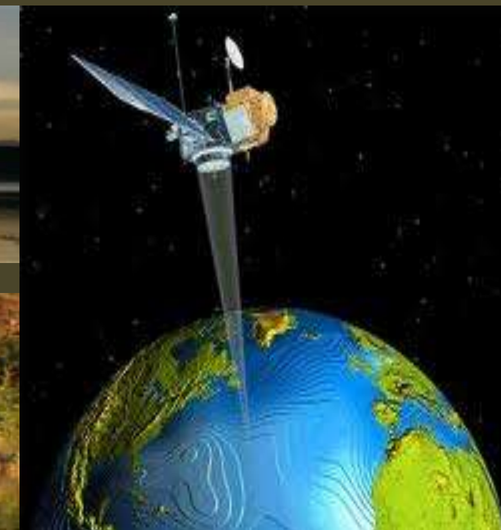
Assessing the impact of metals loads and other contaminants in large freshwater bodies using hyperspectral remote sensing. A challenge for the future of lakes and rivers management.



International Workshop on Advanced remote sensing methodology development to support Natura 2000 management actions across EU

7 December 2011, Budapest, Hungary

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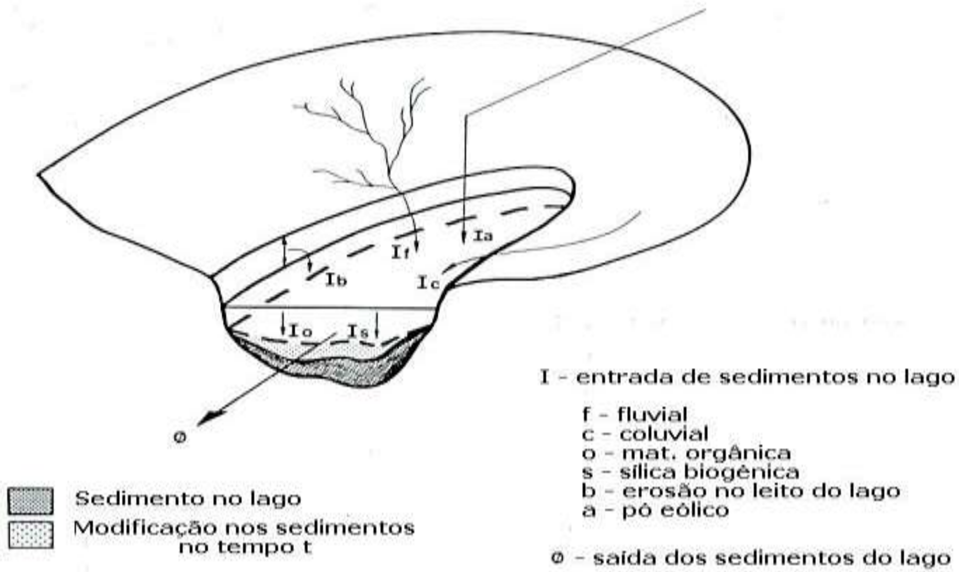
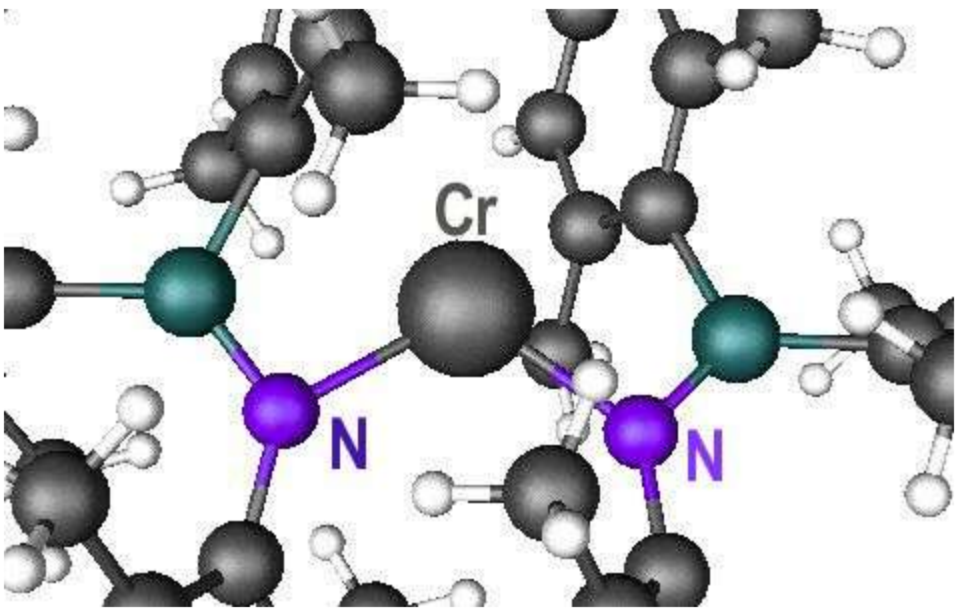
Heavy Metals



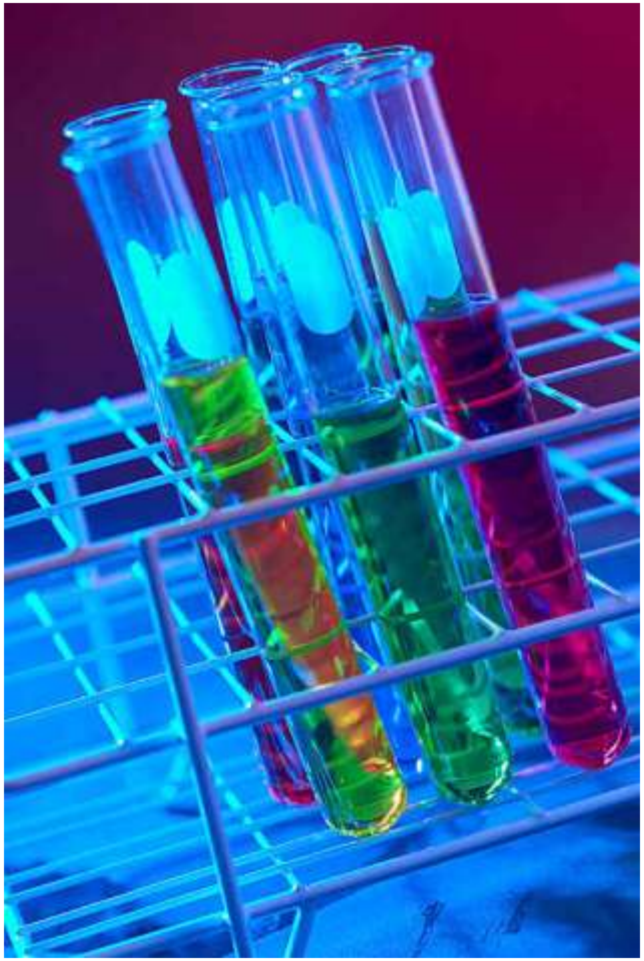


Sediments → last receptacle for metal loads outcoming from drainage basins.

Contents + Distribution + chemical forms in sediments → determined by chemical conditions of the environment + geochemical characteristics of the weathered materials in their sources (soils and layers of rocks alteration) ← parent rocks

Toxicity + ability to accumulate in the biota → serious problems in the environment.

Metals in the water column

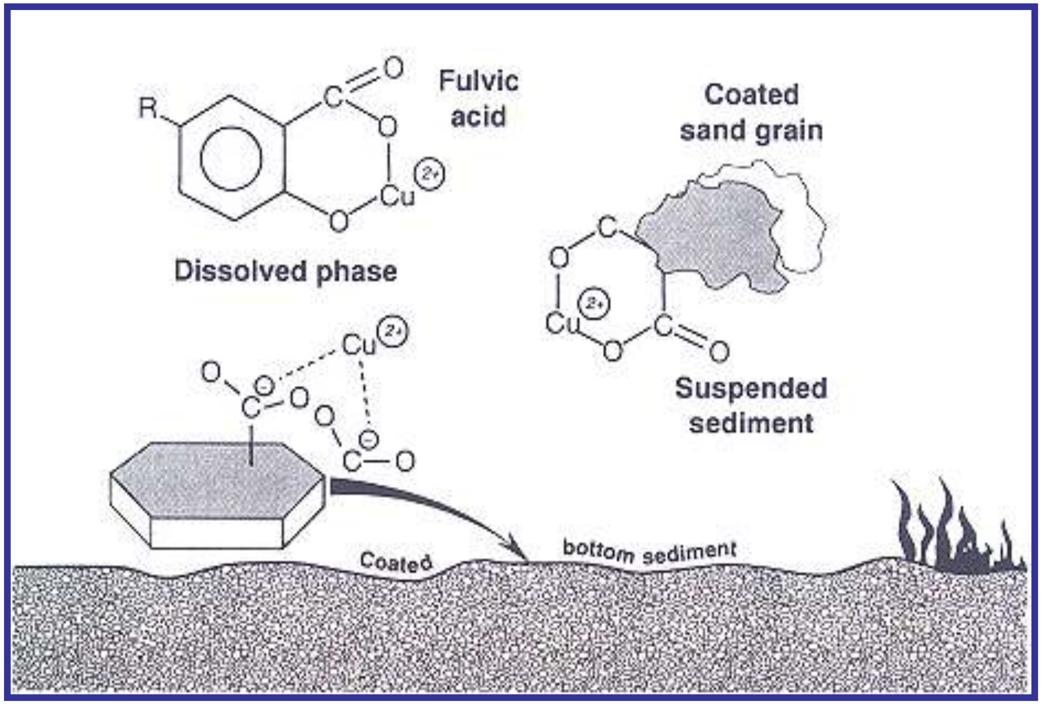


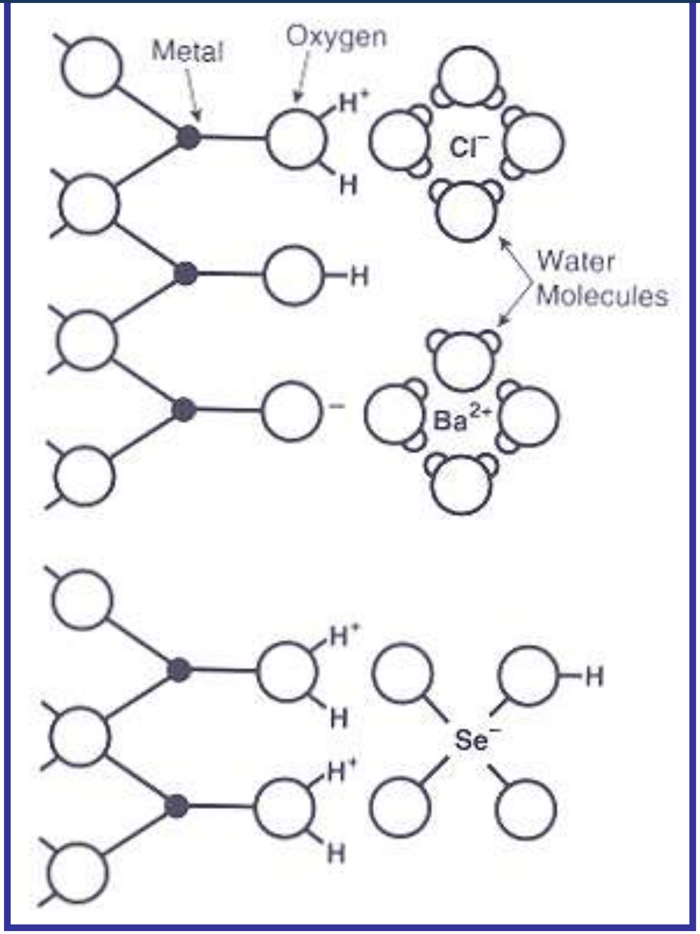
In lacustrine and fluvial systems, concentrations of metals in the water result from (1) entry into the basin through point and diffuse sources, (2) transport as dissolved and particulate forms resulting from erosion processes in the basin, (3) transformations and immobilization by bottom sediments through adsorption, fixation or sedimentation.

SEDIMENTS IN LAKES → Retentive to metals. Majoriry of metals entering a lake → lost to the sediments

Watersheds provide the vast majority of metals through streams and rivers .

1. **Suspended material**: incorporated in solid inorganic/organic phases (clay minerals, oxy-hydroxides Fe/Mn and other fine grained particles (high superficial area), anthropogenic emissions); adsorbed and/or absorbed by these suspended particles
2. Transported in soluble phase in the water column: movement in solution as cations, anions and ionic complexes

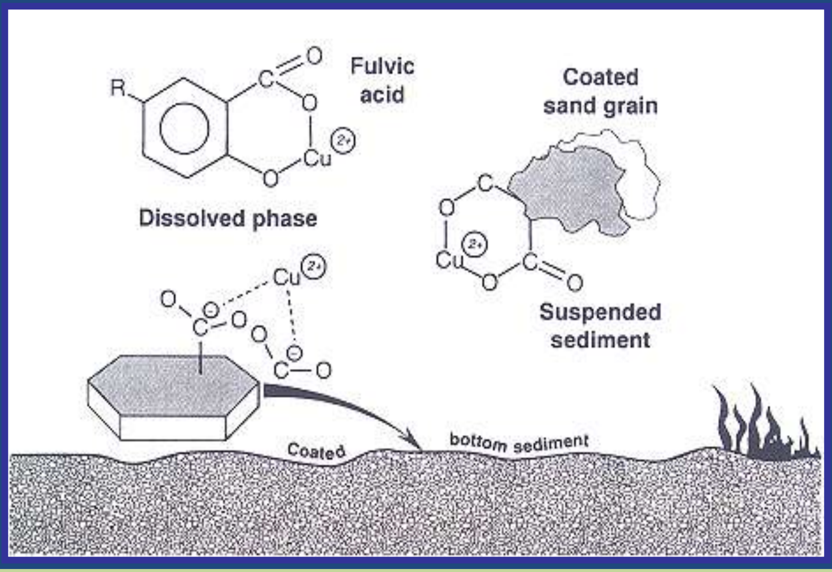


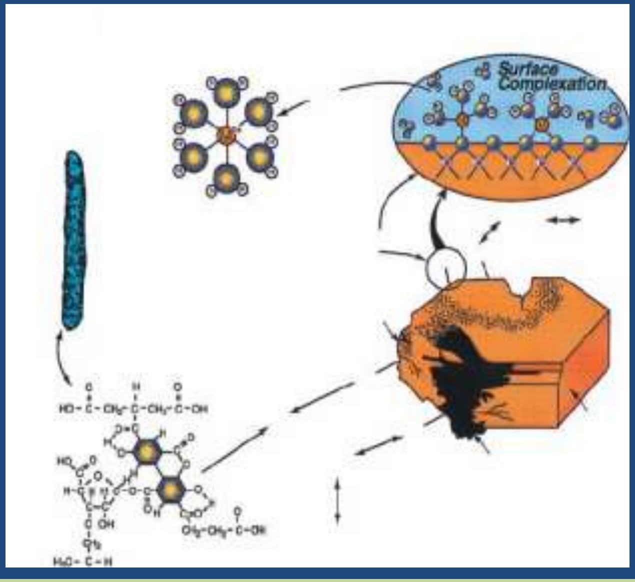


Biogeochemistry of metallic elements in aquatic systems

Sediments → have been recognized as the most important trace metals reservoir in the ecosphere. However, the retention rate depends on the chemical and mineralogical composition of the sediments and on the mixing, trophic status and chemistry of the lake.

Sediments → **main sink for these elements**, when environmental conditions change (pH, redox potential, etc.), sediments → can act as **a source of metals**





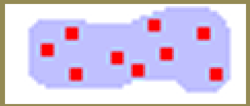
Diversity of metallic elements in aquatic systems

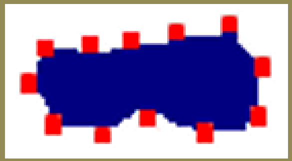
- ≠ chemical forms in the sediments/water
- ≠ oxidation states
- ≠ Organic and inorganic complexes
- Distribution in the water column and sediments (aqueous, solid, colloidal phases)

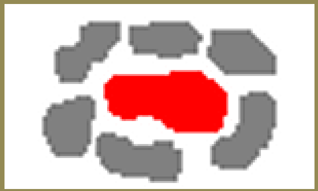
Transport of metals into aquatic systems

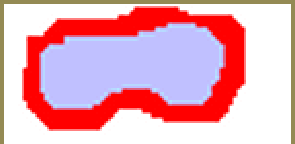
Chemical forms in solid and soluble phases

1. In exchangeable positions – as cations or ionic complexes adsorbed on clay minerals or on organic particles ;
2. As absorbed forms;
3. In carbonate minerals;
4. In easily reducible phases;
5. As sulfides;
6. As residual and resistant forms;
7. As soluble phases – liquid films or pore water





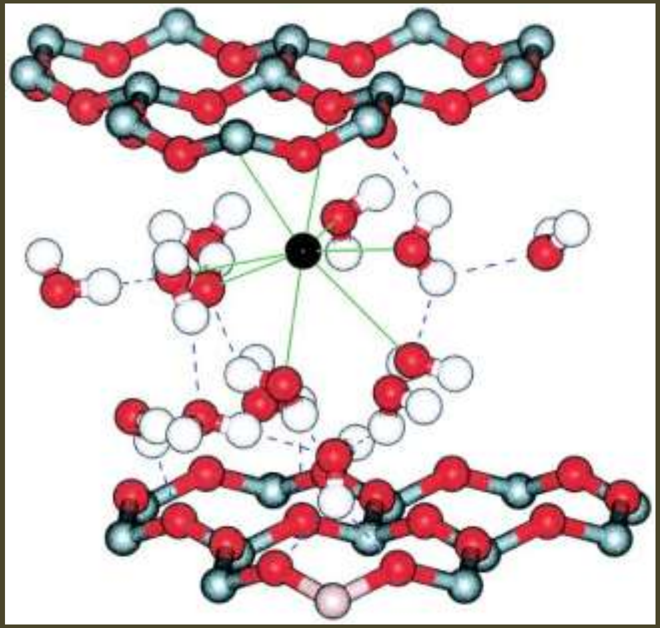




Parameters which control mobility, dispersion, precipitation/deposition and concentration of metals:

- **Chemical conditions**: solubility of the element, concentration, pH, redox potential, temperature, biochemical oxygen demand, salinity;
- **Sediment characteristics**: particle size, mineralogical composition, adsoption and bioacumulation capacity, contents and composition of organic compounds, interaction with pore water and with water column and activity of organisms

determine the chemical forms in which metals are introduced into the environment



Anthropogenic activities

Human activities → increase of the mobility and toxicity of heavy metals and other polluted elements outcoming from geological (natural) sources

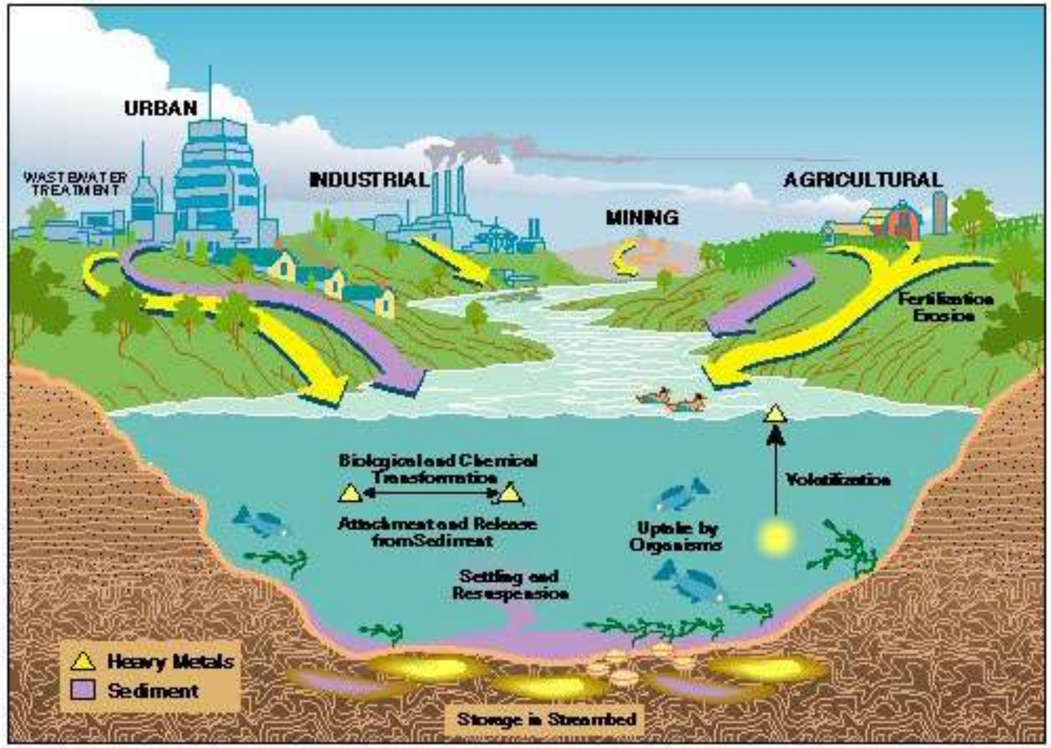
i) Point sources:

- Active and abandoned mines
- Industries: steel and foundry plants

ii) Diffuse sources

- Runoff from agriculture
- Wastewater treatment
- Runoff from urban areas

Figure 21--*Sources and Sinks of Heavy Metals*

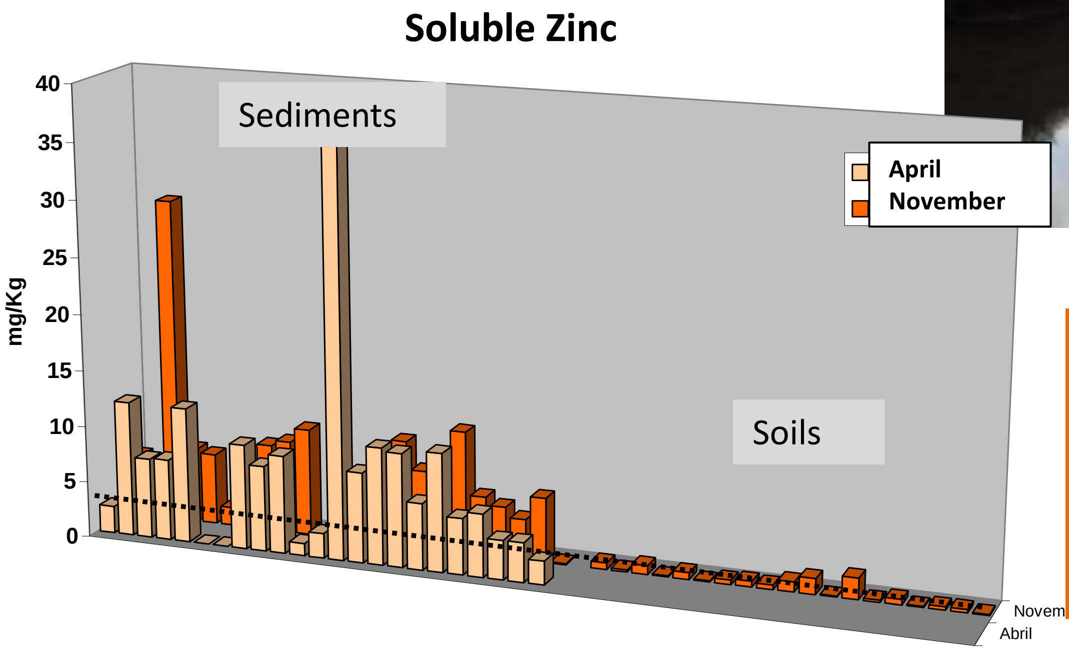



Minas Gerais, Brazil


São Domingos, Portugal

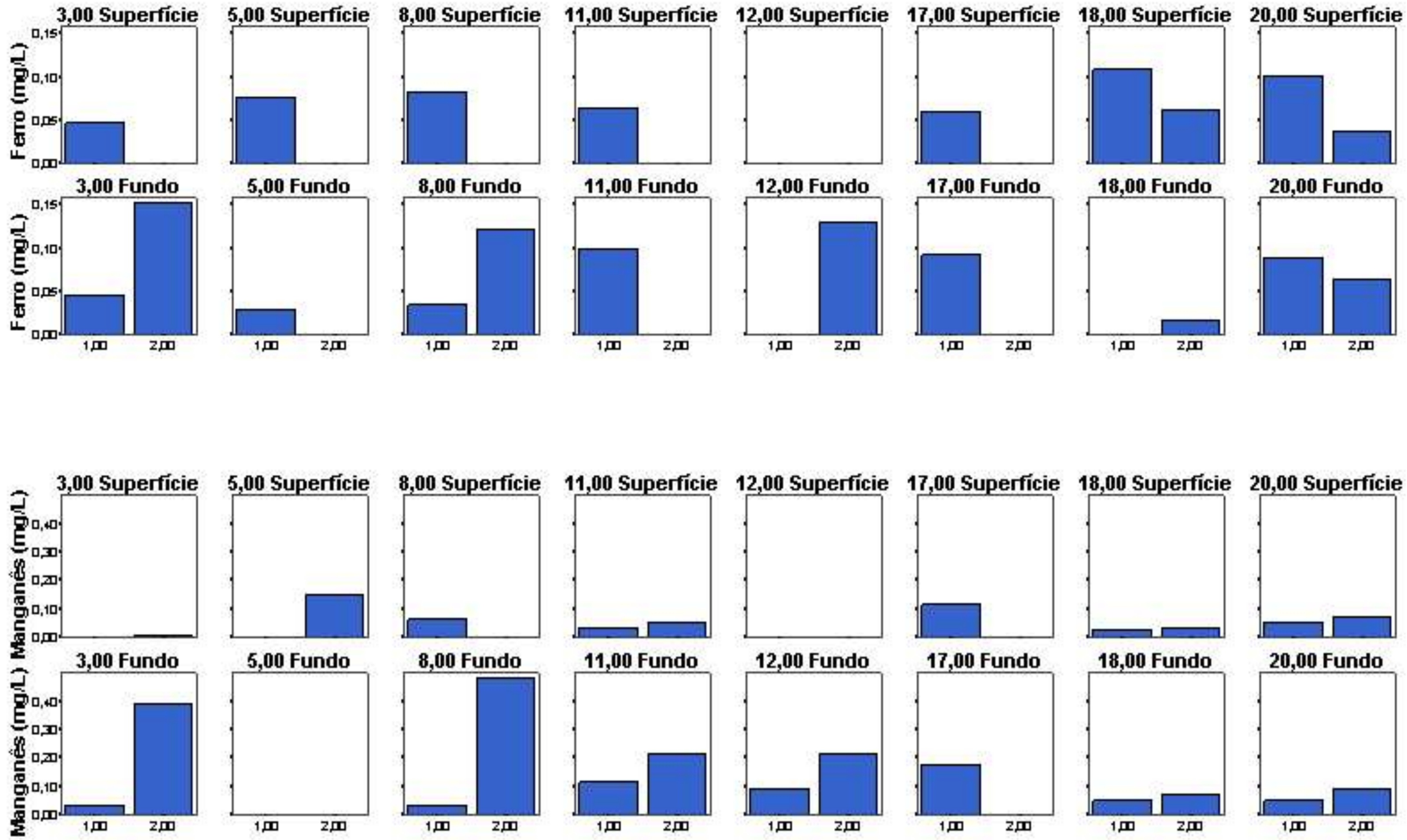
The characterization of heavy metals and other polluted elements derived from active and abandoned mining sites and from agricultural over-eroded regions is a complicated task

- ➢Variable spatial distribution of metals
- ➢Diffuse contamination in soils, freshwater systems and surrounding area

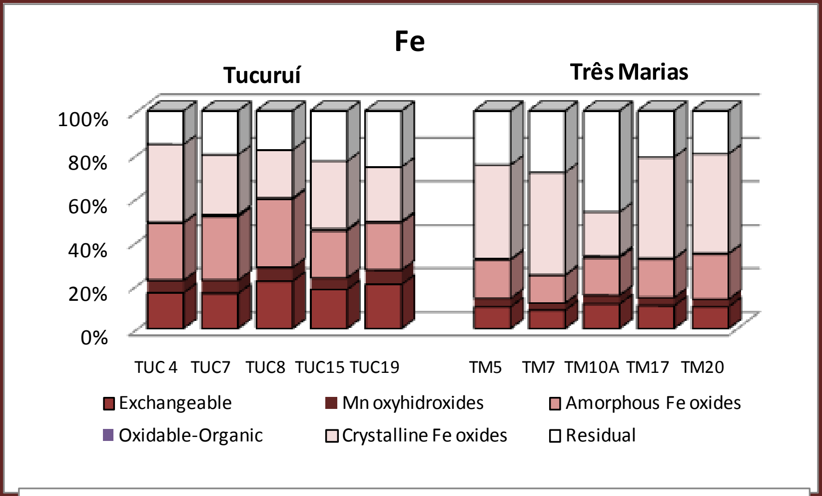


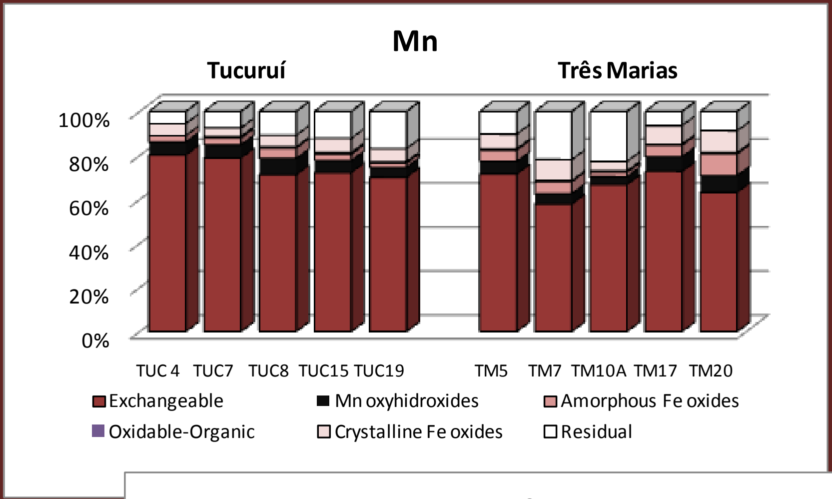
Variable spatial and seasonal distribution of soluble Zn along Tucuruí Reservoir (Amazon region, Brazil) in the bottom sediments and surrounding soils

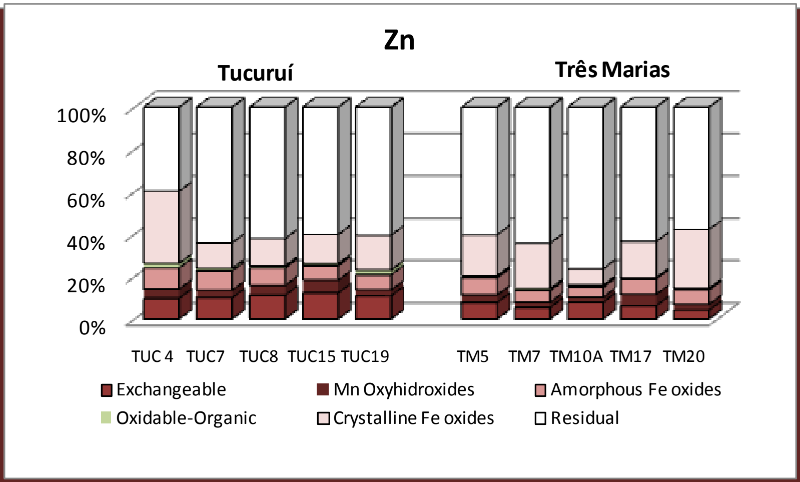
Metals in the water column (Fe and Mn)

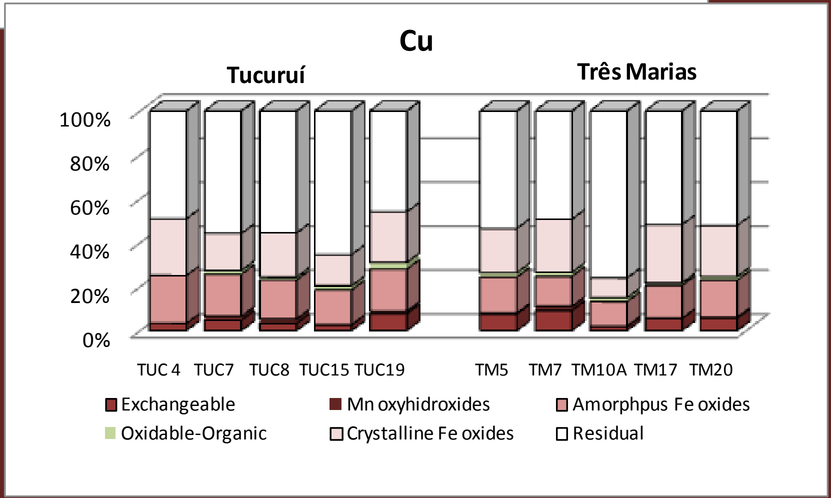


Heavy metals are present in different chemical forms in sediments, which determine their mobilization capacity and bioavailability.







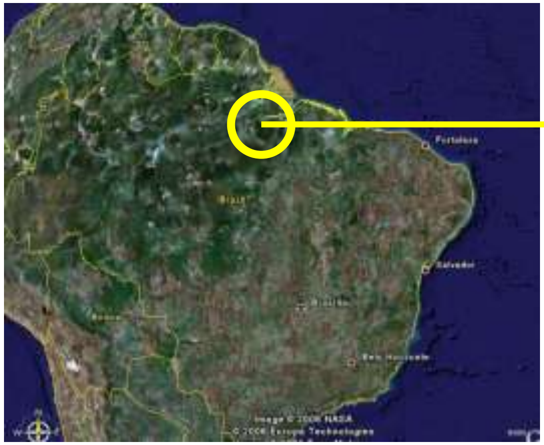


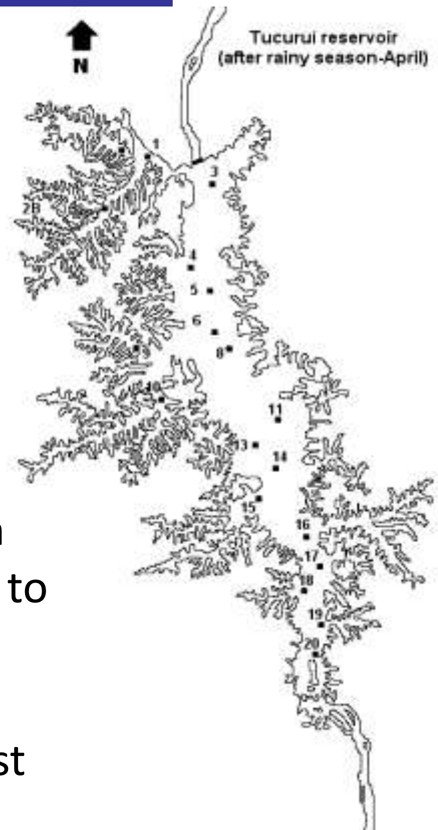
Sequential extraction procedures, associate each element at different metal bearing phases which elucidate the role that the chemical conditions of the environment and the sediments may play in the solubility and flux of these elements to the water column.

Três Marias reservoir (Brazil)

Traditionally, the evaluation of the degree of contamination in a drainage basin requires a dense net of sampling sites, followed by a complex set of chemical and mineralogical analysis

Tucuruí reservoir (Amazon, Brazil)





2nd largest artificial lake in Brazil

Area – 2850 Km^2

Many studies have been done in bottom sediments of reservoirs to evaluate their characteristics concerning texture, mineralogy, especially clay minerals, the most active particles of sediments, chemical parameters, total major elements contents, nutrients, contents and forms of the most abundant metals in the sediments in the total, soluble fractions and by sequential extraction methods (different chemical forms in sediments)

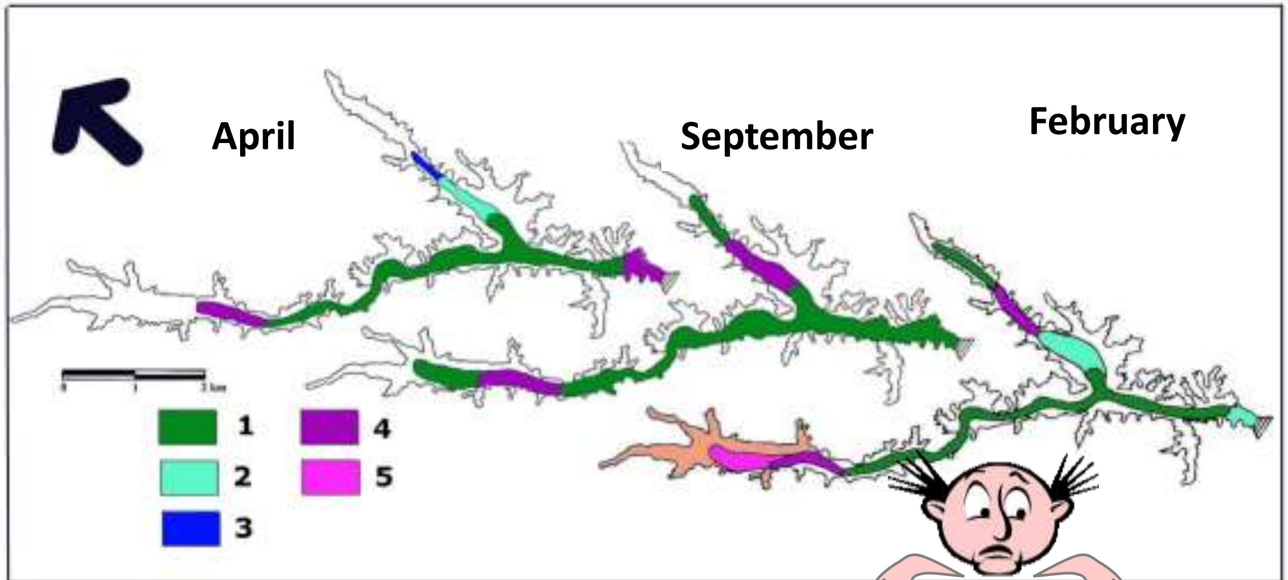
Collection of bottom sediments

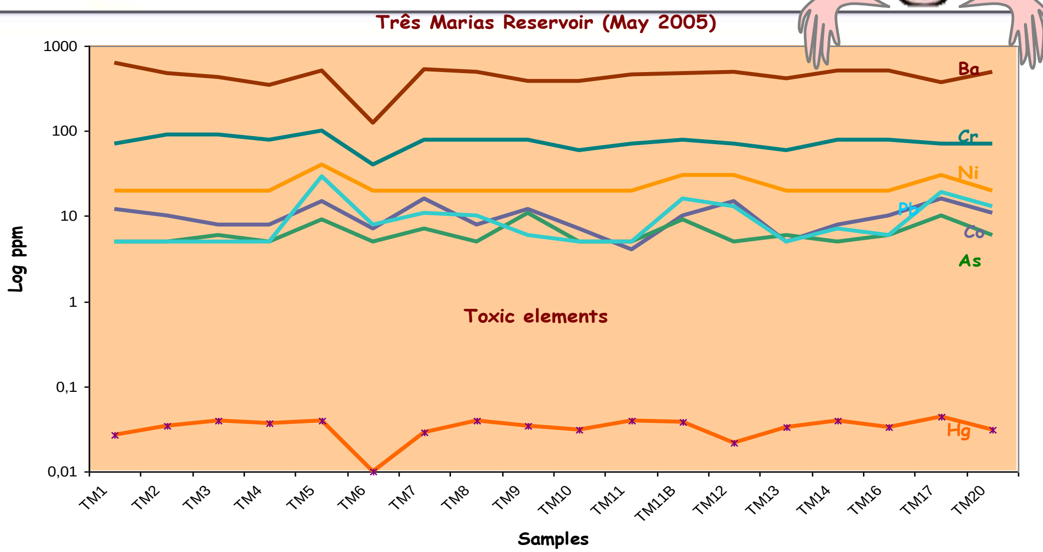
Study of the water column

Collection of water samples at two levels of depth (surface and bottom)

Vertical profiles with analyze of physico-chemical parameters (temperature, pH, BOD, oxygen saturation, redox potential

Analyze of reactive and total nutrients and metals contents



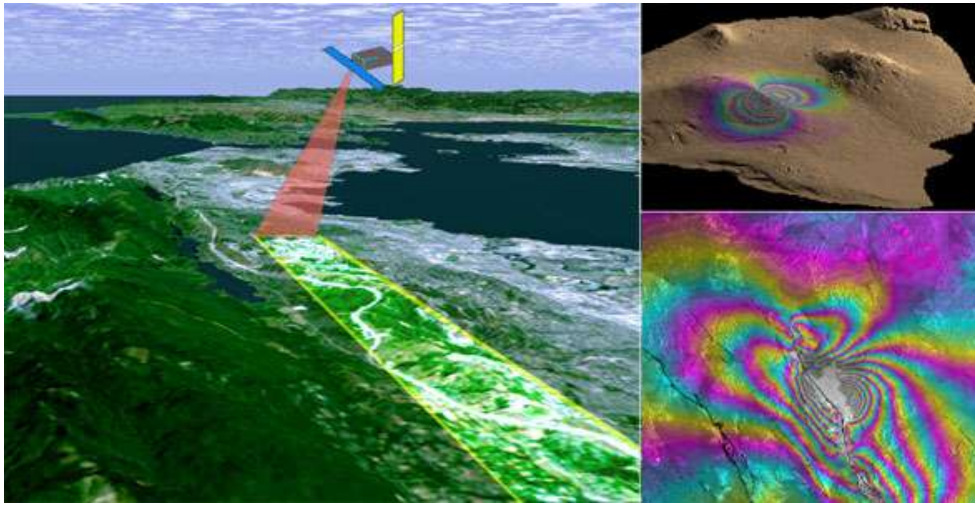


It is essential to have up-to-date spatial informations about the loads and diffusion of the contaminants, a monitoring campaign to control the hydrological balance,

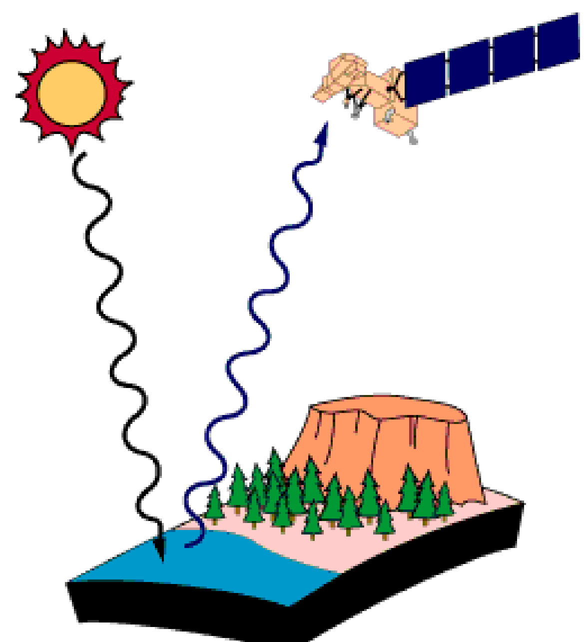
propose adequate measures for the rehabilitation of these freshwaters

This is an intensive, costly and time-consuming labor, which becomes impractical in most research projects and sometimes inapplicable due to the poor accessibility of some areas.

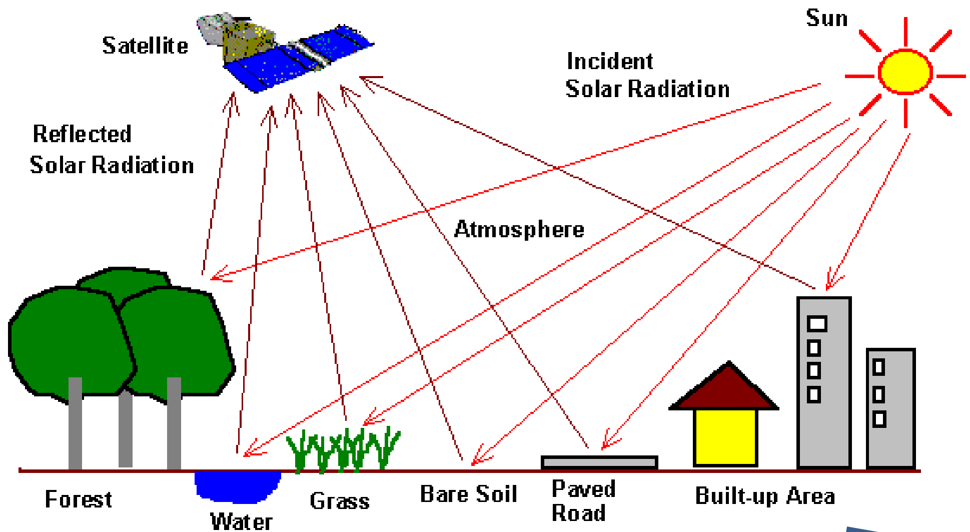
Use of remote sensing in large freshwater bodies



The use of remote sensing to estimate water quality parameters, such as suspended sediments, metals and nutrients distribution, seems to be a useful technology to use as a preliminary study in large freshwater bodies



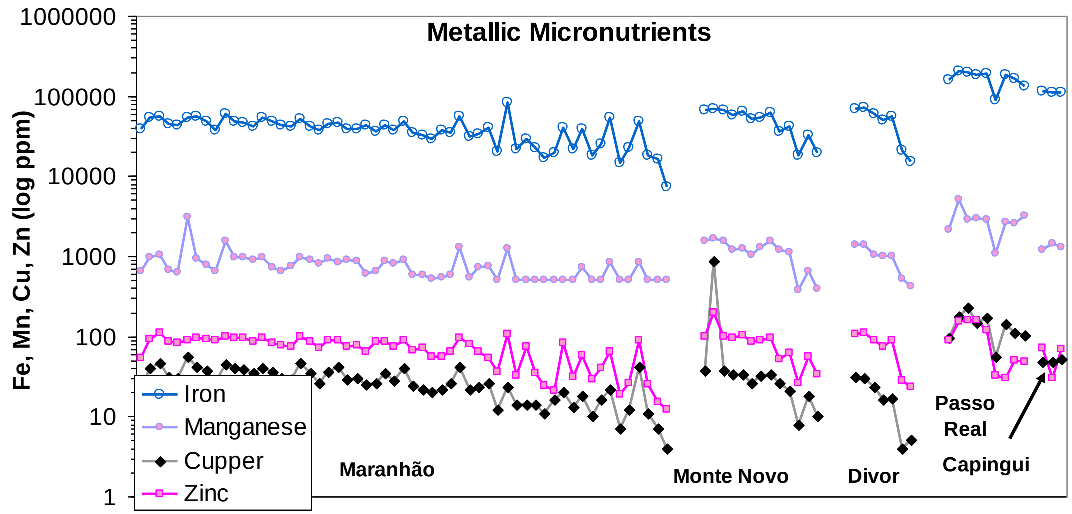
Empirical models based on the relationships between spectral measurements and water and sediments quality analytical data, will decrease the number of sampling sites in the basin

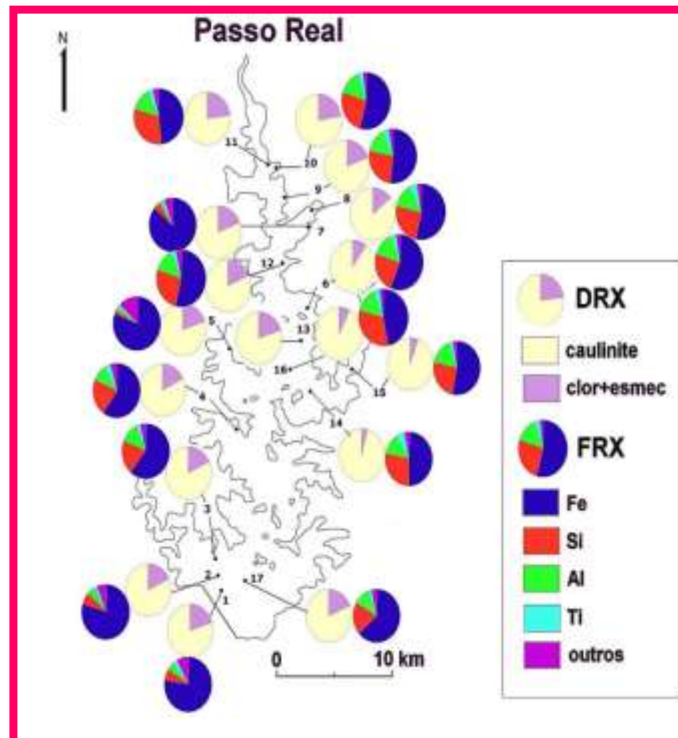


In order of having a synergy between hyperspectral data and geochemical, mineralogical and hydrological information, we would like to use the hyperspectral remote sensing technology in two different scenarios:

(1) A contamination area by intense agriculture and

(2) A contamination area by mine industry.

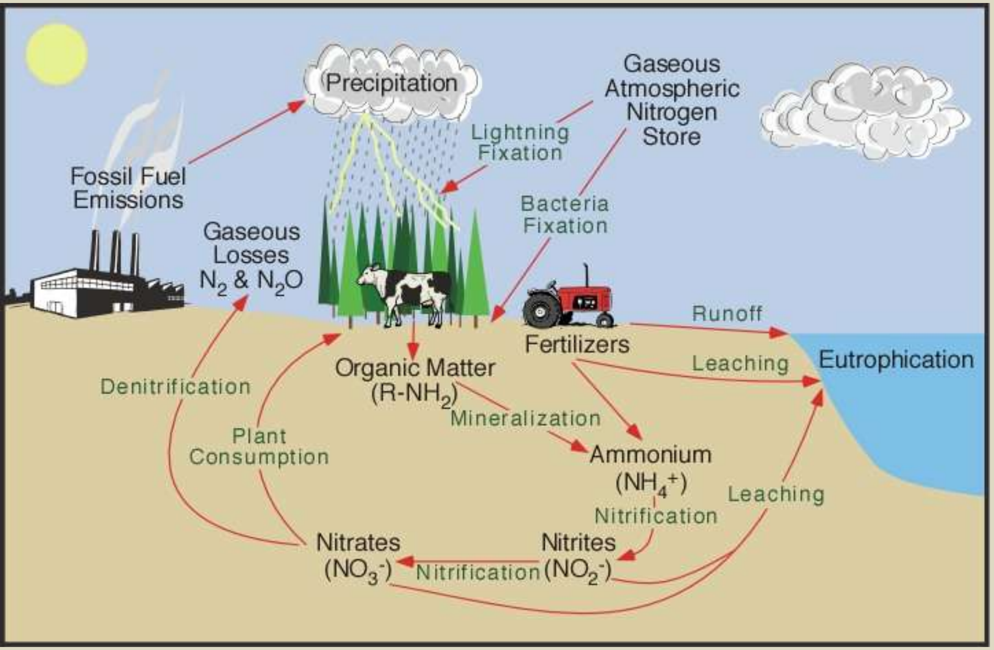




1. **First Scenario**: A contamination area by intense agriculture – Project DVINE

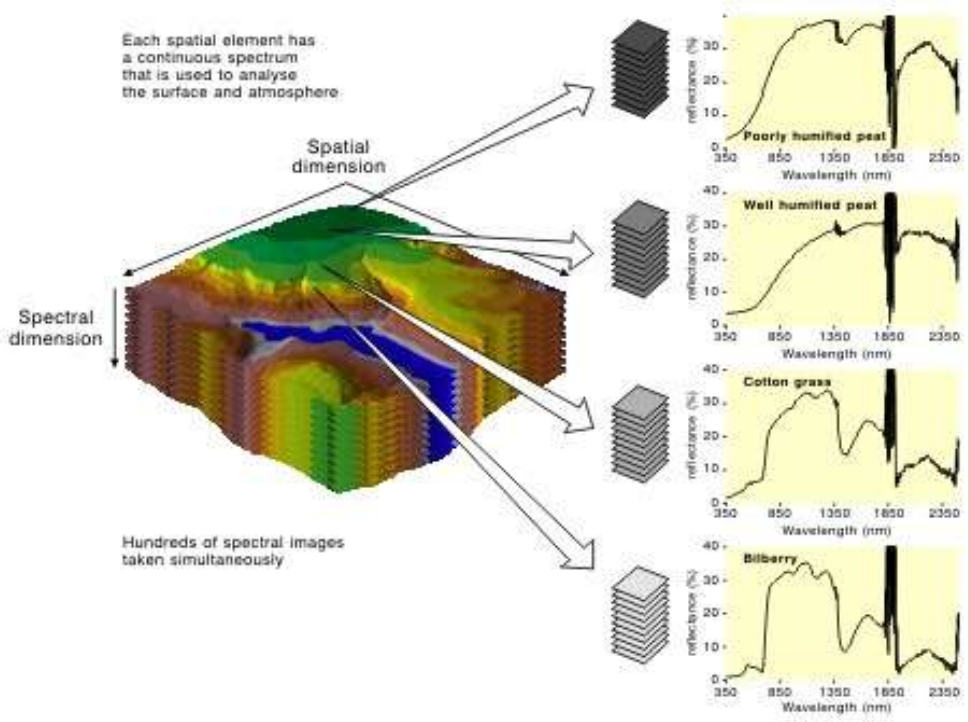
In the Douro vineyards, a World Heritage Patrimony in Portugal, the aim of the study is assessing the impact of an ancient activity in the quality of sediments and water in the Douro River.

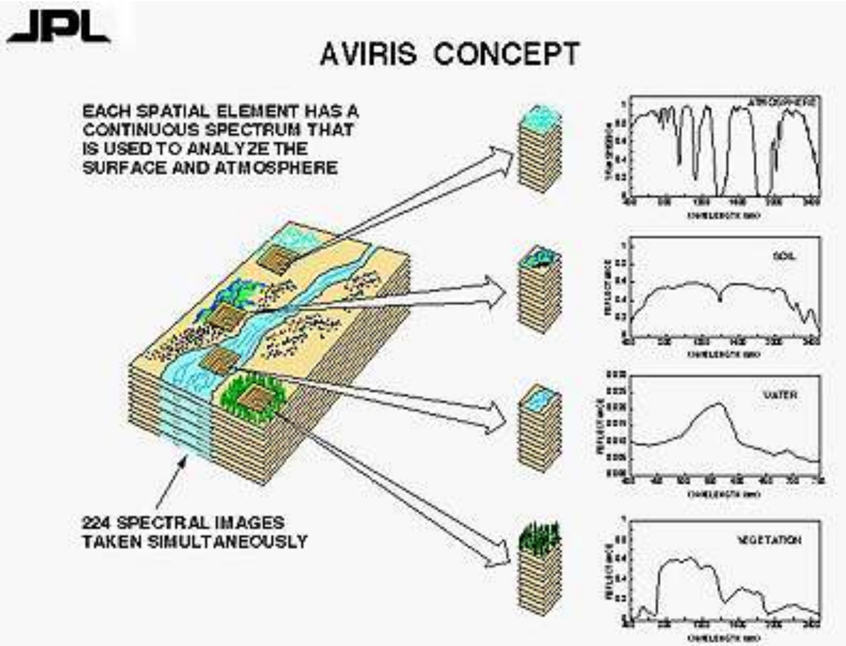
While the tradition and the economic benefits of the Douro vineyards are considerable, fertilizers and pesticides, intensely used in this crop, associated to intense loads of heavy metals and nutrients, are intensely leached by erosion processes from soil surface layers, to streams and catchments



The main goal of this work is to investigate the relationship between the concentration of nutrients and heavy metals in soils and in the river sediments, spatial and temporal, assessing the impact of an ancient agricultural activity in the water quality and estimating the risk posed to biota

In this project the implementation of **hyperspectral remote sensing**, as a preliminary study, would facilitate effort in the geochemical characterization of the flux and loads of nutrients and heavy metals to the hydrologic systems, and in the spatial and temporal monitoring of such contaminants



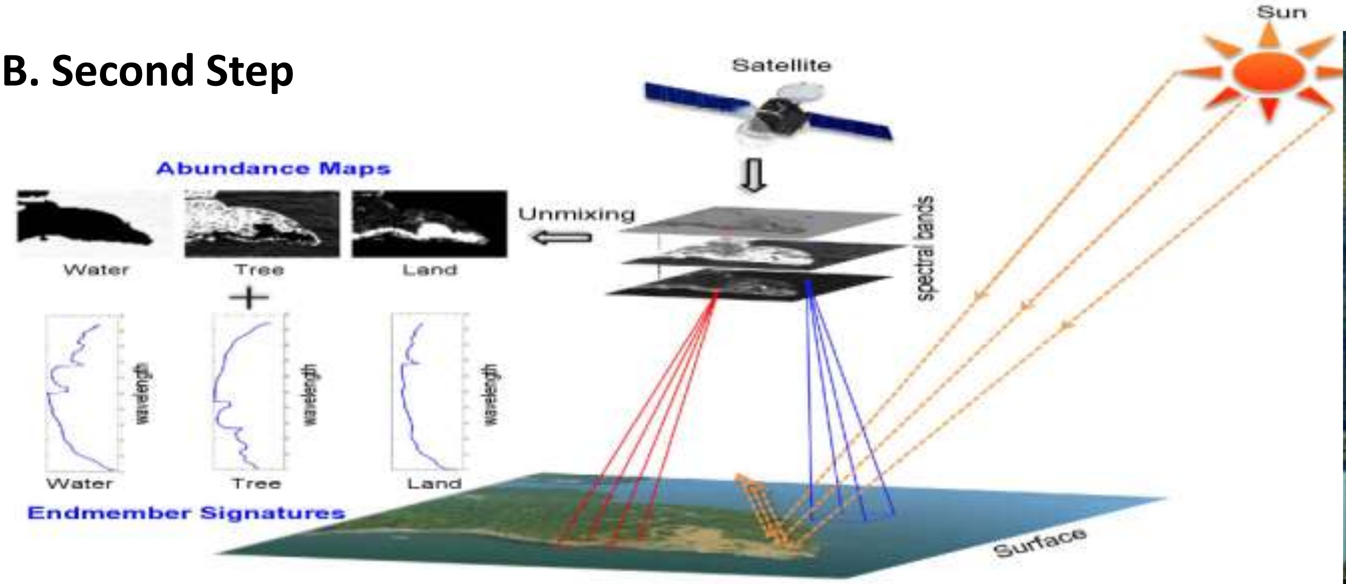


The use of Hyperspectral remote sensing to estimate soils and water quality parameters could follow 2 steps:

First Step

1. Characterization of the spectral patterns of the Douro River and its drainage basin;
2. Relate and calibrate the patterns achieved by remote sensing technique with *in situ* data;
3. Based on the relationship between both technologies we could better chose the most representative sampling sites to assess the impact of the contaminant loads outcoming from the intensive plantation of vineyards, in the Douro River

B. Second Step



If we have success on the integration of the hyperspectal remote sensing pattern and the *in situ* geochemical characterization of the Douro River and its surrounding area, remote sensing could be used for:

1. estimating the fluxes of contaminants entering into the river,
2. monitoring the quality of the river water
3. quantification of long-term of potentially toxic elements in the environment.

(2) Second Scenario: A contamination area by mine industry

Several regions of Brazil, in particular Minas Gerais State, holder a huge hydro potential and an intense mining activity since the last hundred years. The extraction of iron, gold, nickel and other metals of commercial interest, have contribute to the release of wastes which constitute a major form of heavy metal contamination in soils and in the water systems

Large loads of metals are released into the São Francisco River, **the longest river entirely Brazilian.**

In this sense it is crucial to ensure the sustainable development of mining activities, to minimize environmental degradation and without prejudice the economical production of mineral resources

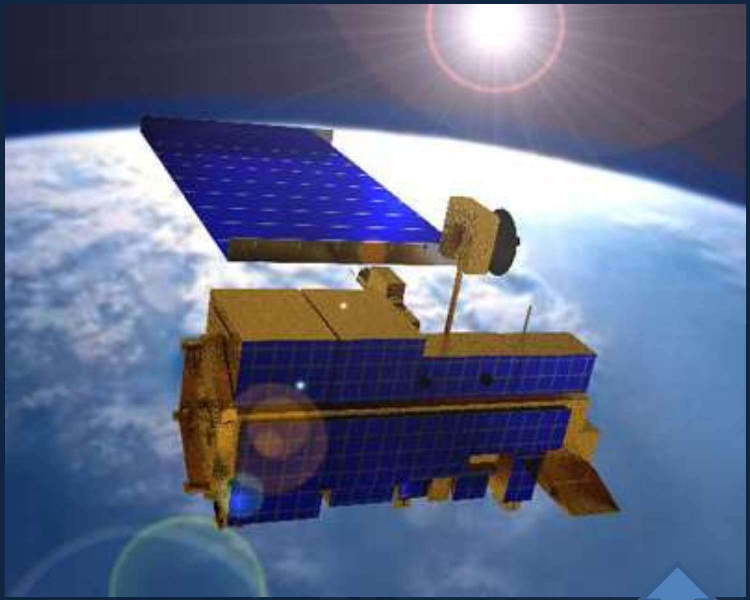
One of the main studies to carry out in this region is to characterize large drainage basins with strong mine impact and to evaluate its environmental quality in order of proposing measures to its rehabilitation.

Currently, it is being carried out the transposition of the São Francisco River to the country's driest region, at NE, process very much opposed by many people. Many studies have been conducted on water quality, given the existence of a large amount of point and diffuse sources of contaminants, namely, the existence of large amounts of mining industries.

This controversial process requires a strict and constant monitoring of short- and long-term of potentially toxic elements in the water column. This is a costly and time-consuming labor, which becomes impractical in most areas of São Francisco.

In the São Francisco Projects, the use of hyperspectral remote sensing on the estimation of the water quality parameters, would facilitate efforts in spatial and temporal monitoring.

The hyperspectral remote sensing patterns calibrated with the geochemistry of metals in the water column, should be an effective tool for the characterization of polluted sites and for modeling the load, fate, distribution and migration of heavy metals. This could be a potential advantage in the increased spatial and temporal resolution, which may be important for the assessment and/or management of the water quality.



The integration of hyperspectral remote sensing and the geochemical characterization of water, soils and sediments could be an effective and useful tool for the characterization of polluted areas. It could detect freshwater bodies undergoing runoff of potentially-toxic elements, allowing for reservoirs or rivers to respond in a timely manner to the potential danger these contaminants could represent.

It could also allow the knowledge of the “hot spots” which will need immediate application of remediation techniques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The authors whish to acknowledge the Foundation for the Science and the Technology for the financial support granted to the project “DVINE - The Douro vineyards, World Heritage Patrimony: Assessing the impact of an ancient activity in the quality of sediment and water in the Douro, PTDC/CTE-GIX/112821/2009”

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