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CRIIRAD Report no. 10-09

Remarks on the radiological situation in the vicinity of the uranium mines operated by SOMAIR and COMINAK (subsidiaries of AREVA) in northern Niger

Study conducted on behalf of Greenpeace International

1 / Context

The companies SOMAIR and COMINAK, subsidiaries of the AREVA group, are mining uranium deposits in northern Niger near the towns of Arlit and Akokan.

In the course of a mission carried out in **November 2009**, a **Greenpeace** International team took radiation measurements in situ, collected samples, and amassed a number of documents provided by the companies.

The aim of this mission was to evaluate how the radiological situation has developed in the vicinity of the industrial sites operated by SOMAIR and COMINAK.

The CRIIRAD laboratory, which carried out earlier missions and studies at Arlit between 2003 and 2009 (see list at Annex 1) helped to accomplish this mission by drawing up a list of documents to be requested from AREVA (see Annex 2) and devising a sampling and analysis strategy.

The sampling procedures and radioprotection instructions were discussed during a preliminary meeting at the CRIIRAD laboratory on **7 October 2009**, between Dr Rianne Teule (chemist, Greenpeace International) and Dr. Bruno Chareyron (nuclear physics engineer in charge of the CRIIRAD laboratory).

The analysis at the CRIIRAD laboratory of the samples brought back by Greenpeace in November 2009 is discussed in CRIIRAD reports nos. 10-05 (soil analysis) and 10-07 (analysis of radon in the air).

The results of the radiological and chemical analysis of five water samples taken by Greenpeace in the Arlit-Akokan district and, as a control, one sample taken in the Imouraren district are reproduced in Annex 4 and discussed in the present report.

The present report represents a summary of the CRIIRAD laboratory's preliminary observations and recommendations on the basis of the analysis conducted and of a preliminary examination of the documents listed in Annex 3.

Three subjects are addressed: the presence of **radioactive material** in the environment; air contamination by a **radioactive gas, radon 222**; and contamination of **groundwater** which supplies the local population.

A more in-depth analysis of the available documentation may be carried out as a second stage. The question of air contamination by radioactive dust, and the problem of transfer into the food chain, are not dealt with in the present document.

It is important to emphasis at the outset that this work suffers from two significant limitations:

1. AREVA was not in a position to provide the documents requested by Greenpeace in August 2009 prior to the field mission. Moreover, the documents finally supplied by AREVA during the mission, in November 2009, do not cover the whole of the data requested, in particular concerning emissions of radon and the diffusion of this gas into the environment,

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the reason for the closure of a number of wells, mapping of gamma radiation levels at Arlit and Akokan, etc.

2. As a result of constraints on the fieldwork, relating in particular to security and to the very limited timeframe for the mission, the Greenpeace team was not able to carry out the planned study of the impact of radon emissions from the air vents, nor the programme of soil and vegetation sampling near to the most significant sources. The mission ultimately had to focus its radiation measurements and taking of samples (soil, air, water) around the urban zones.

2 / Radioactive materials in the environment

Presence of radioactive materials near boreholes and large shafts

In the course of drilling for the purpose of prospecting or creating links between the mine and the surface, the rock drills tend to bring radioactive material to the surface when they cross uranium-bearing zones.

In the course of a mission carried out between March and May **2007** by two students from the Institute of Alpine Geography in Grenoble with technical support from **CRIIRAD** [C3], it was observed that piles of dried mud near to some boreholes in the Imouraren district (a uranium deposit which AREVA is about to bring into production soon) exhibited a radioactivity level **five to nine times** above normal [C6].

In the course of the **November 2009** mission, **Greenpeace** took radiation measurements near to one of COMINAK's mine air vents (number GT 238, see photo below). An area showing a radiation level **seven times above** normal was identified (contact dose rate equal to 1.44 µSv/h or seven times greater than normal).

Air vent no. GT 238 / Photo Greenpeace, November 2009

Analysis at CRIIRAD's laboratory of material which Greenpeace collected at this hot spot showed that this radioactivity is explained by high activity levels of **uranium 238 and its decay products** (thorium 234, radium 226 and lead 210), with values of **6,000-7,000 Bq/kg**, or levels more than **100 times** greater than those recorded from natural soils in the district [CRIIRAD report no. 10-05]. In view of the margins of uncertainty, it can be assumed that uranium is in equilibrium with its decay products.

According to the directive Euratom 96/29, handling of these materials would require measures to be put in place to protect the local population from radiation, since their uranium 238 activity is well above the exemption threshold of **1,000 Bq/kg**.

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It was also noted that the uranium concentration is even higher in the fine fraction (ie under 63 microns), which was measured at over 20,000 Bq/kg for each uranium 238 decay product (**radium 226 = 26,500 Bq/kg**). This raises the question of the impact due to inhalation and ingestion when the radioactive dust is disturbed and put back into the air.

In view of the location of this radioactive matter, it can be assumed to consist of uranium-bearing minerals brought up from the subsoil in the course of the excavation to establish air vent GT 238.

Conclusion and recommendations

These observations demonstrate that, in the course of their activities, the mining companies leave behind solid radioactive matter (mud and earth) in the environment, within reach of the local population. This results in needless exposure of the population to radiation, both by external irradiation and by internal contamination.

Other inspections carried out by CRIIRAD [C1, C2, C3], the NGO AGHIR in MAN [C5] and Greenpeace [S3] have furthermore shown that contaminated scrap metal and geotextiles are being sold in the markets at Arlit, and that radioactive spoil has been used as hard-core for some roads, in particular at Akokan.

Even when this situation has been demonstrated and publicised by independent inspections, the companies have allowed the contamination to continue.

Indeed, following CRIIRAD's discoveries in May 2007 [C3], neither the mining companies nor the staff of Niger's Ministry of Mines and Energy have proved capable of detecting and properly treating all the radioactive contamination sites in the streets of Akokan. This is attested by the fact that in November 2009 Greenpeace found new evidence of seven zones of abnormal radioactivity in the streets of Akokan [S3].

It is time that the companies responsible for this contamination took responsibility for:

- Carrying out a systematic programme of radiation detection to enable contaminated scrap metal, plastic and geotextiles to be pinpointed in both Arlit and Akokan. The inspection methodology must be appropriate (contact measurements of the objects to be inspected, sensitive equipment).
- Buying back the contaminated materials and removing them without delay so as to limit the unwarranted exposure to radiation of the affected populations.
- Carrying out systematic mapping of the ambient radiation level near the mining zones and the urban zones, in order to identify the districts with abnormally high radioactivity resulting from the reuse of mine spoil or the dumping of radioactive materials.
- Decontaminating these districts.
- Preparing a suitable storage site for this very low-level and low-level radioactive waste of long physical half-life (the half-life of uranium is 4.5 billion years).
- Identifying and correcting the organisational failures which permitted such practices, and taking disciplinary action against those responsible for the release of these contaminated materials into the public domain.
- Clarifying in writing the inspection methodologies and the contamination thresholds used for declassifying material
- Carrying out and publishing dosimetric assessments to enable the doses sustained by workers and populations exposed to these materials to be reconstructed (external and internal exposure, including the issues of radon 222 and dust containing uranium, radium, thorium 230, lead 210, polonium 210 etc). The present dosimetric evaluations published by SOMAIR [G1] and COMINAK [G2] do not include these exposures in their dose calculations.

Following the publication of the measurements undertaken by Greenpeace in November 2009 [S3], AREVA undertook to implement an action plan around the issue of spoil and scrap metal at Arlit and Akokan [S4]. Civil society in Arlit and international NGOs should monitor closely the implementation of this plan.

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3 / Air contamination by radon 222

General observations

Radon 222 is a radioactive gas produced by the disintegration of radium 226 associated with uranium 238. Uranium extraction results in an increased concentration of radon in the atmosphere.

There are a number of reasons for this: the exposure to the air of rocks with a high concentration of uranium and radium 226 (in both opencast and underground mines); the storage in the open of heaps of ore at the pitheads and near the uranium extraction plants; excavation and drilling; the pumping of groundwater; the storage in the open of mine spoil from underground and opencast mines; the storage in the open of tailings (waste from uranium extraction); the ventilation of the underground galleries etc.

Even though the physical half-life of radon is relatively short (3.8 days), this radioactive gas can cover dozens or even hundreds of kilometres before it disintegrates totally. It takes 38 days for its radioactivity to fall to a thousandth of its original level.

Radon is an emitter of **alpha** particles, and its disintegration is accompanied by the creation of short half-life heavy metals (polonium 214 and polonium 218) which emit alpha particles in turn. Inhalation of this radioactive gas and its decay products thus leads to irradiation of the respiratory passages.

Radon is classed as **carcinogenic** to man and is reckoned to be the second commonest cause of fatal lung cancer after tobacco. The increased incidence of lung cancer among uranium miners has been known for decades. Recent epidemiological studies have moreover confirmed that inhalation of radon increases the risk of lung cancer even in very low doses and even in the context of exposure at home.

Some researchers think that other conditions may be caused by exposure to radon, in particular leukaemia. After inhalation, a proportion of the radioactive isotopes enter the bloodstream and may reach other organs besides the lungs.

Moreover, the disintegration of radon leads to the formation of heavy metals two of which have a relatively long half-life: **polonium 210** (an alpha emitter with a half-life of 138.5 days) and **lead 210** (a beta and gamma emitter with a half-life of **22.3 years**).

In the vicinity of the uranium extraction zones, significant quantities of radon are emitted into the atmosphere and can lead to an abnormal accumulation of lead 210 and polonium 210 on soil and vegetation surfaces. This accumulation can lead in turn to internal contamination of the local population through ingestion of contaminated foodstuffs. Indeed, polonium 210 and lead 210 are among the most radiotoxic radionuclides by ingestion.

Knowledge of the radon concentrations around mining zones, both in the outdoor air and within buildings, is thus fundamental to assessing the health risks posed to local populations. However, measurements are difficult to conduct on account of the high variation in concentrations over time, in terms of both hourly (daily cycle) and annual (seasonal variation) timescales.

Radioactive gas emissions by COMINAK's air vents

Among the various industrial sources of radon, particular attention should be given to the impact of the air vents of underground mines, which can emit large amounts of radon into the atmosphere. These vents are located over large shafts and bear the code GT followed by a number.

In the course of its investigations in **2004**, CRIIRAD had received the following information from AREVA: *"The concentrations of radon emitted from the air vents (ventilation is mandatory under article 32 of the regulation of 8/01/2001, which also defines maximum radon concentrations acceptable in the workplace) are very variable, depending on :*

- *the nature of the zone being mined*
- *the ventilation of the zone (airflow after it has been mined)*

- *weather conditions.*

*The concentrations measured range from **3,600 to 18,000 Bq/m^3** with an average of **10,000 Bq/m^3** at the level of the outlet itself. The impact of this ventilation is reflected in the measurement of added doses and has no effect on the population."*

COMINAK air vent (source: Greenpeace 2009)

In August 2009, CRIIRAD recommended that Greenpeace obtain from AREVA, in preparation for the field mission, a plan of the air vents and the levels of radioactive gas emitted to the atmosphere by each one. Greenpeace made this request to AREVA in August 2009 (Annex 2).

AREVA did not provide Greenpeace with specific documentation on the effective emissions of the various air vents. The documents sent to Greenpeace by AREVA in November 2009 give no details on this point.

COMINAK's November 2009 PowerPoint presentation [G4] says that the ventilation network consists of 29 large air inlet shafts and **37 large air outlet shafts** and that the suction is significant, with a ventilation flow of 2,100 m^3/s; but it gives no location map for these air vents, nor any information on radioactive gas emissions.

Questions remain over the exact number of air vents, and the ventilation flows, in that the values reported in the June 2009 inspection report of the Niger Centre National de Radioprotection (CNRP, National Radioprotection Centre) [G5] are not comparable with those given by COMINAK. According to this report, the ventilation system of COMINAK's underground mine *"has 36 ventilators for primary ventilation and another 36 for secondary ventilation. This equipment provides an airflow of 1,500 m^3/h on entry and 1,400 m^3/h on exit".*

Exceeding of the dose limits for the local population

It was planned that the Greenpeace team would install radon detectors mostly near to the main sources of radon (the air vents of COMINAK's mine tunnels, SOMAIR's and COMINAK's storage of radon-bearing waste rock and tailings, etc) and at a range of distances from these sources, so as to study the transfer of radon into the environment and evaluate the danger to the population. It was not possible to carry out this work, due to security constraints. The radon measurements were ultimately taken mainly within the urban zone, in other words several kilometres from the sources.

The measurements conducted by the CRIIRAD laboratory on the detectors exposed by Greenpeace between 6 and 8 November 2009 confirm a high concentration of radon in the vicinity of the **Akokan gendarmerie (131 Bq/m^3)**. This result is actually three to seven times as high as those recorded over the same period in four other districts of Arlit and Akokan (between 19 Bq/m^3 and 41 Bq/m^3) [see CRIIRAD report no. 10-07].

Assuming that radon 222 is in equilibrium with its decay products, this corresponds to a potential alpha energy (PAE) of 728 nJ/m^3.

In outdoor air, the equilibrium factor between radon and its short-lived decay products is generally below 1. Assuming a mean factor of 0.4, this would correspond for example to a PAE[1] of 291 nJ/m^3. This estimate is consistent with the data provided by AREVA.

It is in fact stated in COMINAK's report Surveillance Radiologique de l'environnement 2008 (see extract E1 below) that, in 2008, the PAE of radon 222 at the Akokan gendarmerie averaged 216 nJ/m^3, or 2.4 times the level recorded at the Arlit customs house at the same time (88 nJ/m^3).

Extract E1 (page 5) from the COMINAK 2008 radioprotection report

Le tableau ci-dessous présente l'évolution des moyennes annuelles en EAP Rn222 depuis 2001.

Stations de surveillance	Niveau moyen annuel en nJ.m^{-3}								
	Zone Urbaine Akokan NCC	Zone Urbaine Gendarmerie	Zone Urbaine COFITEC	Z.I. Poste de Garde	Z.I. extérieur	Aguelal	AFASTO	COMI 16	Niveau Naturel Douanes Arlit
	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222	EAP Rn222
2008	92	216	178	203	328			163	88
2007	88	187	135	279	173		185	131	91
2006	119	159	163	411	153	92	185	103	84
2005	128	199	138	606	220	81	190	201	102
2004	91	155			274	110			103
2003	96	184			257	136			98
2002	140	154			322	135			51
2001	134	192			340				

This concentration of radon could be linked to mining activity, and in particular to the radioactive atmospheric emissions from the COMINAK mine, some of whose air vents are only two kilometres away.

In order to clarify this point, in August 2009 a copy of the studies of atmospheric transfer and dispersal of radon in the Arlit and Akokan area was requested from AREVA (see Annex 2). **These documents have not yet been received.**

This is a crucial issue, however, since on the basis of AREVA's own measurements it can be seen that some population groups in the mining zone have for years been subject to a radiation exposure markedly above the maximum permitted annual dose of one millisievert a year, chiefly as a result of inhaling radon 222 in the outdoor air.

This is the case for the population group designated **"Akokan gendarmerie"**, for whom the **2008 COMINAK** report [G2] estimates an annual added dose of **1.36 millisieverts**, 90% of which is due to radon 222 (see extract E2 below).

[1] Potential alpha energy (PAE) is the sum of the energies of the alpha particles emitted by radon 222 and its short-lived alpha-emitting decay products. It is measured in nanojoules (nJ). The PAE of 1 Bq of radon 222 in equilibrium with its decay products is 5.56 nJ/m^3.

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Extract E2 from the COMINAK 2008 radioprotection report / result of monitoring of effective annual added doses (Annex 5).

Tableau N° COMI-7

SURVEILLANCE RADIOLOGIQUE DE L'ENVIRONNEMENT PROCHE DES SITES MINIERS

Réseau de : COMINAK - AKOKAN

ANNEE : 2008

DOSE EFFICACE ANNUELLE AJOUTEE en mSV par an pour un ENFANT de 2 à 7 ans

GROUPE DE REFERENCE :	
AKOKAN Gendarmerie =	1.35

AREVA's estimate of the added dose linked to radon may moreover be an underestimate, in that the added dose is calculated by taking the activity measured in a particular place and subtracting from it the activity recorded at the Arlit customs house (mean of 88 nJ/m^3 measured in 2008). AREVA in effect considers the values recorded at the Arlit customs house as representative of the background level. In reality, this station is only a few kilometres from the mining zones and may already be affected by industrial activities. If AREVA uses this station as a baseline, it ought first to demonstrate that it is not affected by uranium extraction activities.

Miscommunication by AREVA

AREVA has made some astonishingly inaccurate statements: its internal reports clearly establish that the radiological impact of uranium extraction results in the population receiving an exposure above health limits (one millisievert added per year), while its press packs claim the opposite (see extract E3 from the January **2009** press pack "AREVA in Niger", below).

Extract E3 from the press pack "AREVA in Niger", January 2009

Protection radiologique des populations riveraines

L'arrêté du 8 janvier 2001 reprend la réglementation européenne et fixe pour le public une limite à 5 mSv de dose ajoutée reçue en 5 ans (soit 1mSv par an).

Cette limite est respectée autour des mines et dans les villes voisines d'Arlit et d'Akokan. L'exposition des populations riveraines est en moyenne inférieure à 0,5 mSv par an, soit l'équivalent d'une radiographie des poumons. Les valeurs sont comprises entre 0,3 et 1 mSv ajouté à l'environnement naturel.

Page 8 *Janvier 2009*
AREVA au Niger

Translation :

Radiological protection of neighbouring populations

The regulation of 8 January 2001 is based on European regulations, and sets a limit for the public of an added dose of 5 mSv received over five years (or 1 mSv per year).

This limit is adhered to around the mines and in the neighbouring towns or Arlit and Akokan. The exposure of the neighbouring populations is on average below 0.5 mSv a year, equivalent to a lung x-ray. The values range between 0.3 and 1 mSv added to the natural environment.

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However, the exceeding of the maximum permitted annual dose of one millisievert was already clearly indicated in report which AREVA commissioned from the IRSN (France's Institute of Radioprotection and Nuclear Safety) in **2004**.

As the chart below (E4) shows, the IRSN concluded that in the case of the population group "Akokan 2", corresponding to the gendarmerie monitoring station, the estimated added dose exceeded one millisievert per year, even on the basis of non conservative assumptions.

It should be emphasised that, as far as radon is concerned, these estimates were produced by the IRSN entirely on the basis of measurements provided by AREVA. Moreover, this assessment grossly underestimated the true level of added exposure.

In its calculations, the IRSN did not take into account external and internal irradiation caused by the radioactive fill material dispersed in the streets of Akokan, nor that linked to the dispersal of contaminated scrap metal, nor the internal exposure resulting from inhalation of radioactive dust. According to the IRSN, this last omission was due to the fact that AREVA had been unable to provide measurements of the radioactivity of the dust (see extract E5 below).

The fact that the maximum permitted annual dose of one millisievert was exceeded was thus highly significant.

Extract E4 from the report commissioned from the IRSN by AREVA in 2004

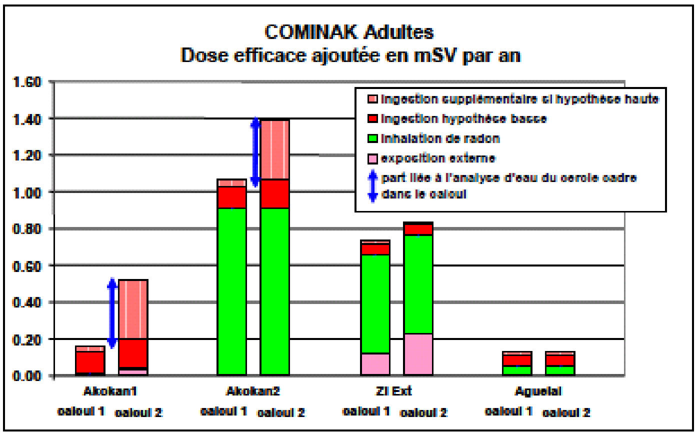

figure 21 : part des diverses voies d'exposition dans le calcul de la dose efficace ajoutée pour les adultes -COMINAK

Figure 21: Proportion of the various means of exposure in the calculation of the effective added dose for adults – COMINAK

IRSN Rapport DEI/SARG/05-05 44/71

Extract E5 from the report commissioned from the IRSN by AREVA in 2004

Rappelons que, pour les calculs autour du site COMINAK, la voie d'exposition liée à l'inhalation de poussières n'a pas pu être prise en compte étant donné l'absence de résultats de mesure.

Translation : It should be borne in mind that, for the calculations relating to the vicinity of the COMINAK site, exposure via dust inhalation has not been taken into account due to the lack of measurement data.

IRSN Rapport DEI/SARG/05-05 44/71

Conclusion and recommendations

The absence of effective remedial action on the part of AREVA and the responsible authorities in order to reduce the population's exposure to radon 222 must be emphasised. It has in fact been clear since at least 2004 that health limits are being exceeded.

It is essential that AREVA make public documents that would enable the different sources associated with radon to be evaluated, with precise descriptions of the locations of these sites (air vents, ore yards and radioactive waste) and an assessment of the quantities of radon produced and the dispersal of the gas into the environment.

The impact of radon emissions into the atmosphere must also be studied through knowledge of the deposition onto the soil and vegetation of its long half-life decay products that are especially radiotoxic by ingestion, namely lead 210 and polonium 210.

The environmental impact assessment for the extension of the West Afasto site (COMINAK) states:

> *"Respiratory diseases hold first place at Arlit and Agadez, particularly because of the climate, which is characterised by persistent dust-bearing winds. … In terms of morbidity… respiratory infections hold first place at Arlit. … Health impacts: possible appearance or aggravation of ENT and eye diseases linked to the continual production of dust and noise by mining activities."*

The study states that the mortality rate associated with acute respiratory infections is given as 16.19% at Arlit, compared to 10.95% at Agadez and 8.54% nationally. In addition, the study states:

> *"The sand-bearing winds and the atmospheric emissions of the mine works could be aggravating factors in pulmonary terms in this locality."*

Significant efforts must be made to limit contamination of the ambient air:

- Filtration of air in the air vents before emission. The amounts of radioactive gas emitted into the atmosphere may be very sizeable (for example, in the case of AREVA's underground mines in Limousin, emissions from the Bellezane, Fanay and Margnac sites with 20 air vents operational in 1991, totalled 31.8 billion becquerels of radon 222 per hour).
- Containment of SOMAIR's and COMINAK's radioactive spoil dumps and ore heaps.
- Removal of the radium-bearing waste (spoil, contaminated scrap metal) present in the urban areas of Arlit and Akokan.
- Containment of the tailings storages. It should be reiterated that at present over 35 million tonnes of tailings from SOMAIR's and COMINAK's leaching plants are stored in the open a few kilometres from a conurbation of 85,000 inhabitants. The analysis conducted by the CRIIRAD laboratory in June 2009 on a sample of tailings revealed a radium 226 specific activity of 36,000 Bq/kg. According to COMINAK's data it may even reach 50,000 Bq/kg [C6]. Yet this waste is stored with no cover to reduce radon 222 emissions.

In the absence of effective preventative measures, the population of the mining zone will continue to be exposed to internal contamination giving rise to doses above the healthy limit.

4 / Groundwater contamination

The population of the Arlit and Akokan area is also exposed to ionising radiation by ingesting water contaminated with uranium and its decay products.

Water contamination by uranium (CRIIRAD measurements of 2003–05)

The fossil aquifer from which is pumped water intended both for the operation of the uranium extraction plants and for the drinking water supply lies within the uranium-bearing geological formations mined by SOMAIR.

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The mining operations involve the moving of millions of tonnes of more or less radioactive rock (10.6 million tonnes by SOMAIR in 2004) and make the radioactive metals in the ore more readily mobilised, so increasing the risk of this groundwater being contaminated by radioactive heavy metals as well as by chemical pollutants.

The measurements taken by CRIIRAD from **2003** until 2005 [C1, C6] on samples of water distributed by the mining companies at Arlit showed a total alpha activity index 10 to 100 times above the guidance value beyond which the WHO recommended further investigation.[2]

CRIIRAD has shown that the strong alpha activity was due to high concentrations of **uranium**. In February 2005 the uranium 238 and uranium 234 concentrations in the water of well ARLI-2002, utilised by SOMAIR, were 0.58 Bq/l and 1.4 Bq/l respectively (or a total uranium concentration 46 µg/l above the WHO guidance value of 15 µg/l). Due to the radioactivity level of the water, regular consumption would have produced an annual dose above the value of **0.1 mSv per year** recommended by the WHO[3].

Internal AREVA documents make clear that SOMAIR had known for several years about the uranium levels of water supplied for drinking (levels that can be shown to lead to doses above the WHO recommendations). CRIIRAD also has a copy of a letter of 12 February **2004** in which the laboratory responsible for radiological testing of the water told SOMAIR that the radiation criteria were not being met.

Nevertheless, the COGEMA/AREVA press release of 23 December 2003 mentioned the *"absence of (water) contamination"*; and the "AREVA in Niger" press pack of February 2005, which can be downloaded from the AREVA website, still stated (on page 10, in the paragraph on water) that *"Bacteriological (monthly), radiological (half-yearly) and chemical (yearly) analyses show the absence of contamination".*

The study which AREVA commissioned from the IRSN in 2004 also confirmed that some wells used for drinking water supply were contaminated with uranium.

Extract E6 below shows that the uranium concentration of numerous wells is above the guidance value of **15 µg/l** set by the WHO[4].It is actually over **ten times** as high at SOMAIR's well 214 (**156 µg/l**) and at COMINAK's well COMI 8 (**183 µg/l**).

Extract E6 from the report commissioned from the IRSN by AREVA in 2004

tableau 8 : résultats des analyses d'eau - SOMAIR - mission IRSN mai 2004

Nom de l'échantillon	Activité en radium dissous (Bq.l⁻¹)		Concentration en uranium total (µg.l⁻¹)	
	activité	incertitude	concentration	incertitude
Puits 214	0,06	0,01	156	15
Puits 248	0,03	0,02	41	4
Puits 2002	0,12*	0,01	66	6
Jardin d'Arlit	0,02	0,01	8,4	0,8
Zone urbaine	0,04*	0,01	**	**

* mesure à partir d'un échantillon prélevé après la mission

** absence de mesure

tableau 9 : résultats des analyses d'eau - COMINAK - mission IRSN mai 2004

Nom de l'échantillon	Activité en radium dissous (Bq.l⁻¹)		Concentration en uranium total (µg.l⁻¹)	
	activité	incertitude	concentration	incertitude
COMI8	0,01	0,004	183	19
Jardin Akokan	0,05	0,01	3,0	0,3
COMI12*	0,14	0,01	**	**
Cercle Cadres*	0,14	0,02	**	**

* mesure à partir d'un échantillon prélevé après la mission

** absence de mesure

IRSN Rapport DEI/SARG/05-05 25/71

[2] Total alpha activity indices of 1.0 Bq/l (urban area) to 11 Bq/l (industrial estate); WHO guidance value 0.1 Bq/l, given in *Guidelines for drinking water quality*, second edition. WHO, 1994, page 129

[3] *Guidelines for drinking water quality*, second edition. WHO, 1994, page 129

[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.

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Uranium contamination (AREVA measurements, 2006–08)

From the document [W1] sent to Greenpeace by AREVA in November 2009, we have reproduced in tables T1 and T2 below the results of the radiological inspections carried out by AREVA between 2006 and 2008 on water intended for consumption, at COMINAK and SOMAIR sites respectively (radium 226, total uranium, total alpha activity index).

It will be noted that the data supplied by **SOMAIR** does not include the **total alpha** activity index values.

Regarding the measurements for the facilities operated by **COMINAK**, it will be noted that the total alpha activity indices are invariably above 0.1 Bq/l, are regularly above 0.5 Bq/l and exceed 1 Bq/l at some facilities.

These values are thus in every case higher than the threshold of 0.1 Bq/l above which the WHO used to recommend further investigation, and frequently above the new threshold of 0.5 Bq/l.

T1 /Radiological measurements of COMINAK drinking water facilities, 2006–08: AREVA data

Station	Ra 226 (Bq/l)	Uranium (µg/l)	Alpha total (Bq/l)
COMI 12	< 0,02	3,1 à 5	0,22 à 0,34
COMI 15	< 0,02	10 à 12,8	0,5 à 0,74
COMI 16	< 0,02 à < 0,04	17 à 35	0,6 à 0,91
COMI 17	0,01 à < 0,03	3,4 à 6,4	0,28 à 0,39
COMI 20	< 0,02 à < 0,03	11 à 16	0,48 à 0,67
COMI 22	< 0,02	0,8 à 13	0,58 à 0,81
COMI 23	< 0,02 à < 0,03	3,4 à 5,5	0,25 à 0,41
COMI 24	0,02 à < 0,03	12 à 29	0,95 à 1,47
COMI 39	< 0,02 à 0,05	2,3 à 3,6	0,16 à 0,39
ARLI 2721	< 0,02 à 18	1,76 à 28	0,49 à 1,54
TARAT 001	< 0,02	3,2	0,31
Château Nord	< 0,02	9,9 à 21	0,2 à 1,07
Château Sud	0,01 à < 0,02	10 à 19,2	0,16 à 0,84
Château ZI	0,01 à < 0,02	11 à 16,3	0,19 à 0,94

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Over the period 2006–08, the results for the water supply points for which COMINAK was responsible show **uranium** contamination regularly above the guidance value of 15 µg/l in four of the eleven boreholes, and the value invariably exceeded in the three water towers (north, south and industrial estate). The highest figure was for well COMI 16 (35 µg/l).

In the case of SOMAIR's wells, the guidance value of 15 µg/l was exceeded by six out of seven wells, the two boosters for the urban zone (1 and 2) and the booster for the industrial estate. **The highest reading (69 µg/l) was taken at well 2002. For the three boosters, over the period 2006–08, the uranium concentration was permanently above 15 µg/l (17–28 µg/l).**

T2: Radiological measurements of SOMAIR drinking water facilities, 2006–08: AREVA data

Station	Ra 226 (Bq/l)	Uranium (µg/l)	Alpha total (Bq/l)
ARLI 2002	0,07 à 0,15	40 à 69	?
ARLI 2020	0,01 à 0,02	10 à 20	?
ARLI 2028	0,01	12 à 22	?
ARLI 2039	0,01 à 0,02	10	?
ARLI 248 ter	0,02	22 à 51	?
ARLI 252-2	0,02	30 à 55	?
ARLI 295-2	0,02	21 à 35	?
ARLI 837 ter	NM	NM	?
Surpression 1	0,01 à 0,02	20 à 28	?
Surpression 2	0,02 à 0,03	17 à 25	?
Surpression ZI	0,02 à 0,035	17 à 27,5	?

Anomalies in AREVA's measurements

It can be noted that the tables of results [W1] sent to Greenpeace by AREVA contain aberrant results.

For example, for borehole ARLI 2721, the radium 226 activity measured on 3 October 2006 and 6 December 2006 was 18 Bq/l and 12 Bq/l respectively (as against the usual figures of 0.02 Bq/l and < 0.02 Bq/l). This is an increase of a factor of between **600 and 900**. On the same dates, the uranium concentration was 1.76 µg/l and 1.77 µg/l compared to usual levels of 17 µg/l to 28 µg/l.

The anomalous nature of these results is confirmed by the total alpha activity indices, whose values (0.49 Bq/l and 0.5 Bq/l) are incompatible with the activities of radium 226. Since radium 226 is an alpha emitter, the total alpha activity should necessarily have been higher than that of radium 226 alone.

Other anomalies concern all the measurements from the water towers on 13 March and 2 July 2008. While the radium 226 (0.01 Bq/l to < 0.02 Bq/l) and uranium (12 µg/l to 36 µg/l) concentrations are comparable to those of the preceding months, the total alpha activity indices are astonishingly low for all three water towers on 2 July 2008 (0.2 Bq/l, 0.16 Bq/l and 0.19 Bq/l), and high on 13 March 2008 (1.3 Bq/l, 0.84 Bq/l and 0.94 Bq/l).

All these anomalies cast doubt on the reliability of the radiological inspection results published by AREVA and on the ability of the responsible authorities to ensure rigorous inspection of the self-monitoring carried out by the operators.

Results of the tests carried out in November 2009 (Greenpeace/CRIIRAD study)

The results of the radiological tests carried out by the CRIIRAD laboratory and partner laboratories on the six water samples collected by Greenpeace in November 2009 are shown in Table T3 below. The locations from which the samples were taken are given in Table A of Annex 4.

T3: Radiological tests on water samples collected by Greenpeace in November 2009

Sample no. (CRIIRAD)	Location	Radon 222 (Bq/l)	U 238 (µg/l)	Alpha total (Bq/l)	Ra 226 (Bq/l)	Pb 210 (Bq/l)	Po 210 (Bq/l)	Bêta total (Bq/l)	K (mg/l)
121109 B1	Tchit in Taghat (secteur IMOURAREN)	< 39	4,0	0,10 +/- 0,03	< 0,012	< 0,081	< 0,007	0,09 +/- 0,05	1,27 +/- 0,05
121109 B2	Well COMI24	< 28	25,0	0,87 +/- 0,17	Not measured	Not measured	Not measured	0,22 +/- 0,05	0,90 +/- 0,04
121109 B3	Well Akokan	30 +/- 12	33,1	0,54 +/- 0,10	< 0,014	< 0,076	0,005 +/- 0,003	0,20 +/- 0,08	1,73 +/- 0,07
121109 B4	Tap Arlit	< 23	23,2	1,25 +/- 0,24	Not measured	Not measured	Not measured	0,32 +/- 0,06	1,52 +/- 0,06
121109 B5	Tap Arlit North	22 +/- 11	63,8	3,32 +/- 0,49	0,031 +/- 0,015	< 0,071	< 0,008	0,73 +/- 0,17	1,81 +/- 0,08
121109 B6	House Akokan	< 6	10,1	0,30 +/- 0,07	Not measured	Not measured	Not measured	0,18 +/- 0,06	1,96 +/- 0,08

Total alpha activity

The water drunk by the population is still contaminated with uranium, as shown by the measurements conducted on the water samples taken by Greenpeace between **4 and 6 November 2009**.

The total alpha activity exceeds 0.1 Bq/l in all five samples taken at Arlit and Akokan and 0.5 Bq/l in four of the five samples. It reaches 3.32 Bq/l in the sample taken at Arlit North.

These results are thus in every case higher than the threshold of 0.1 Bq/l above which the WHO used to recommend further investigation, and in four out of five cases above the new threshold of 0.5 Bq/l.

Total beta activity

The total beta activity (excluding potassium 40) is also higher at Arlit and Akokan (0.12 to 0.68 Bq/l) than in the reference sample (< 0.08 Bq/l). However, it remains below the limit of 1 Bq/l recommended by the WHO.

Uranium

It is chiefly the presence of alpha-emitting uranium isotopes that explains the high total alpha activity index values.

It is especially notable that the uranium level is above the WHO guidance value (15 µg/l) for four out of five water samples taken at Arlit and Akokan with the help of the inhabitants. The figures range from **23.2 µg/l to 63.8 µg/l** – between one-and-a-half and four times the norm.

The highest level was recorded in a well connected to well no. 252.

In comparison, the uranium concentration at Tchit in Taghat in the district of Imouraren, which is beyond the influence of SOMAIR's and COMINAK's industrial activities, is a mere 4 µg/l.

Remarks on the U234/U238 ratio

It is worth analysing in more detail the results obtained from the tap "Arlit North". A total uranium concentration of 63.8 µg/l corresponds to a uranium 238 activity of the order of 0.8 Bq/l and, on the conventional assumption that the isotopes U238 and U234 are in equilibrium, this corresponds to a total alpha activity of 1.6 Bq/l.

The fact that measurement of the total alpha activity index gives 3.32 Bq/l (even though the activity levels of the other alpha emitters such as radium 226 and polonium 210 are below 0.1 Bq/l) suggests that the U234/U238 ratio is not equal to 1.

In the course of the measurements carried out in February 2005 in well 2002 operated by SOMAIR, CRIIRAD in fact obtained a U234/U238 ratio of 2.4. Applying this ratio to the November 2009 sample gives a total alpha activity of 2.7 Bq/l, compatible with the result of the measurement (3.32 ± 0.49 Bq/l).

This confirms that the calculation of the dose received by those who consume the water, if carried out on the basis of the total uranium measurement without taking account of the excess of uranium 234 by comparison to uranium 238, could result in underestimation by over 60%.

Radon 222 in solution

The measurements conducted by the CRIIRAD laboratory on the water samples collected by Greenpeace in November 2009 reveal that some of them contain dissolved radioactive gas, radon 222 (**20 Bq/l to 30 Bq/l**).

CRIIRAD recommended that this type of measurement be carried out, since in groundwater, particularly in uranium-bearing areas, the concentration of radon 222 can be significant (generally several dozen Bq/l, and sometimes reaching levels above 1,000 Bq/l and even higher).

These results will need to be confirmed by new measurement operations.

The quantity of radon 222 dissolved in groundwater can vary a great deal over time, all the more so in an area whose hydrodynamic characteristics are severely disturbed by mining.

It is possible that water taken directly from the pumps may show much higher concentrations, in view of the gradual decay of radon in the pipelines.

These preliminary measurements show that it is vital that the activity of radon 222 dissolved in water is measured at Arlit and Akokan as part of the monitoring programmes.

The dose attributable to radon 222 dissolved in the water may be very significant. For example, drinking just 33 cl a day of water whose radon 222 activity by volume is 30 Bq/l results, for an infant, in an annual dose of 0.29 mSv, markedly above the WHO recommendation of 0.1 mSv per year (this calculation does not take into account the contribution of the other radionuclides present in the water).

Other radionuclides

In view of the cost of some analyses, it was not possible to test the dosage of all the radionuclides associated with uranium in all the samples. The radium 226 and polonium 210

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concentration measurements carried out on three of the samples in some cases show values above the threshold of detection:

- Water from north Arlit: radium 226 = 0.031 ± 0.015 Bq/l
- Well water at Akokan: polonium 210 = 0.005 ± 0.003 Bq/l

For all three samples, lead 210 activity was below the threshold of detection (< 0.07 Bq/l to 0.08 Bq/l).

Dosage of the main anions and cations

The results of the measurements of the main anions and cations in the six water samples analysed are shown in Table B in Annex 4.

By comparison with the reference site of Tchit in Taghat (Imouraren district not yet mined), there are notably high concentrations of:

- Sulphates: 98 mg/l at north Arlit (compared with 13 mg/l from the reference well)
- Nitrates: 62 mg/l in a well at Akokan (compared with 6.5 mg/l from the reference well)
- Nitrites: 0.43 mg/l at well COMI 24 (compared with 0.02 mg/l from the reference well)
- Chlorides: 62 mg/l at north Arlit (compared with 3.6 mg/l from the reference well)
- Bromides: 0.407 mg/l at north Arlit (value below the threshold of detection at the reference well)
- Ammonium: 0.19 mg/l in a house at Akokan (value below the threshold of detection in the other five samples).

Dosage of the main metals

The results of the measurements of the main metals in the six water samples analysed are shown in Tables C and D in Annex 4.

By comparison with the reference site of Tchit in Taghat, there are notably high concentrations of:

- Iron: 171 µg/l in a house at Akokan (compared with 1.8 µg/l from the reference well)
- Manganese: 3.3 µg/l in a house at Akokan (compared with 0.3 µg/l from the reference well)
- Molybdenum: 116 µg/l and 118 µg/l at the two locations in Arlit (compared with 0.6 µg/l from the reference well)
- Selenium: 13.1 µg/l at north Arlit (compared with 1.1 µg/l from the reference well)
- Tungsten: 6.6 µg/l and 7.1 µg/l at COMI 24 and Arlit (compared with 0.1 µg/l from the reference well).

These initial results show that:

- For a number of chemical parameters, the water samples analysed exceed the values recommended by the WHO. This is the case, for example, for **nitrates** (50 mg/l), **molybdenum** (70 µg/l), **selenium** (10 µg/l) etc.
- It would be worth extending the list of chemical pollutants which AREVA tests for in water drunk by the population.

The measurements conducted by AREVA [W1] actually include only the following elements: sodium, potassium, calcium, magnesium, chlorides, sulphates, phosphates, nitrates, silicon and iron.

However, the measurements carried out on the samples collected by Greenpeace in November 2009 indicate the presence in some samples of other substances, at levels markedly higher than those recorded at the reference site (namely **ammonium ions, nitrites, bromides, manganese, molybdenum, selenium and tungsten**). As indicated above, in some cases the measured concentrations of these substances exceed the WHO recommendations.

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It must not be forgotten that the industrial activities of SOMAIR and COMINAK utilise large quantities of chemical products.[5] Moreover, uranium extraction exposes groundwater and buried rocks to the air, which may bring about changes in the chemical reactions that can affect the characteristics of the water (increased transfer of sulphates, for example). The origin of these substances in the groundwater at Arlit and Akokan (industrial pollution, domestic pollution or natural causes) deserves detailed study.

Closure of some wells

For decades, AREVA's mining subsidiaries have supplied the population of Arlit and Akokan with water contaminated with uranium beyond the health limits set by the World Health Organization.

The alert about water radioactivity sounded by CRIIRAD from December 2003 seems to have led to some wells – among those most heavily contaminated with uranium – being closed.

The documents sent to Greenpeace by AREVA in November 2009 [W3] show that wells were closed: **COMI 8** in January 2005 and **ARLI 214-5, ARLI 762-2 and ARLI 837-2** between January and July 2005.

When questioned by the journalist Dominique Hennequin in June 2009 about water contamination, AREVA Niger's director of communications, M Moussa Souley, began by declaring that there was *"no pollution of the groundwater by uranium mining"*. When the journalist insisted on knowing the reasons why some wells had been closed, M Souley said that these wells were *"apparently affected by nitrates"* and that this was *"natural pollution"*.

We do not have measurements of the nitrate concentrations of the wells that were closed. The question of why they were closed (uranium concentrations above the WHO guidance value and/or high **nitrate** concentrations).

The presence in numerous wells of nitrate concentrations above the guidance value of **50 mg/l** is evidenced by the measurements for **2006–08** given to Greenpeace by AREVA [W1]. Specifically, this concerns the wells COMI 12 , COMI 15, COMI 16, COMI 17, COMI 20, COMI 22, COMI 23, ARLI 2020, ARLI 2028, ARLI 2039, ARLI 295 etc.

However, these wells were still in use in 2008.

The measurements carried out on the samples brought back by Greenpeace in November 2009 show nitrate concentrations of between 15 mg/l and 62 mg/l at Arlit and Akokan, as against 6.5 mg/l for the reference sample collected in the Imouraren district (see Annex 4).

The origin of the nitrate contamination at Arlit and Akokan deserves detailed study. While domestic causes are possible, the influence of mining activity is also conceivable (the use of explosives in mining is a source of pollution: in 2002, for example, COMINAK used 1,487 tonnes of **ammonium nitrate**).

In any event, it is worth recalling that the wells COMI 8, ARLI 214 and ARLI 837, closed by AREVA in 2005, were among the wells with the highest concentrations of uranium. The total alpha activity was 7.8 Bq/l at well ARLI 837 in November 2004 [CRIIRAD report C2]. The uranium concentration of wells ARLI 214 and COMI 8 was 156 µg/l and 183 µg/l respectively in May 2004 according to the IRSN.

[5] So for example in 2002 COMINAK used the following consumables: sulphur (11,768 tonnes), cement (5,160 tonnes), sodium chloride (3,799 tonnes), sodium carbonate (2,955 tonnes), ammonium nitrate (1,487 tonnes), oils (893 m^3), magnesium (637 tonnes), solvents (364 m^3), explosives (325 tonnes)[, caustic soda (211 tonnes), sodium chlorate (79 tonnes), conveyor belts (3 kilometres), tyres, metal, batteries etc.

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Recommendations

If the situation is to improve, it is vital that the company acknowledges that uranium concentrations are above the WHO guidance value and commits to implementing practices that would enable groundwater contamination to be limited.

Without giving an exhaustive list, such measures might include:

• Instigating safer drilling practices to limit the contamination of aquifers crossed by test drilling.

• Ensuring the containment of spoil and radioactive waste stored above ground.

• Reclamation of the opencast workings and mine galleries.

It is however unlikely that the impact of mining in terms of the reduction and degradation of water resources could be seriously improved.

Progress must also be made in the following areas:

• Improving the quality of radiological and chemical testing by extending it to radionuclides (radon 222, lead 210, polonium 210 etc) and chemical substances that are currently not measured.

• Conducting a retrospective analysis of the doses received by the water consumers of Arlit and Akokan since uranium extraction began.

Written by Bruno Chareyron, nuclear physics engineer in charge of the CRIIRAD laboratory.

Approved by Corinne Castanier, director of CRIIRAD.

ANNEX 1: Documents published by the CRIIRAD laboratory concerning the radiological situation around AREVA's mines in Niger between December 2003 and August 2009

[C1] CRIIRAD Report No. 03-40 / Report of mission to Arlit, 3 to 11 December 2003 / Exploratory mission in order to produce an independent evaluation of the radiological impact of the SOMAIR et COMINAK uranium mines / B Chareyron, 19 December 2003.

[C2] CRIIRAD Report No. 05-17 / Impact of uranium mining by the subsidiaries of COGEMA-AREVA in Niger / Results of the analyses conducted by the CRIIRAD laboratory in 2004 and early 2005 / B Chareyron, April 2005.

|C3] CRIIRAD Note No. 07-53 / Presence of radioactive material in the public domain at Arlit and Akokan (Niger), close to the mines of SOMAIR and COMINAK (AREVA) / B. Chareyron, May 2007.

[C4] CRIIRAD press release / AREVA in Niger / CRIIRAD and AGHIR IN MAN call for the immediate removal of the radioactive waste discovered in the streets of Akokan in Niger, and question Mme Lauvergeon, president of AREVA, about the practices of her group's subsidiaries / 15 May 2007.

[C5] Letter from B Chareyron, head of the CRIIRAD laboratory, to Mme Anne Lauvergeon, president of AREVA : "Impact of uranium mining at Arlit and Akokan / Presence of radioactive waste in the streets of Akokan" / 15 May 2007.

[C6] CRIIRAD Note No. 08-02 / AREVA: From rhetoric to reality / The example of uranium mines in Niger / B Chareyron, 30 January 2008.

[C7] Letter from B Chareyron, head of the CRIIRAD laboratory, to Mme Anne Lauvergeon, president of AREVA : "Impact of uranium mining at Arlit and Akokan / Presence of radioactive material in the streets" / 31 July 2009.

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ANNEX 2 / Documents requested by GREENPEACE and CRIIRAD to AREVA before the mission of GREENPEACE in November 2009

ANNEX I – LIST OF REQUESTED DOCUMENTS AND INFORMATION

GREENPEACE mission to Niger
Analysis of the radiological impact of uranium mining at Arlit and Akokan, 2009
List as suggested by CRIIRAD (list no. BC 090807 / B Chareyron)

- Installation plan of air vents for COMINAK's underground galleries, with indication of the vents functional in 2009.
- For each air vent, results of the measurements of extraction rate, radon activity concentration and radon emission flux.
- Evaluation of the dispersion of radon and radioactive dust from COMINAK's air vents, the heaps of crude ore alongside the SOMAIR and COMINAK plants, and SOMAIR's and COMINAK's static and/or dynamic leaching waste heaps.
- Evaluation of the radon- and dust-associated dosimetric impact on the populations of Arlit and Akokan (methodology and results for the period 2006-08).
- Installation plan for the on-site dosimeters (measurement of the ambient gamma radiation dose rate, measurement of dust activity concentration, measurement of radon activity concentration), and 2006, 2007 and 2008 measurement results.
- Installation plan for the wells, piezometers and boreholes enabling monitoring of the radiological and chemical quality of the groundwater.
- Detailed results of the radiological and chemical analyses conducted between 2006 and 2008 on the wells, piezometers and boreholes.
- Description of the modifications effected since 2003 in the supply of drinking water (for employees and the population). Creation and closure of wells, volumes extracted, results of the radiological and chemical analyses.
- Description of the strategy for monitoring the radiological and chemical impact of SOMAIR's and COMINAK's activities on the food chain at Arlit and Akokan (methodology and results 2006-2008).
- Annual radiological protection reports for SOMAÏR and COMINAK for 2006, 2007 and 2008 (results of environmental monitoring and monitoring of radiological protection of employees).
- Results of aerial mapping of the gamma radiation level above the Arlit and Akokan zones.
- List of the sectors accessible to the public at Arlit and Akokan where radioactive waste rock originating from SOMAIR and COMINAK mines has been reused. Results of the radiation measurements conducted on these sectors. List of sectors decontaminated.
- Summary of the radiation monitoring operations carried out on scrap metal, plastics and geotextiles originating from SOMAIR and COMINAK mines and uranium extraction plants and reused in the public domain (2006 to 2008). Description of the method of radiation monitoring, results of the monitoring, number of radioactive items recovered. Estimate of the dosimetric impact on the individuals concerned.

ANNEX 3: Documents obtained by Greenpeace in the context of the mission of November 2009

General documents

[G1] Report "AREVA / SOMAIR Société des Mines de l'Aïr SSR / Radioprotection / Radiological monitoring of the environment / Annual Report 2008" / 31 March 2009.

[G2] Report "Akouta Mining Company / Radioprotection / Radiological monitoring of the environment / Results for the year 2008" / 27 April 2009.

[G3] AREVA power point presentation: "SOMAIR: An overview. The site and the processes" / Mahamadou I., site manager, Arlit-Niger / November 2009.

[G4] AREVA power point presentation: "General presentation on COMINAK" / Harouna Doundo and Issoufou Tsalhatou, Miming Director and Environment Officer, Akokan / November 2009 (27 pages).

[G5] "Report of Compagnie Minière d'Uranium d'Akokan (COMINAK) radioprotection inspection mission, 28 May 2009 to 3 June 2009" / Republic of Niger: Ministry of Public Health; Centre National de Radioprotection.

Documents on problems associated with soil radioactivity

[S1] Note "Summary of the radiological inspection mission conducted in the town of Akokan between 20 May and 24 May 2007" / Mr Alfari Salou / Republic of Niger, Ministry of Mines and Energy / 29 May 2007.

[S2] Correspondence of 6 October 2008 of COMINAK with the Department of Mines and Energy concerning the radiological inspection of the urban zone, along with a map of the work carried out.

[S3] Greenpeace briefing "Uranium mines in Niger – radioactivity in the streets of Akokan "/ 27 November 2009.

[S4] AREVA press release: "Greenpeace report: AREVA Niger responds" / 23 December 2009.

[S5] COMINAK / Report of inspection of treated points / 22 December 2009.

Documents on water

[W1] Data from chemical and radiological analysis of SOMAiR and COMINAK drinking water infrastructure (measurements from 2006 to 2008).

[W2] Graph of the production of industrial water and drinking water.

[W3] Tables on the history of COMINAK's and SOMAÏR's drinking water wells (3 pages).

[W4] AREVA COGEMA Niger / "Aman Project / Hydrogeological summary / The Tarat aquifer in the Arlit – Akokan region" / May 2004

ANNEX 4: Chemical analysis of the six water samples collected by Greenpeace in the course of the November 2009 mission

A / Location of the samples (Greenpeace data)

Sample no.	Date	Name location	Coordinates location	Description location	Remarks	Sample no. (CRIIRAD)
N041109.01	4 November 2009	Tchit in Taghat (secteur IMOURAREN)	N18°07.894' E7°27.079'	Village well, 60 meter deep, at north side of village. Water is kept in storage tank at ~8m height. Used for drinking water and animals.	Clear water. Time: ~11hr	121109 B1
N051109.02	5 November 2009	Well COMI24	N18°40.867' E7°20.206'	Well in desert, south of Akokan, east of COMINAK mine. Sample taken from tap outside of monitoring station. Tap is used as drinking water by nomads, people passing by. Connected to water system Akokan.	Well identified in COMINAK report as containing high levels of uranium (& …?). Time:16:00 hr	121109 B2
N051109.04	5 November 2009	Well Akokan	N18°42.007' E7°20.391'	Village well, south side of Akokan, at small community next to gardens. Tap located near garbage belt.	Clear water. Time: 17:35hr	121109 B3
N061109.02	6 November 2009	Tap Arlit	N18°44.427' E7°23.311'	Village well, at the corner of street. Used by all families in neighbourhood.	Clear water. Time: 15:50hr	121109 B4
N061109.03	6 November 2009	Tap Arlit North	N18°44.659' E7°22.374'	Village well connected to Arli252 well, which is about 200 meter NNW. Used by Mr. A. and surrounding community and nomads. Next well to E was recently closed.	Clear water. Time: 16:18hr	121109 B5
N061109.05	6 November 2009	House Akokan	N18°42.653' E7°20.147'	House of Mr. T., Akokan. Water is from general water supply in Akokan	Clear water. 17:15hr	121109 B6

B / Results of the chemical analysis (anions and cations)

Sample no. (CRIIRAD)	Lieu	Conductivité (µS/cm)	pH	Sulfates (mg/l)	nitrates (mg/l)	Nitrites (mg/l)	calcium (mg/l)	Sodium (mg/l)	Chlorures (mg/l)	Fluorures (mg/l)	Bromures (mg/l)	Ammonium (mg/l)
121109 B1	Tchit in Taghat (secteur IMOURAREN)	295	7,95	13	6,5	0,02	9,9	67	3,6	0,147	< LD	< LD
121109 B2	Well COMI24	719	8,7	32	15	0,43	2,3	203	27	0,48	0,165	< LD
121109 B3	Well Akokan	589	8,35	29	62	0,02	3,7	141	45	0,141	0,247	< LD
121109 B4	Tap Arlit	710	8,50	58	29	0,02	3,6	183	43	0,398	0,268	< LD
121109 B5	Tap Arlit North	741	8,30	98	40	0,03	4,9	177	62	0,154	0,407	< LD
121109 B6	House Akokan	541	8,35	31	38	0,07	6	129	31	0,185	0,168	0,19

Analysis conducted by LDA 26, commissioned by CRIIRAD.

< LD = below threshold of detection

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C / Results of the chemical analysis (metals)

Sample no. (CRIIRAD)	Lieu	Ag (µg/l)	Al (µg/l)	As (µg/l)	B (µg/l)	Ba (µg/l)	Be (µg/l)	Cd (µg/l)	Co (µg/l)	Cr (µg/l)	Cu (µg/l)	Fe (µg/l)	Mn (µg/l)	Mo (µg/l)
121109 B1	Tchit in Taghat (secteur IMOURAREN)	< LD	4,7	1,9	32,7	97,5	< LD	< LD	< LD	3,4	0,3	1,8	0,3	0,6
121109 B2	Well COMI24	< LD	7,2	2,9	114	43,4	< LD	< LD	< LD	< LD	0,2	0,3	1,9	18,3
121109 B3	Well Akokan	< LD	6,0	0,8	35,4	38,7	< LD	< LD	< LD	5,9	0,4	2,1	0,3	5,6
121109 B4	Tap Arlit	< LD	11,2	1,7	99,1	68,0	< LD	0,2	< LD	1,4	0,5	1,1	0,4	116
121109 B5	Tap Arlit North	< LD	5,5	0,6	29,6	26,3	< LD	0,2	< LD	0,3	0,5	1,4	0,1	118
121109 B6	House Akokan	< LD	6,4	1,1	43,7	98,2	< LD	< LD	< LD	3,9	2,9	171	3,3	4,5

Analysis conducted by LDA 26, commissioned by CRIIRAD (semi-quantitative screening by ICP-MS).

< LD = below threshold of detection

The values in yellow are more that 10 times greater than those measured from the reference sample (Tchit in Taghat). The values in orange are more than 90 times greater.

D / Results of the chemical analysis (metals)

Sample no. (CRIIRAD)	Lieu	Ni (µg/l)	Pb (µg/l)	Sb (µg/l)	Se (µg/l)	Sn (µg/l)	Te (µg/l)	Ti (µg/l)	Tl (µg/l)	U (µg/l)	V (µg/l)	W (µg/l)	Zn (µg/l)
121109 B1	Tchit in Taghat (secteur IMOURAREN)	< LD	0,1	< LD	1,1	< LD	< LD	3,9	< LD	4,0	75,2	0,1	4,5
121109 B2	Well COMI24	< LD	< LD	< LD	9,3	< LD	< LD	1,8	< LD	25,0	134	6,6	1,3
121109 B3	Well Akokan	0,1	< LD	< LD	5,5	< LD	< LD	1,8	< LD	33,1	74,7	0,4	3,6
121109 B4	Tap Arlit	0,1	0,1	< LD	7,8	0,1	< LD	1,7	< LD	23,2	52,1	7,1	4,7
121109 B5	Tap Arlit North	0,1	< LD	< LD	13,1	< LD	< LD	1,7	< LD	63,8	35,1	0,1	2,7
121109 B6	House Akokan	0,1	0,3	< LD	4,2	< LD	< LD	1,8	< LD	10,1	51,5	1,3	10,4

Analysis conducted by LDA 26, commissioned by CRIIRAD (semi-quantitative screening by ICP-MS). < LD = below threshold of detection

The values in yellow are more that 10 times greater than those measured from the reference sample (Tchit in Taghat).

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