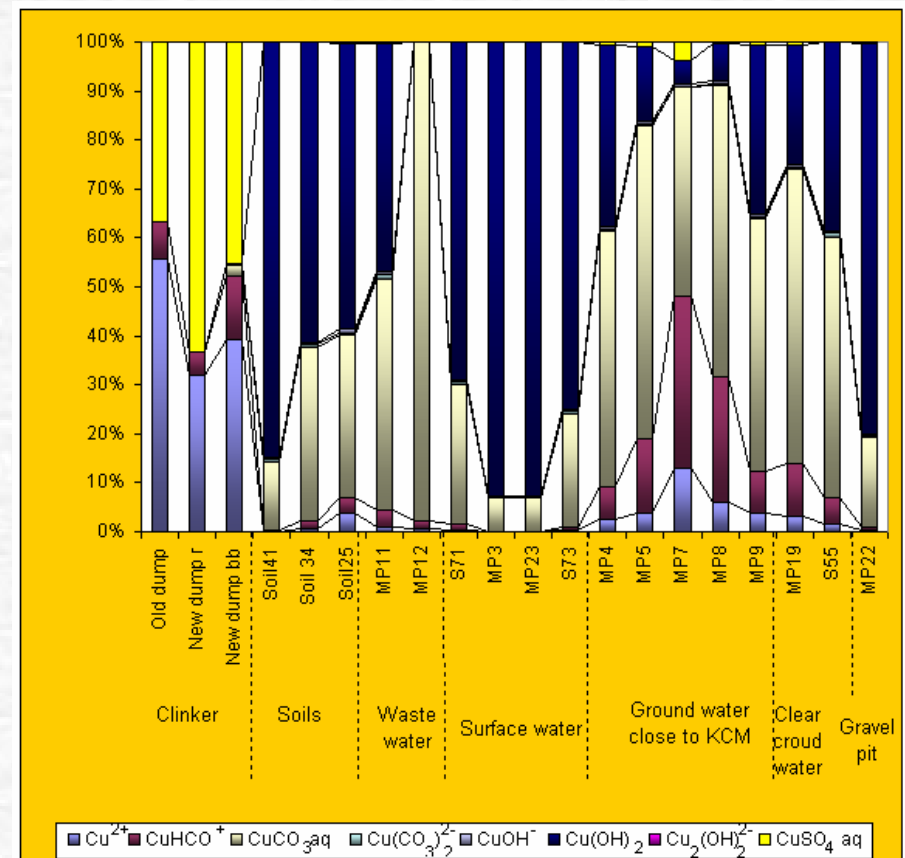
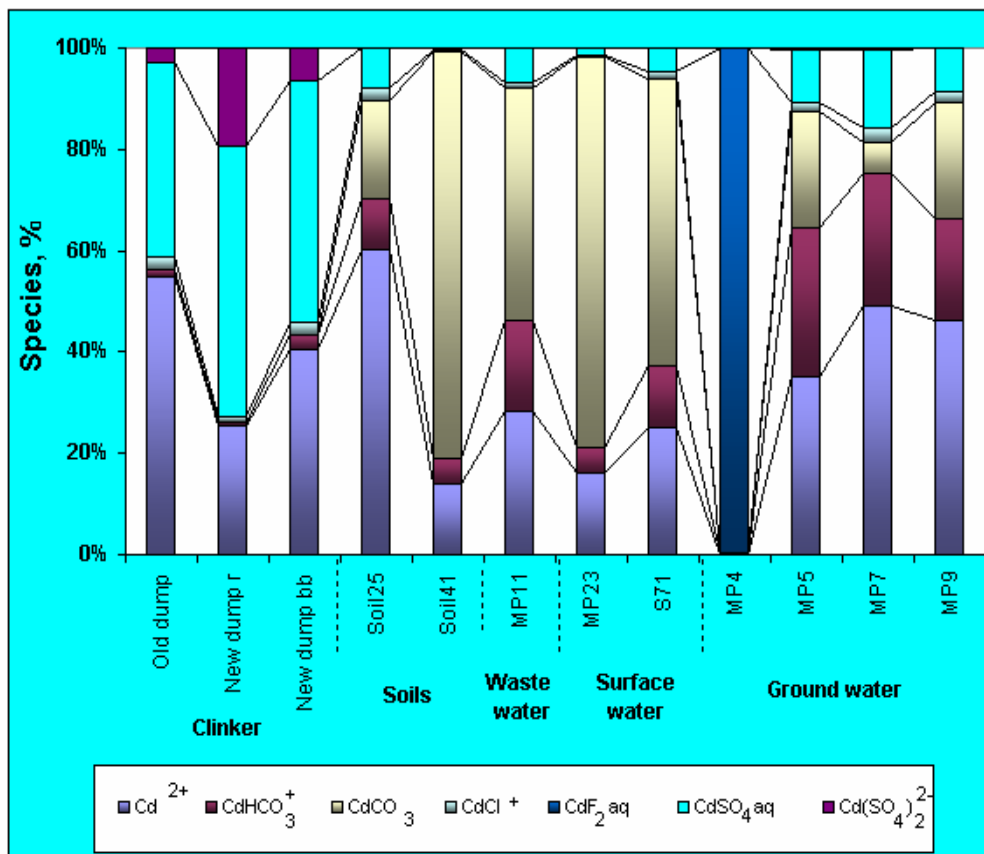
Experimental modeling of interphase processes "water – geochemical environment" and determination of the migration ability and the chemical speciation of metal (+As) pollutants in these systems are accomplished.



Water -Soil interaction model – Cd lixiviation

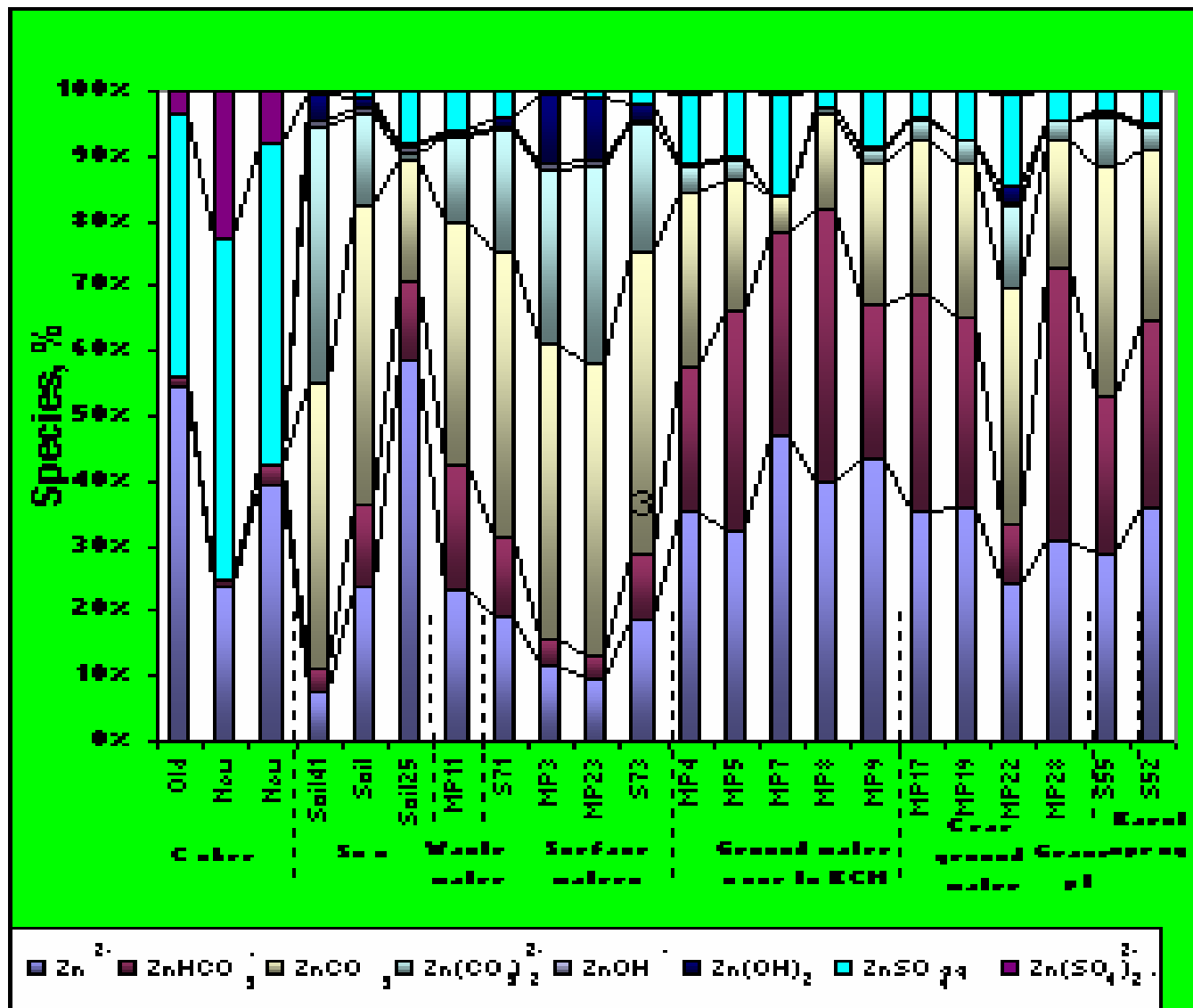


## Water –waste interaction model

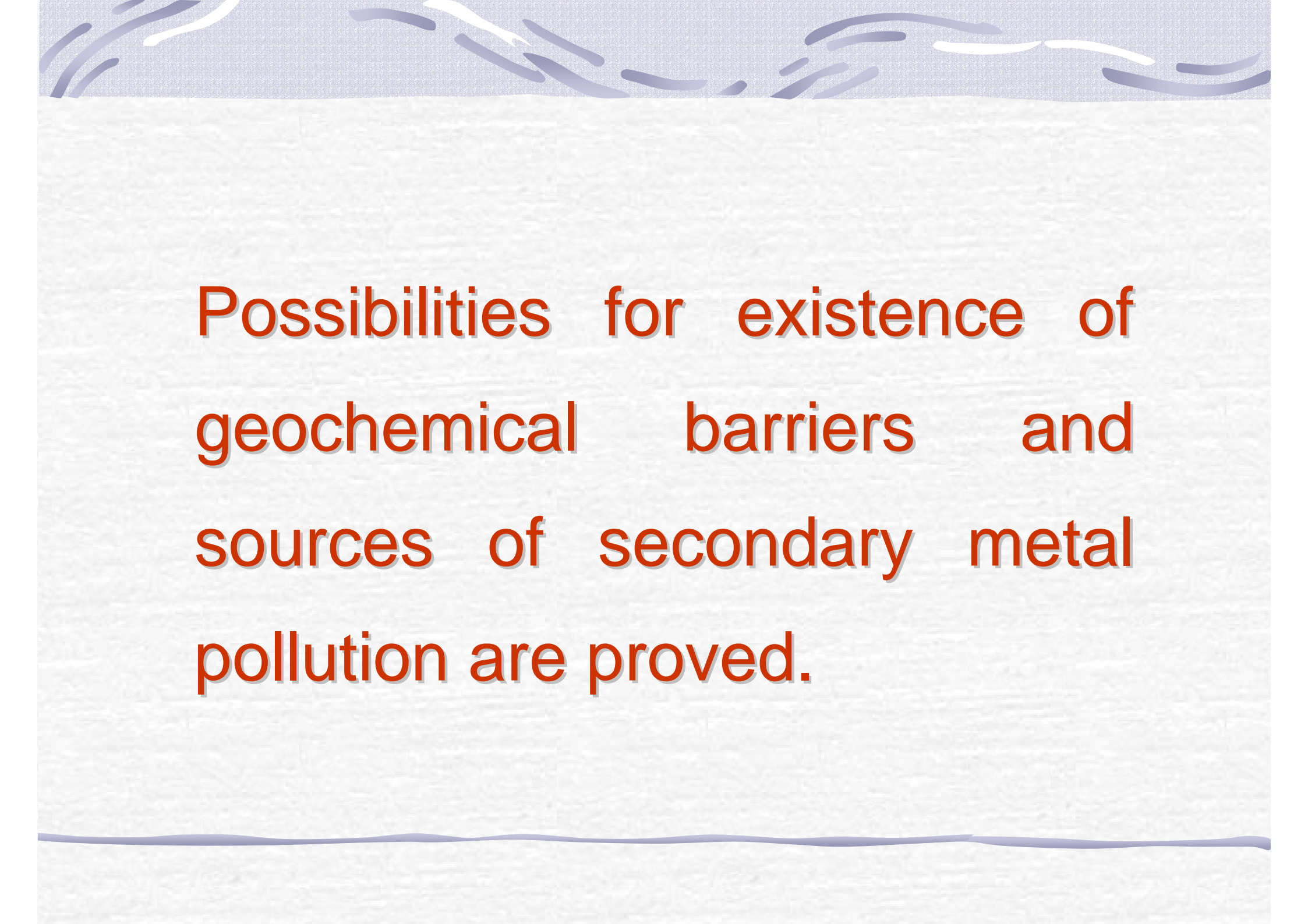


Cd and Cu speciation in waters and in experimental model water eluates



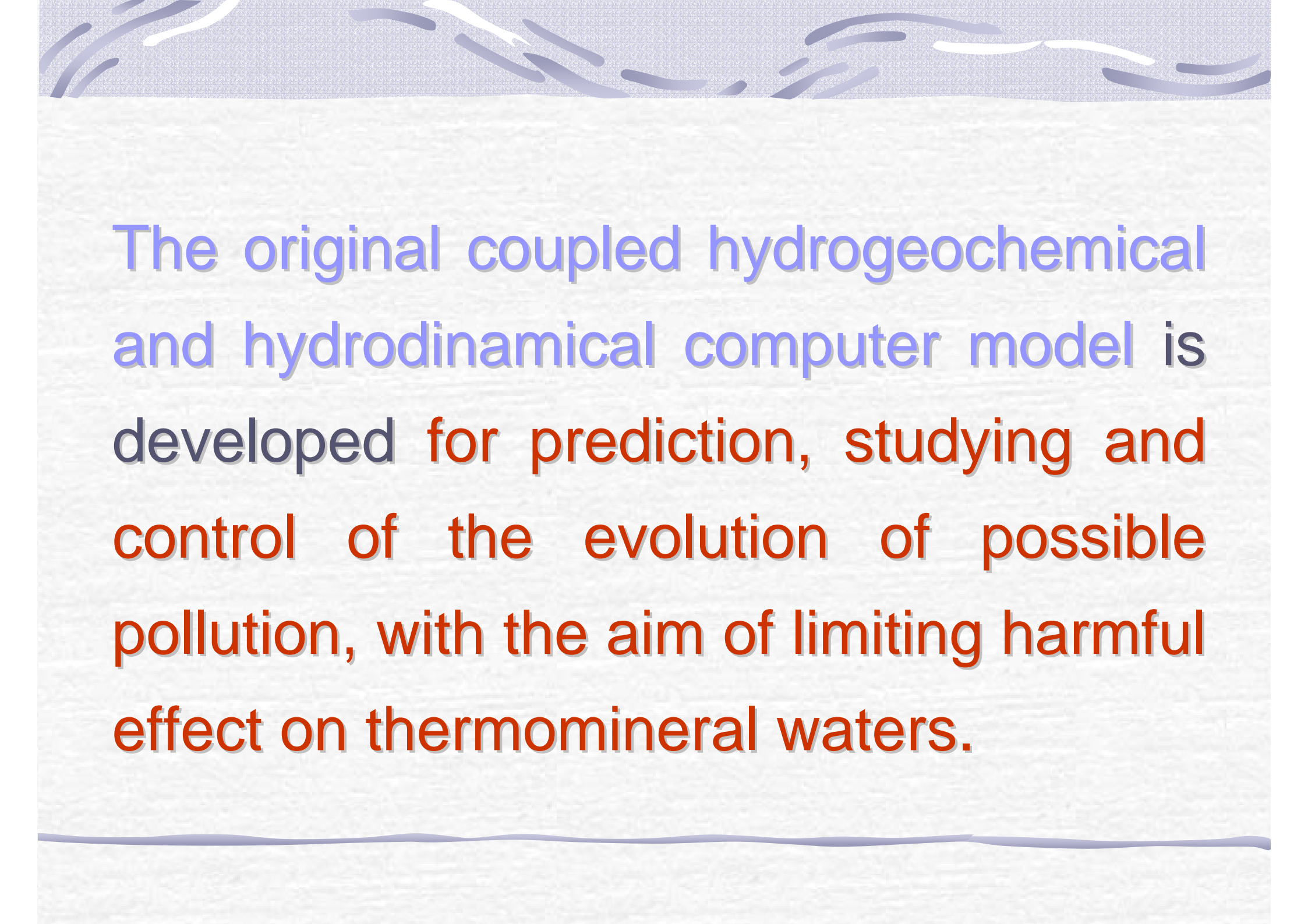


Speciation of Zn in water phase




Possibilities for existence of geochemical barriers and sources of secondary metal pollution are proved.






The original coupled hydrogeochemical and hydrodynamical computer model is developed for prediction, studying and control of the evolution of possible pollution, with the aim of limiting harmful effect on thermomineral waters.



The GIS based risk management and decision making specific tool was developed for Internet Explorer and is ready to be used. The models produced can be applied successfully in other regions and in different countries.



Plovdiv

Soil surface

Vertical cross section

Maritza River

Chepelarska River

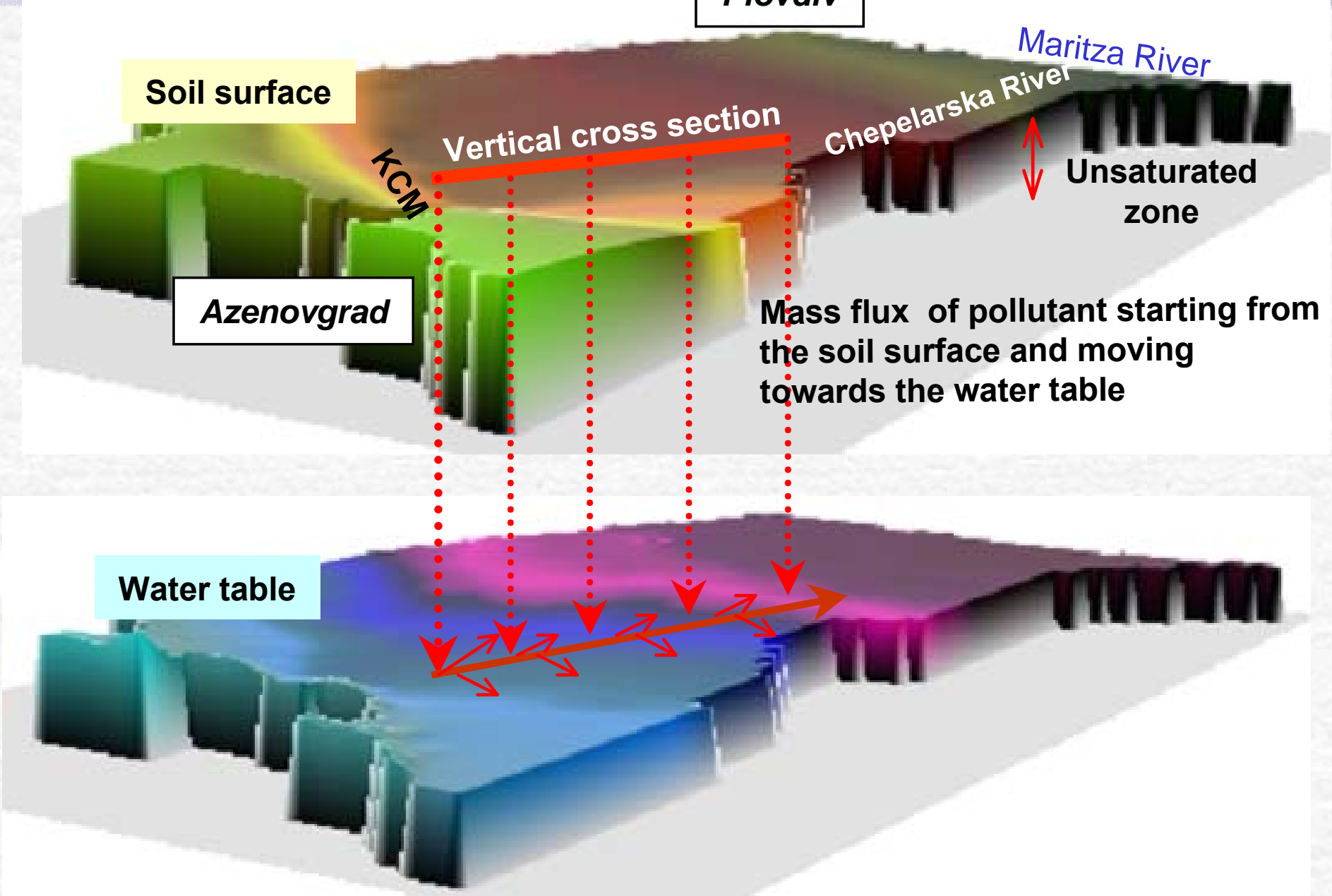
Unsaturated zone

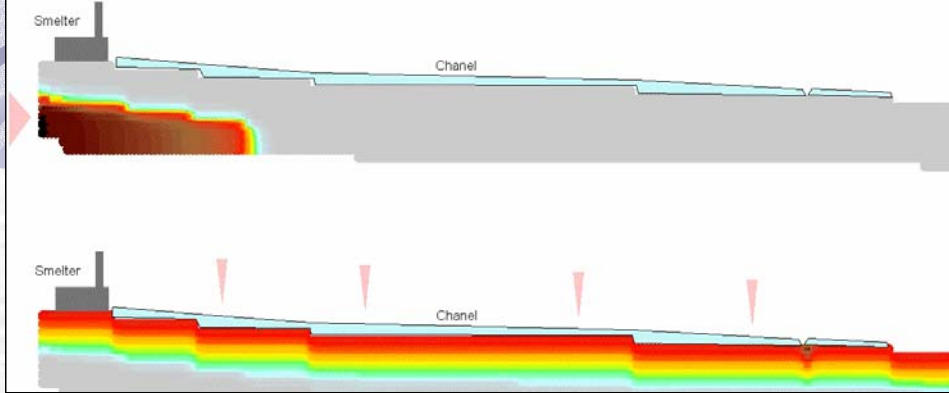
Azenovgrad

Mass flux of pollutant starting from the soil surface and moving towards the water table

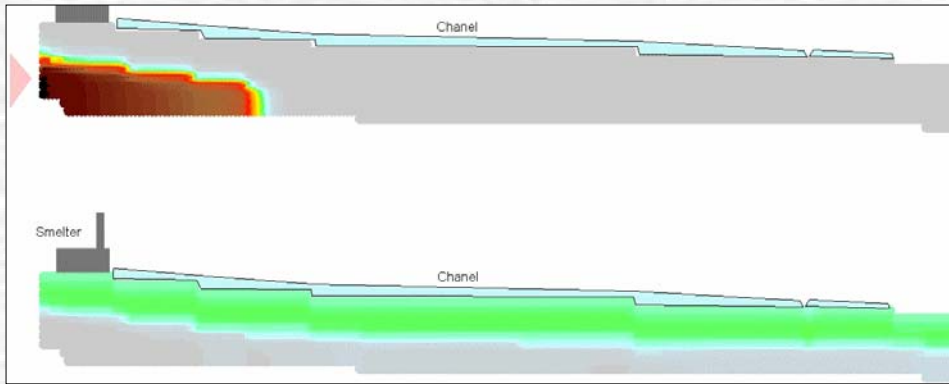
Water table

Modelling strategy

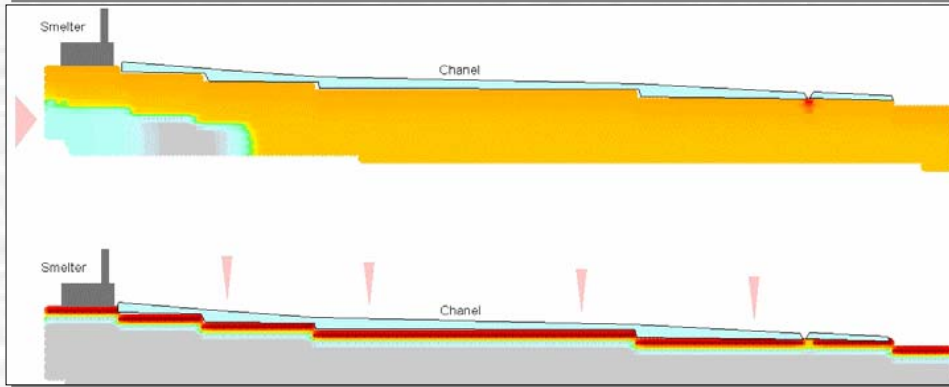




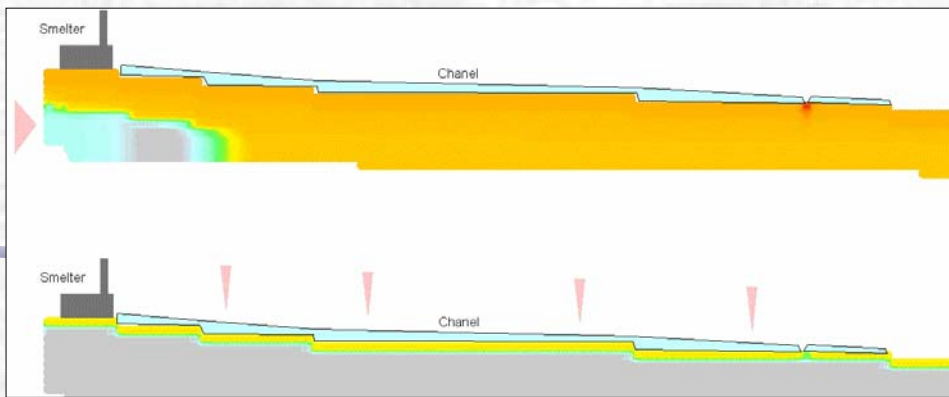
Scenario#1 : non reactive tracer  
input: during all the simulation



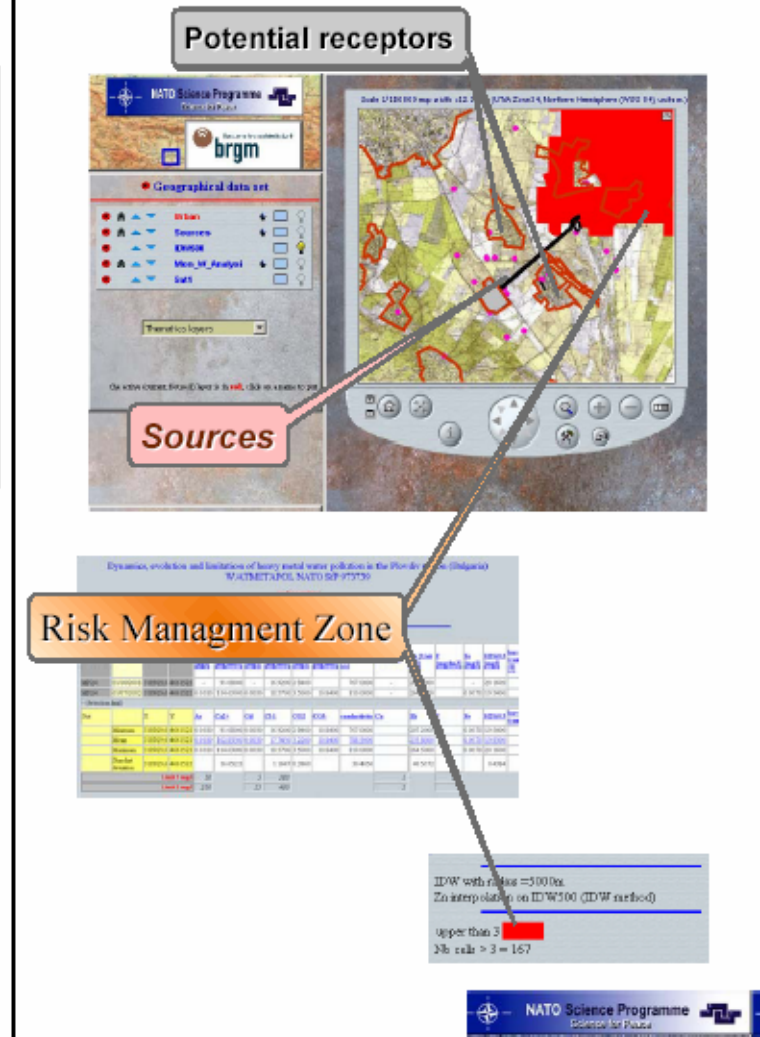
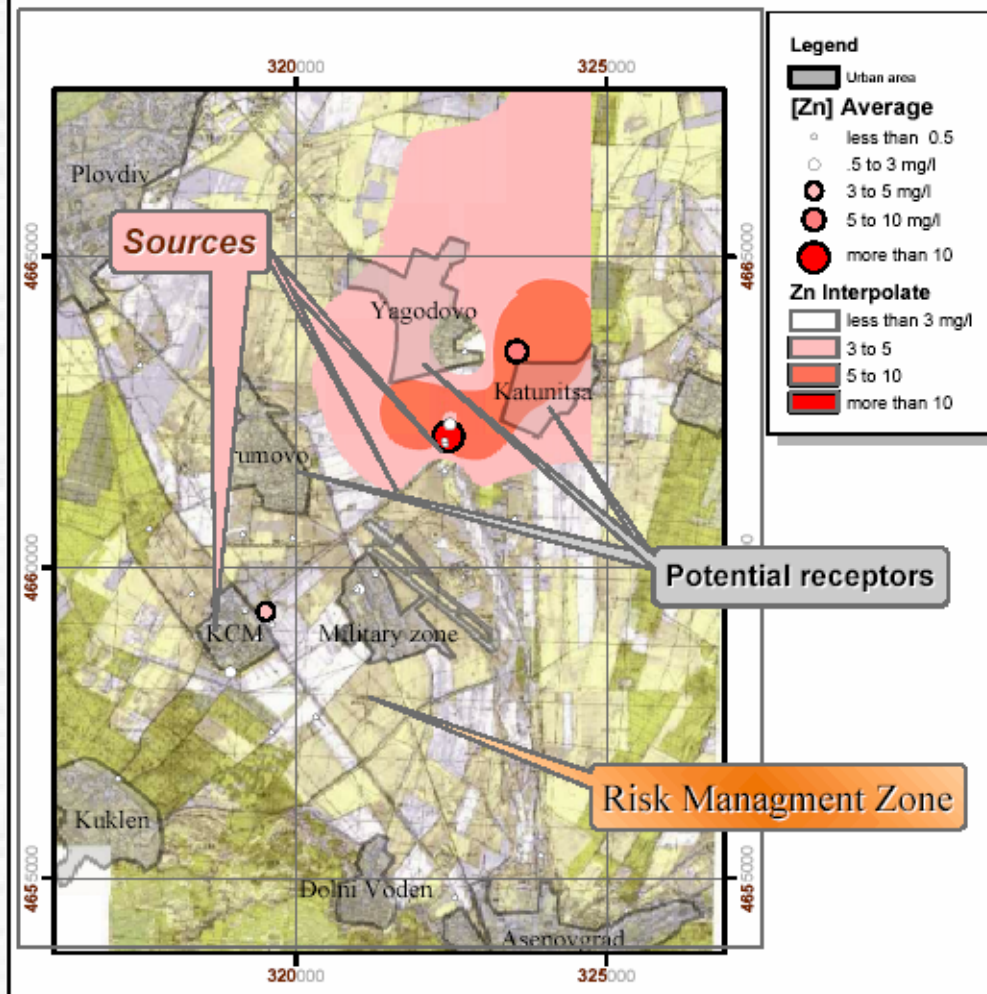
Scenario #2 : non reactive tracer  
input: only during the first 2 years of  
simulation



Scenario #3 : polluted rainwater  
input during all the simulation



Scenario # 4 : polluted rainwater  
input from 0 to 2 years. Non polluted  
rainwater input from 2 to 6 years






Example of a risk management map showing zinc concentrations in groundwater (the risk management zone is delineated for a concentration in zinc higher than 3 mg/l = European guideline for a sensitive use of water)



D:\Travaux\BULGARIE\Serveur\siteweb\watmetapol\Conceptual2.html - Microsoft Internet Explorer

Fichier Edition Affichage Favoris Outils ?

- Risk assessment
  - GIS
  - Modeling approach and forecast
  - Risk-based action
- Pollutants
- Glossary

- Sources
  - Pictures
    - [KCM Plant](#)
    - [Channelize discharge](#)
  - Characteristics
    - [Process description](#)
  - Datas
    - [Production over 11 years](#)
    - [Dust estimation over 42 years](#)

- Targets

- Media transfert
  - Waters
  - Soils
  - Sediments

Example of the toolbox display related to the different components of a risk assessment.


## II. Bulgarian hydrothermal system legislation

The last 10 years it has been a time of testing and completing the new legislation concerning thermal waters and geothermal energy use, of orientation toward market economy and of harmonization with EC country legislation.


The discussed and adopted laws, ordinances and rules defined the basic principles of study, prospect ion use and protection of the national curative resources –

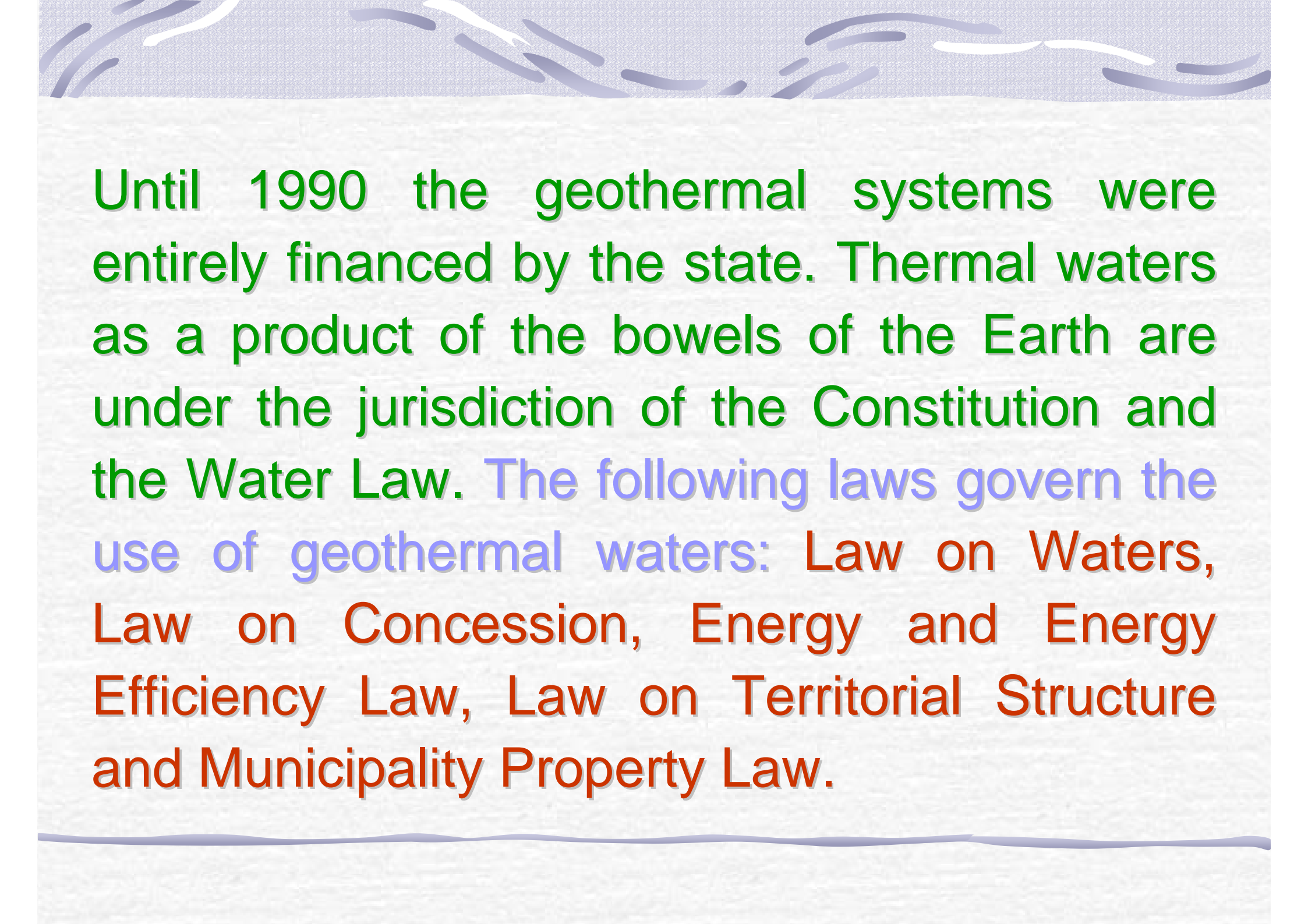
Bulgarian precious health richness: thermomineral waters curative pelloids, sea resources, climatic resources, etc.

According to the Water Law (1999, completed and actualized in 2005) thermal waters are owned by the State or by the Municipalities. Ministry of Environment and Waters (MOEW) approves the exploitable thermal water resources and hydrothermal energy and sets up the wellhead protection zones of all reservoirs (state-owned and municipal). Ministry of Health controls mineral composition and general state of all water and peloid sources.




State-owned thermal waters are administered by the Council of Ministers according to the **Concession Law (1995)** through concession regime and by the MOEW – according to the **Water Law (1995)** through permission regime. The Municipalities carry out the management of local thermal waters according to the **Municipality Property Law (1996)**.






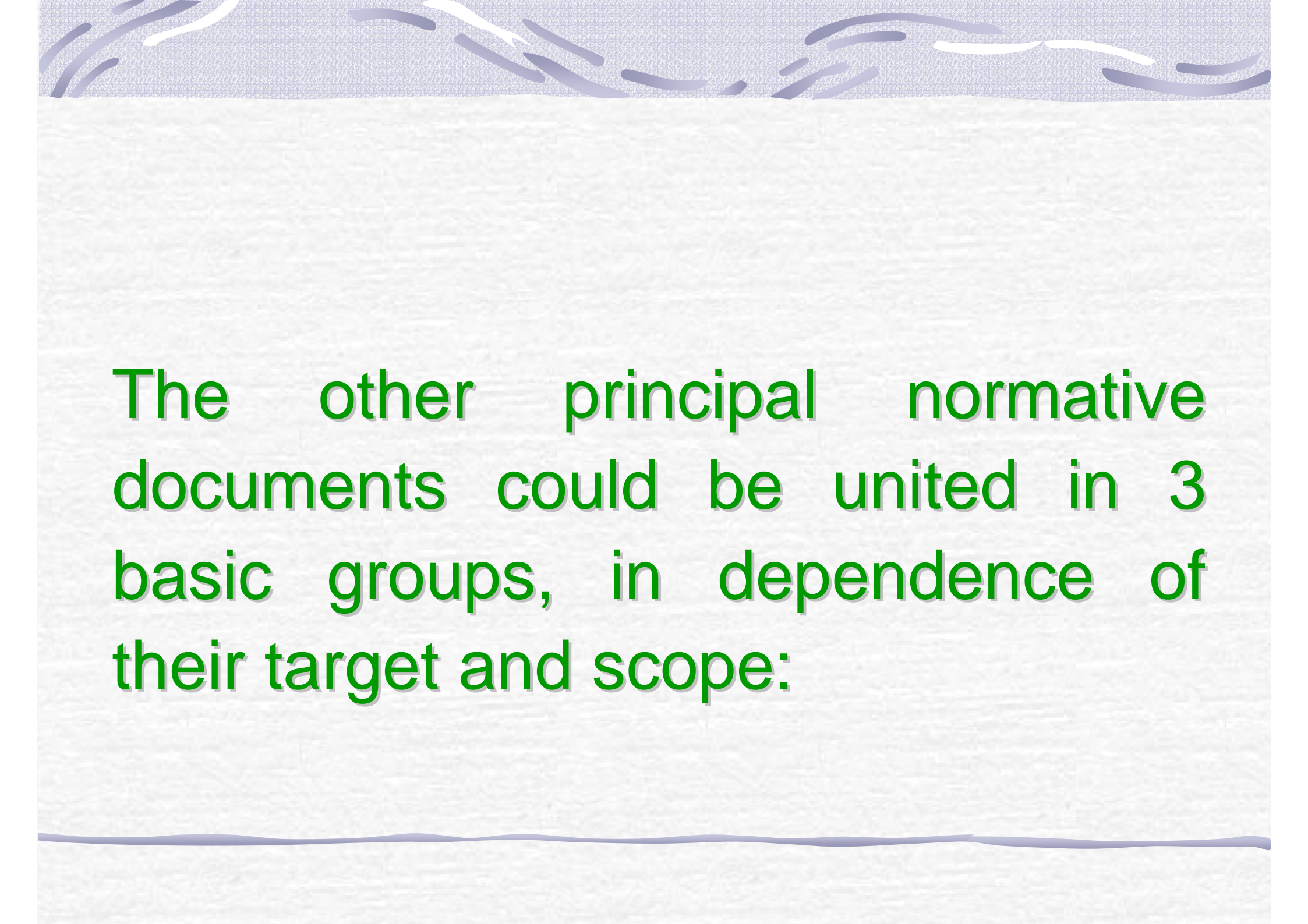
Until 1990 the geothermal systems were entirely financed by the state. Thermal waters as a product of the bowels of the Earth are under the jurisdiction of the Constitution and the Water Law. The following laws govern the use of geothermal waters: Law on Waters, Law on Concession, Energy and Energy Efficiency Law, Law on Territorial Structure and Municipality Property Law.



The **Law on Waters** states that the sole right for the use of waters is owned fully by the State and may be delivered via concession only for mineral waters when the use is for bottling, energy generation and extraction of chemical elements and derivatives.

Permits issued by the Minister of Environment and Water are required for state-owned thermal waters used for treatment, rehabilitation and prevention, swimming pools, thermal water supply for domestic, technical and industrial aims.





The other principal normative documents could be united in 3 basic groups, in dependence of their target and scope:



# **1.– Documents of the organization of the territories, related to thermomineral waters use:**

- **Law for protected territories – 1998**
- **Law for regional development – 2004**
- **Law for protection of the environment – 1995**
- **Ordinance for the resort resources – 1987**
- **Ordinance for hygienic requirements for health protection of the settlement environment – 1992**
- **Decision of the Ministry Council for defining of the settlement of resort formations with national importance – 2003**

## **2. – Documents of organization and government of resort activities:**


- Law for the health – 2004
- Law for tourism – 2002
- Rules for the activities of National tourist organisations – 2002, 2004

### **3. – Documents for the research protection and use of thermomineral waters and curative pelloids:**

- Rules of application of the laws of concessions – 1995
- Rules for the activities of the Regional inspections of the environments and waters – 2004
- Ordinance for research, use and protections of underground waters – 2000
- Ordinance for approval of the exploitation resources of the underground waters – 1999
- Ordinance for requirements concerning the bottling of mineral waters for drinking use – 2004
- Ordinance for the conditions and the order for research, design, approval, and exploitation of sanitary – protected zones around the thermomineral water sources, use for treatment, prophylactics, drinking and hygienic needs - 2000


## Major current barriers for hydrogeothermal development in the country are:

- - Lack of administrative and practical expertise in hydrogeothermal development under the new social and economic conditions in Eastern Europe after 1990;
- - It is allowed non observance of the requirements and the norms by the documents application, especially in the case of protection and use of the natural curative resources. This is particularly valid in respect to the curative pelloids, because of existing omissions in normative documents;



- The procedure for obtaining a concession for water use is very complicated and time consuming. In some cases, the investors have to finance complex preliminary geological and hydrogeological study without having guarantee for gaining the concession after completing the procedure;

- Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets. The Municipalities are also not allowed to influence on the size of these taxes;



# **Cooperative research project on “National health systems and spa treatments in Europe”**

- Existing thermalist associations: “Balneology and spa centers” and “Balneotourism”, Regional groups of private spa proprietors
- National health system does not pay for spa treatment! Only for invalids I-st group expenses for accommodation, 3 kinds of treatments and traveling (1 time in 3 months) are refunded, but from the side of the National Insurance Institute!
- Some rich private societies are covering the treatment and travel expenses of their own employees.

- Sickness funds and friendly societies existed in Bulgaria, but they are destroyed by the totalitarianist government.
- National and regional register of thermomineral resources and spa are not existing. It is very important to create Bulgarian business organizations, contacting with European ones. And to create and impose directives from the side of the European organisms – to oblige the Bulgarian spa systems to operate at the European level.



**Thank you!**