

Electrical Resistivity And Induced Polarization Used On Investigation Of Ionic And Hydrocarbon Pollutants Contaminated A Shallow Area. Ambohimambola Site

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ABSTRACT:Based on the electrical resistivity and the Induced Polarization (Chargeability) properties, we have displayed on three sites the ERT techniques to see if the presence of ionic solute and hydrocarbon pollutants change the geoelectrical response of the aquifer medium.

We have taken as an experimental site the Ambohimambola area, upstream of Antananarivo plain. We have considered a reference zone, in order to have a reference value of the aquifer resistivity and chargeability without pollutant.

The studies area are located near the retention lake, where the ionic solute from the colorant product are dumped, and downstream of the current generator that spills their waste oil on shallow area.

The geoelectrical section result of the ERT show that the pollutants change the electrical resistivity of the aquifer medium and their chargeability. This change is so obvious in using the statistical tools, histogram of resistivity and chargeability values.

KEYWORDS:Electrical Resistivity Tomography (ERT), Electrical resistivity, Induced polarization, chargeability, aquifer, pollutant, ionic, hydrocarbon, statistic.

I. INTRODUCTION

Agglomeration of Antananarivo, as well as the alluvial flat around the hilly area are so favourable on reception both industrial and household wastes. Cause of the pollutant discharged, the groundwater is exposed on contamination.

Antananarivo plain, known under "Betsimitatatra plain" name, can be divided into two areas, upstream and downstream, if we refer into the river which drains and crosses it [1]. However, the presence of manufactory which discharged dumped their wastes inside the basin without adequate protection, active the contamination of the plain groundwater.

Under this study, we take particularly an upstream area where the groundwater is again in its initial state without contamination. Also to highlight the effect of both ionic and hydrocarbon wastes on geophysical parameters that we consider the Ambohimambola area where the current generator of JiRaMa Company sent its hydrocarbon waste (photo1) and the paper mill of PapMad manufactory dumped their colorants residues waste on shallow zone (Photo 2).

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(Photo 1) (Photo 2)
Photo 1: Hydrocarbon residue, Photo 2: Retention Lake of colorant

II. RELATED WORK

Location of survey area

The survey area is located at the East of Antananarivo. The Ikopa River drain the ground and surface water on our zone. This River delineate the area at its West part.

Three sites, one reference and two contaminated, are considered under this study. The distance between reference and contaminated areas is about 2.3km (see fig 1).

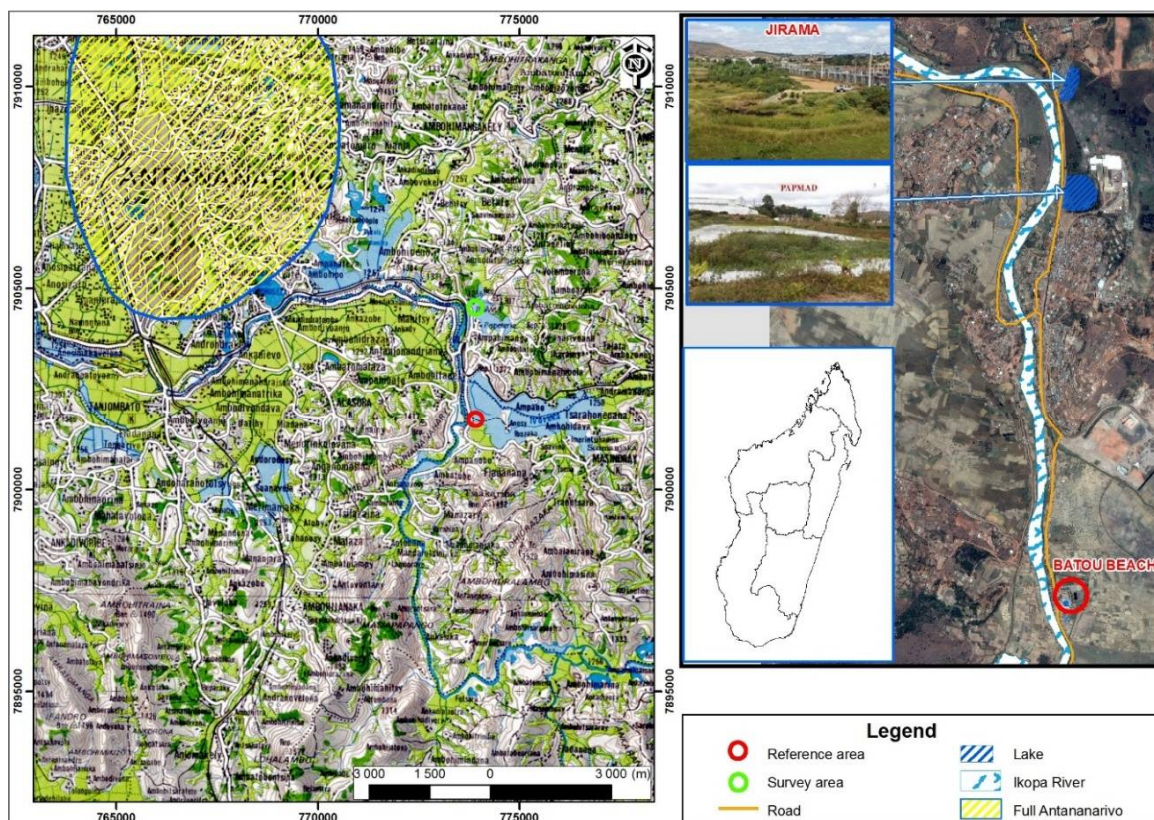


Fig. 1. Location of survey areas

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Geological setting

Each site is situated on the shallow zone, where the alluvium deposit cover the weathered and crystalline rock (Fig. 2). The underground rock is formed by old metamorphic rock of Antananarivo block. The hilly area is covered by weathered rock, especially constitute by migmatitic, mica schist, granitoid and gneiss. The plain is covered by alluvium deposit.

Two areas, affected by the pollution are located on downstream of retention pond, and the reference area is out of any groundwater contaminant influence.

The drilling done on the shallow zone, paddy field, gives us the section of the superposed layer deposited one crystalline zone (see fig 2). This alluvium deposit has about 20m thick, it is constituted by fine and medium sand and clay. Some isolated peat are sometime found and hit in some layer. The successive alluvium is lied on the weathered rock, formed by series of laterite, clayed sandy and boulders [1], [3], [4], [5]. The bedrock is constituted by migmatite.

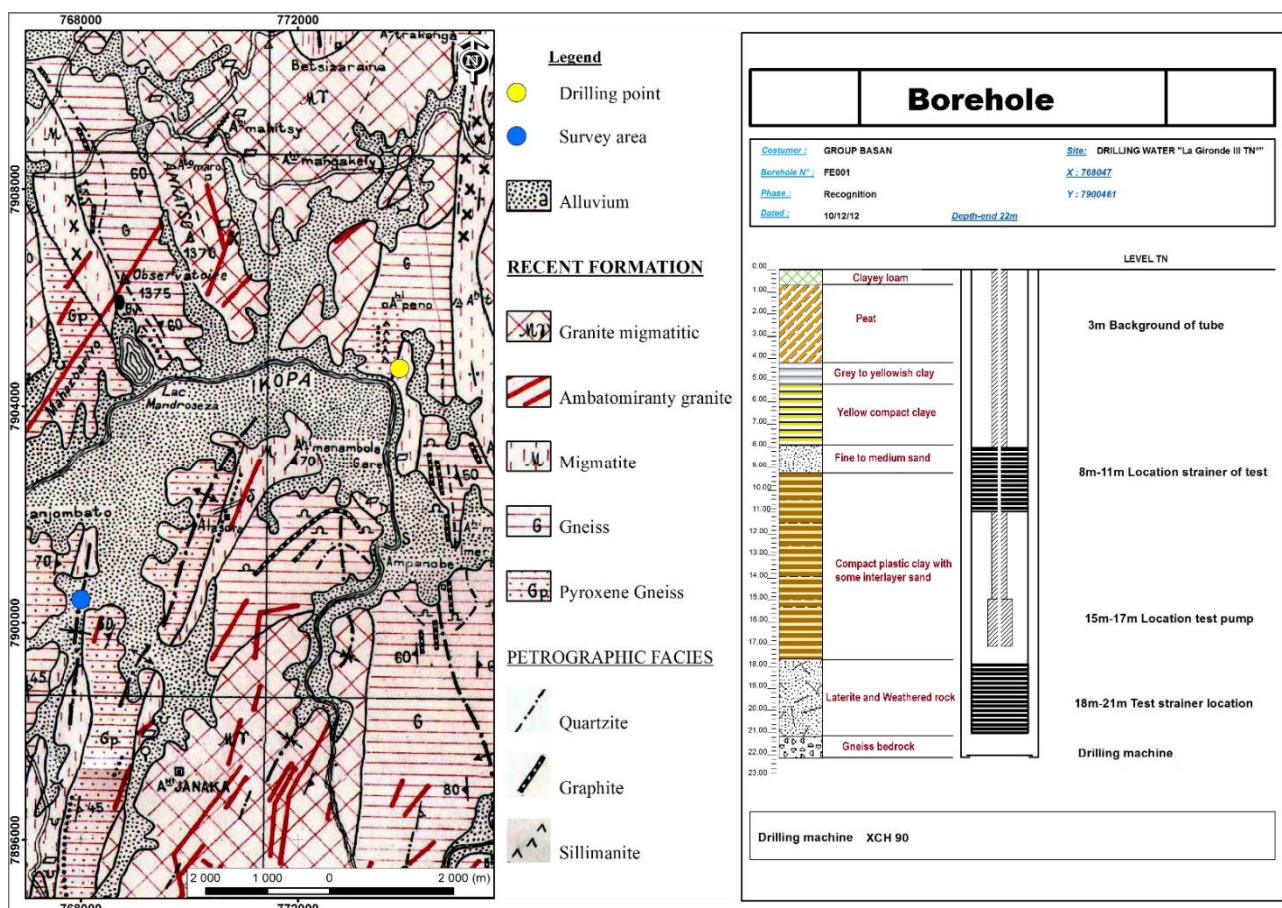


Fig 2. Regional geological map and lithological section see on borehole

Hydrology and hydrogeological settings

In order to have a same aquifer system, on reference zone and on two contaminated zones, that we have chosen the upstream of Ikopa River where contamination from the human activities is so delimited again. The Ikopa River receive on its right bank Varahina and Ivovoka rivers after taken its source on Tsiazompaniry Lake. The river cross its bed in sixty kilometers distance before reaching the Betsimitatatra plain (see Fig 3).

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The multi-layer aquifers develop on this alluvial plain, unconfined (phreatic aquifer) and confined aquifers [4]. They are constituted by two types of media: a) porous and b) fissured or fractured media. The porous medium is found on lateritic and alluvium areas, and the fissured medium is developed on the crystalline rock. The groundwater system are drained by the river during the drought season and they are recharged by the river on flood season [7].

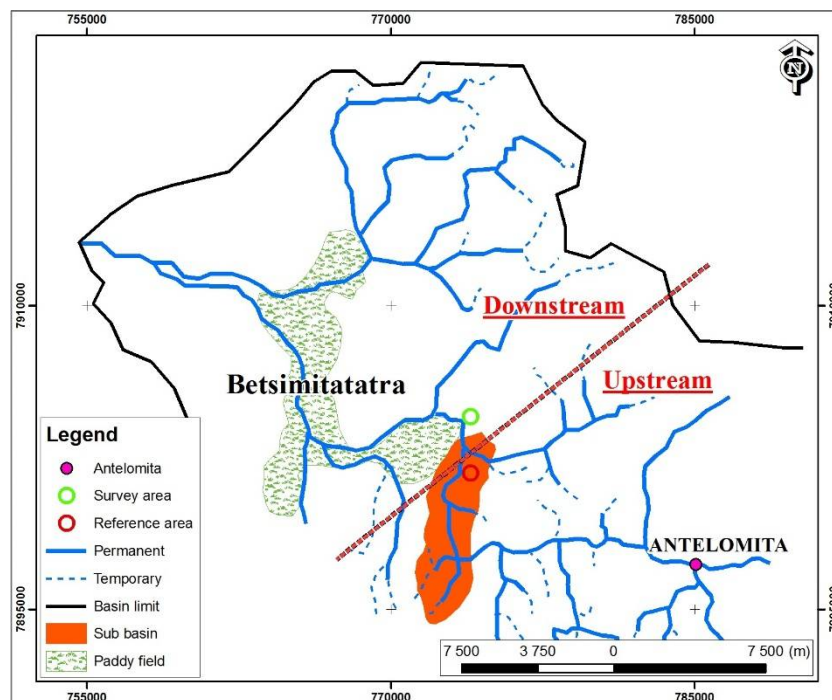


Fig 3. Hydrography of Betsimitatatra plain

III. METHODS

Notion of pollutants

Dispersions of liquid industrial pollutants are characterized by a great diversity, depending on the use of water during its process. As a good solvent, the water receive and dissolve the waste from the human activity, such as organic materials, greases (food industry), hydrocarbons (refinery), acids, bases, various chemicals (chemical industry and synthesis), metals (surface treatment, metallurgy).

Electrical resistivity and Induced polarization

The electrical resistivity is depending on lithology formation [8], on water content [9], [10], on electrical charge nature [11], [12], [13], on nature and metal quantity [14] or on temperature [15], [16]. We are interesting especially on the electrical charge nature on this work. The hydrocarbons pollutants are completely different with the ionic solution pollutant.

Considering Archie's law [17], 1942, aquifer resistivity is proportional with electrical resistivity of its brine. The hydrocarbons are electrically resistive but the ionic solutes are conductive. The electrical effect of their pollutants is so obvious on aquifer electrical properties, the hydrocarbons increase but the ionic solute decrease the aquifer electrical resistivity value.

$$\rho_a = \rho_w a \Phi^{-m} S^{-n}(1)$$

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Here, ρ_a denotes electrical resistivity of fluid saturated rock in (Ωm), ρ_w electrical resistivity of the brine in (Ωm), Φ is the porosity, S presents brine saturation, m is the cementation exponents of rock, n is the saturation exponents and a is the tortuosity factor.

The following parameters have a significant effect on induced polarization response of rock:

- Nature and bulk (volumetric) metallic mineral [14], [18].
- Ionic content of solute [19]
- Nature and bulk (volumetric) clayey mineral [20], [21]
- Water saturation [22]; [10]
- Petrophysics properties : porosity, permeability, pore size [23], [24], [12]
- Temperature [16].

Based on this induced polarization properties, both hydrocarbons and ionic presented in aquifer change successively its petrophysics properties and its water ionic content. In fact, its IP value increase, according to reference zone IP value. Note that the induced polarization is characterized by the chargeability parameter. It presents the relaxation time of rock after cutting current injection.

$$m = \frac{1}{V_p} \int_a^b V_t(t) dt \quad (2)$$

Here, m denotes chargeability in (ms or mV/V), V_p is current potential just before its cutting of, $V_t(t)$ presents potential in t time.

As the measurement of the $V_t(t)$ is physically impossible. After Seigel [25], in 1959, the chargeability can be obtained through the partial chargeability m_i , the apparent resistivity ρ_a and the partial resistivity ρ_i

$$m \approx \sum_i m_i \frac{\partial \log \rho_a}{\partial \log \rho_i} \quad (3)$$

We are carried out the electrical method, the Electrical Resistivity Tomography (ERT) using resistivity and chargeability parameters. The Wenner was adopted on their three sites.

IV. RESULTS AND DISCUSSIONS

Location of geophysical lines

Four geophysical lines were displayed on alluvial area, where the aquifer, unconfined and sustained by direct vertical and lateral flows, is formed by sand, gravel. The phreatic aquifer is exposed on the pollutant which can change its geoelectrical properties.

The reference is placed upstream, at about 2.3 km from the survey area affected by pollutants (see Fig 4).

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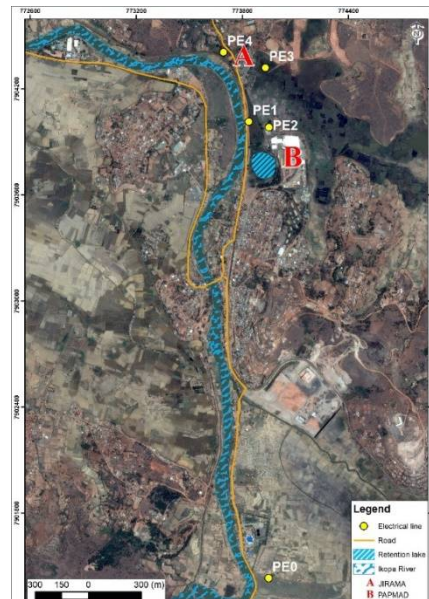


Fig 4. Location of geophysical lines

Reference geoelectrical section PE0

The line is displayed on East West direction. The adopted inter electrode distance is $a = 5\text{m}$, which reach 25m depth

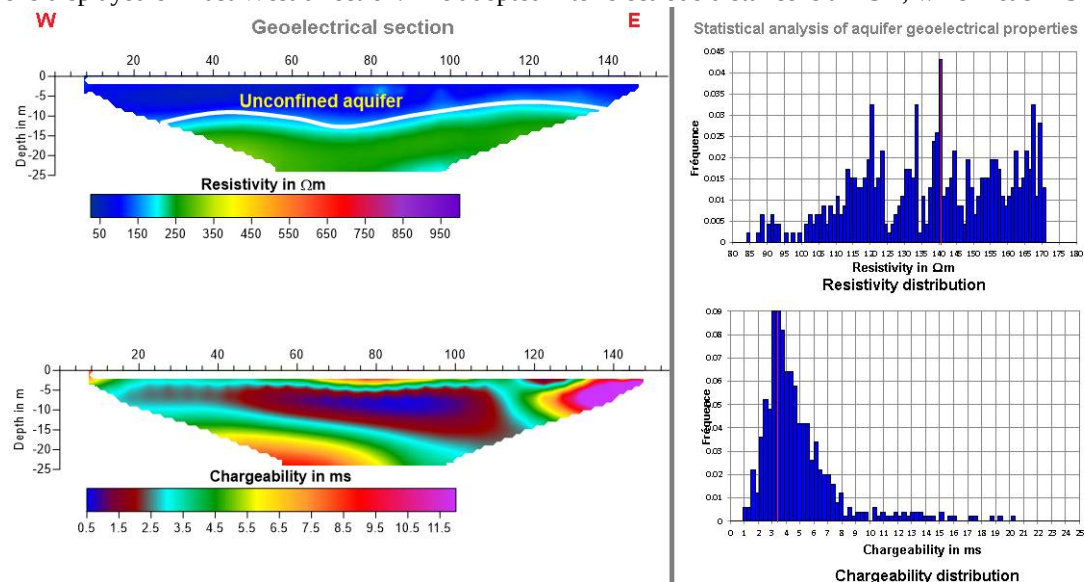


Fig 5. Geoelectrical section and histograms of resistivity and chargeability of PE0 line

The statistical analysis of the true resistivity and the chargeability, from the apparent resistivity and apparent chargeability inversions in using the res2inv software, shows that the resistivity of aquifer is about $140\ \Omega\text{m}$, and its chargeability is around 3 ms (see. Fig 5). Theirs values are the most repetitive on the unconfined aquifer zone.

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Geoelectrical sections PE1 and PE2

The two lines were displayed near the PapMad manufactory which send the ionic solute on retention basin. The unconfined aquifer is contaminated with this ionic solute, cause of direct vertical percolation and the lateral recharge. PE1 line was installed on the way which lead to JiRaMa current generator. The profile was done with inter-electrode distance $a = 5\text{m}$.

The geoelectrical section shows that the unconfined aquifer, characterized by the low value of electrical resistivity (less than $200\ \Omega\text{m}$), is about 25m thick. The weathered zone is so deep and it is not reach with the installed spread.

The chargeability section shows that the chargeability value vary from 0.5 ms to 12ms.

The statistical analysis of the geoelectrical value, resistivity and chargeability, of the aquifer zone gives us likely value $120\ \Omega\text{m}$ for electrical resistivity and 5.3 ms for chargeability.

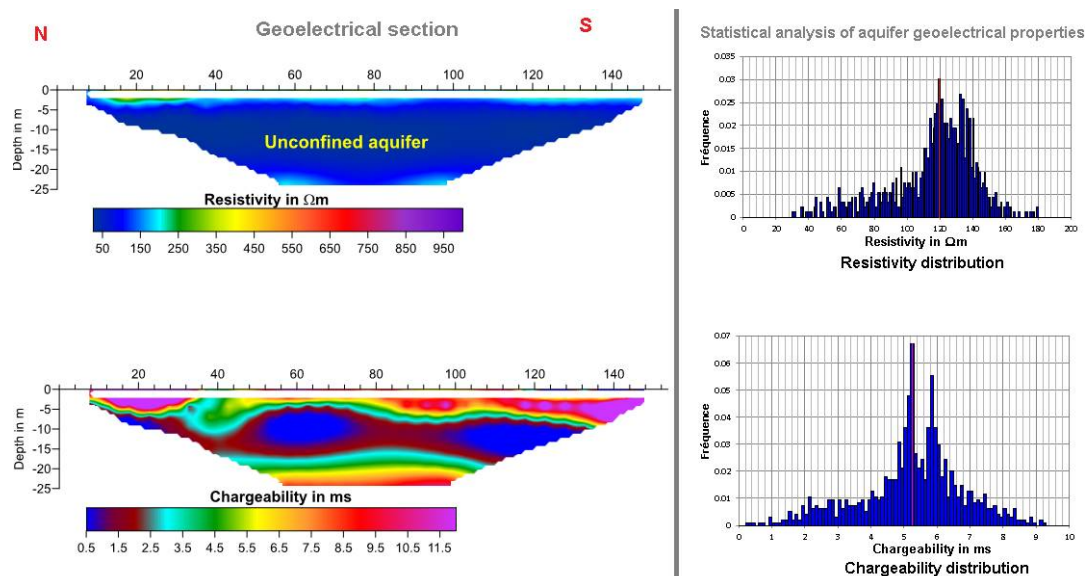


Fig 6. Geoelectrical section and histograms of resistivity and chargeability of PE1 line

PE2 line was displayed on the shallow zone, paddy field and it was installed with inter-electrode distance 3m which gives an investigation depth 15m.

The statistical analysis of aquifer geoelectrical parameters gives the following likely values: the electrical resistivity is about $72\ \Omega\text{m}$ and the chargeability is around 5ms

According to the geoelectrical properties of aquifer on reference zone, the result shows that the resistivity value on PE1 and on PE2 is less than resistivity value on PE0.

The ionic solute dissolved in the groundwater and added the free charge inside its. This phenomenon decrease considerably the resistivity value of the brine, consequently, the aquifer zone.

The change of ionic content in aquifer zone conduct on raise of chargeability value.

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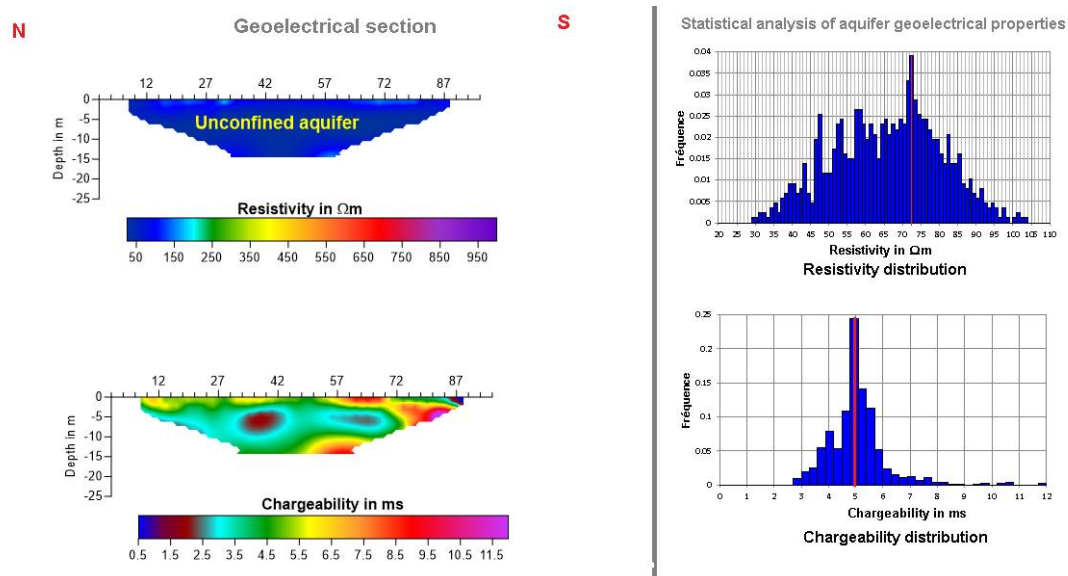


Fig 7. Geoelectrical section and histograms of resistivity and chargeability of PE2 line

Geoelectrical sections PE3 and PE4

ERT, PE3 and PE4 are implanted near the hydrocarbon waste dump by JiRaMa on shallow zone.

PE3 followed the direction West East and displayed along the pouring and reached the shallow zone covered by alluvium formation.

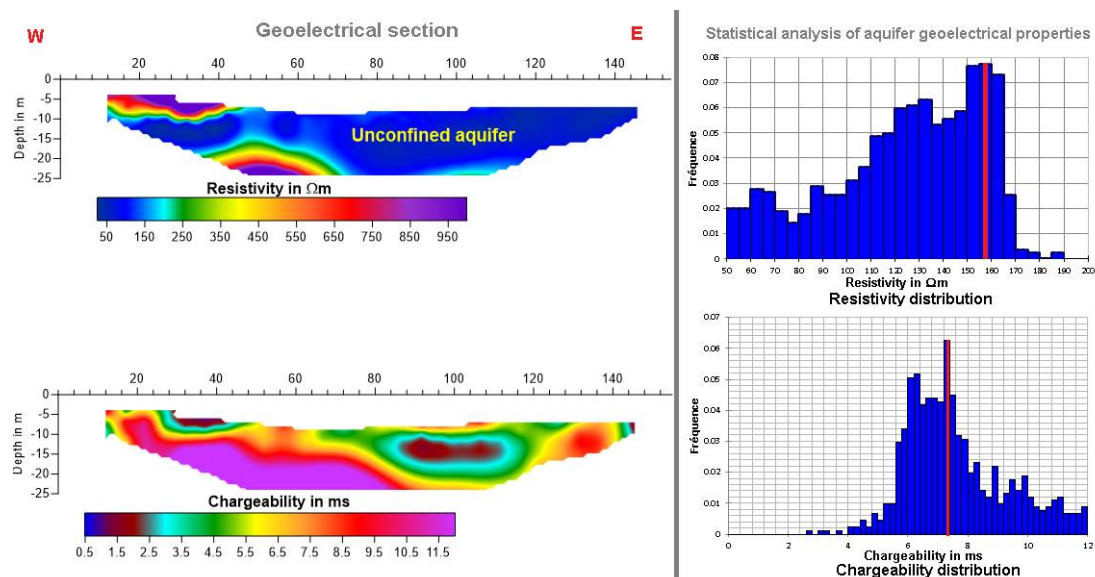


Fig 8. Geoelectrical section and histograms of resistivity and chargeability of PE3 line

The geoelectrical section bring out two resistivity's layers, conductive zone at East on flat area and resistive formation at West on lateritic area.

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The comparison of the electrical resistivity from reference zone and the PE3 sections shows that the resistivity value is so high on PE3 than on PE0.

Also, the chargeability is much higher on PE3 section, after the statistical analysis result (see Fig 8)

The PE4 line is displayed on North South direction. North part of line is installed on the lateritic area and the rest on the alluvium. As on PE3 section, the separation of lateritic couverture and the alluvium deposit is highlighted with its electrical resistivity formation. The resistivity value is less than 200 Ωm in alluvium zone. The alluvial deposit has a 15m thick, at south near the Ikopa River.

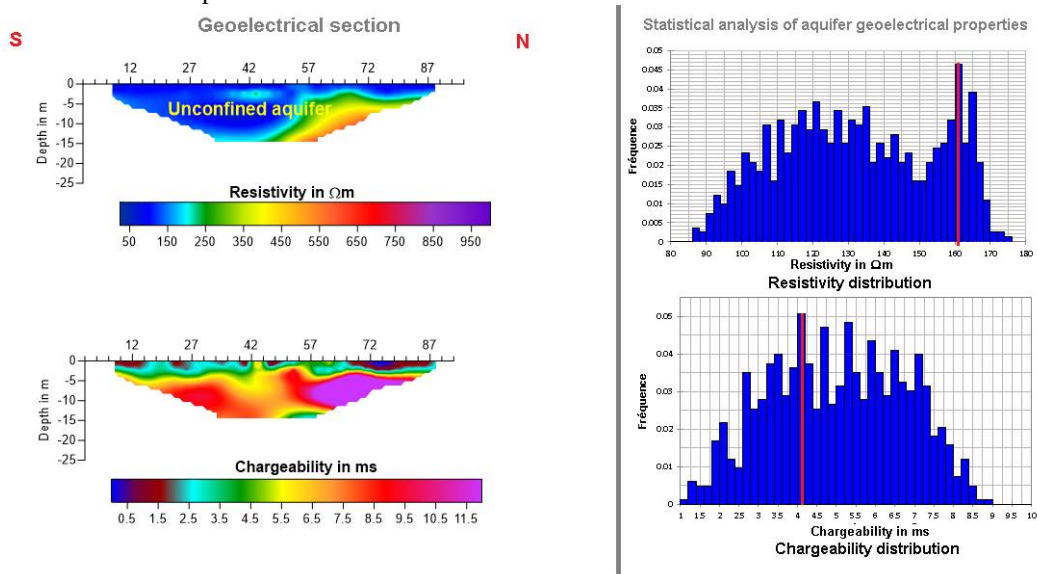


Fig 9. Geoelectrical section and histograms of resistivity and chargeability of PE4 line

The statistical analysis of the resistivity model shows that the likely resistivity value of PE4 section is around 160 Ωm . This resistivity is much higher than we see on reference zone.

The chargeability shows also this slight value increase. Its value is about 4ms under PE4 line.

V. CONCLUSION

The using of the ERT on three sites, one on reference zone (away of the pollutant source) and two sites successively polluted by ionic solute and hydrocarbon waste dump, shows the difference of theirs geoelectrical properties.

The study area is located on alluvial plain of Antananarivo, and we are interested particularly on the unconfined aquifer, which has a direct relation with the pollutant by vertical and horizontal flows.

According to the electrical resistivity of aquifer medium, the ionic solute increase the electrical charge (ion) inside the water and decrease the electrical resistivity value of aquifer. The comparison of the likely resistivity value in aquifer medium bring out this effect.

The electrical resistivity of the aquifer on reference zone, under PE0 line is around 140 Ωm , this value decrease on 120 Ωm under PE1, displayed on the way near the Ikopa River it is 72 Ωm , on flat area near the retention lake under PE2. The resistivity value is less and less weak in approaching the lake. Cause of the ionic content increase, the chargeability value is also growth. The hydrocarbon pollutant has an effect to increase the electrical resistivity and the chargeability value.

So the two pollutants are really marked by the change of the geoelectrical properties, decrease of resistivity value and grow of chargeability value for the ionic solute, increase of the resistivity and chargeability for the hydrocarbon pollutant.

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