Arsenic in shallow aquifers linked to the electrical ground conductivity: the Mekong Delta source example

Van Phan T.H [1,2]*, Timothée Bonnet [1], Stéphane Garambois[1], Delphine Tisserand [1], Fabrizio Bardelli [1], Rizlan Bernier-Latmani [3], Laurent Charlet [1]

[1] Université Grenoble Alpes - Institut de Science de la Terre (ISTerre), Grenoble, France; *email: phanhaivan@gmail.com

[2] Ho Chi Minh City University of Technology - Faculty of Environment and Natural Resources, Ho Chi Minh City, Vietnam

[3] Ecole Polytechnique Fédérale de Lausanne (EPFL) - Environmental Microbiology Laboratory (EML), Lausanne, Switzerland

INTRODUCTION

16 million people in Vietnam and Cambodia living in the Mekong Delta River area are therefore at risk due to **high As concentration levels in their drinking water** (up to 1600 mg/L) [1-2]. **Frequency inductive electromagnetic (EM)** geophysical surveys have been used widely in hydrology to map infiltration of water within near-surface formations, to estimate the extent and internal structure of shallow aquifers, and to **determine the extent of groundwater contamination like aqueous As** [3-4].

Here, the study is an attempt to express the origin of this spatial variability by applying a simple **geophysical surveying technique** (EM31**)**, and investigate **the correlation between deduced electrical conductivity variations to As concentration and water chemistry** in Mekong Delta shallow aquifers. Field observations extend over a 9 km² area in the An Phu district, An Giang province (Fig. 1)

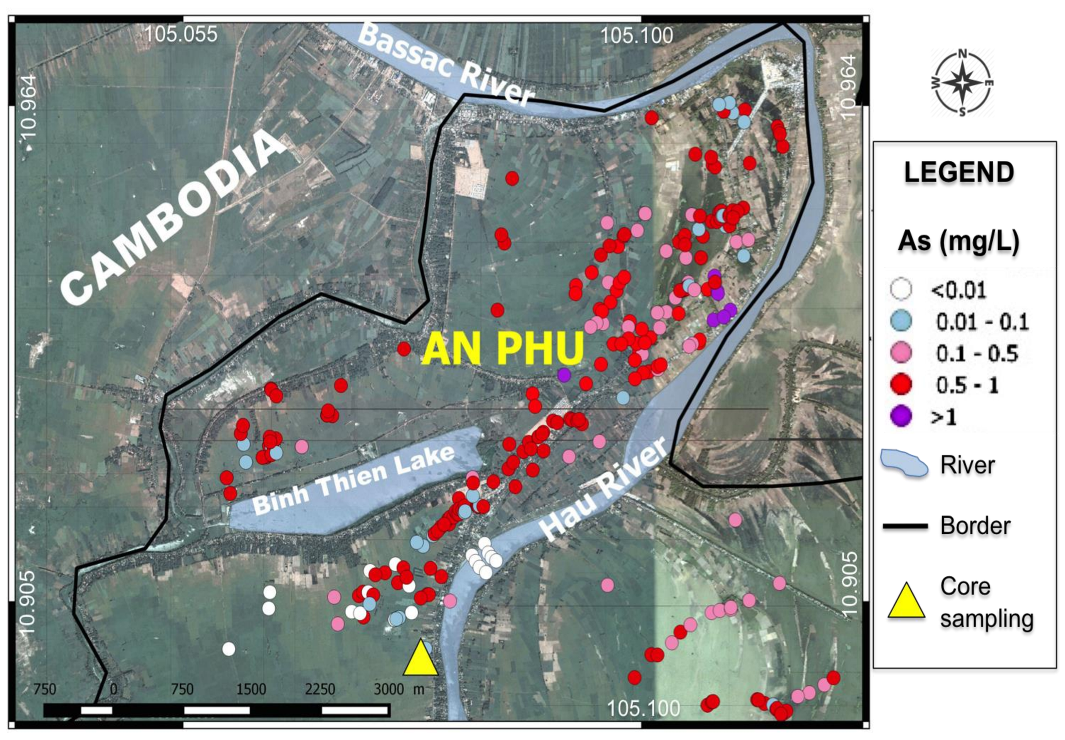


***Fig. 1**. Distribution of arsenic in An Phu groundwater of An Giang province, the vicinity of Hau River of Mekong Delta (modified from [1])*

METHODOLOGY

Geophysical survey

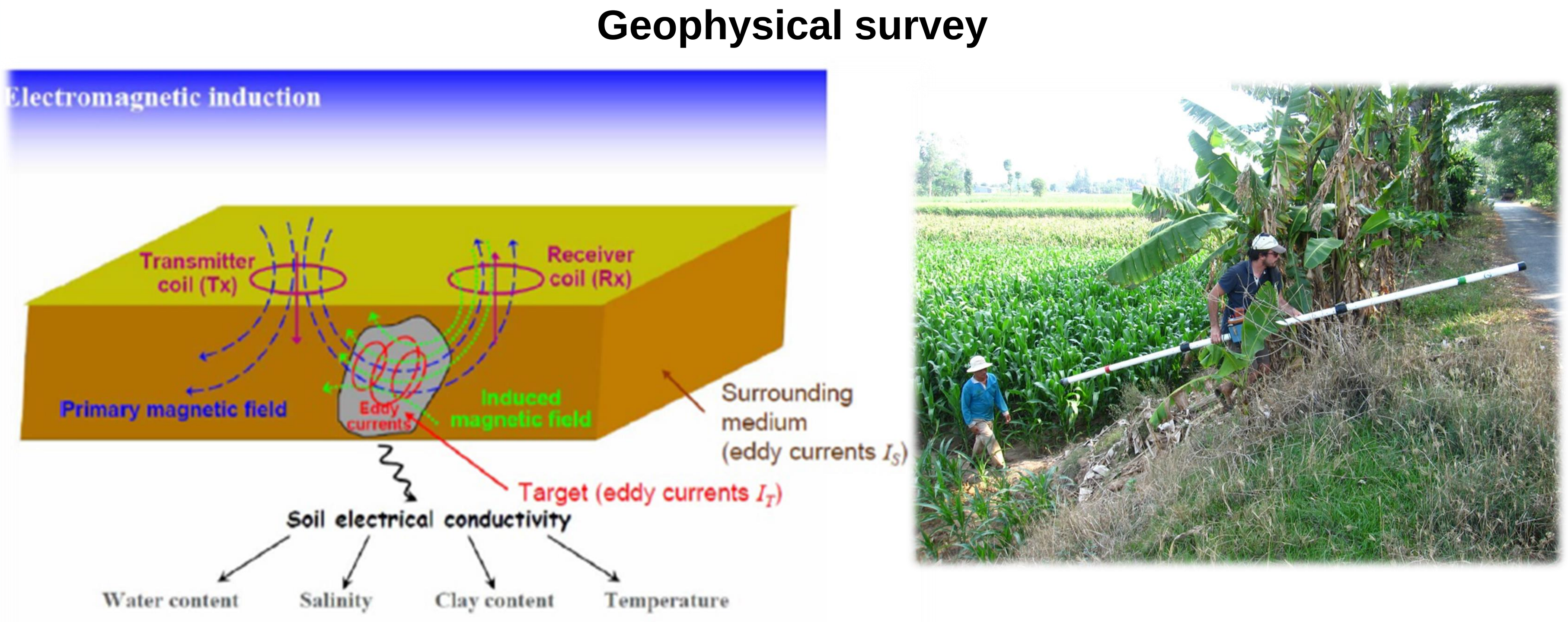
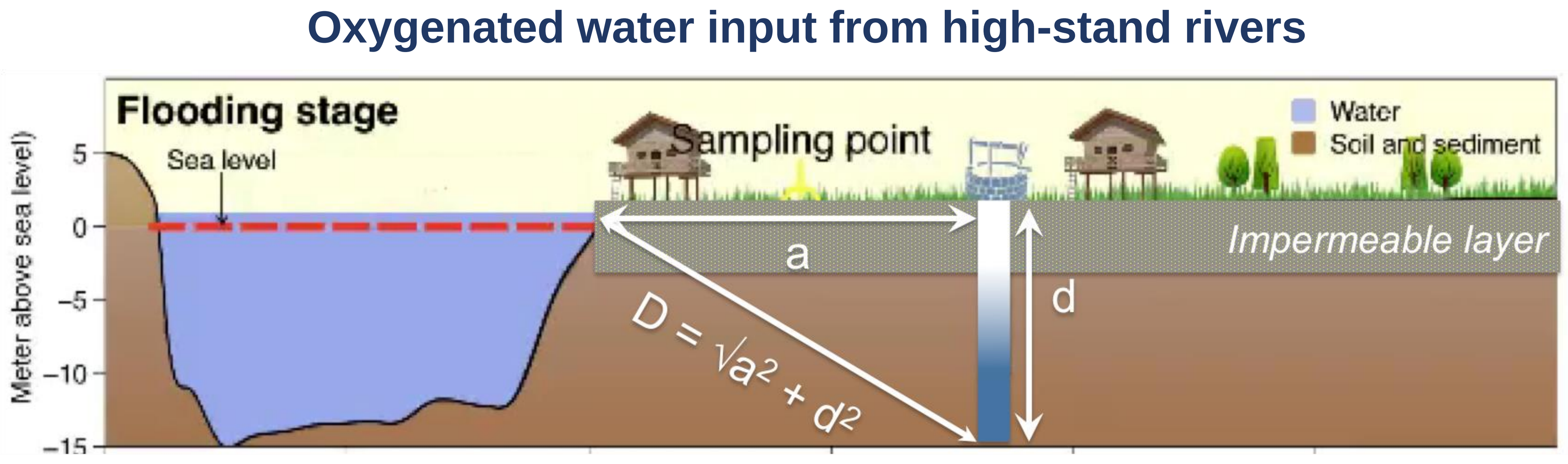


***Fig. 2**. Soil electrical conductivity measurements using a Geonics® EM31 in An Phu, An Giang*

Correlations between electrical ground conductivity (σ) and clay content

Place	Instrument	Prediction of clay content (%)	R^2	Reference
Germany	EM38	Clay = - 6.4 + 0.75 × σ	0.85	[5]
Bangladesh	EM31	Clay = - (3.97±1.5) + (0.91±0.1) × σ	0.85	[3]
New Zealand	EM38	Clay = - 22.496 + 1.682 × σ	0.72	[6]

Oxygenated water input from high-stand rivers



Estimate: $D = \sqrt{a^2 + d^2}$: average transport distance

Aqueous measurements in groundwater samples

***Fig. 3**. Groundwater sampling, on site and laboratory analyses*

- Sampling campaigns during the dry seasons (April 2015)
- pH, DO, alkalinity and conductivity: measured on site
- Sample for cations, anions, DOC: preserved for laboratory analysis

RESULTS AND DISCUSSION

As distribution and EM conductivity

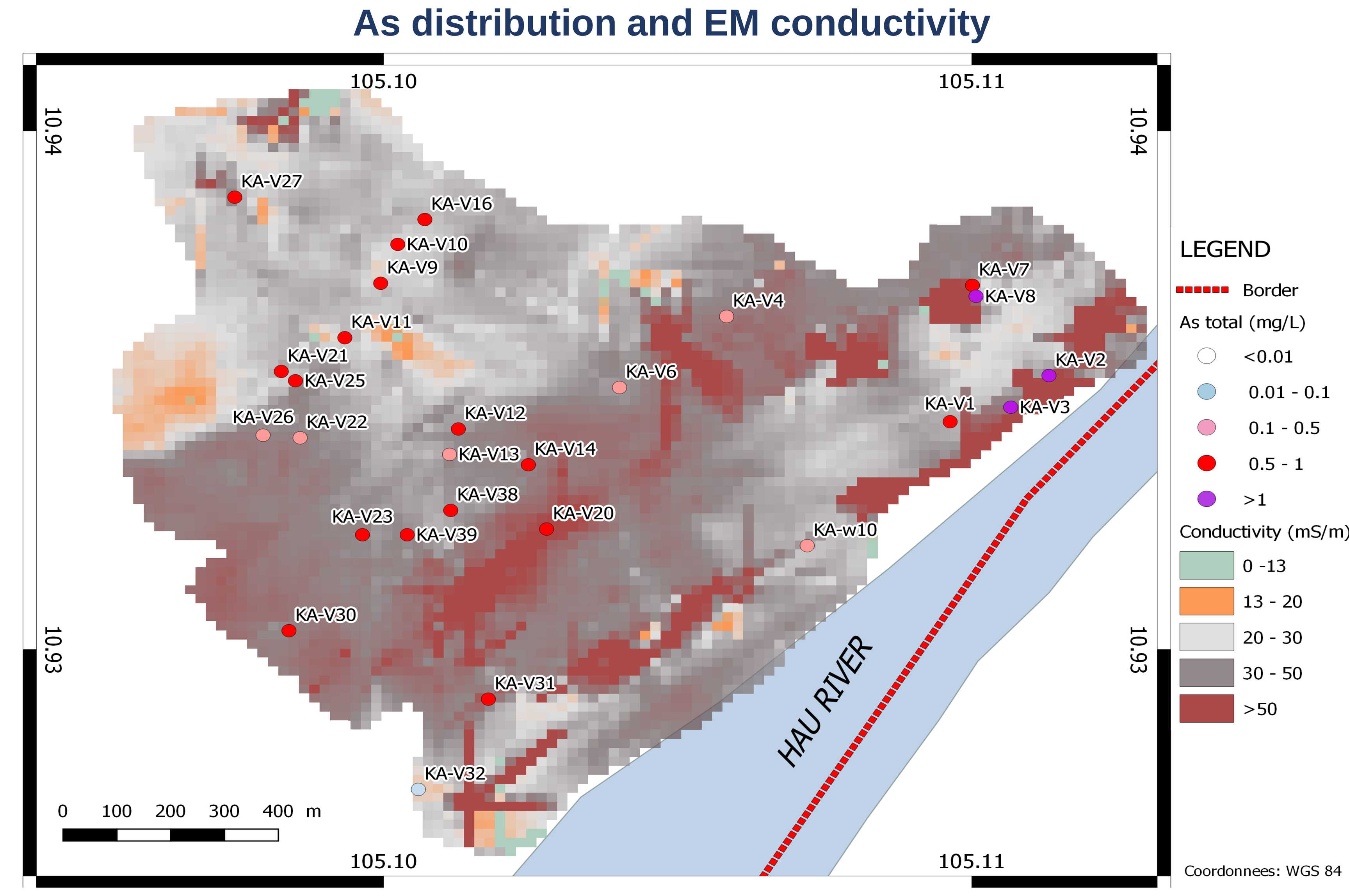


***Fig. 4**. Map showing As concentrations and the electrical conductivity data distribution using EM31 device in An Phu district*

Local top 3 – 5 m heterogeneity: Distinguish permeable (EM < 30 mS/m) from impermeable (EM > 30 mS/m): sandy soils on the west and sticky clay along the River EM > 50 mS/m: anthropogenic effects (roads and dikes)

As content function of the average transport distance (D) and EM conductivity (σ)

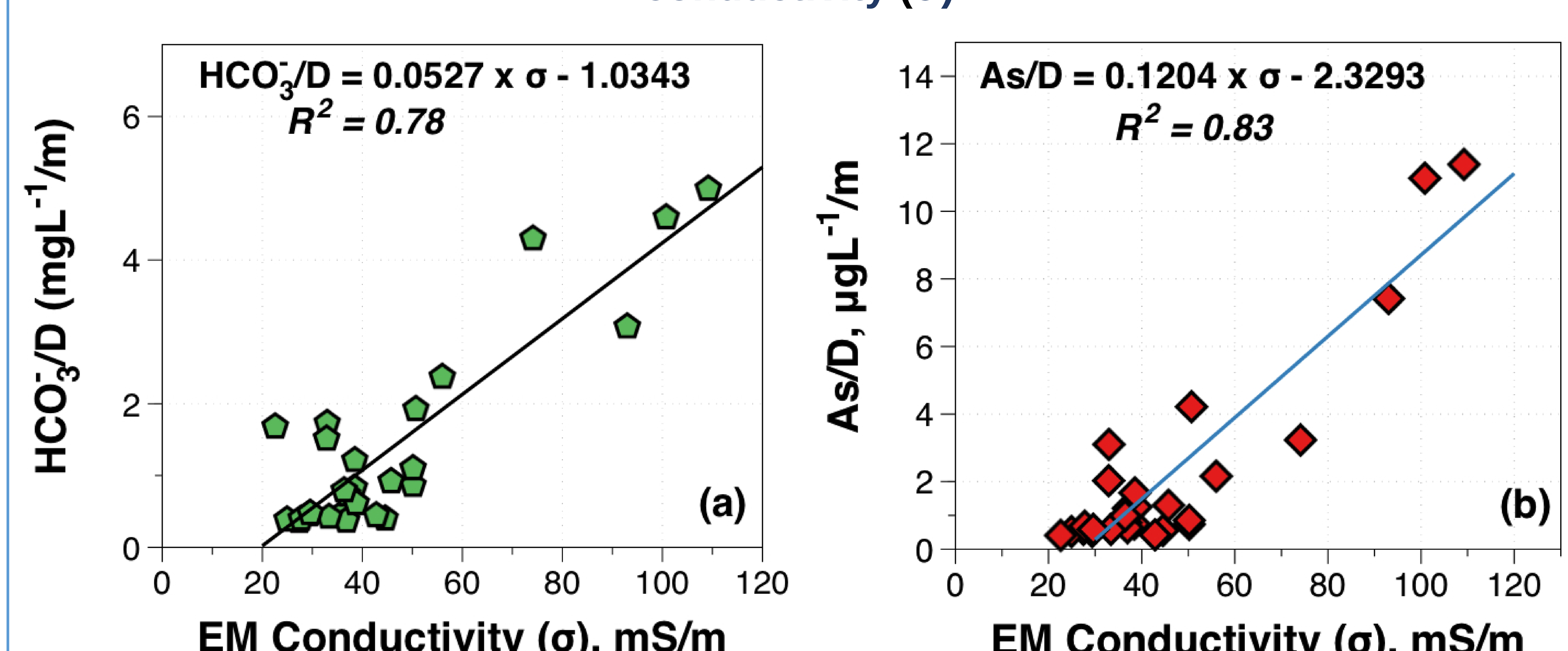


***Fig. 5**. Comparison of (a) HCO_3^-/D and (b) As/D as a function of the closet electrical conductivity measurement (σ)*

Significantly positive correlation between:
- **[As]/D and EM Conductivity (σ)**
- **[HCO_3^-]/D and EM Conductivity (σ)**

CONCLUSION

- **Easy and cheap electrical conductivity measurements** can be used to differentiate areas where this recharge may occur (low EC) from areas where it does not (high EC, high clay soil content) and where high As are favored in the underlying "sealed" aquifer.
- Average EM conductivity has a high value (40 – 50 mS/m) in this area → Natural soil are mostly **thick layers of sticky clay.**
- The geophysical data reveal **a significant correlation between EM conductivity (σ), As concentration and alkalinity** in shallow aquifers (**R^2 = 0.83, 0.78, n = 26**).
- **Mechanisms of As release** in An Giang groundwater: **dissolution of Fe (oxyhydr)oxides and carbonate minerals and oxidation of organic matter** in anoxic aquifers.

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