GROUNDWATER QUALITY IN OMAN: INVESTIGATION OF ARSENIC CONCENTRATIONS

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CONTENTS

Water resource problems in Oman

- - Groundwater depletion due to an increase in water demand (increase in the populations, Drough, climate change)
- - salt intrusion
- - Pollution (mining: heavy metals) (agriculture: fertilizers, pesticides…)
- -Wastewater disposal

Water resource problems in Oman

- Vulnerability of waters in previous studies:
- 1) (Yaghi, 2007): Pb and Cr exceed safe levels in groundwater of Batina (North of Oman)
- 2) AL Maashri S. A et al (2011): High concentrations in Ni in groundwater of Batina

- **No investigation of arsenic concentrations in the system water-plants-soil has been carried in Oman before**

Objectives of this study

- To determine the concentrations of As in groundwater affected by:

1- sewage

2- Cu mining

3- Agriculture

Comparison of data with recommended drinking water standards

The new aspect of this study is the investigation of arsenic, and its correlation with main activities (mining, sewage and agriculture)

Arsenic in soils

- Arsenic occurs in more than 200 minerals (ex: Seligmannite $PbCuAsS_3$),
- present mainly in the heavy mineral fraction of the soil.
- chemical form in minerals is **arsenate**.
- The lowest levels of arsenic can be found in sandy soils.
- Higher arsenic concentrations are associated with alluvial soils, soils rich in organic matter, and soils derived from shales

Arsenic in waters

In ground water, arsenic occurs primarily in two main oxidation states,

As^{+3} (arsenite) and

As^{+5} (arsenate).

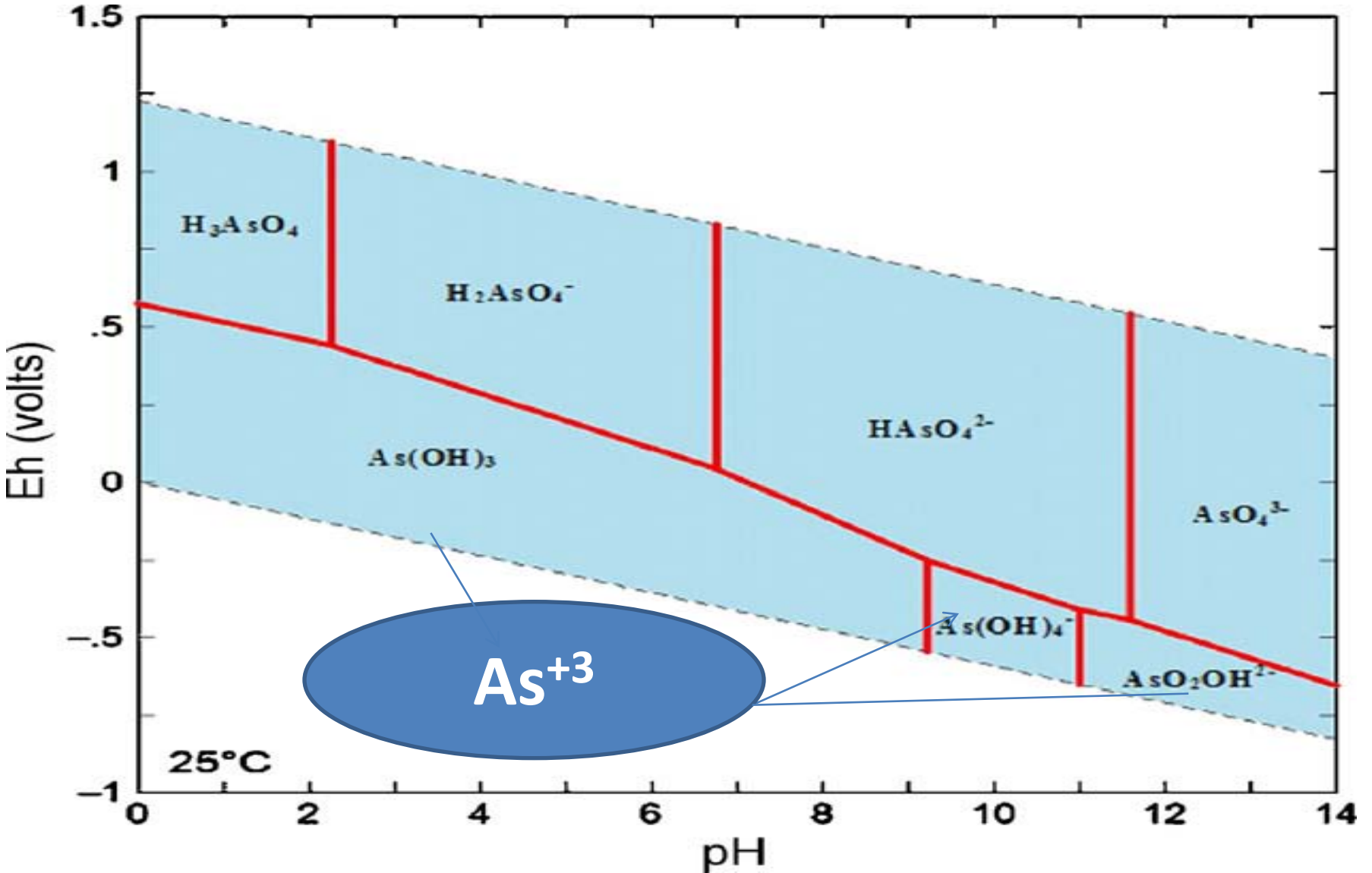
Redox-pH conditions affect the specification and solubility of arsenic

As^{+3} is more toxic and more mobile than As^{+5}

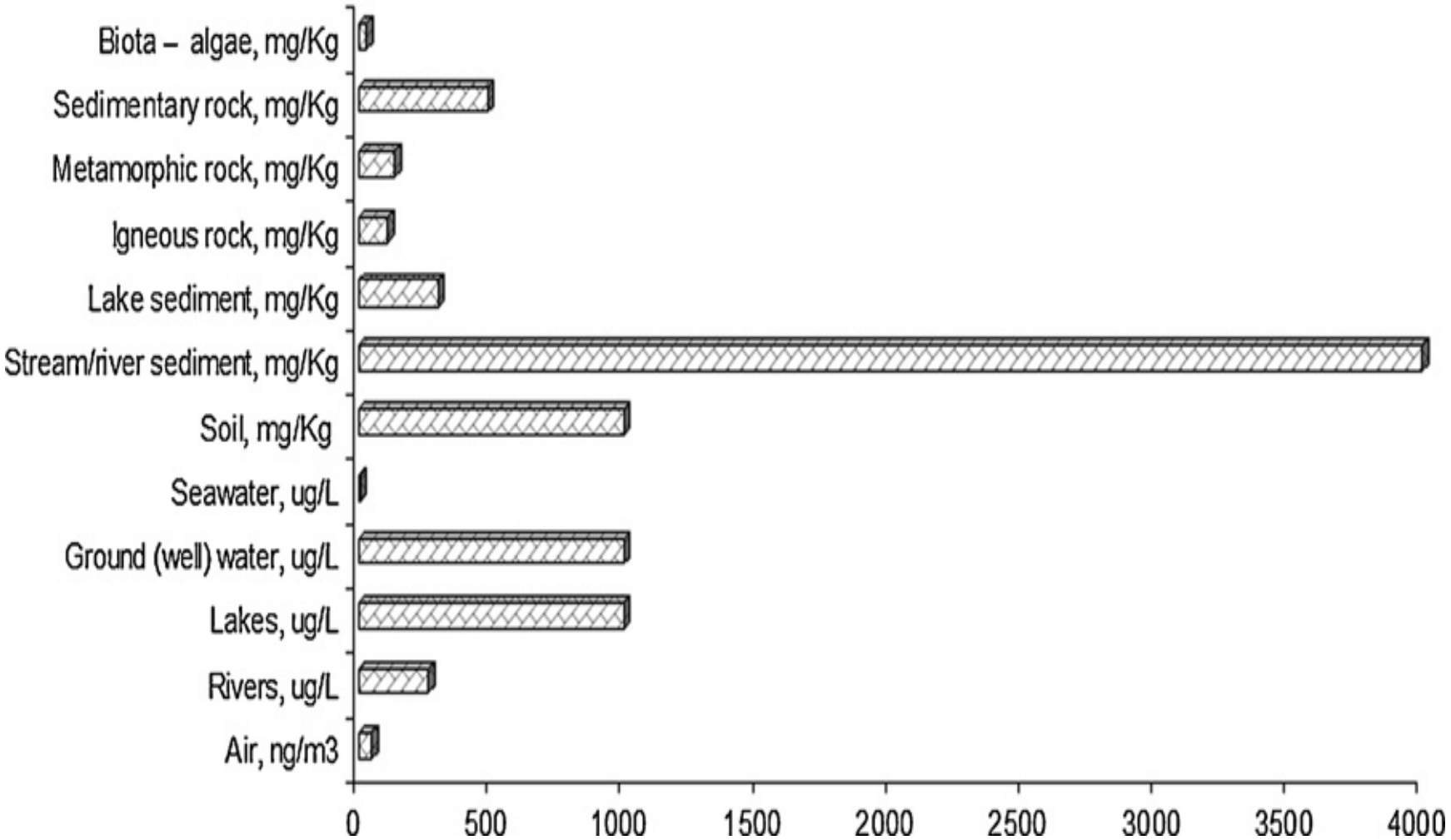
The predominate oxidation state depends on the pH and the redox potential. Both forms have strong affinities for iron complexes however they behave oppositely with respect to pH.

Organic arsenicals are not known to occur at significant levels in ground water.

Eh-pH diagram for arsenic species



As concentrations in environmental media (Cheng et al, 2009)

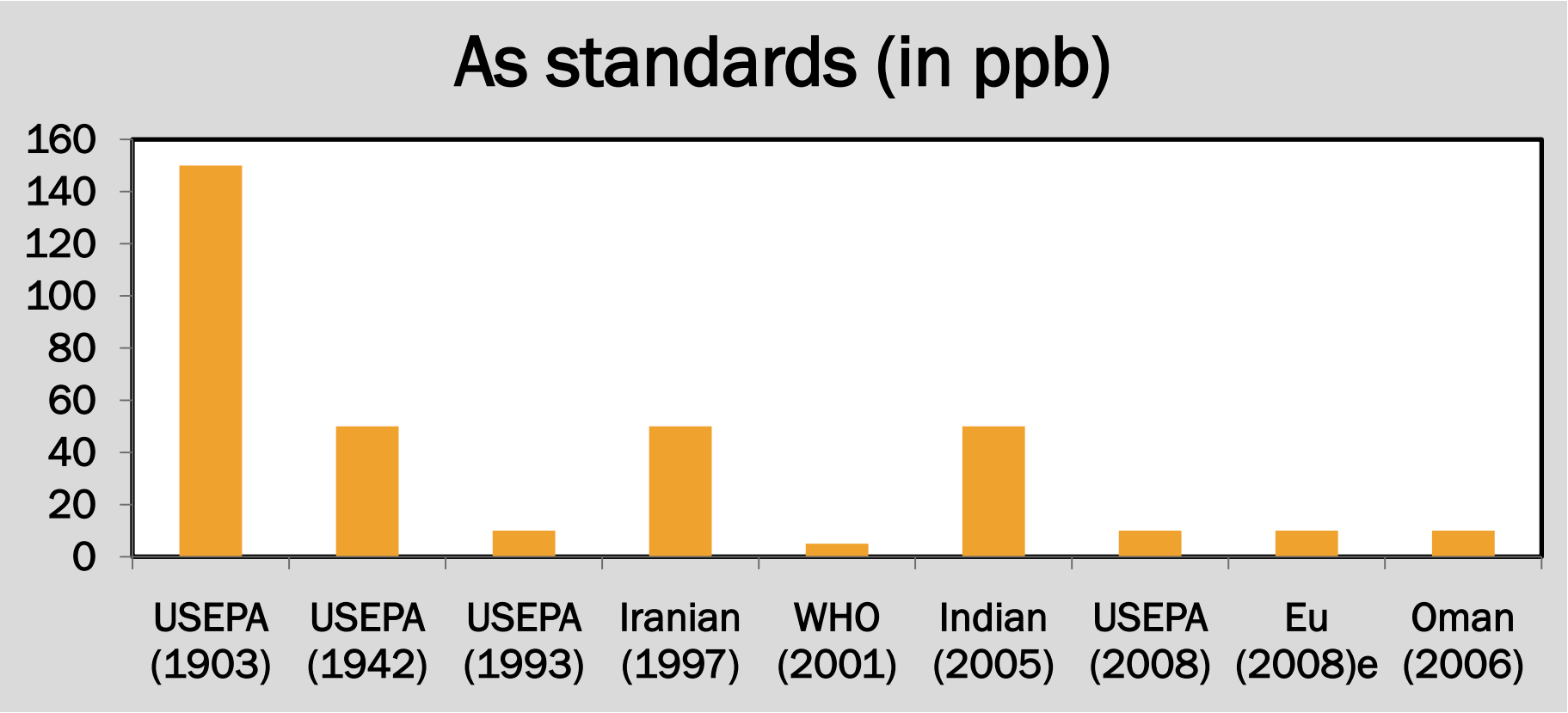


Source of As

- Natural sources: weathering of arsenic bearing minerals
- Mining activities
- Agriculture pesticides and fertilizers

Maximum level for health: As standards in drinking waters

- World Health Organization (WHO)
- USEPA [Environmental Protection Agency]

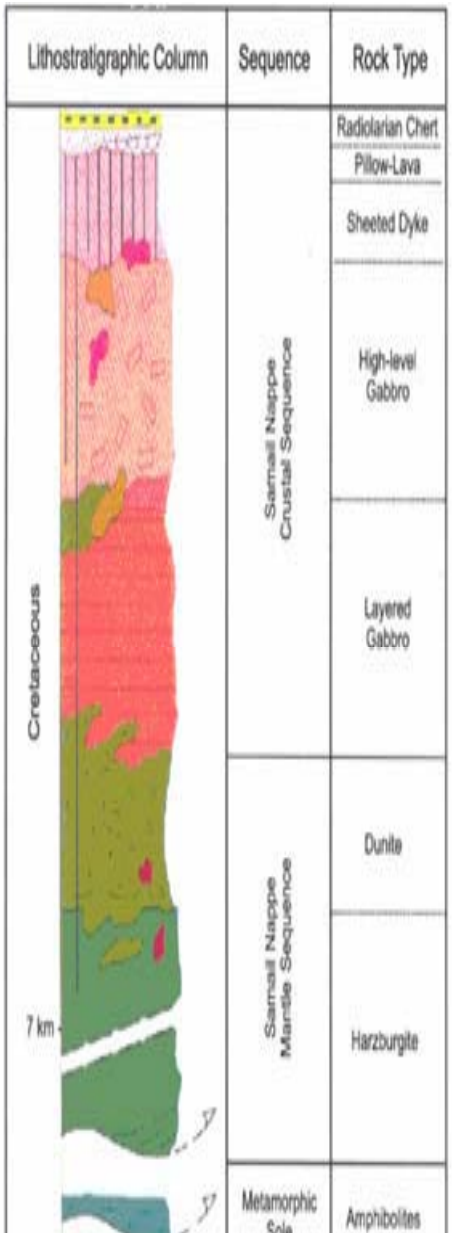


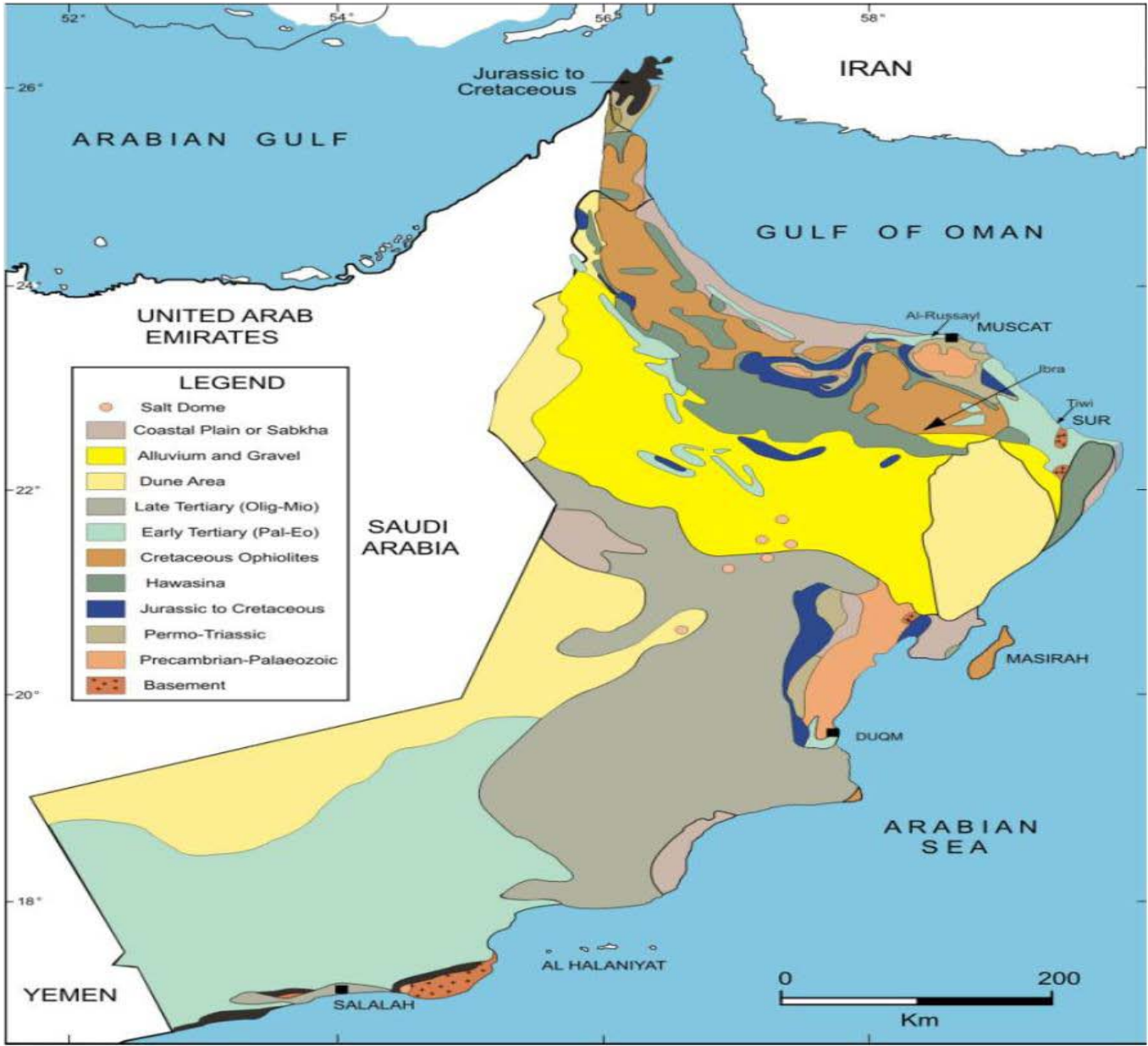
- Many developing countries are still using the standard of 1993 (50ppb).

Geological context of the study Area

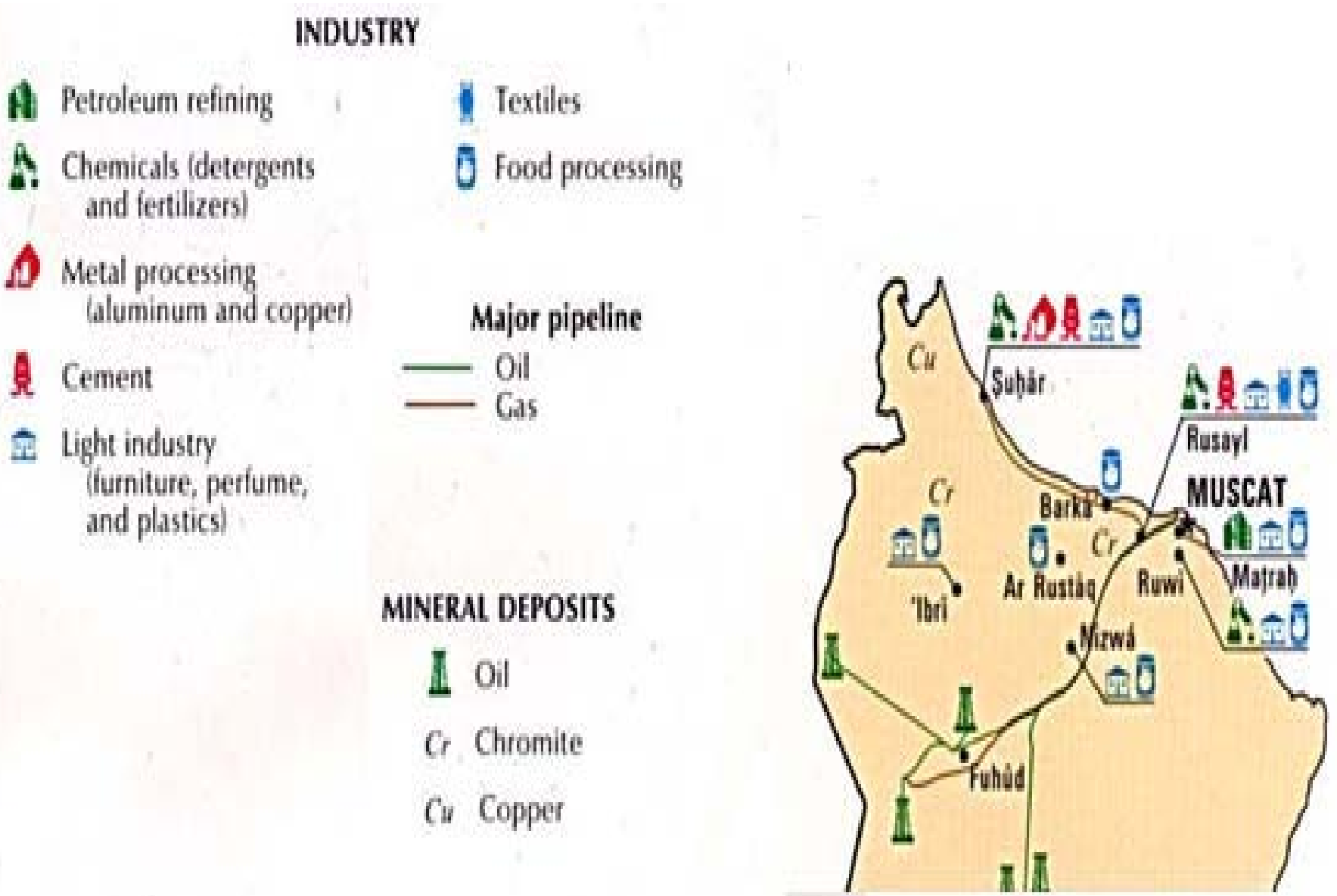
- **The geologic setting of basin (Batina, NE Oman):**
- **1) crystalline bedrock formations: ophiolites which define the base of the hydrogeologic system**
- **2) alluvium deposits**

Stratigraphy of Nothern Oman mountains





Economic activities



Hydrology

- **Total annual rainfall averages 100 mm/year with 0 and 350 mm extremes.**

- **Evaporation rates estimated to about 5 to 15 mm/day,**

MATERIAL and METHODS

- - About 15 wells from Cu mining area
- - 9 wells from sewage area
- - 5 wells from agricultural lands
- - 2 wells from undisturbed area (control zone)
- - Samples from several species of plants
- - Samples from shallow soils

MATERIAL and METHODS

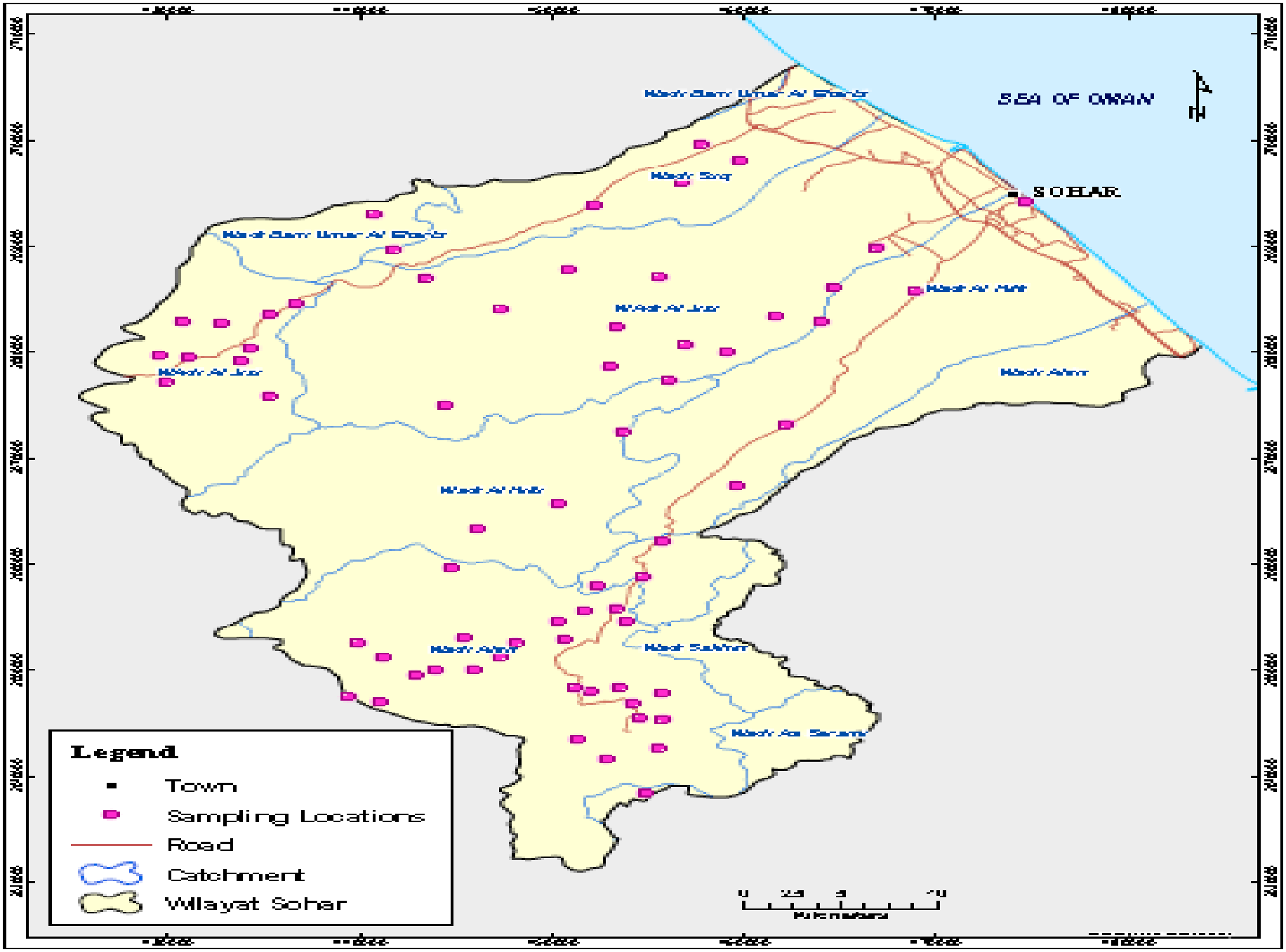
About 15 wells from Cu mining area

9 wells from sewage area

Groundwater+plants+ shallow soils

5 wells from agricultural area

2 wells (control)


SEA OF OMAN
SOHAR
Wadi Bani Umar Al Gharbi
Wadi Siraj
Wadi Bani Umar Al Gharbi
Wadi Al Jizzi
Wadi Al Jizzi
Wadi Al Awr
Wadi Awr
Wadi Al Awr
Wadi Awr
Wadi Suhum
Wadi Ad Sarami
Legend
Town
Sampling Locations
Road
Catchment
Wilayat Sohar

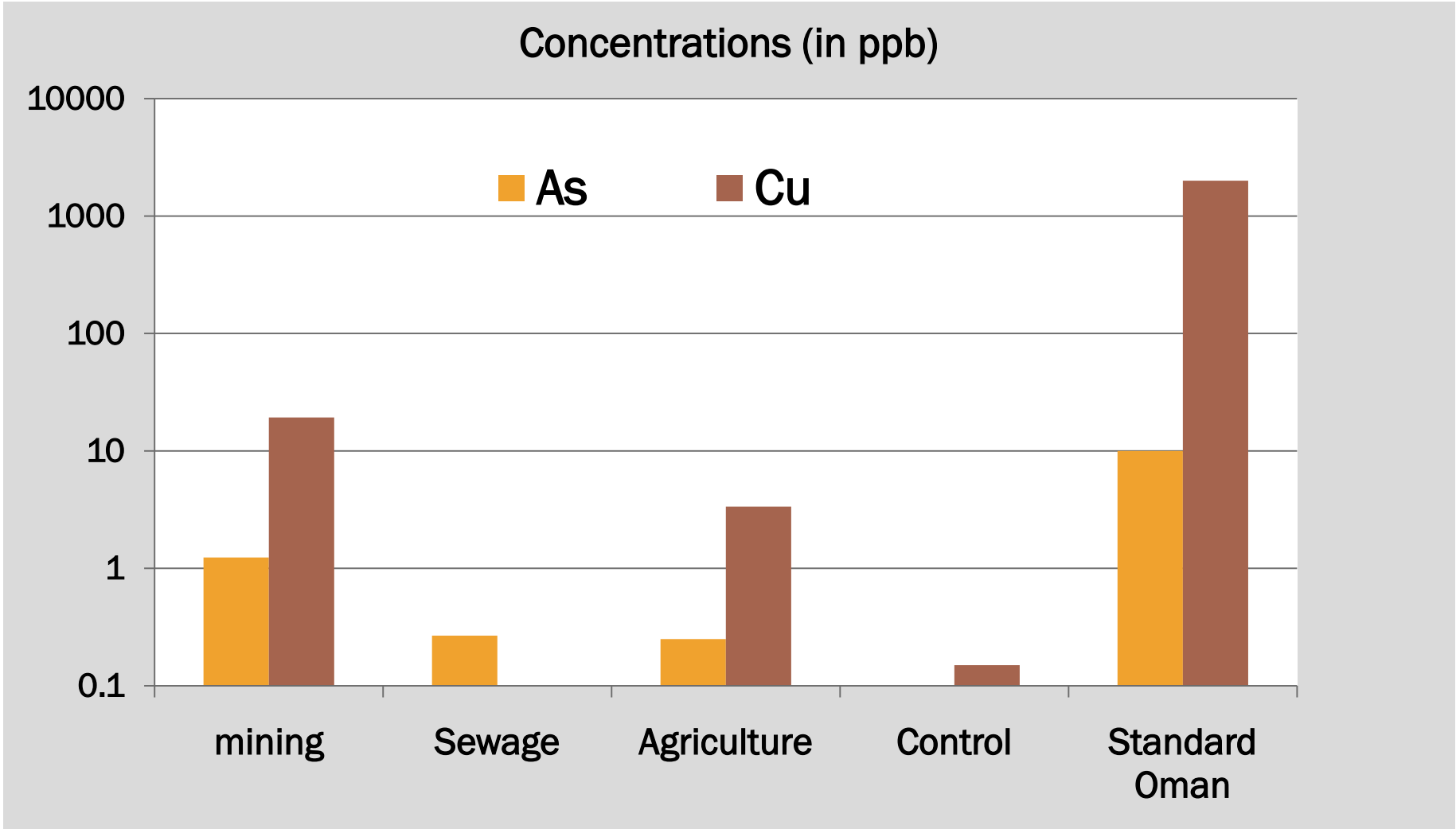
Analysis

- - In-situ measurements (such as electrical conductivity (EC), pH, T, ….)

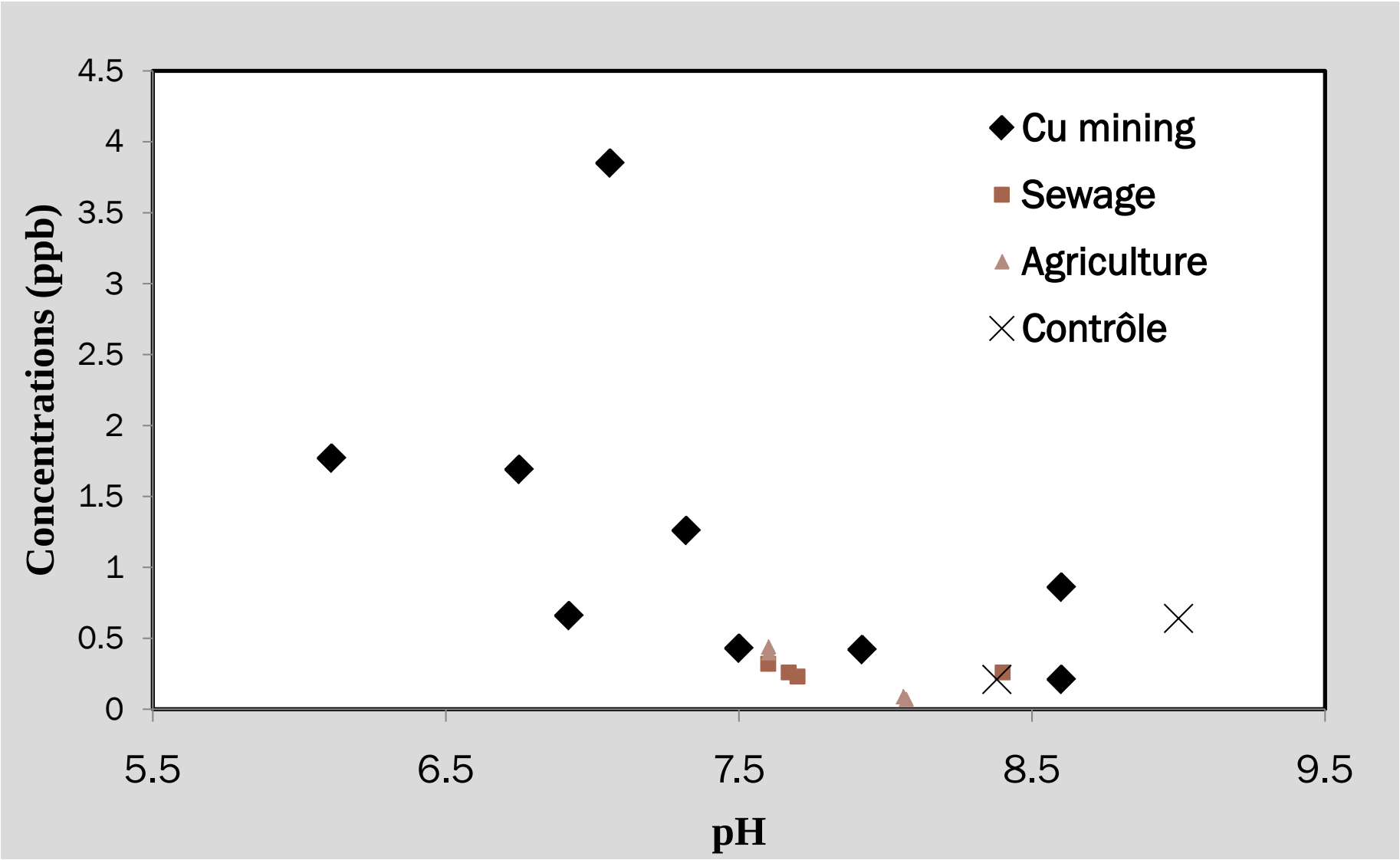
- - Laboratory analysis:
- a- As using ICP-OES
- b- trace elements using Atomic absorption

RESULTS

Results: average concentrations in groundwater
(more As in mining area than in sewage area)



Arsenic Concentration-pH

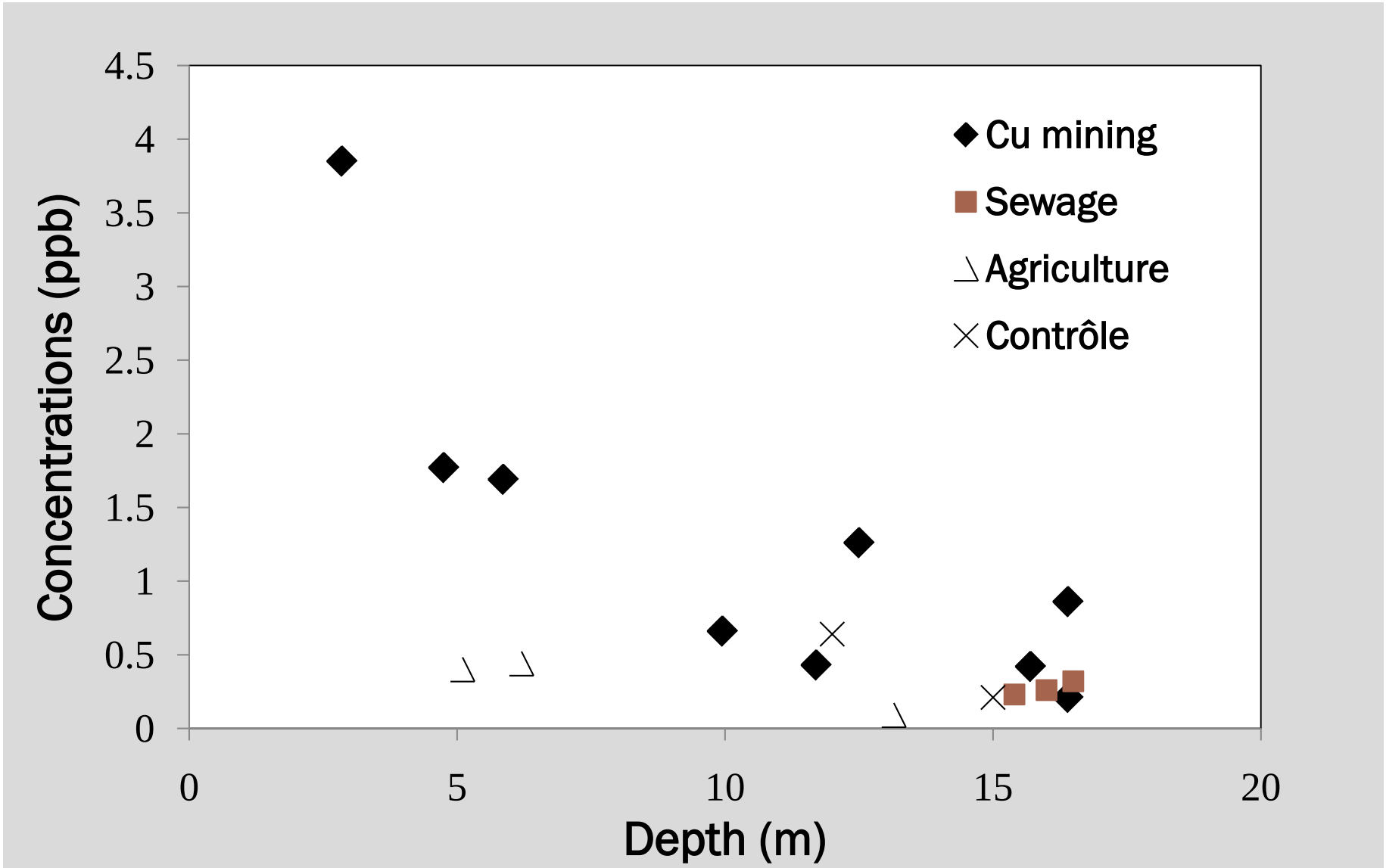


Concentrations-pH

- - High concentration of As in waters of mining area at high pH ⟹ Desorption of As from minerals in shallow waters or precipitation in deep waters
- Same tendency in waters from agriculture area
- Weak correlation between [As] and pH for waters from sewage area

- **Similar results have been found by Jing et al, (2002) in laboratory experiment of leachability of As.**

Arsenic Concentration- Depth



Vertical variations

- **- Decrease of As with the increase of depth in mining area and agricultural area**

- **- Increase of As with the increase of depth in sewage area**

- **Arsenic from minerals (desorption) hypothesis is not enough to explain the whole concentrations in waters**

- **Role of plants**

Concentration of As in plants of this study

As (in ppb) in Plants from:	Leaves	Stems	Roots
Cu mining area	1196.1	77.5	86.5
Sewage area	70.5	nd	I: 29 II: 51
Agriculture area	40	nd	nd

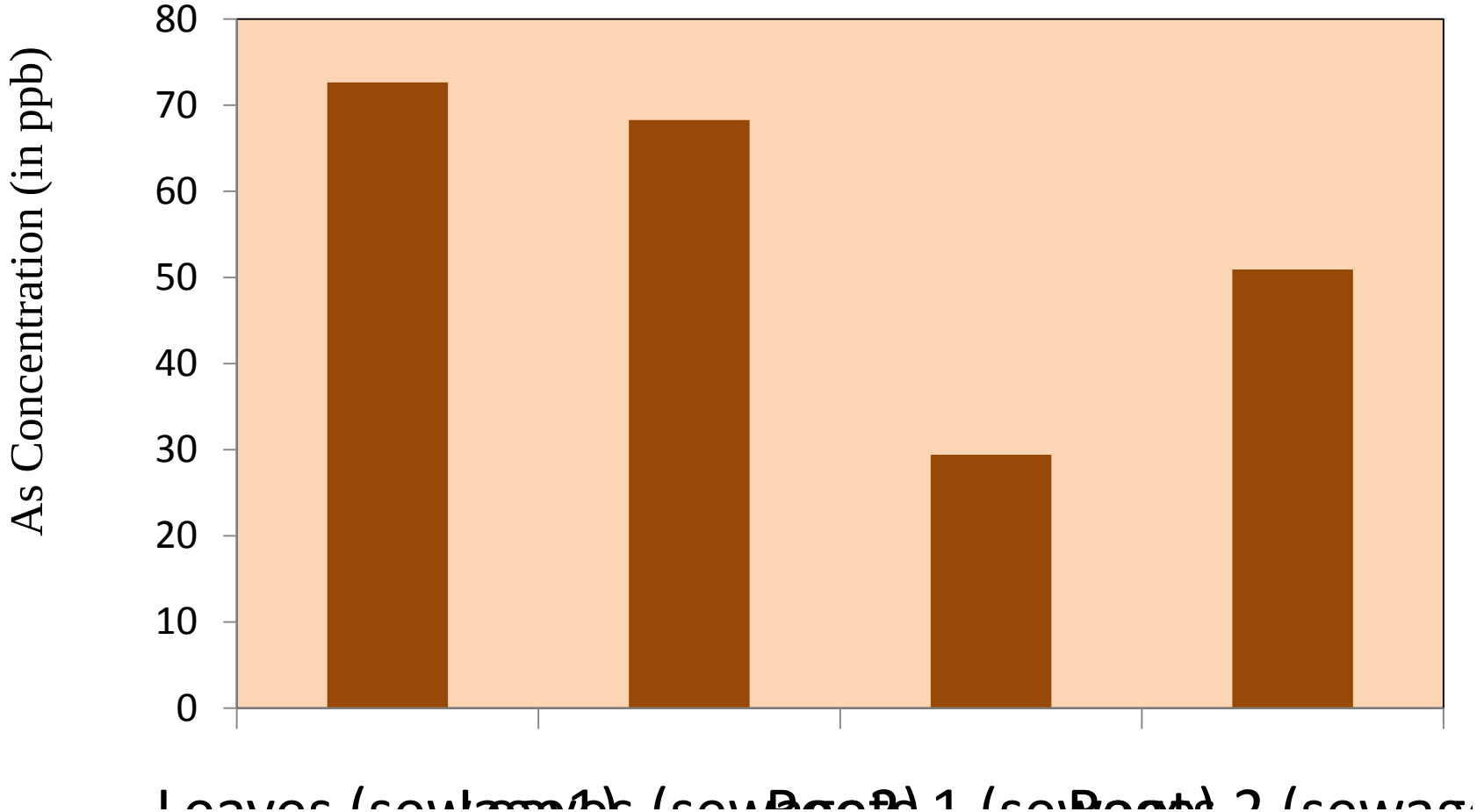
Availability of As in soils: *Rhazya stricta*

Availability of As in soils: *Rhazya stricta*

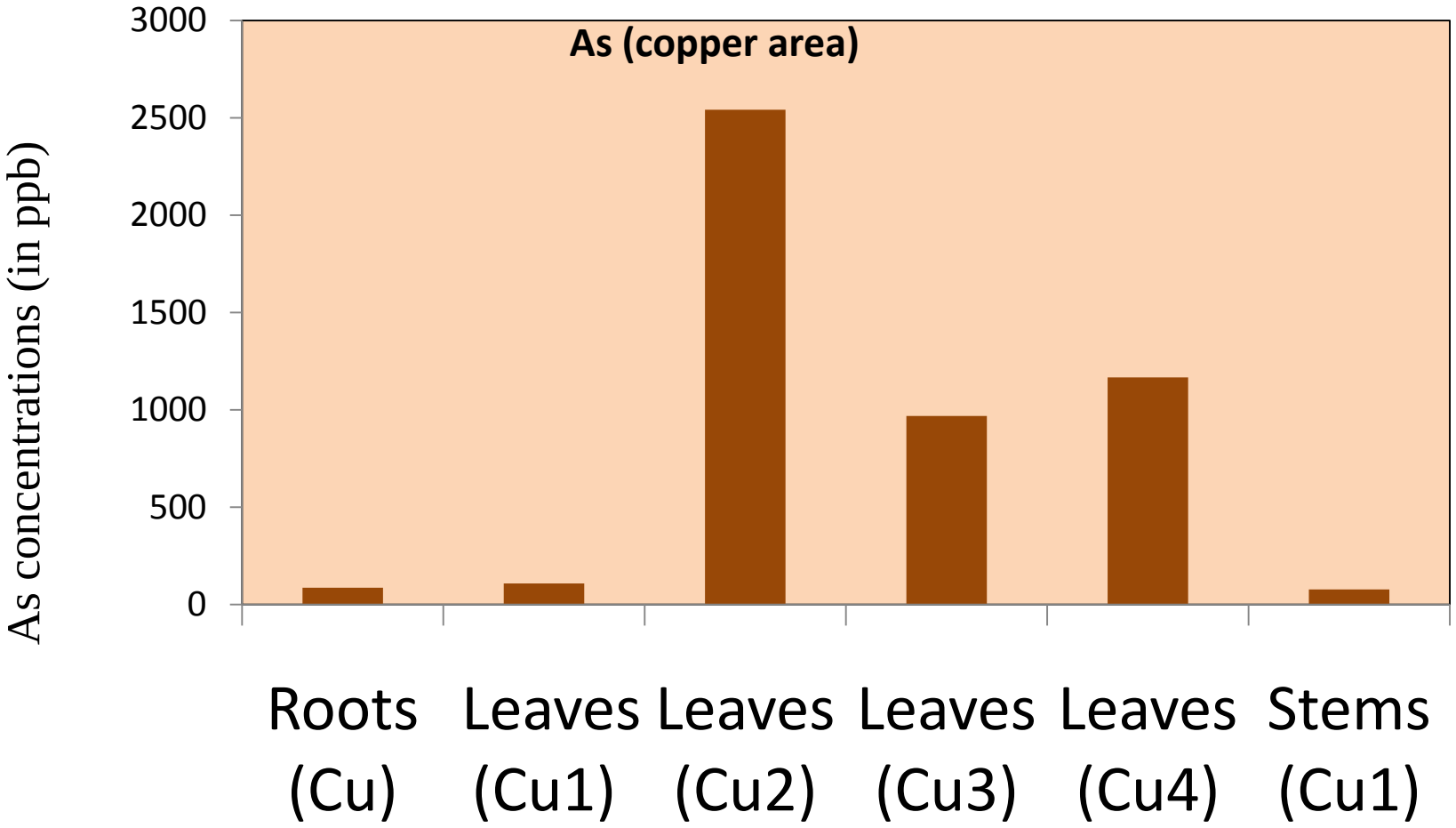
- As in leaves>As in roots>As in stems

- As in leaves (copper mining area)> As in leaves (sewage area)

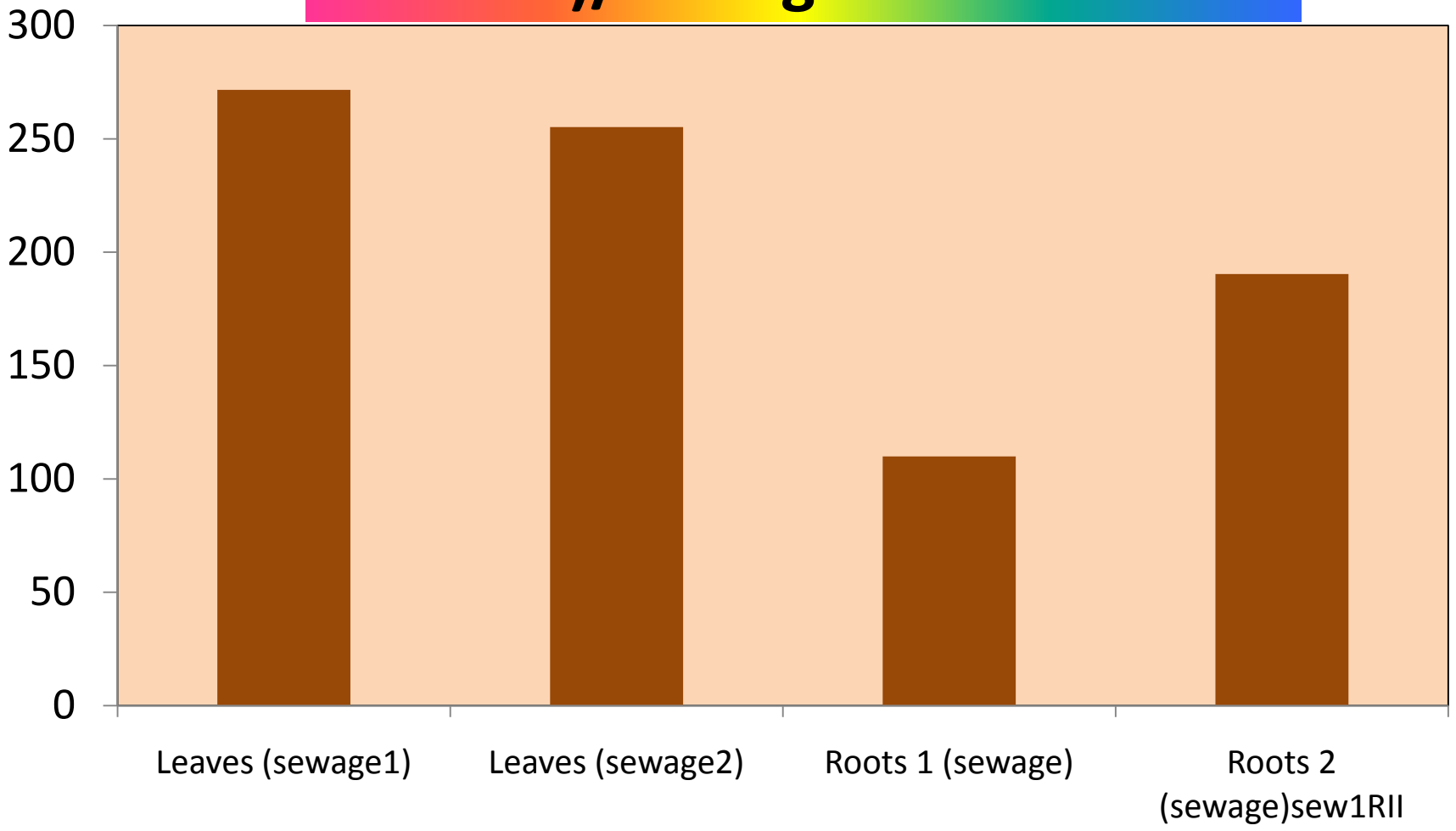
Average concentrations in plants from sewage area

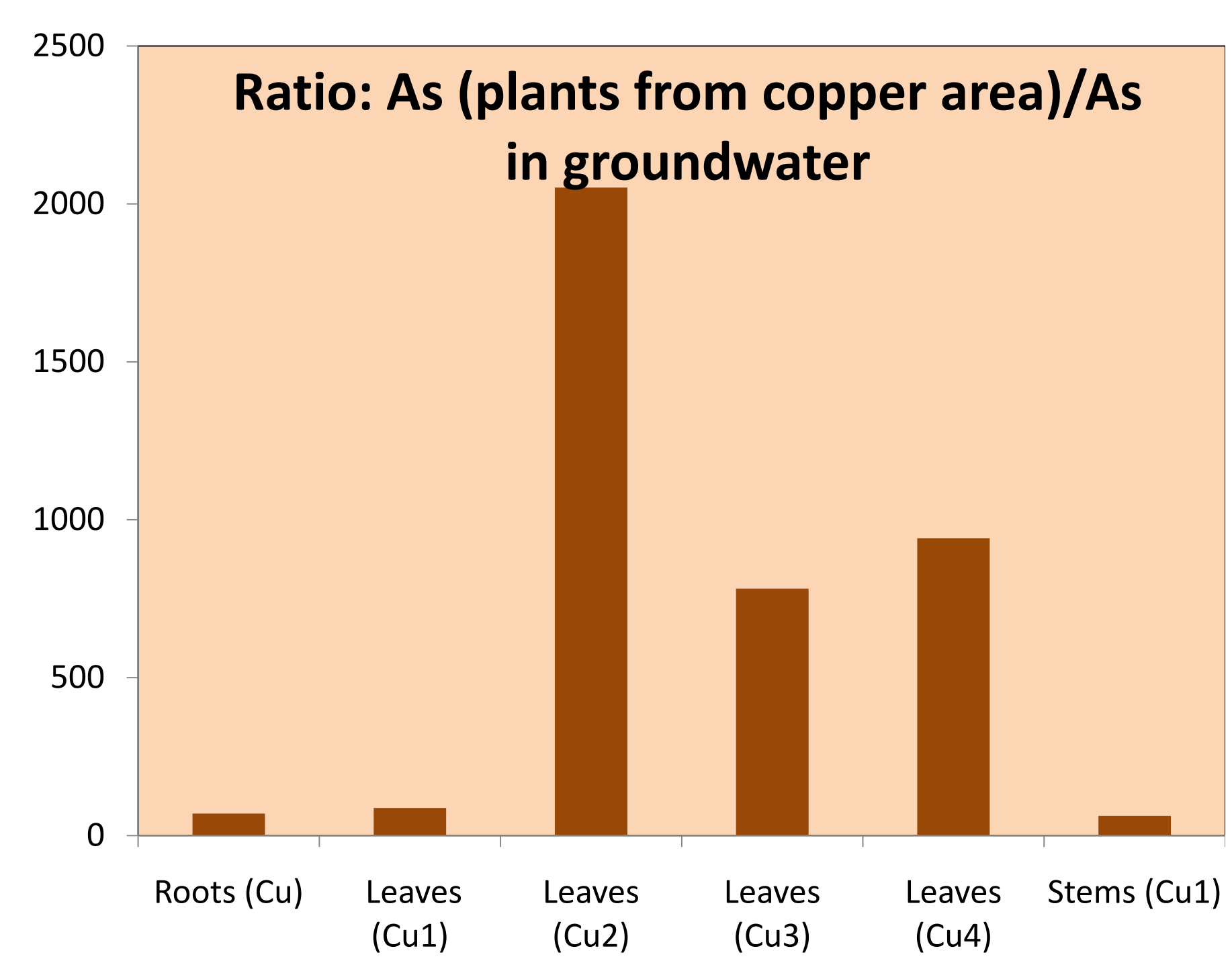


Average concentrations in plants from copper mining area

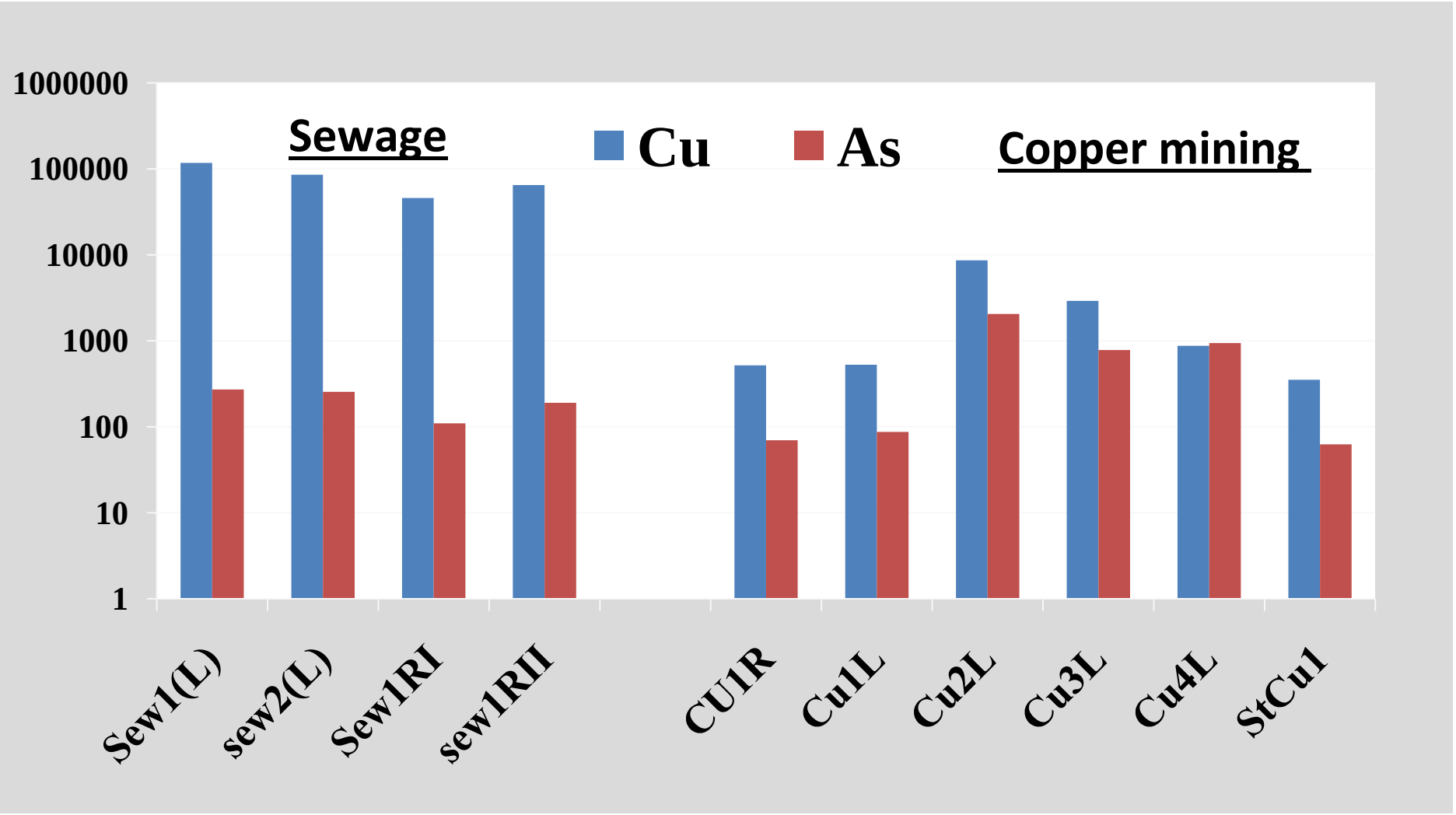


Ratio: As (in plants from sewage area)/As in groundwater




Ratio: As (plants from copper area)/As in groundwater
2500
2000
1500
1000
500
0
Roots (Cu)
Leaves (Cu1)
Leaves (Cu2)
Leaves (Cu3)
Leaves (Cu4)
Stems (Cu1)

Relative to concentration in groundwater: more accumulation of Cu and less As in plants of sewage area than in mining areas



- Less transfert of As from roots to leaves in sewage area than in mining area

- More mobility of As in mining area

Summary

- **Relative to concentrations in groundwater:**
- **Higher concentrations of As in plants which grew in mining area**

CONCLUSIONS

- Comparison with standards showed that there is no risk in groundwater of Sohar area in term of arsenic levels.
- Larger variations of As concentrations in mining areas than sewage areas
- A good correlation between As and pH
- The source seems be:
- a-the oxidation of As bearing minerals and desorption of As from minerals
- b- decay of plants

Recommendations

- More studies are needed
- - Speciation of As in the aquifer materials (in progress)
- Isotopic data are needed
- Investigation of other metals such as Mn and Fe and rare earth elements for redox condition purpose
- Redox potential : biodegradation of organic matter

- **Thank you for your attention**