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The radiological impact of INB uranium mine in Caetité (BAHIA / BRAZIL)

Description of CRIIRAD second mission to Caetité with FIOCRUZ and CPMA /

This second mission has received the support of "Medico International"

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0 / Introduction

In Brazil, uranium is currently extracted at a mine operated by INB (Indústrias Nucleares do Brasil) at approximately 40 km from the locality of Caetité (state of Bahia).

CRIIRAD (Commission for Independent Research and Information about RADiation) is a French NGO whose goal is to improve people information and protection against the effects of ionizing radiation. CRIIRAD is independent from the French state and nuclear operators. CRIIRAD is running its own laboratory with a team of 7 engineers and technicians specialised in radiation monitoring.

In the course of the EJOLT[1] project, FIOCRUZ[2] organised a "toxic tour" to Caetité in June 2012. CRIIRAD, which is a partner of the EJOLT project, contributed to this tour through education of people about the impact of uranium mining and making very preliminary radiation monitoring and sampling near the mine. The results of this first mission are presented in CRIIRAD report N° 12-87 (October 2012).

1 / Context and description of activities performed on April 7th to 11th 2014 in Caetité

A second mission (April 7th to 11th 2014) was organised with the support of FIOCRUZ, Medico International, the Comissão Paroquial de Meio Ambiente (CPMA) de Caetité, the Comissão Pastoral da Terra (CPT-BA), the local communities of Caetité, and Associação Movimento Paulo Jackson-Ética, Justiça, Cidadania (Mrs Zoraide Vilasboas).

The goal of this mission was not to conduct an impact study (which would require much more resources), but to organize limited sampling activities in order to improve the ability of the communities and workers in the field of radiation monitoring. That is why voluntary people participated in the sampling activities and training sessions. The sampling activities included sampling of underground and rain water, monitoring of gamma radiation and sampling of top soil in areas affected by prospection activities and locations potentially affected by dust deposition or contamination by seepage. The point was to get independent data in order to make comparisons with the information given by the company.

The activities are presented below.

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[1] Environmental Justice Organisations, Liabilities and Trade (EJOLT) (FP7-Science in Society-2010-1). EJOLT aims to improve policy responses and support collaborative research and action on environmental conflicts through capacity building of environmental justice groups around the world. www.ejolt.org

[2] The Oswaldo Cruz Foundation (Fundação Oswaldo Cruz, also known as FIOCRUZ) is a scientific institution for research and development in biomedical sciences located in Rio de Janeiro (Brazil). It is considered one of the world's main public health research institutions. It was founded by Dr. Oswaldo Cruz, a noted physician and epidemiologist.

Map of some villages around INB uranium mine (GoogleEarth)

1-1 / Training and communication activities

Monday 7th April 2014

A one day training session took place in the Centro Paroquial in Caetité, with about 30 participants : citizens from the communities of Lagoa Real, São Timóteo, Maniaçu, Caetité; villagers living close to the mine; Health Agents ; workers of INB; students; a representative of the communities of Ceará (confronted to the project of a uranium and phosphate mine undertaking the process of licensing), etc..

The training dealt with the impact of uranium mining on health and the environment and was organized in three sections :

1 / general information about radioactivity, main types of radiation, health effects of ionizing radiation, radioprotection principles.

2 / general presentation about the impact of uranium mining activities based on CRIIRAD studies performed in France or Africa : impact of prospection, mining, milling, problem of waste rocks, scrap metal, tailings, etc..

3 / information about the specific impact of INB Caetite based on CRIIRAD preliminary mission of June 2012 (EJOLT Project) and the analysis of additional documents provided by the local community.

The training was given in English by M. Chareyron and translated into Portuguese by M. Renan Finamore (FIOCRUZ).

Picture N°1 / Training activities, April 7th 2014 at the Paroquial Centre in Caetité

Tuesday 8th April 2014 / training activities for the workers

Additional training activities were organized for the workers of the uranium mine including a training about the use of a radiation monitor (Radex). In the afternoon, the sampling strategy was discussed with members of the community and M. Lucas Mendonça, representative of the union of mine workers SINDMINE (Sindicato do Mineradores de Brumado e Micro Região). CRIIRAD could explain its strategy of sampling and received the advice of the locals regarding the topography, accessibility, etc..

April 9th-10th 2014 / training associated with sampling activities

Training activities also took place during the sampling performed on April 9th and 10Th. M. Chareyron explained how to use a Geiger Müller counter and a scintillometer, how to select samples of soil and water, etc… Due to the short duration of the mission, training activities took place also during the meals. For example, the use of the radon monitor RAMON was presented to members of CPT-BA by M. Chareyron during the diner of Thursday 10th 2014.

Thanks to the financial support of Medico International, some radiation monitoring equipment has been left by CRIIRAD to the communities for additional monitoring activities : two Geiger Müller counters (RADEX RD 1503) and two electronic radon monitors (RAMON 2.2).

Friday 11th April 2014 / public debate

The CPMA organised a public debate “Mineração de Urânio: Riscos, Saúde e Ambiente” that took place from 9H30 to 12H30 in the University of the State of Bahia, campus Caetité.

More than 200 people were attending this meeting including many students of the Mining section of the university, the representative of Caetité municipality in charge of the Environment, the Bishop, the former parish priest of Caetité, padre Osvaldinho Barbosa.

CRIIRAD gave a 40 minutes presentation (in English with immediate translation into Portuguese by M. Renan Finamore). M. Chareyron gave examples of the impact of uranium mining activities in France, Africa and Caetité and asked for more transparency of INB in the area of environmental monitoring and monitoring of the exposure of the workers.

The debate was broadcasted live by the radio “Educadora Santana”.

Picture N°2 / Public debate, April 11th 2014 at the University of Caetité

1-2 / Sampling and on site radiation monitoring activities (9th-10th April 2014)

The team in charge of sampling was composed of 4 people: M Bruno Chareyron (CRIIRAD); M Renan Finamore (FIOCRUZ), M Lucas Mendonça (SINDMINE), M. Joao Batista (CPT-BA) on April 9th and M Marcelo Firpo (FIOCRUZ) on April 10Th.

Each member had a specific function: driving and logistics, localization with GPS, monitoring of gamma radiation, contact with the inhabitants, translation, sampling of water and top soil, etc..

Due to the fact that CRIIRAD professional equipment (DG5 gamma scintillometer) was available only on April 10Th (the luggage was not delivered on time by the plane company); the mapping of gamma radiation was less efficient than expected (the RADEX Geiger Müller monitor that the team could use is less efficient than a professional scintillometer). So, in order to accomplish the tasks initially planned, the team had to perform some of the measurements at night in order to compensate for the late delivery of the equipment.

The team collected **10 samples of top soil** and or sediments and **3 samples of water**.

The list and characteristics of the samples is given in table 1 (solid samples, page 10) and table 4 (liquid samples, page 13).

A short description of the sampling activities is given below.

Wednesday April 9th 2014

In **Gameleira**, INB has undertaken **intensive drilling activities** during year 2013. In order to determine if the level of radiation had been enhanced by the drilling activities, the team monitored natural background radiation in the vicinity of the affected locations and directly on the former drills. Top soil samples **TS5** and **TS6** were collected in two fields in Gameleira affected by the drilling campaign (pictures N°3-4, next page).

A sample of **underground water** (**UW3**) was collected in a well drilled by INB on the property of M. Lucio Fabio (Picture N°6, next page). This well is located downstream the prospected area. According to M. Fabio, INB advised him not to drink the water anymore due to high uranium content. CRIIRAD decided to get a sample of this water in order to evaluate the uranium content. Other chemicals have been analysed in order to get baseline results which will be useful in case INB would open a new mine there.

Then, the team performed gamma radiation monitoring and sampling of top soil and or sediments (**TS8, TS9, TS10, TS11, TS12**) in the area between **Tamandua and the open pit**. This sector was selected taking into consideration the main wind direction. Samples of fine sediments accumulated in the natural drainage zones at the surface of the soil were also collected (pictures N°7 to 9, next page).

Pictures N°3 to N°6 / Area of Gameleira impacted by uranium prospection activities

Monitoring of gamma radiation, picture of a drill, meeting with local inhabitant, sampling of underground water.

Pictures N°7 to N°9 / Area between Tamandua and the open pit

Monitoring of gamma radiation, sampling of sediments TS9

Picture N°10 / View of the open pit from the fence (CRIIRAD)

Picture N°11 / View of the tailings and waste rock dump (CRIIRAD)

The team could also visit **monitoring post LR010** located near **Tamandua**. This post includes a TLD monitor (thermoluminescent dosimeter) for the monitoring of ambient gamma dose rate, an air sampler (connected to electricity); passive equipment for the collection of dust and rain water, radon monitors, etc.

Picture N°12 / Monitoring post LR010 near Tamandua

Thursday April 10th 2014

On April 10th, the team performed additional gamma radiation monitoring and sampling activities :

Sample **TS 13** was collected in a **quarry** located **between Maniaçu and the INB mine**. This carry shows quite high gamma radiation rates (up to 640 c/s with the DG5 scintillometer). Some streets of **Maniaçu**, are covered with material from this quarry. This material may have been used as well for building.

Top soil **TS 14** was sampled in the **vicinity of Area 170**. Area 170 is the section of INB plant where the uranium concentrate (yellow cake) is produced and packed into metallic drums. CRIIRAD was willing to check for a possible contamination of the soil with uranium concentrate discharged by the chimney of Area 170.

Monitoring of gamma radiation and sampling of top soil (**TS 15**) took place in **Mangabeira about 800 m downstream of the tailings dump**. At the entrance of Mangabeira property, besides the road; higher gamma flux values (420 c/s with the DG5 scintillometer) were monitored on top of an orange layer of clay deposited by the rain just under a tree (pictures N°13 to 18, next page). This situation may be due to the fact that the radioactive dust blown from the waste rock dump, can be deposited on the leaves of the tree, and then be washed down at the bottom of the tree when it is raining.

Note : During the first CRIIRAD mission in this area (June 2012), CRIIRAD could take a sample of contaminated soil at the bottom of the valley directly under the influence of the tailings and waste rock dump (sample TS4 was collected at the bottom of the fence, pictures N° 27-28, page 20). Later on, the fence has been moved closer to the road, so that during April 2014 mission, it was no longer possible to access directly the contaminated area where sample TS4 had been collected.

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Pictures N°13 to N°18 / Mangabeira, sampling of soil sample TS 15 (April 2014)

Later in the evening of April 10Th 2014, the team decided to look for a **well located under the influence of the waste rock and tailings dump**, in order to sample underground water. The team had to make many attempts in order to get a sample of underground water in the Riacho da Vaca alluvium downstream the mine. In effect, it was not possible to get samples in Mangabeira (INB property), Varginha (no access to the wells, the local people told us that the water was now provided by truck), or Fazenda Capoeira (the farmer was not there).

Eventually, we could get a sample of **underground water** (sample **UW4,** pictures N°19-20 below) in a tank at **Pega Bem**. This house is located about 1.5 km downstream the dam built by INB in the Riacho da Vaca valley and 4 km downstream Mangabeira (see map on page 2). The underground water is pumped once or twice a week in the tank and used for cooking or washing but no more for drinking.

The family is now using rain water for drinking. Sample **RW1** was collected in the **rainwater** tank.

Pictures N°19 to N°20 / Sampling of water UW4 in Pega Bem (April 2014)

On the way back to the city of Caetité, M. Chareyron decided to make preliminary measurements in the **uranium prospection area of Juazeiro** (see map on page 2 and picture N°21 below).

The team could see that trench digging had removed the protective layer of soil covering the naturally radioactive rocks. CRIIRAD monitored dose rates about 10 times above basic natural values at different **locations along an exploration trench 4 metres wide and hundreds of metres long (see picture N°21** below). At the surface of some rocks left uncovered after the prospection, the flux of gamma radiation was above 1 300 c/s (scintillometer DG5), and the doserate **above 2 µSv/h** (Radex). It would be necessary to get a copy of the baseline studies performed by INB before the prospection activities in order to evaluate more precisely the impact of these activities.

Picture N°21 / View of the trenches in the forest at the uranium prospection area of Juazeiro

(INB uranium concentration plant can be seen on the top of the picture)

Table 1 / List of samples of soil or sediments collected by CRIIRAD on April 9th-10Th 2014 and results of gamma radiation monitoring

Code	Sampling day	Sampling hour (local time)	Op.	Location	Description	Gamma Dose Rate (µSv/h), Radex		Gamma Radiation flux (c/s), DG5		GPS	GPS
						Contact of soil	1m above soil	Contact of soil	1m above soil		
A (no sample)	09/04/2014	9H10	BC, RF, JB, LM	Main road in front of **Gameleira** prospected area (reference)	Natural soil	0,28	0,21	NM	NM	S13º50.652'	W042º19.048'
TS-5	09/04/2014	10H50	BC, RF, JB, LM	Field affected by uranium prospection activities in **Gameleira**	top soil (disturbed) close to drill N° F33	0,41	0,35	NM	NM	S13º50.669'	W042º18.970'
TS-6	09/04/2014	11H0	BC, RF, JB, LM	Field affected by uranium prospection activities in **Gameleira**	top soil, brown, close to drill N° F31	0,45	0,36	NM	NM	S13º50.694'	W042º18.968'
TS-8	09/04/2014	17H10	BC, RF, JB, LM	Between **Tamandua** and the Open pit	Fine sand with clear colour, in the middle of a natural drainage besides the fence of the open pit	0,27	0,22	NM	NM	S13º49.742'	W042º17.746'
TS-9	09/04/2014	17H15	BC, RF, JB, LM	Between **Tamandua** and the Open pit, downstream TS-8	Extremely Fine red clay (wet) in a hole in the middle of a natural drainage besides the fence of the open pit, but possibly under influence of the tailings pile	0,27	NM	NM	NM	S13º49.762'	W042º17.700'
TS-10	09/04/2014	17H25	BC, RF, JB, LM	Between **Tamandua** and the Open pit, besides the main road in the middle of the path leading to TS-9	Fine black material in the middle of a natural drainage of the road	0,34	0,23	NM	NM	S13º49.529'	W042º17.772'
TS-11	09/04/2014	17H40	BC, RF, JB, LM	On the way to **Tamandua** , near INB monitoring post LR10, besides the main road in a small drainage	Fine material with clear colour, in the middle of a natural drainage besides the road	0,22	0,15	NM	NM	S13º49.689'	W042º18.349'
TS-12	09/04/2014	18H25	BC, RF, JB, LM	At the bottom of the valley before reaching **Tamandua** (downwind the open pit in the center of the wind axis)	Fine sand without clay (clear colour) besides the road (accumulation by the rain)	0,18	0,18	NM	NM	S13º49.236'	W042º18.917'
TS-13	10/04/2014	14H40	BC, RF, MF, LM	In a **quarry** located between **Maniaçu** and INB. This material is used for the roads and possibly for building	Small rocks and soil (the sample is taken at a place with mean values of gamma flux : 400 c/s). On the walls of the quarry higher measurements are monitored up to 640 c/s DG5	0,38	0,31	400	290-360	S13º51.498'	W042º20.404'
TS-14	10/04/2014	15H10	BC, RF, MF, LM	Close to **AREA 170** of INB where uranium concentrate is put into drums. The objective is to look for possible accumulation of yellow cake dust in the soil	Fine grained material (red and beige colour) in a natural drainage of the plateau , besides the road	0,22	0,19	200	160		
TS-15	10/04/2014	17H	BC, RF, MF, LM	In **Mangabeira**, downstream the tailings dump at the entrance of Mangabeira property, besides the road ; higher gamma flux values are monitored on top of an orange layer of clay deposited by the rain under the tree. This material very probably comes from the deposition of the dust accumulated on the leaves of the tree and washed by the rain.	Very thin layer (< 2 mm) of clay on top of the road below the tree (alpha-bêta-gamma counting rate monitored with MCB2 detector without cap is 1.6 to 5.2 c/s)	0,40	0,31	420	360	S13º49.405'	W042º17.295'
K (no sample)	10/04/2014	16H50	BC, RF, MF, LM	In **Mangabeira**, on the main road (reference)	Natural soil	0,21	0,17	220	190	S13º49.413'	W042º17.325'

1-3 / Results of laboratory analysis of the solid samples

All solid samples (10 samples) have been brought to CRIIRAD laboratory in France, but due to budget limitations, **only two samples of soil could be analysed**. CRIIRAD decided to analyse:

- Sample **TS 14** collected besides the road in a natural drainage of the plateau located immediately below **AREA 170 building**.
- Sample **TS 15**: fine grained material deposited on the soil under a tree in **Mangabeira** under the influence of the dust from the waste rock and tailings dump.

In both cases, the objective was to look for the deposition of fine radioactive material transported by the wind in connection with uranium mining activities. Therefore, the samples were sieved and the **fraction below 63 micrometres** analysed at CRIIRAD laboratory. The measurements were performed by HpGe gamma spectrometry.

The CRIIRAD laboratory is agreed by the French Nuclear Safety Authority (ASN) for the monitoring of radiation in the environment (see details on ASN web site).

The results are plotted in table 3 below (uranium 238 decay chain) and table 4 (other radionuclides, next page).

Table 3 / Analysis of top soil by gamma spectrometry at CRIIRAD laboratory

Uranium 238 decay chain

Code	Location	Description	Uranium 238 (Bq/kg)	Radium 226 (Bq/kg)	Lead 210 (Bq/kg)
TS-14	Close to **AREA 170** of INB where uranium concentrate is put into drums. The objective is to look for possible accumulation of yellow cake dust coming from the vents of the plant.	Fine grained material (red and beige colour) in a natural drainage of the plateau , besides the road	68 ± 37	81 ± 15	131 ± 42
TS-15	In **Mangabeira**, downstream the tailings dump at the entrance of Mangabeira property, besides the road ; higher gamma flux values are monitored on top of an orange layer of clay deposited by the rain under the tree. This material very probably comes from the deposition of the dust accumulated on the leaves of the tree and washed by the rain.	Very thin layer (< 2 mm) of clay on top of the road below the tree (alpha-bêta-gamma counting rate monitored with MCB2 detector without cap is 1.6 to 5.2 c/s)	160 ± 60	191 ± 33	180 ± 60

In both samples, the uranium 238 to radium 226 ratio is close to one (taking into consideration the uncertainties associated with the measurements).

There is no indication of a contamination with yellow cake dust in sample TS14.

Sample TS 15 has a higher uranium 238 activity (close to 200 Bq/kg for radium 226) and thorium 232 activity (390 Bq/kg). This material is not made of tailings but more probably comes from **particles associated with the waste rocks or due to blasting**, as there is no significant disequilibrium in the uranium 238 decay chain.

The contaminated soil TS4 sampled by CRIIRAD in June 2012 at the bottom of the valley, about 20 meters from TS15, was very probably contaminated by material including tailings (the radium 226 to uranium 238 ratio was 5.4).

The results obtained after analysis of samples TS4 and TS15 indicate different contamination routes from the tailings and waste rock dump:

- a transfer of radioactive material (including tailings) by the water from seepage (sample TS4),
- a transfer of fine particles by the wind (sample TS15).

It should be noted that the activity of thorium 232 in sample TS15 is about twice as high as uranium 238. This means that when evaluating the radiological impact of the mining activities on the workers and general public, the company and the authorities should take into consideration not only uranium 238 and its decay products but also thorium 232 and its decay products.

The impact of this environmental contamination on the flora, fauna and human beings should be monitored precisely.

Table 4 / Analysis of top soil by gamma spectrometry at CRIIRAD laboratory

(Uranium 235, lead 212 from the thorium 232 decay chain, other radionuclides)

Code	Location	Description	U235 (Bq/kg)	Lead 212 (Bq/kg) (Th 232 decay chain)	Potassium 40 (Bq/kg)	Be7 (Bq/kg)	Cs 137 (Bq/kg)
TS-14	Close to **AREA 170** of INB where uranium concentrate is put into drums. The objective is to look for possible accumulation of yellow cake dust coming from the vents of the plant.	Fine grained material (red and beige colour) in a natural drainage of the plateau , besides the road	< 17	137 ± 20	660 ± 150	41 ± 25	< 1,6
TS-15	In **Mangabeira**, downstream the tailings dump at the entrance of Mangabeira property, besides the road ; higher gamma flux values are monitored on top of an orange layer of clay deposited by the rain under the tree. This material very probably comes from the deposition of the dust accumulated on the leaves of the tree and washed by the rain.	Very thin layer (< 2 mm) of clay on top of the road below the tree (alpha-bêta-gamma counting rate monitored with MCB2 detector without cap is 1.6 to 5.2 c/s)	< 29	390 ± 50	< 500	< 20	< 2,9

1-4 / Results of laboratory analysis of water samples

All water samples (3 samples) have been brought to CRIIRAD laboratory in France, but due to budget limitations, and the limited amount of water per sample, all pertinent chemicals and radionuclides could not be monitored in all samples. CRIIRAD decided to analyse the following parameters:

- Dissolved radon 222 in all samples. This monitoring is not destructive so that the sample can then be used for the measurement of other parameters.
- pH, conductivity, main anions and cations, main metals (including uranium) in samples UW3 and UW4.
- Gross alpha and gross bêta activity in samples UW4 and RW1.

Dissolved radon 222 has been monitored at CRIIRAD laboratory (gamma spectrometry), main anions and cations, main metals including uranium have been monitored by the LDA 26 Laboratory in France. Gross alpha and gross bêta activity have been monitored by EICHROM laboratory in France.

Table 4 / List of water samples collected by CRIIRAD on April 9th-10Th 2014

Code	Sampling day	Sampling hour (local time)	Op.	Location	Description	GPS	GPS	Sample amount
UW3	09/04/2014	12H28	BC, Joao Batista	Water from a well in Gameleira , installed by INB (Well n°171, year 2013), but no more used because of high uranium concentration, located on the right bank of a small river donwstream the prospection area, property of Luciou Fabio	water no more used for drinking (depth 64 m, water surface - 5 m top of tube), sampled by aspiring with a small plastic tube	S13º50.664'	W042º19.129'	250 cc of water
UW4	10/04/2014	18H10	BC, MF, RF, LM	Water from a tank in PEGA BEM on the right bank of Riacho da Vaca downstream the dam. This tank is filled with underground water once or twice a week. The well has been installed by INB. The water is used for cooking but not used for drinking since the installation of a rainwater collector.	water no more used for drinking sampled from a tap at the bottom of the tank	S13º49.959'	W042º15.201'	500 cc of water
RW1	10/04/2014	18H15	BC, MF, RF, LM	Rain water from a tank in PEGA BEM.The water is used for drinking since the installation of the rainwater collector.	Water used for drinking sampled from a tap at the bottom of the tank	S13º49.959'	W042º15.201'	250 cc of water

The results of radiological monitoring and monitoring of chemicals are given in tables A1 and A2 in Appendix (page 24 and 25)

Picture N°22 / View of the uranium prospection area in Gameleira (location of drills) and UW3 underground water sample

Picture N°23 / View of Pega Bem , samples of underground water UW4 and rainwater RW1

Underground water UW3 (Gameleira)

Dissolved radon is detected in sample UW3 (Gameleira). The **radon 222** activity (107 ± 41 Bq/l) may be above the value of **100 Bq/l** set by the European Commission[3]. According to the Commission, if the radon 222 activity exceeds this limit, an evaluation of the dose to the consumer should be made and appropriate countermeasures taken when necessary.

The concentration of **uranium** is **11.5 µg/l**. The former guidance value set by the WHO[4] for drinking water was 15 µg/l. The value recommended in 2011 is **30 µg/l.**

In sample UW3, the concentration of **nitrates** (**180 mg/l**) is above WHO limit of 50 mg/l, therefore the consumption of this water is not recommended.

The owner of the property told us that he was not drinking this water anymore as INB had mentioned high uranium concentrations (we could not see the results of the monitoring performed by the company). The family is now using rainwater for drinking (see picture N°24 below). **Monitoring of the rainwater should be performed taking into consideration the risk of airborne contamination by radioactive dust and radon in connection with mining activities.**

Picture N°24 / tank for rainwater storage in Gameleira

Underground water UW4 (Pega Bem)

The activity of radon 222 is below the detection limit (< 37 Bq/l) in sample UW4 (underground water) collected in Pega Bem. The storage of the water in a tank enables a certain lowering of radon 222 activity. As the half-life of radon 222 is 3.8 days, its activity is divided by 2 every 3.8 days.

The **uranium 238** concentration of **20.6 µg/l** monitored in sample UW4 is above the former guidance value set by the WHO for drinking-water (**15 µg/l)**, but remains below the value recommended in 2011 (**30 µg/l).**

The uranium 238 concentration of 20.6 µg/l corresponds to an alpha activity of 0.26 Bq/l (uranium 238). If we assume that uranium 238 and its by-product uranium 234 are in equilibrium in the samples, the gross alpha activity would be twice as high which is 0.52 Bq/l. This evaluation is coherent with the measured value of 0.55 Bq/l (gross alpha activity), taking into consideration measurement uncertainties. This suggests that the concentration of other alpha emitters in sample UW4 (like radium 226, polonium 210, thorium 232, etc…) is low. But additional monitoring would be necessary to get a more comprehensive view of the radiological and chemical characteristics of this water.

[3] A discussion about the dose due to ingestion of radon dissolved in water can be found at pages 29-31 of http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf

[4] *Guidelines for drinking water quality*, first addendum to third edition. Vol 1: Recommendations. WHO, 2006. This version of the guidelines integrates the third edition, which was published in 2004. The second addendum to third edition published in 2008 did not recommend a different value for uranium.

Rainwater RW1 (Pega Bem)

The owner of the property told us that he was no more using underground water for drinking.

The family is now using rain water.

The activity of dissolved radon 222 (< 11 Bq/l), gross alpha activity (< 0,02 Bq/l) and residual bêta activity (< 0,04 Bq/l) of the rainwater sample RW1 collected in the rainwater collection tank are below the detection limits.

These results suggest that the radioactivity of the rainwater collected in Pega Bem is low. Additional monitoring (chemicals) would be necessary to get a more comprehensive view of the quality of the rainwater as it may be more sensitive to atmospheric contamination. **The risk of contamination will depend of the activities performed at INB and the wind direction.**

2 / Summary of CRIIRAD main findings

Section 2 of the present document summarises CRIIRAD main findings.

Some of these preliminary conclusions have been presented by CRIIRAD during the public debate organised on April 11th 2014 in University of the State of Bahia, campus Caetité and were included in the preliminary report prepared by FIOCRUZ (Marcelo Firpo, Renan Finamore) and CRIIRAD (B. Chareyron). This report in Portuguese can be downloaded at http://www.criirad.org/mines-uranium/bresil/relatorio-prelim-fiocruz-CRIIRAD-caetite-11-4-2014.pdf

Some additional comments have been included in the version below, taking into consideration the analytical results presented in chapter 1.4 above.

2-1 / The environmental monitoring program of INB-URA suffers from important weaknesses

It is extremely difficult for the local community of Caetité to get access to the results of the radiation monitoring performed by INB around the mine. It took 6 month for CPT to get of copy of these results. The INB document (RT-URA-05-14) gives the results of **uranium** monitoring and **radon 222** monitoring in the **air** and monitoring of **uranium, radium 226** and **lead 210** in **underground water** samples.

This information suffers from many insufficiencies:

1 / No results are given for the monitoring of **ambient gamma radiation**, **dust deposition** on the soil, monitoring of the contamination of the soil and the **food chain**, monitoring of **surface waters** and **sediments**. The analysis of top soil TS15 collected by CRIIRAD in Mangabeira suggests that dust containing uranium 238 and thorium 232 and their decay products is deposited on the tree leaves, then washed down by the rain and accumulates on the soil. Dust deposition on the crops and edible food should be studied in detail in order to perform a proper evaluation of the contamination of the foodchain and the dose to the population.

2 / For the monitoring of **radon concentration in the open air**[5], it is impossible to analyse the impact of the mine due to the fact that the amount of monitoring posts located in the immediate environment of the mine is too limited (only **3 monitoring posts** are located at a distance **below 3 kilometres from the mine**, but all posts are located in **the north-western corner**). No monitoring post is located in the valley of Riacho da Vaca where the impact from the tailings and waste rocks dump may be significant (radon concentration is usually higher in depressions and valleys). In addition, INB does not monitor the equilibrium factor between radon and its decay-products whose radiotoxicity is higher than radon one, therefore it is not possible to make accurate evaluation of the doses received by the population living close to the mine.

3 / Regarding the monitoring of radiation in the **air**, CRIIRAD noticed on April 9th 2014 that the pumping system of the **air sampler** located in Tamandua (monitor LR010) **was not operating on a continuous mode**. This raises the question of the representativity of the results of air monitoring by INB.

4 / For the monitoring of radiation in **underground water samples**, only 3 radioactive substances are analysed by INB (**uranium, radium 226** and **lead 210),** while the uranium 238 and uranium 235 decay chains contains more than 20 radioactive substances. Thorium 232 and its decay products should be monitored as well. CRIIRAD recommends the monitoring of the following parameters : activity of dissolved radon (radon activity may be particularly high in underground waters and may deliver a dose to the consumer much higher[6] than uranium itself), activity of polonium 210 (this radioactive heavy metal associated with uranium 238 is among the most radiotoxic substance when ingested), gross alpha and gross beta activities (in order to check for the presence of other nuclides), main anions and cations like sulphates, nitrates that are usually indicators of the impact of mining activities, non radioactive metals that may be associated with the uranium ore, organic chemicals that are used in the chemical part of the uranium extraction process, etc..

[5] Radon is a radioactive gas permanently created by the disintegration of radium 226 contained in the uranium ore, the waste rocks from the mine and the tailings created by the leaching of the ore. Radon is carcinogenic to humans and is the second cause of lung cancer after tobacco.

[6] A discussion about the dose due to ingestion of radon dissolved in water can be found at pages 29-31 of http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf

2-2 /Examples of present impacts of INB

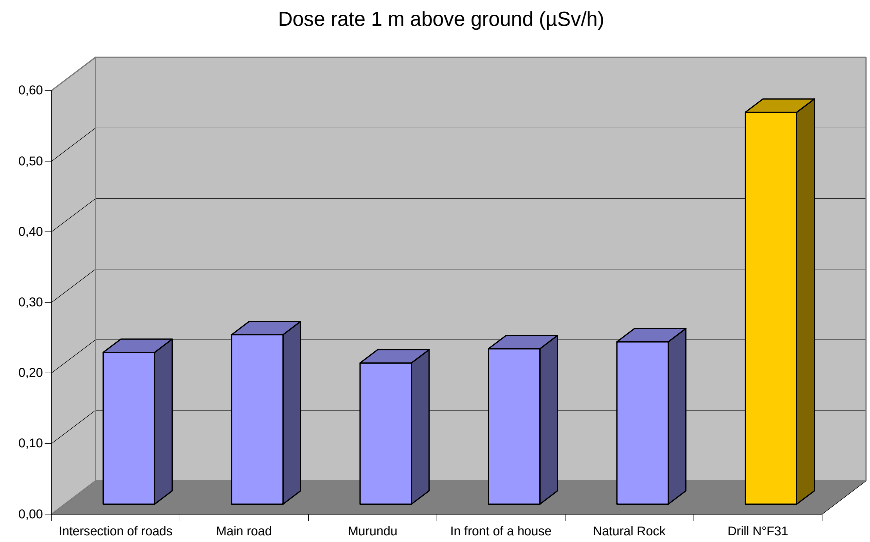
Without the results of a comprehensive monitoring programme, it is not possible to evaluate properly the actual impacts of INB-URA activities on the environment and local population.

Nevertheless, a first analysis of the data mentioned above, in addition with the results of the preliminary monitoring activities performed by CRIIRAD, FIOCRUZ and CPT-BA on June 9th 2012 show various impacts. Some examples are described below.

Prospection activities / contamination of the soil and increase of gamma doserate

During year 2013, INB commissioned intensive prospection activities especially in **Gameleira** (at about 2 km from the mine). Some of the drills have a depth of 70 meters and more. When the drill encounters the uranium deposits, radioactive material is brought to the surface. If this material is not removed, the radiation at the surface of the soil is much higher compared to the situation before the prospection activities. This is illustrated by CRIIRAD monitoring performed on April 9Th 2014 in a field in Gameleira. The gamma dose rate in the vicinity of drill N°F31 was 2.5 times above the natural background monitored by CRIIRAD at 5 different locations undisturbed by the drilling activities (see picture N°25 below).

Picture N°25 / Dose rate monitored by CRIIRAD 1 meter above ground in Gameleira



Spending 5 minutes per day near this drill during 365 days will induce a non negligible cumulative dose at the end of the year.

Other impacts of the drilling activities should be evaluated properly like the contamination of the air by radon created by the contaminated material deposited on the ground, the amount of radioactive particles inhaled by the population living there and ingested through the deposition on the leaves of the plants and the transfer to the cattle which is grazing in this field, the possible contamination of underground water due to the modification of the circulation of the water because of the numerous drills. It could be noted on one of the pictures of the drill (see page 4); that the plastic tubes are already broken in some cases. Therefore the rainwater can be transferred directly into the aquifer without natural filtration by the soil.

On April 10th 2014, CRIIRAD performed very preliminary monitoring activities in a new prospection area in **Juazeiro** (see page 9) and discovered that radioactive rocks with a dose rate more than ten times above the normal background where laying on the edge of a 4 metres wide and hundreds of metres long trench digged by the companies. A consequence of such prospection activities is that the soil that was initially covering these radioactive rocks has been removed, increasing therefore the local level of gamma radiation, the risk of contamination of surface and underground water and the risk of transfer of radionuclides to the atmosphere.

Comprehensive baseline studies describing the natural level of radiation before prospection should be made available in order to properly evaluate the impact of the prospection activities.

Impact of mining activities / radioactive dust in the air

Mining activities, especially blasting and crushing of the radioactive ore generates huge amounts of contaminated dust that his inhaled by the workers and the population leaving downwind of the mine.

According to INB, the **uranium content of the ore** in Caetité is about **0.3 %.** The radioactivity of the ore is therefore about **37 500 Bq/kg** (uranium 238 only), which means **more than 500 000 Bq/kg** when considering[7] all uranium decay products (like thorium 230, radium 226, radon 222, lead 210, polonium 210, etc..).

INB official data show that, during the period 2011-2012, the mean concentration of uranium in the air at Tamandua (at about 2 km downwind of the open pit) was 6 times above the value monitored at Juazeiro located upwind, about 7 km from the mine.

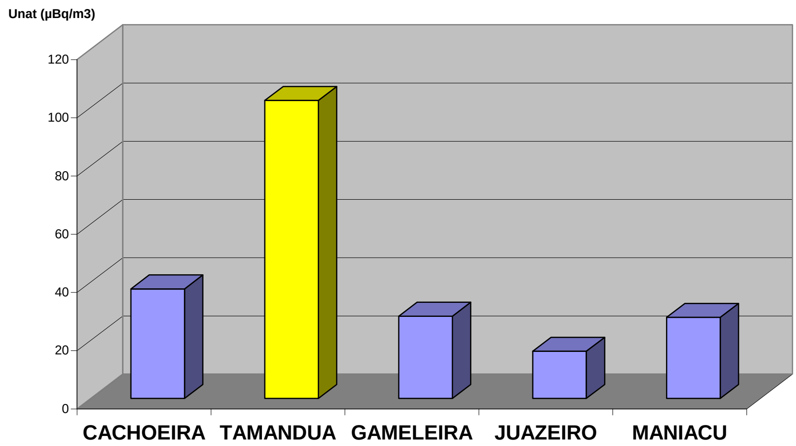
The inhalation of this contaminated air leads to non-negligible doses to the population[8].

In addition, the radioactive dust will contaminate the soil, the surface waters in the ponds, the leaves of the plants and lead therefore to additional doses by ingestion.

Taking into consideration the contamination detected by CRIIRAD in soil sample TS15 located under the influence of the waste rock and tailings dumps, a monitoring post should be installed in Mangabeira.

Picture N°26 / Mean uranium activity in the air (µBq/m^3)

according to INB official data (2011-2012)



Impact of the storage of radioactive waste / contamination through spills and airborne contamination

The mining activities generate huge amounts of radioactive waste rocks and solid waste called tailings. Taking into consideration the activity of the ore, one can show that the total activity of some of the tailings is above 300 000 Bq/kg. These radioactive materials are dumped by INB on the edge of the plateau above the valley of the Riacho da Vaca (see picture N°11 , page 6).

When it is raining, the rain carries the finest fraction of the contaminated material. That is why INB installed a system of drains at the bottom of the dump, in order to collect the contaminated water coming from the mine and the solid waste dump. This water is sent to a pond located downstream the dump, where it should evaporate before reaching the environment (see picture N°18, page 8).

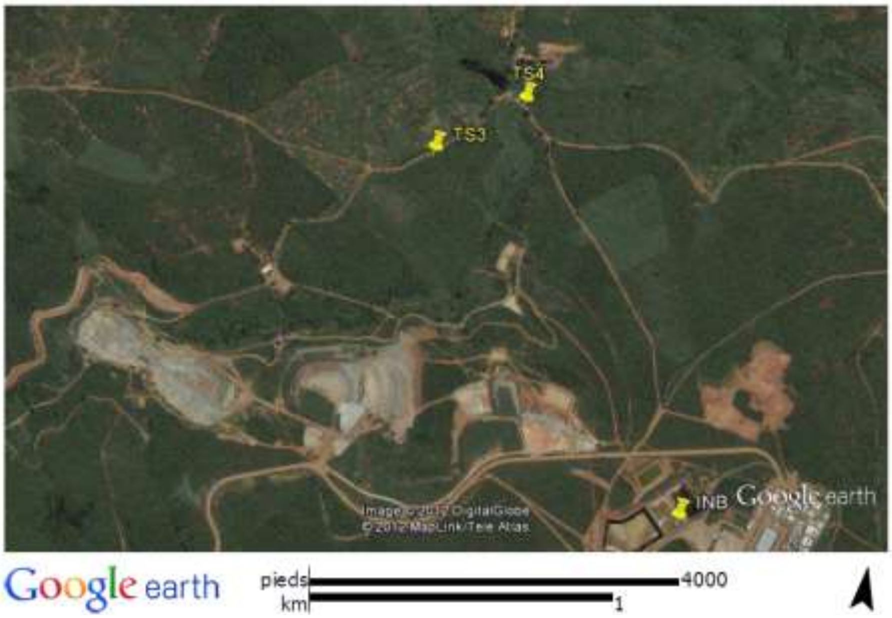
During the summer of 2004, due to high rainfall and an inaccurate conception of the water collection system, the contaminated water **overtopped 7 times the settling pond**.

[7] See pages 15 to 20 of http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf

[8] See page 33 of http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf

On June 9th 2012, CRIIRAD monitored a **high gamma radiation rate in the bottom of the valley** where the contaminated material had settled. The measurements performed one meter above ground changed from about 200 c/s on the upper borders of the valley, to 700 c/s in the centre of the depression. The analysis of this contaminated soil (sample TS4) at CRIIRAD[9] laboratory showed that it is contaminated with long lived radioactive heavy metals associated with the tailings (thorium 230 activity of 1 000 Bq/kg, radium 226 activity of 2 430 Bq/kg and lead 210 activity of 1 870 Bq/kg). This contamination of the soil will then, in the long term, increase the contamination of surface and underground water through natural leaching and also impact the quality of the air (re-suspension of contaminated dust, exhalation of radon gas) and the nearby cultures.

Picture N°27 / Location of sample TS4 in Mangabeira, at the bottom of a valley downstream the waste rock and tailings dump



Picture N°28 / Sampling of contaminated soil TS4 in Mangabeira (CRIIRAD, June 2012)

Gamma radiation rate is 3 to 6 times above normal values (the waste rocks and tailings dumps can be seen on the upper part of the picture)

[9] CRIIRAD laboratory is agreed for environmental radiation monitoring by the French ASN (Autorité de Sûreté Nucléaire).

CRIIRAD considers that this area should be decontaminated by INB and the design of the contaminated water collection system be improved in order to cope with situations of heavy rain. Again, it should be noted that the tailings are radioactive, contain very radiotoxic heavy metals with an extremely long half-live (75 000 years for thorium 230) and that the confinement of such a huge amount of radioactive material is a struggle.

In addition, in Mangabeira, the radioactive material **transported by the wind** is deposited on the leaves of the trees and then washed down by the rain. This phenomena explains the abnormal level of gamma radiation monitored by CRIIRAD on the thin layer of clay deposited near a tree on the road leading to the horticultural center in Mangabeira (see CRIIRAD results, page 10 and 11).

Appropriate measures should be taken to limit the transfer of radioactive substances (aerial dispersion and transfer by the rain) from the waste rock and tailings dumps.

INB should explain how it plans to guarantee the confinement of this type of waste on the long term.

2-3 / Bad working conditions

CRIIRAD could not visit the mine, but during training activities organised for the workers, CRIIRAD could collect some information that raise questions and suggest that the protection of the health of the workers is not a priority for INB. In effect, workers have reported to CRIIRAD and FIOCRUZ the following facts:

1 / There is no filtration system at the **stack of area 170** where the uranium is concentrated and conditioned in drums. The uranium concentrate is called "yellow cake" due to its yellow colour. Assuming a purity of 80 % of the concentrate, one can calculate that the uranium concentration is above 10 million Becquerels per kilogram in this material. Workers say that many times each year, when the temperature increases too much in the chemical process, uranium concentrate is transferred directly into the air. In such cases, the surroundings of the stack are covered with yellow dust showing that the radioactive material is discharged to the atmosphere. There is therefore a significant risk of contamination of the workers by ingestion and inhalation of this highly radiotoxic dust.

2 / The **drums containing the yellow cake** are stored a few meters only from the cabin where the guard is staying. In France, at AREVA-COMURHEX uranium conversion plant, CRIIRAD could monitor an excess of gamma radiation at a distance of more than 200 meters from the fence of the facility where drums of uranium concentrate are stored. In the case of Caetite, the guard is very probably exposed to non negligible gamma radiation doses while an appropriate implantation of his cabin would enable a lowering of his exposure to radiation.

Picture N°29 / Drums containing yellow cake stored close to the guard cabin at INB-URA (source : plant worker)

3 / The workers have no access to the **results of the monitoring of the doses** they receive, neither the results of exposure to gamma radiation (individual dosimeters or badges), neither the results of internal contamination (analysis of urine and faeces). Individual results should be given to the workers by INB radioprotection staff. A compilation of the data should be published by INB every year (global results without reference to individual names of the workers). This will enable to check if there are improvements in the reduction of the doses through the implementation of best practice. It should be noted that, according to UNSCEAR, uranium mining and milling activities are the step of the whole nuclear electricity production process where the workers and population receive the highest doses[10] of radiation.

4 / At INB-URA, the **contaminated equipment** is stored in the open air (pumps, drums, valves, etc.). Some of this equipment is decontaminated and recycled. In this case, it is given by INB to local communities, but the workers emit doubts on the quality of the decontamination and the accuracy of the radiation monitoring of the material before it leaves the facility. CRIIRAD has been told that the training of some of the radioprotection operators consists simply of a 30 minutes meeting with their supervisor. In the case of AREVA uranium mines in Niger, CRIIRAD and the local NGO AGHIRIN'MAN discovered[11] that very contaminated pieces of equipment (pipes, tissues, etc.) were sold on the market. In Caetité, INB should provide guarantees about the methodology applied to check the residual contamination of the recycled material and mention the standards applied (residual contamination limits in Bq/cm^2 and residual dose rate on contact of the equipment in µSv/h). If a residual contamination is left, this should be justified ; the radiological impact be evaluated and the people informed.

Pictures N°30 and 31 / Provisory storage of contaminated equipment at INB-URA (Caetité)

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[10] See http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf , page 84 to 85.
[11]See http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf , page 58 to 61.

3 / Summary of recommendations

Uranium extraction implies a long term contamination of the environment[12] (water, soil, fauna and flora). Detailed studies are necessary to properly evaluate these impacts.

- A better transparency is needed :
  - INB-URA did not give the results of monitoring of gamma radiation , the deposition of radioactive dust, soil contamination, contamination of rainwater and the food chain. These results should be given to the communities.
  - Workers of uranium mines and mills are among the most exposed to radiation in the whole nuclear process, in the case of Caetite, the workers say they have no access to the results of their monitoring. This information should be given to them.
- The monitoring methodologies at INB-URA should be improved :
  - More radon samplers in the immediate vicinity of the mine including the monitoring of the equilibrium factor between radon and its by products, and the monitoring of thoron.
  - Monitoring of radon, polonium 210, other chemicals in the underground water,
  - Clarification about the operation of the air samplers (are they working on a continuous base ?)
- Uranium mining at INB creates huge amounts of radioactive and radiotoxic waste, with a very long half-life and no appropriate confinement:
  - The system for the collection of contaminated water downstream the tailings dump should be improved.
  - The contaminated area downstream the settling pond in the Riacho da Vaca valley should be decontaminated.
  - The waste dumps should be covered in order to limit the transfer of radioactive particles by the wind.
  - The stability of the dump should be reviewed by independent experts.
  - The plan proposed by INB in order to monitor the stability of the dumps and their impact on the very long term should be made public.
- Protection of the workers : the information given to us by the workers indicate bad radioprotection practices at INB in violation of the ALARA principle (no filtration of the effluents at the chimney of Area 170, location of the guard cabin too close to the radioactive drums, etc..). This situation must be improved.
- Citizens have to be given tools and training in order to participate more efficiently to the preservation of the environment and their health, through the implementation of their own assessments and radiological checks. Independent assessments have to be promoted.

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[12]See http://www.ejolt.org/wordpress/wp-content/uploads/2014/11/141115_U-mining.pdf

Table A1 / Analysis of water samples collected by CRIIRAD on April 9th-10Th 2014 (radionuclides)

Sample Code (on site)	**UW3**	**UW4**	**RW1**
Lab Code	**150414A1**	**150414A2**	**150414A3**
Amount collected (cm3)	250 cc	500 cc	250 cc
Sampler	CRIIRAD (B. chareyron)	CRIIRAD (B. chareyron)	CRIIRAD (B. chareyron)
Location	Borehole N°171 in Gameleira downstream uranium prospection area	Tank in PEGA BEM, downstream INB-URA dam	Tank in PEGA BEM, downstream INB-URA dam
Water type	Underground water (depth 64 m) / no more used for drinking	Underground water (no more used for drinking)	Rainwater used for drinking
GPS coordinates	S13º50.664'	S13º49.959'	S13º49.959'
GPS coordinates	W042º19.129'	W042º15.201'	W042º15.201'
Sampling day	09/04/2014	10/04/2014	10/04/2014

pH and conductivity (laboratory measurements)

pH	7,30	7,80	Not monitored
Water T°C when pH was measured	16,3	16,8	Not monitored
Conductivity at 25 °C (µS/cm)	979	954	Not monitored
Conductivity at 20 °C (µS/cm)	883	861	Not monitored
T.A.C (degré français)	21	30	Not monitored
T.A. (degré français)	< 2	< 2	Not monitored

Uranium

Uranium 238 (µg/l)	11,5	20,6	Not monitored
Calc. U238 activity (Bq/l)	0,14	0,26	Not monitored
Uranium 235 (% uranium 238)	0,72	0,70	Not monitored

Radon 222

Radon 222 (Bq/l)	**107 ± 41**	< 37	< 11

Global radiological parameters

Gross alpha activity (Bq/l)	Not monitored	**0,55 ± 0,25**	< 0,02
Gross bêta activity (Bq/l)	Not monitored	0,63 ± 0,08	0,06 ± 0,02
Potassium (mg/l)	Not monitored	14,55 ± 0,61	1,48 ± 0,06
Potassium 40 (Bq/l), calculated	Not monitored	0,401 ± 0,017	0,041 ± 0,002
Residual Gross bêta activity (Bq/l)	Not monitored	0,23 ± 0,03	< 0,04

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Table A2 / Analysis of water samples collected by CRIIRAD on April 9^{th}-10^{Th} 2014 (chemicals)

Sample Code (on site)	UW3	UW4	RW1
Lab Code	150414A1	150414A2	150414A3
Amount collected (cm3)	250 cc	500 cc	250 cc
Sampler	CRIIRAD (B. chareyron)	CRIIRAD (B. chareyron)	CRIIRAD (B. chareyron)
Location	Borehole N°171 in Gameleira downstream uranium prospection area	Tank in PEGA BEM, downstream INB-URA dam	Tank in PEGA BEM, downstream INB-URA dam
Water type	Underground water (depth 64 m) / no more used for drinking	Underground water (no more used for drinking)	Rainwater used for drinking
GPS coordinates	S13°50.664'	S13°49.959'	S13°49.959'
GPS coordinates	W042°19.129'	W042°15.201'	W042°15.201'
Sampling day	09/04/2014	10/04/2014	10/04/2014

Anions and cations (semi-quantitative screening by ion chromatography)

	UW3	UW4	RW1	WHO guideline for drinking water
Bicarbonates (Hydrogénocarbonates) mg/l	256,2	367,2	Not monitored	
Calcium mg/l	18	70	Not monitored	
Chloride (chlorures) mg/l	65	87	Not monitored	250 mg/l
Magnesium mg/l	5,7	11	Not monitored	
Nitrates mg/l	**180**	< 1	Not monitored	50 mg/l
Potassium mg/l	2,1	15	Not monitored	
Sodium mg/l	**200**	120	Not monitored	200 mg/l
Sulfates mg/l	44	68	Not monitored	250 mg/l

Metals / semi-quantitative evaluation by ICP * / results in µg/l

	UW3	UW4	RW1	WHO guideline for drinking water
Ag	0,00	0,00	Not monitored	-
Al	77,3	6,80	Not monitored	200 µg/l
As	0,00	0,00	Not monitored	10 µg/l
B	86,80	90,9	Not monitored	300 µg/l
Ba	97,90	124,0	Not monitored	700 µg/l
Be	0,30	0,00	Not monitored	
Cd	0,00	0,00	Not monitored	3 µg/l
Co	0,90	0,00	Not monitored	
Cr	1,00	0,00	Not monitored	50 µg/l
Cu	7,70	1,80	Not monitored	2 000 µg/l
Fe	88,40	3,90	Not monitored	300 µg/l
Li	20,50	62,4	Not monitored	
Mn	17,20	3,00	Not monitored	500 µg/l
Mo	0,24	10,3	Not monitored	70 µg/l
Ni	1,80	3,60	Not monitored	20 µg/l
Pb	5,40	0,00	Not monitored	10 µg/l
Sb	0,00	0,00	Not monitored	5 µg/l
Se	0,40	0,00	Not monitored	10 µg/l
Sn	0,00	0,00	Not monitored	-
Sr	65,10	343,7	Not monitored	
Te	0,00	0,00	Not monitored	
Ti	12,70	6,70	Not monitored	
Tl	0,00	0,00	Not monitored	
U	11,50	20,6	Not monitored	15 then 30 µg/l
V	20,3	0,5	Not monitored	
Zn	6,90	106,7	Not monitored	3 000 µg/l