

# The radiological impact of uranium mining (France and Africa)

CRIIRAD laboratory  
Studies performed from 1992 to 2006

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# 0 / A few words about CRIIRAD and its laboratory

- What is CRIIRAD

- French NGO created in 1986 (Chernobyl)
- Commission for Independent Research and Information about RADiation
- Scope : to inform people about the health risks induced by ionizing radiation and to improve their protection
- 4,000 members (supporters) give 1/3 of the budget
- Independent from the State, the nuclear industry and political parties
- Private laboratory equipped for radiation monitoring (7 engineers or technicians) : 2/3 of the budget
- Studies made for the people, other NGO's, local authorities.
- Areas of interest : Natural radiation, medical use of radiation, nuclear industry (mines, NPP, reprocessing plants, disposal, etc..)

1986

Caesium  
137 fallout  
on the  
French  
territory /  
CRIIRAD  
map

CRIIRAD / B. Chareyro

## Contamination des sols par le césium 137

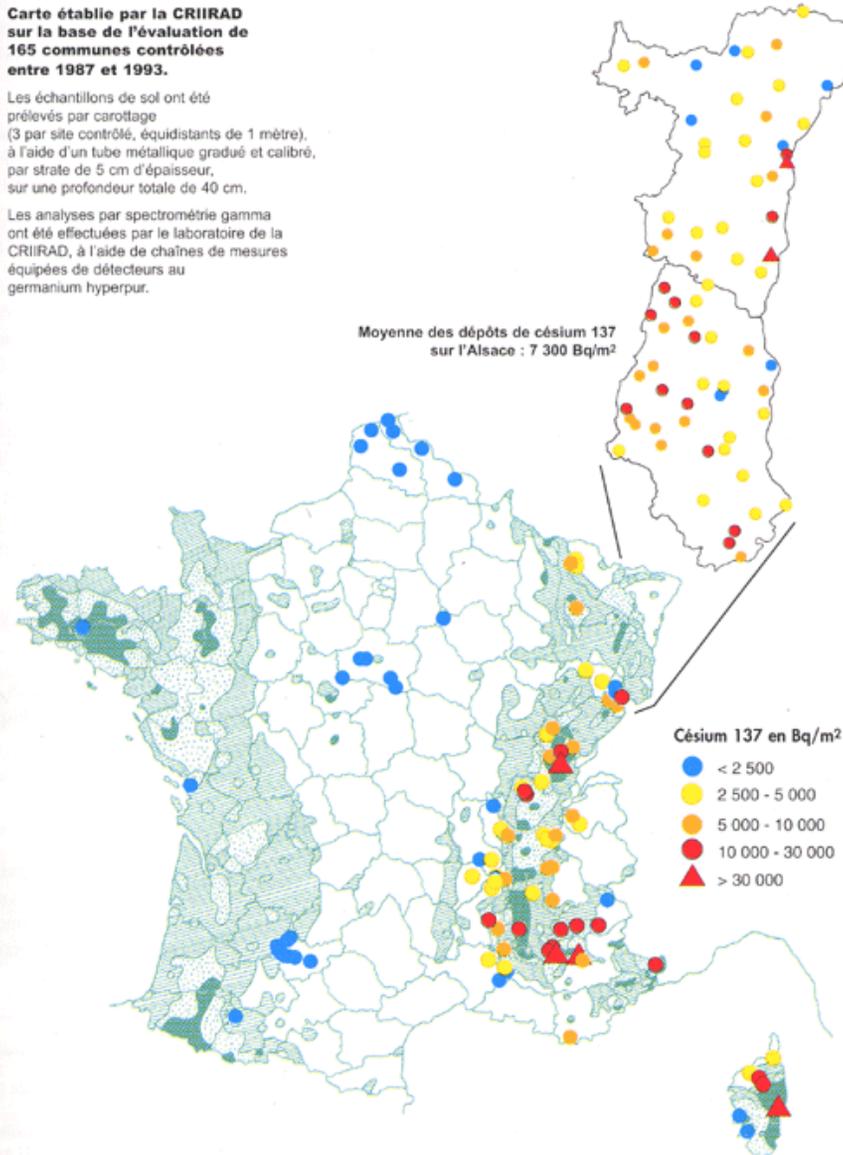
### Évaluation des retombées de l'accident de Tchernobyl

Carte établie par la CRIIRAD  
sur la base de l'évaluation de  
165 communes contrôlées  
entre 1987 et 1993.

Les échantillons de sol ont été  
prélevés par carottage  
(3 par site contrôlé, équidistants de 1 mètre),  
à l'aide d'un tube métallique gradué et calibré,  
par strate de 5 cm d'épaisseur,  
sur une profondeur totale de 40 cm.

Les analyses par spectrométrie gamma  
ont été effectuées par le laboratoire de la  
CRIIRAD, à l'aide de chaînes de mesures  
équipées de détecteurs au  
germanium hyperpur.

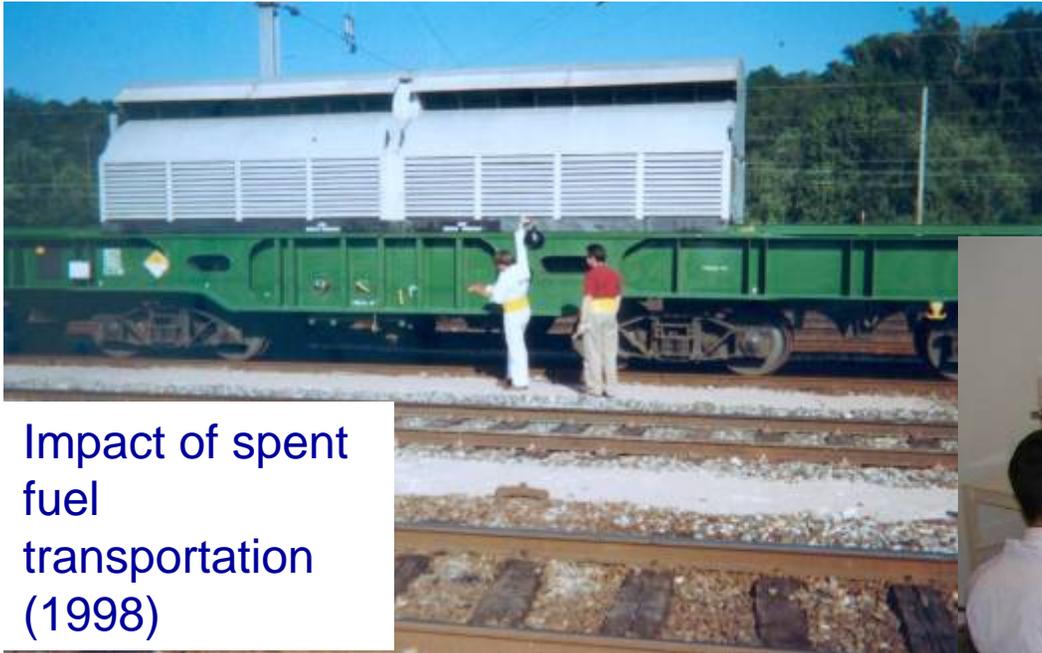
Moyenne des dépôts de césium 137  
sur l'Alsace : 7 300 Bq/m<sup>2</sup>



Fiche CRIIRAD n°2 - Annexe - Novembre 2001.



Red spots =  
10,000 to  
30,000 Bq/m<sup>2</sup>  
(Caesium 137)



Impact of spent fuel transportation (1998)



CRIIRAD gamma spectrometry laboratory



Sample preparation

La Hague  
Reprocessing  
Plant (1997) for  
Greenpeace



French Polynesia impact  
of nuclear tests (2005)



ANDRA  
LLW  
repository  
(2006)





Japan / ROKKASHO  
MURA (2002-2006) for  
GREENPEACE



- Uranium mining in France

- About 200 mines : open pits and underground mines
- Uranium mining took place from the end of the 40's to 2001.
- Today the French uranium is imported from foreign countries Niger, Canada, etc..

Photographic credit

- CRIIRAD (C. Courbon et B. Chareyron)
- Thierry Lamireau,
- André Paris,
- Jeff Rachel
- AREVA-COGEMA web site



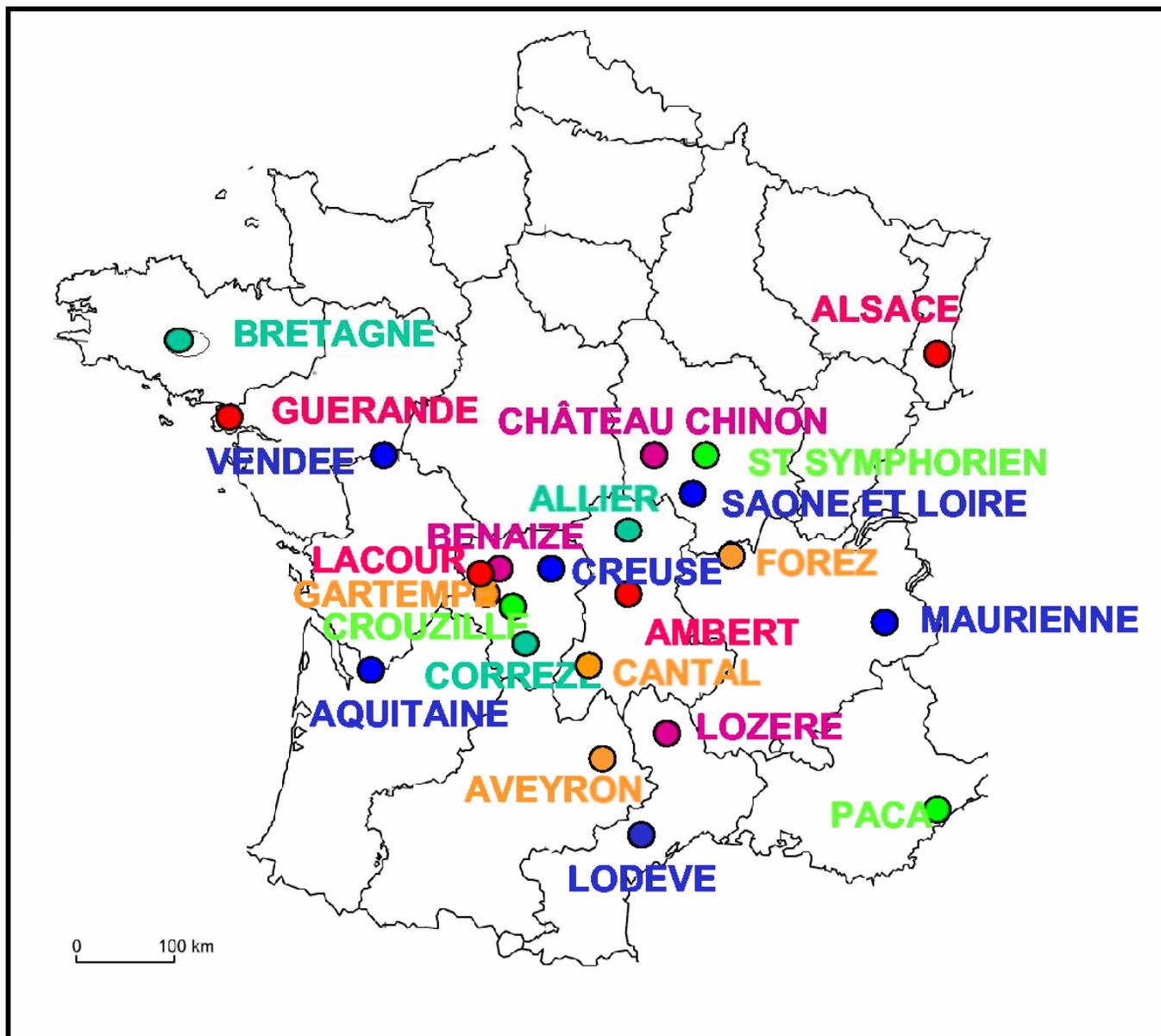


figure 2 : répartition des 23 zones minières définies

Open pit / SOMAÏR / Niger



Mine / COMINAK / Niger



# 1 / Coping with radioactive rocks

used for road construction or under  
buildings

Radionuclide	Half-life	Decay mode	X or gamma emission	Example of gamma emission (Energy, %)
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Natural nuclides / earth crust / uranium 238 decay chain / Main nuclides

Uranium 238	4.46 billion years	Alpha	weak	16.16 keV	4.1 %
Thorium 234	24.1 days	bêta	yes	63.3 keV	3.8 %
Protactinium 234m	1.17 Minutes	bêta	yes	1 001 keV	0.65%
Uranium 234	245 000 years	Alpha	weak	53.2 keV	0.119 %

Thorium 230	75 400 years	Alpha	yes	67.7 keV	0.376 %
Radium 226	1 600 years	Alpha	yes	186.1 keV	3.28 %
Radon 222	3.82 days	Alpha	weak	510 keV	0.07 %
Lead 214	26.8 minutes	bêta	yes	351.9 keV	37.1 %
Bismuth 214	19.9 minutes	bêta	yes	609.3 keV	46.1 %
Lead 210	22.3 years	bêta	yes	46.5 keV	4 %
Polonium 210	138.4 days	Alpha	weak	803.1 keV	0.001 %

Radioactive rocks extracted from the mine are « stored » locally or re-used. Their uranium content can exceed 4,000 Bq/kg  
This is 100 times above the average natural activity of the earth crust (40 Bq/kg)



CRIIRAD discovered that radioactive rocks extracted from the mines had been used without limitation.

Car parking of a ski resort ( Loire / Allier, year 2001) :  $2 \mu\text{Sv/h}$  on the ground = 10 times above natural background level.



Court-yard of a farm at Saint-Priest-La-Prugne (France).  
Doserate 1 m above radioactive rocks from the mine :  $1.1 \mu\text{Sv/h} = 5$   
times above natural level  
The « official » doserate monitoring station is located 100 m away from  
the court-yard  
In a place where gamma radiation is normal.

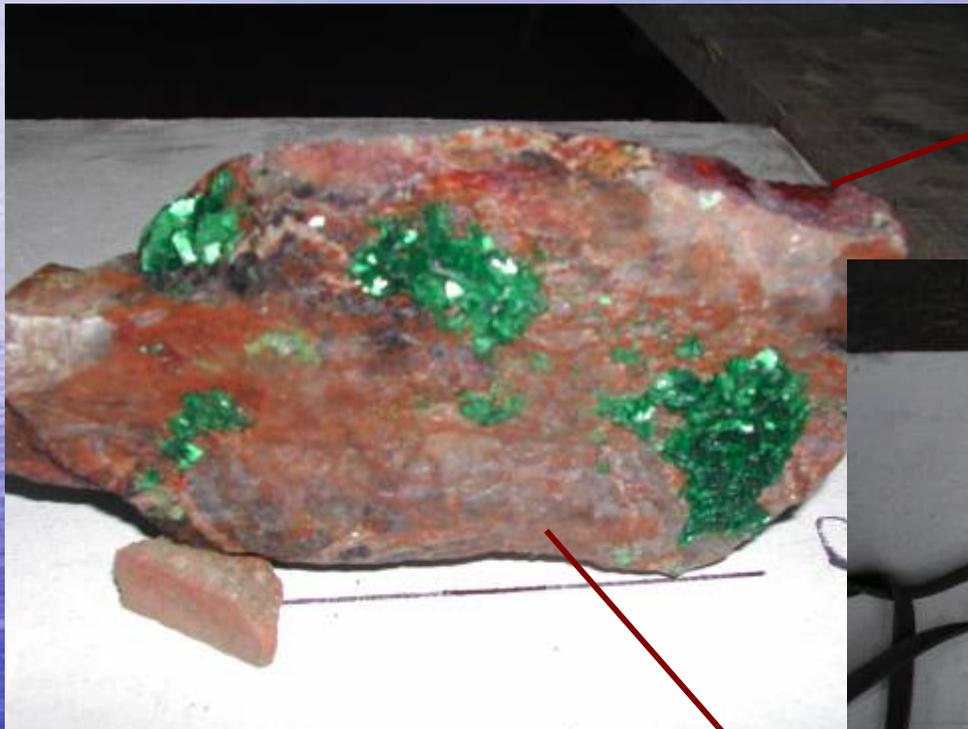


Due to CRIIRAD and local NGO pressure and media coverage, the mining company (AREVA-COGEMA) had to remove 250 m<sup>3</sup> of radioactive rocks from the farm courtyard (year 2004)



CRIIRAD and a local NGO tried to improve people awareness about the radiological risks induced by uranium minerals coming from the former mines.

(March 2003) at Saint-Priest-La-Prugne



A citizen was keeping a sample of mineral coming from the mine in her garden (Saint-Priest-La-Prugne, June 2002)





Doserate measured by CRIIRAD:

- \*1 milliSievert/h in contact = 5 000 times above background level
- \* 18,3  $\mu$ Sv/h at a distance of 1 m

Comparison of radiation dose with EURATOM 96/29 limits :

- \*Staying one hour at 1 meter : cancer risk is « non negligible »
- \*Staying 10 minutes per day, each day of the year : cancer risk is unacceptable.

CRIIRAD asked COGEMA-AREVA to remove the mineral

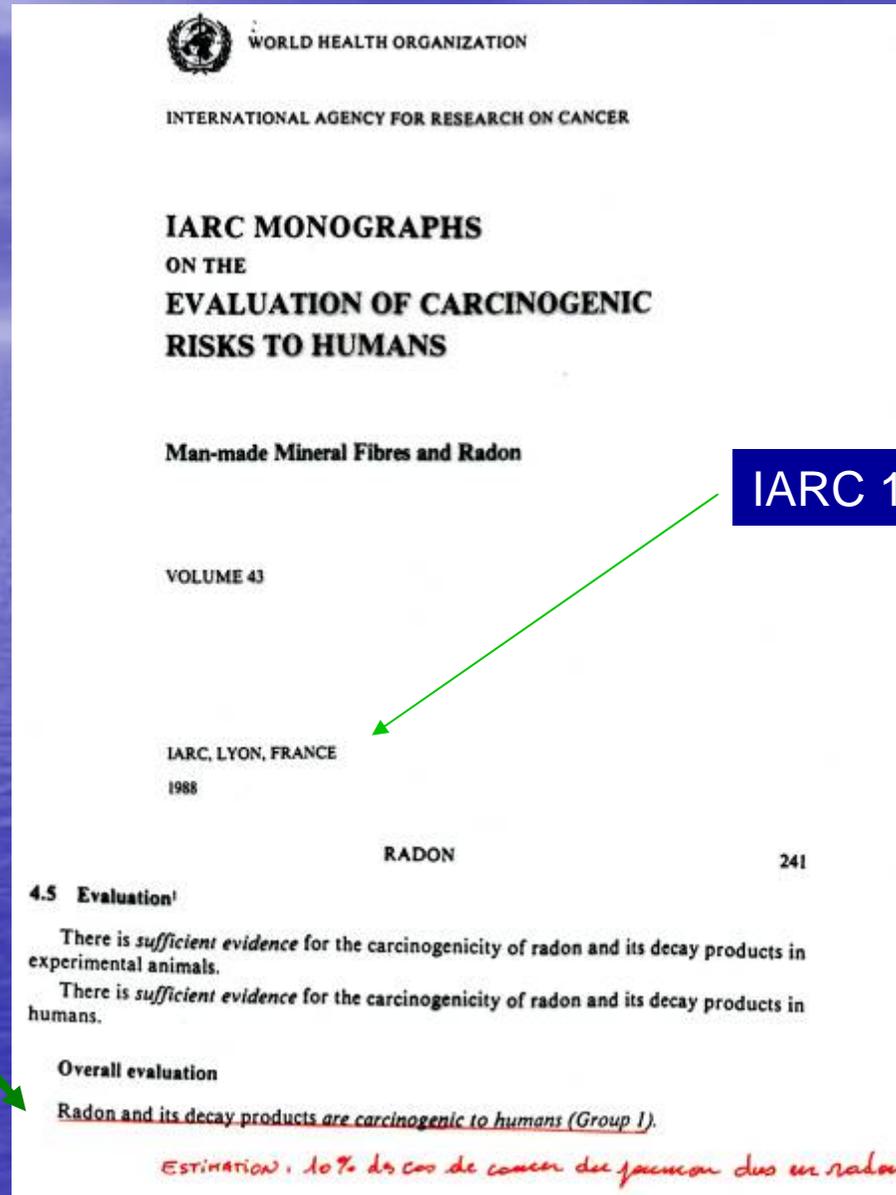
- CRIIRAD proposals

- Global inventory of places where radioactive rocks may have been used years ago
- If radioactive rocks are present, this should be written in official documents
- Elaboration of a national strategy : definition of decontamination levels and creation of storage facilities for radioactive rocks
- Creation of a national fund to help citizens willing to get rid off radioactive rocks situated in their property.

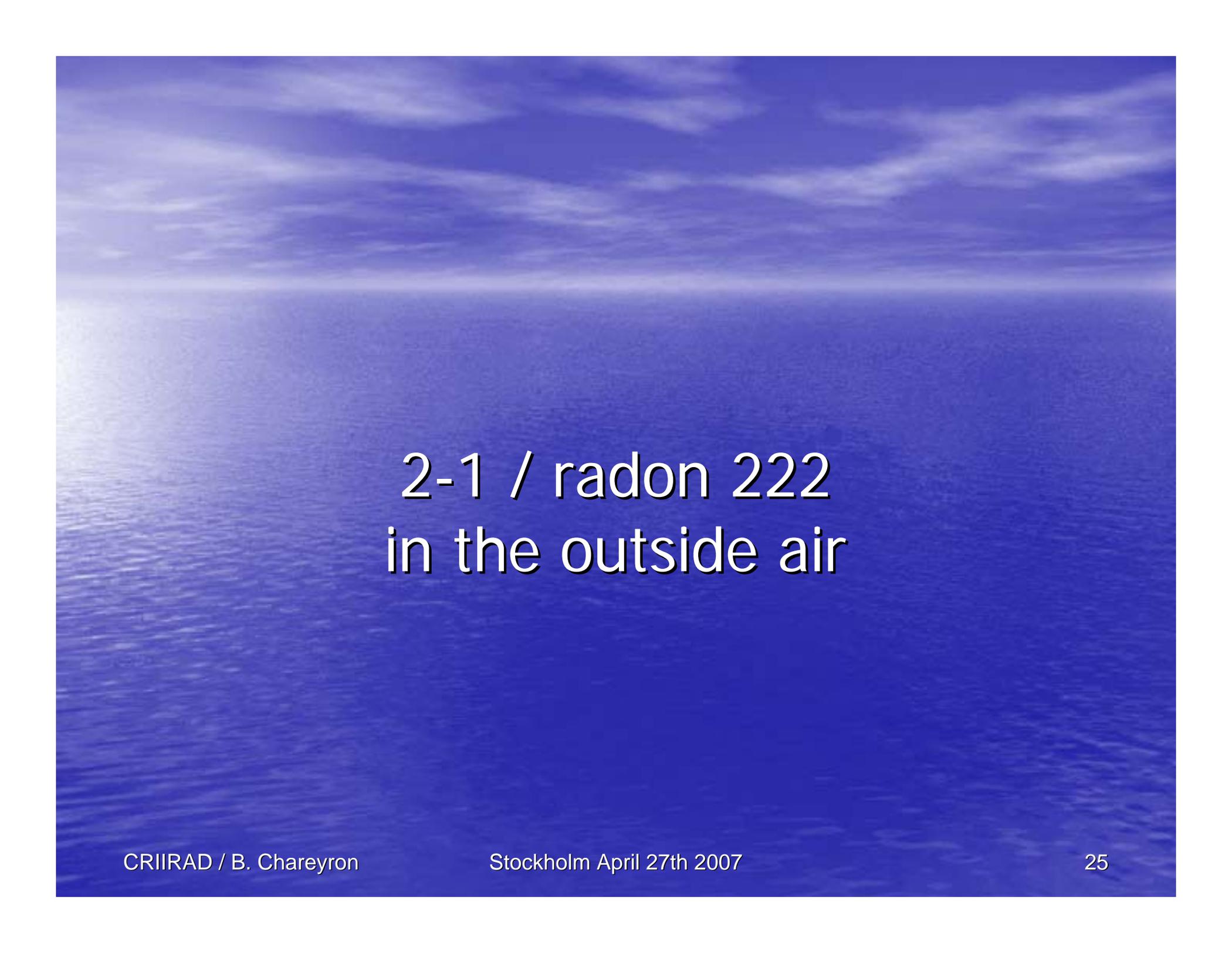
## 2 / Coping with a radioactive and very mobile gas : radon 222

10 % of lung cancer probably due to radon

“Radon and its decay products are carcinogenic to humans”



IARC 1988



2-1 / radon 222  
in the outside air

While uranium mines are in operation, radioactive gas (radon 222) and radioactive dust are discharged into the atmosphere in huge quantities. In France, in several cases the stacks were located near dwellings.



Stack from COGEMA mine (France)



Stack from COMINAK mine (Niger)

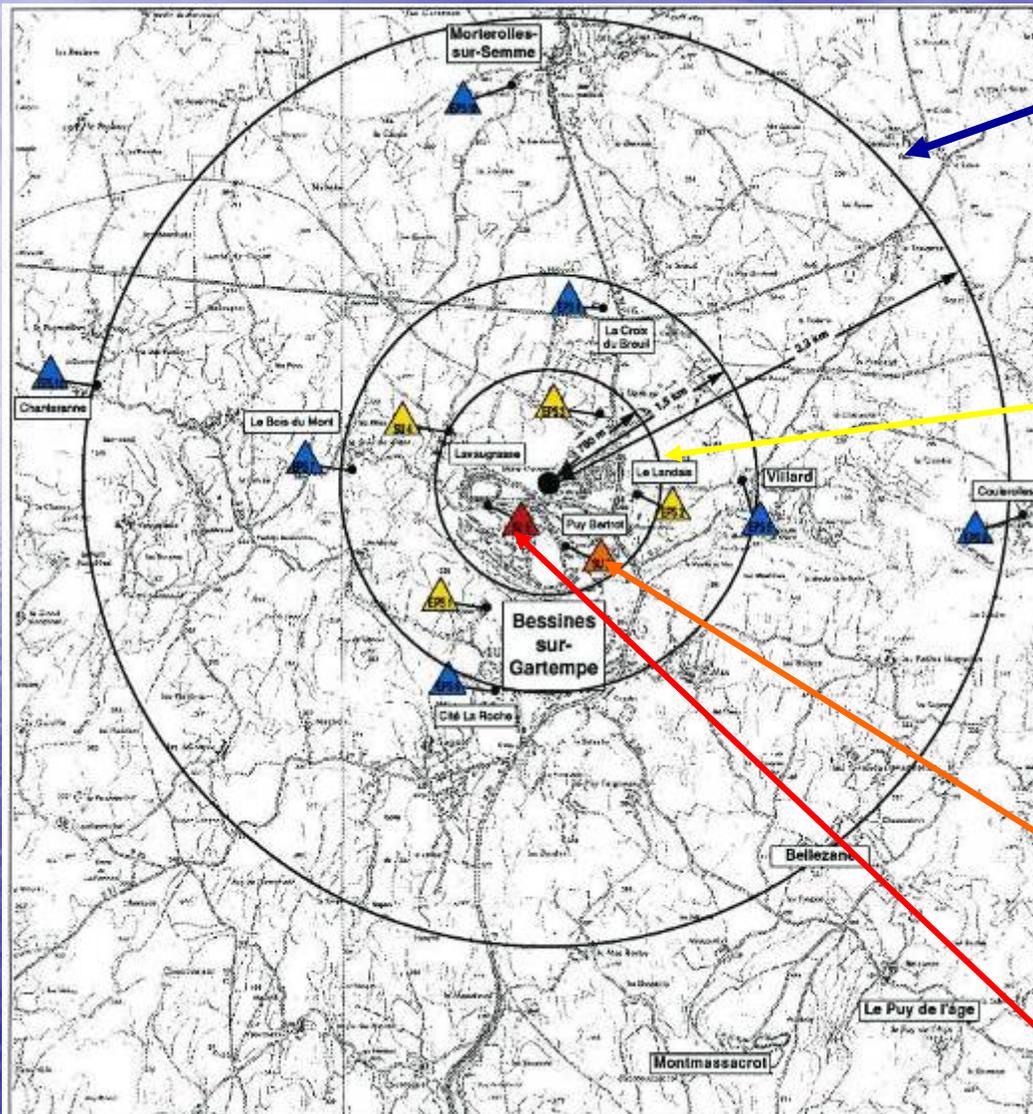
## COGEMA AREVA Mines at "La Crouzille" (France)

### Estimation of radon discharge into the atmosphere

Mining area	Number of stacks	Hourly radon 222 discharge (Bq/h)	Annual radon 222 discharge (Bq/an)
Year 1991			
Bellezane	6	3.4 billion	30,000 billion
Fanay et Margnac	14	28.4 billion	249,000 billion

CRIIRAD estimation is based on figures given by the mining operator  
 calculation is made with the assumption of permanent venting

Radon 222 mean activity in the outside air near COGEMA mines and uranium mill at Bessines (Limousin) / CRIIRAD measurements with charcoal canisters during 48 hours in June 1993



Remote places :

27 Bq/m<sup>3</sup> (average value 7 locations)

Close to the industrial center (780 metres) :

87 Bq/m<sup>3</sup> (average value, 4 locations)

Very close to the site :

294 Bq/m<sup>3</sup> (small village)

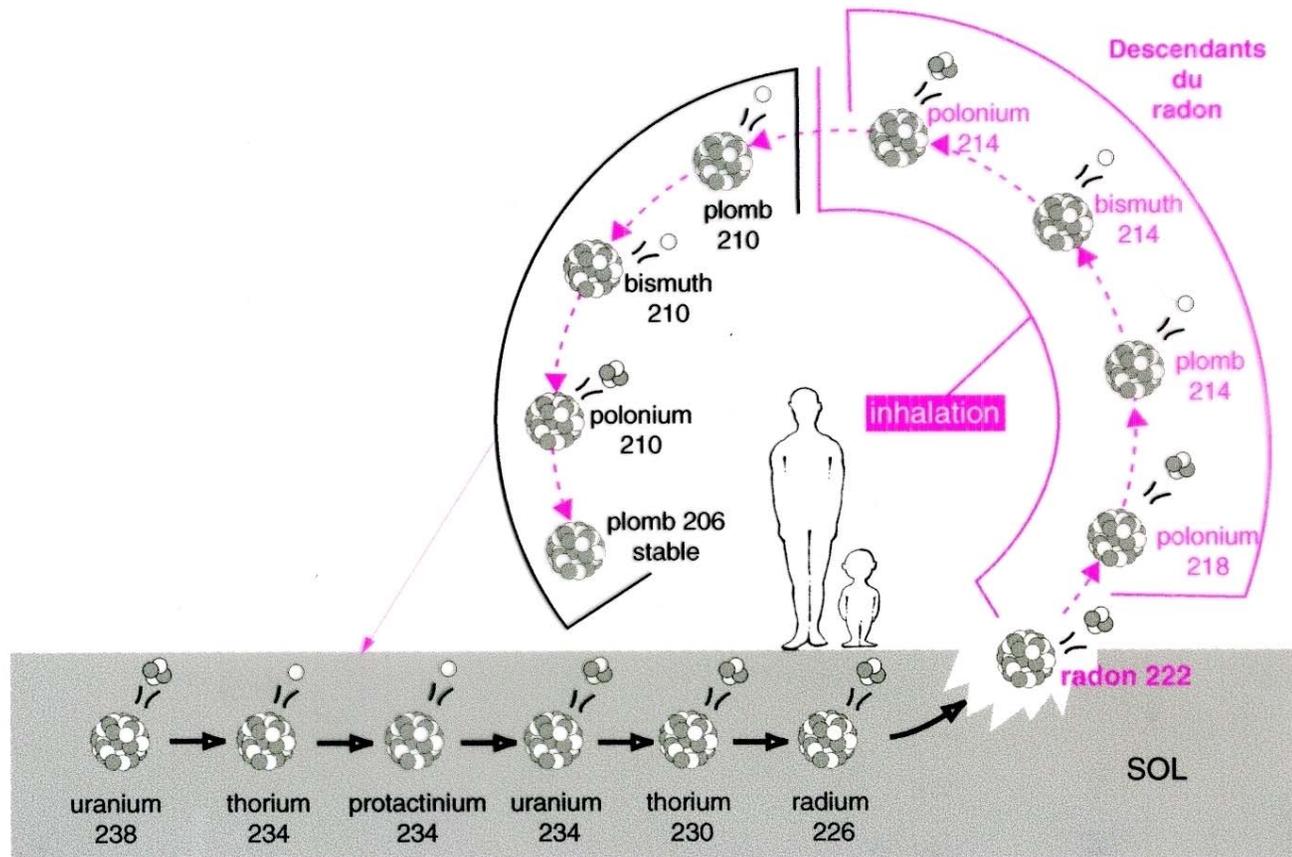
Public road :

895 Bq/m<sup>3</sup>.

# 2-2 / radon 222 inside buildings

Radioactive material containing uranium-radium 226 will permanently generate radon gas.  
Lung cancer risks are especially high when the gas may accumulate inside buildings

### Radon escapes from rocks containing uranium-radium 226



Document CRII-RAD

Emanat' dispers.radon-NM/MR-99/02-J1

This sawmill had been built a few decades ago on radioactive waste rocks used for landfill. Those rocks came from a COGEMA uranium mine.

(France, Allier, near Saint-Priest-La-Prugne)

CRIIRAD (2001) discovered that radon gas accumulation inside the building was very high (7 700 Bq/m<sup>3</sup>) and more than 7 times above emergency levels.

. Surprisingly a few years before, a COGEMA technician had checked radiation level and had noted « no radiological problem »



In the end, the mining company (COGEMA-AREVA) paid for the removal of 8,000 m<sup>3</sup> of radioactive rocks (under and near the sawmill) (year 2003)

Picture below : CRIIRAD technician is measuring gamma radiation at the sawmill while decontamination is going on



# 3 / Coping with radioactive scrap metal from the uranium mines and mills (CRIIRAD mission to Niger)

# ARLIT (NIGER) / December 2003



- Uranium mines and mills operated by SOMAIR and COMINAK, subsidiaries of COGEMA-AREVA in Niger
- Preliminary study made by the CRIIRAD laboratory in cooperation with SHERPA and on request of a local NGO : AGHIR IN MAN
- The companies tried to stop CRIIRAD mission
- CRIIRAD scintillometers have been confiscated at Niamey airport



Gamma radiation measurement with a small Geiger Muller counter.  
Streets of ARLIT City.  
Gamma radiation is 10 times above natural background.



Pipe from the uranium mill. A few grams of radioactive crust inside the pipe are brought back to the CRIIRAD laboratory :

uranium 238 / thorium 230 = 10,000 Bq/kg,  
radium 226 = 240,000 Bq/kg : tailings from the mill



In ARLIT people commonly use scrap metal for their everyday life



CRIIRAD press release (December 2003)

« *Mining companies should*

*1 / act in order to prevent contaminated scrap metal from their facilities to be sold on Arlit market*

*2 / Perform gamma scanning in ARLIT city and take back scrap metal already acquired by the public ».*

## AREVA-COGEMA answer (summer 2004)

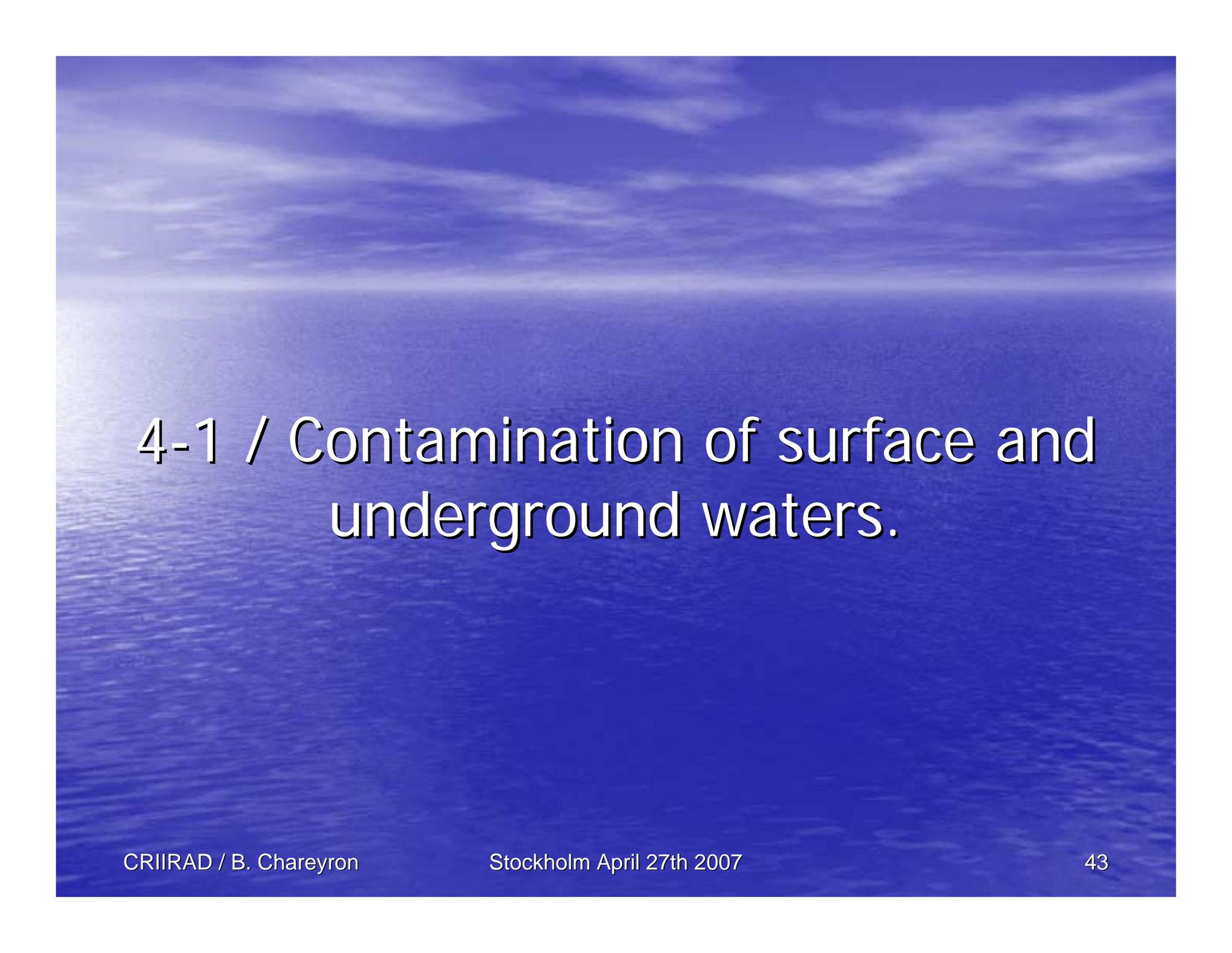
- Initially the regulations did not require radiological checks on scrap metal from the mines;
- In 1999 COGEMA used gamma dose rate limits (from SCPRI, French official radiological protection board) : 1 microGray/hour at 50 cm.

## CRIIRAD comments :

- If somebody stays 3 hours a day, all year long, 50 cm away from a metallic piece with a dose rate of 1 microGray per hour, the cumulated dose will exceed the international limit of 1 milliSievert per year (limit above which the risk of dying from cancer is estimated unacceptable)
- The total risk estimate should also integrate internal irradiation by radioactive dust, radon gaz diffusion, etc..
- It seems that AREVA subsidiaries organized a campaign to take back some of the contaminated scrap metal at the beginning of 2005.

# 4 / Coping with radioactive liquid effluents and the long term contamination of the aquatic environment during and after mining operations

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# 4-1 / Contamination of surface and underground waters.

# Contamination of underground water tables (ex : Arlit, Niger)

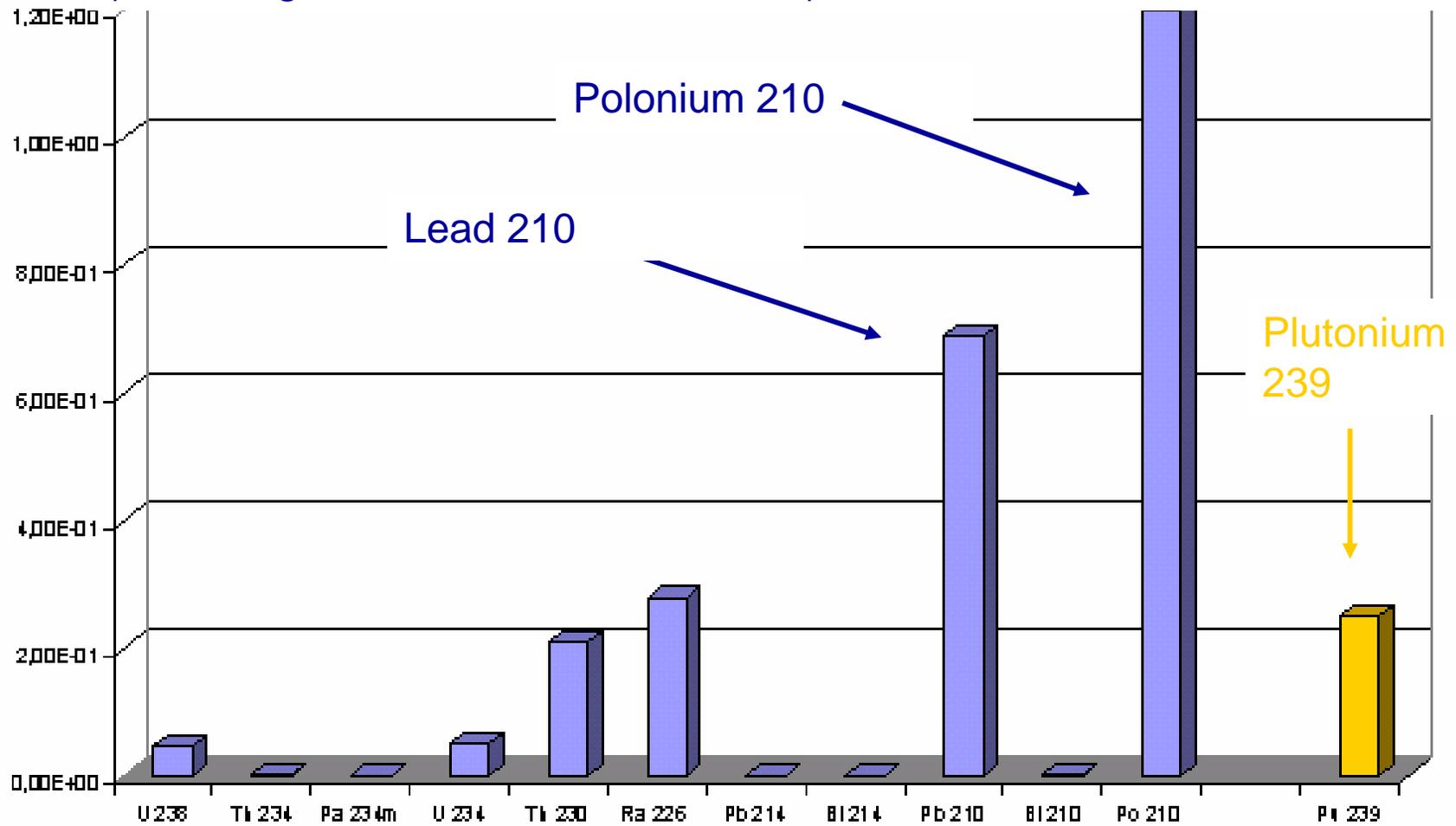


- ARLIT : water is pumped from a non renewable resource at a depth of 150 m (40 % is used for industrial process)
- AREVA press release (December 2003) : "no contamination" of water
- In fact CRIIRAD showed that COGEMA-AREVA subsidiaries were giving water to the population and workers with Uranium and decay products contamination above WHO standards.
- Some of the drills have been closed since CRIIRAD and SHERPA press conference

## Surface water and groundwater coming from uranium mines and open pits are contaminated by radionuclides

- Usually the radioactivity of waters is higher during and after operation than before
- The type of nuclides will depend on local conditions
- Some of these nuclides are among the most radiotoxic ones when ingested (for example Lead 210-polonium 210)
- Examples of measurements in raw water from uranium mines (CRIIRAD, 1993, Limousin, France) :
  - uranium 238 ( 90.3 Bq/l, Bellezane mine),
  - radium 226 ( 3.2 Bq/l, Bellezane and le Brugeaud mine)
  - lead 210 (3 Bq/l, Henriette mine).

Dose coefficients for an adult (ingestion) in microSievert/ Becquerel  
(Official figures from EURATOM 96/29)



Radium 226 activity in raw waters usually exceeds the discharge limit (about 0.37 Bq/l).

In order to cope with French regulation, waters have to be treated. But the treatment process is very raw (radium insolubilisation)



Augères

COGEMA mine (1997) /  
Limousin

Puy de l'Age COGEMA mine (1993) / Limousin



The water treatment plants are not efficient enough and discharge limits are currently exceeded  
(example of COGEMA mines in Limousin / France)

- CRIIRAD measurements (1993) :
- 2 samples out of 5 exceeded discharge limits (radium 226 and uranium 238)
  - Soluble radium 226 (0.67 and 1.1 Bq/l) : above 0.37 Bq/l limit
  - Soluble uranium 238 (40,6 and 33,6 Bq/l) : above 22 Bq/l limit
- According to French regulation « décret n° 90-222 du 9 mars 1990 », those waters should not be discharged to the environment unless local water policy Agency gives a special permit (which was not the case).

- CRIIRAD asked the files with the measurements performed by COGEMA laboratory (C.R.P.M) and discovered that discharge limits were frequently exceeded <sup>(1)</sup> but the French administration did nothing.
- Even at present, in some areas, liquid discharges from old mines (closed more than 20 years ago) do exceed the limits (ex: Les Bois Noirs, COGEMA mine).
- But even if the discharge levels were below the official limits the contamination of the environment would go on because of the accumulation of radioactive heavy metals in the environment.
- (1) Year 1991, **Puy de l'Age** mine discharge was exceeding the soluble Ra 226 limit (0.37 Bq/l):
  - In May (0.64 Bq/l.),
  - June (0.72 Bq/l.),
  - August (0.39 Bq/l.) et
  - September (0.38 Bq/l.).
  - The annual mean was : 0.39 Bq/l.
 Such problems occurred as well in 1991 for liquid discharges from other mines :
  - **La Traverse mine** : between March and June 1991 (annual mean value : 0.43 Bq/l)
  - **Pierre Belle** point 117mine : in June, July and December 1991,
  - **Venachat** mine : in June and July 1991, etc...



# 4-2 / Long term contamination of sediments and aquatic flora and fauna

## Sampling of water and sediments (CRIIRAD) / Limousin area

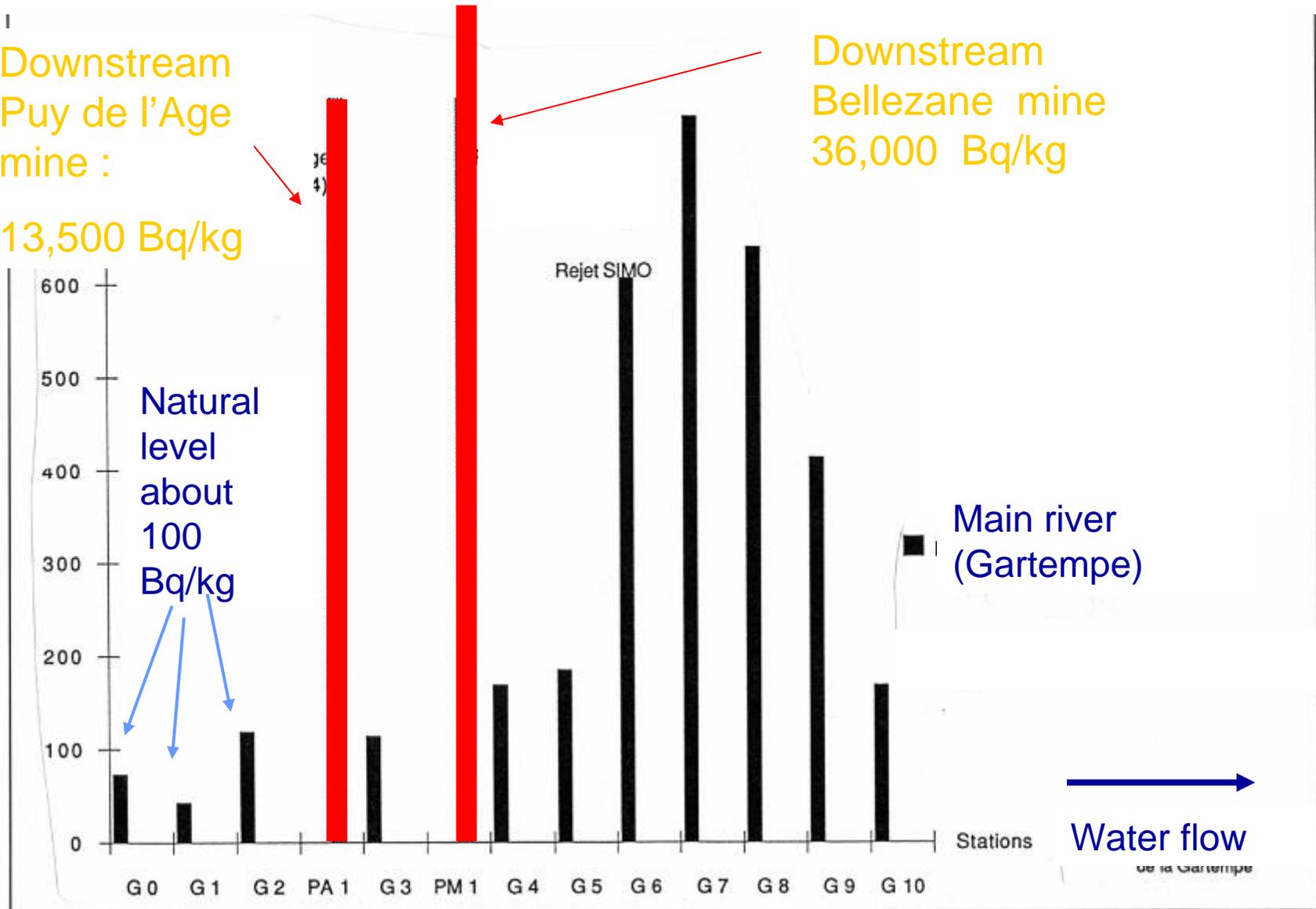


# Uranium 238 (thorium 234) activity in sediments / CRIIRAD Measurements / Limousin 1993

Downstream  
Puy de l'Age  
mine :

13,500 Bq/kg

Downstream  
Bellezane mine  
36,000 Bq/kg



- 1993, CRIIRAD shows that downstream COGEMA uranium mines (Limousin area), sediments and aquatic plants contamination is so high that they may deserve the terminology « Radioactive waste ».
- Sediment contamination :
- Downstream Puy de l'Age mine :
  - Uranium 238 (thorium 234) = 13,500 Bq/kg
  - Radium 226 = 28,700 Bq/kg
- Downstream Bellezane mine :
  - Uranium 238 (thorium 234) = 36,000 Bq/kg

Small river downstream Puy de l'Age  
uranium mine. Contaminated sediments



The former Puy de l'Age mine (Limousin area)  
Picture taken after « Official » rehabilitation.



- Puy de l'Age mine after rehabilitation: 1998
- New CRIIRAD measurements
- River sediments contamination is still very high
- Mine liquid effluents treatment is stopped
- Former water treatment basin contains no more water but radioactive mud is still inside and nothing prevents people or children from going inside the basin
- Nonetheless, the local administration (Prefecture) will agree (1999) with the company statement : the radiological situation is normal and there is no need for further water treatment or environmental monitoring.

Downstream Puy de l'Age mine /  
November 2003 / New CRIIRAD  
measurements



Contamination of the soil of  
the meadow  
Uranium 238 = 20 000 Bq/kg  
Radium 226 = 33 000 Bq/kg

20 times above VLL Radioactive waste  
(Euratom 96/29)

# Downstream Puy de l'Age mine / contaminated meadow with cows / 2003



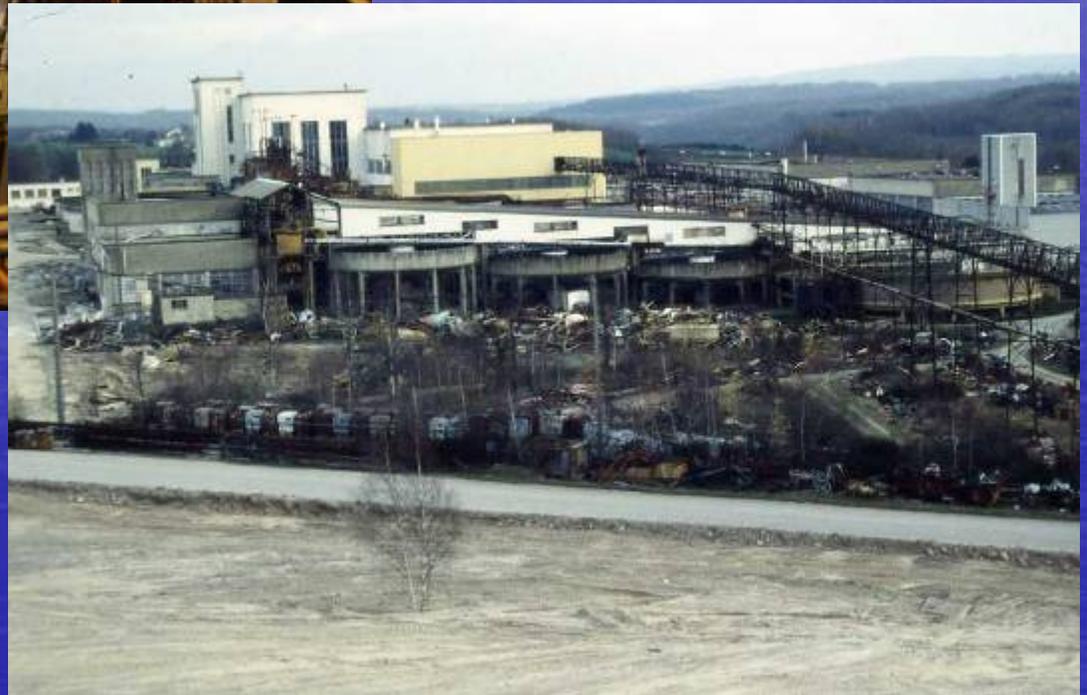
- CRIIRAD comments
- Radiological limits applied to Liquid Discharges from uranium mines are much too high and have to be totally re-assessed
- Water contamination with long lived radioactive metals is too high and create a contamination of sediments, soil near rivers, aquatic plants, etc..
- Environmental monitoring methodologies have to be improved (selection of samples, list of radionuclides to be measured)
- Water treatment plant technologies have to be improved, but it is not sure that affordable technologies exist ... and for the long term.

# 5 / Coping with huge amounts of long lived radioactive waste (tailings)

# 5-1 / What are tailings ?



Uranium mills  
(FRANCE)°



Radionuclide	Half-life	Decay mode	X or gamma emission	Example of gamma emission (Energy, %)
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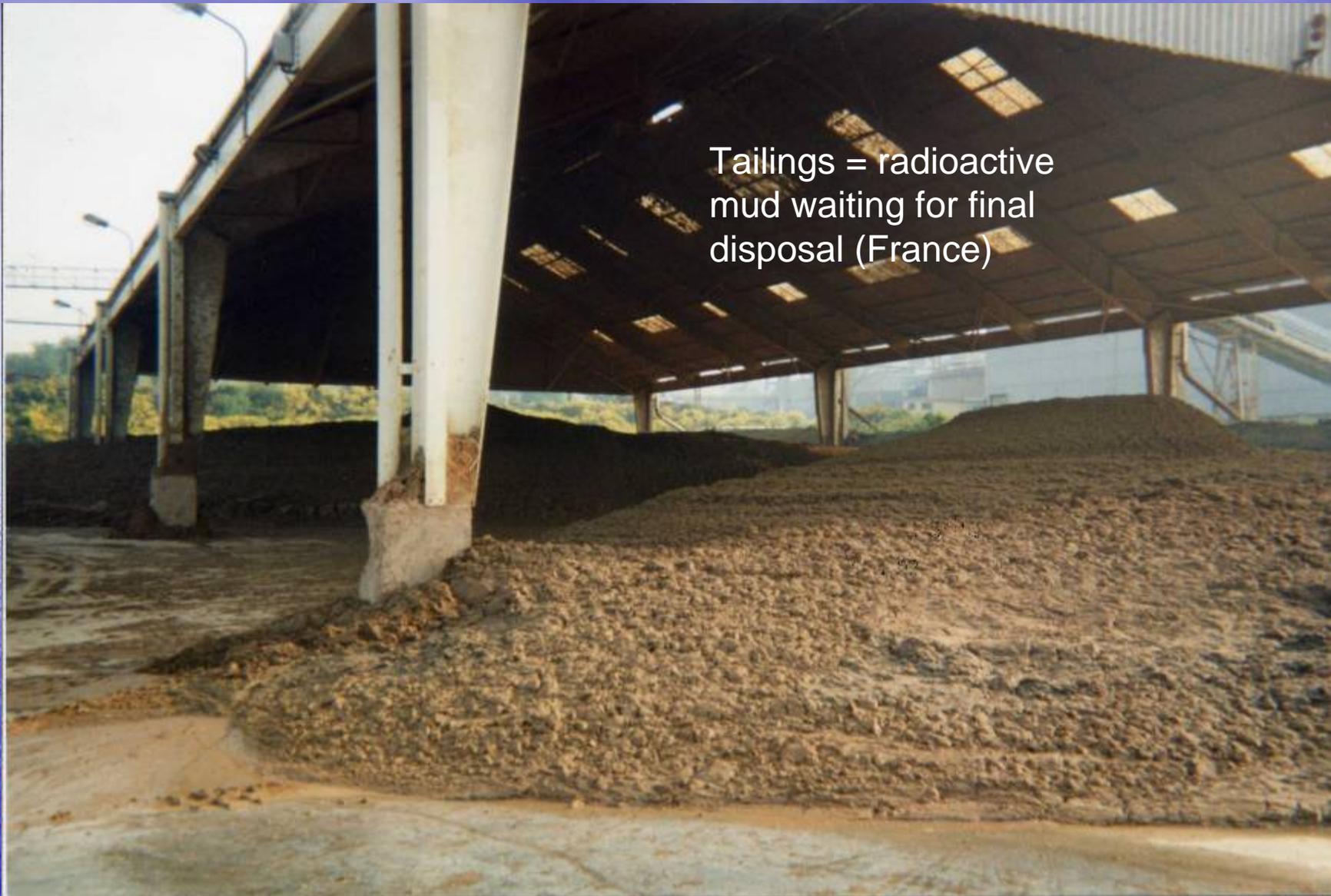
Natural nuclides / earth crust / uranium 238 decay chain / Main nuclides

Uranium 238	4.46 billion	years	Alpha
Thorium 234	24.1	days	bêta
Protactinium 234m	1.17	Minutes	bêta
Uranium 234	245 000	years	Alpha

Most uranium is removed from the ore (ex : chemical reaction with sulfuric acid)

Thorium 230	75 400	years	Alpha
Radium 226	1 600	years	Alpha
Radon 222	3.82	days	Alpha
Lead 214	26.8	minutes	bêta
Bismuth 214	19.9	minutes	bêta
Lead 210	22.3	years	bêta
Polonium 210	138.4	days	Alpha

But other radioactive metals from the U decay chain will remain in the tailings (about 80 % of the initial activity of the ore)



Tailings = radioactive  
mud waiting for final  
disposal (France)

- Tailings do contain radioactive elements
  - Tailings keep about 80 % of the initial activity of the uranium ore
  - They contain : a fraction of uranium isotopes and 10 decay products ( from thorium 230 to polonium 210)
  - Total activity of tailings is
    - higher than 100,000 Bq/kg
    - and sometimes higher than 500,000 Bq/kg

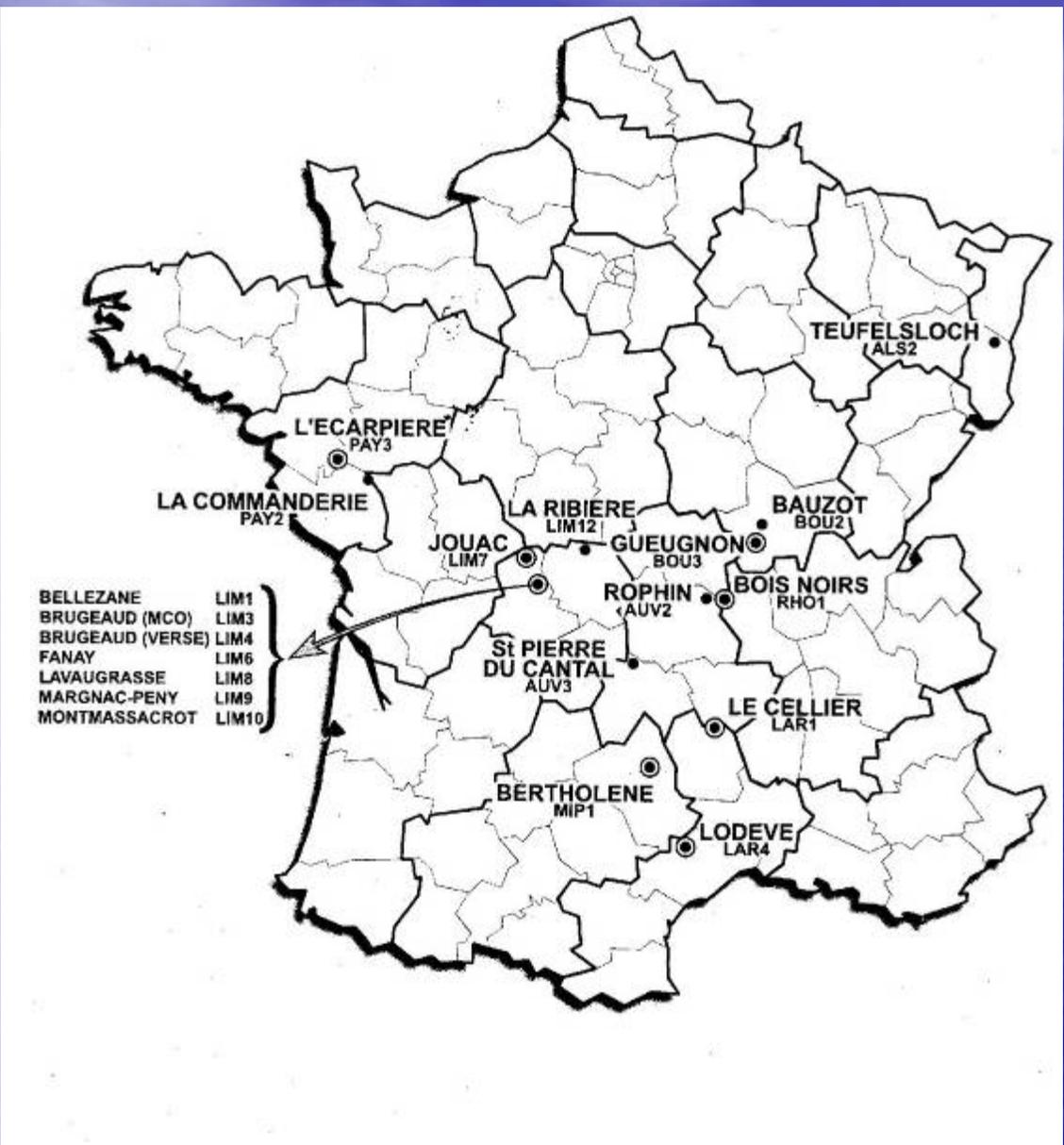
- Tailings are very hazardous substances

- Nuclides with very long half-lives :
  - Thorium 230 = 75,000 years
  - Radium 226 = 1,600 years
- Radionuclides with high radiotoxicity when ingested (Polonium 210 dose coefficient ( $\mu\text{Sv/Bq}$ ) is higher than plutonium 239 one)
- Radionuclides with high radiotoxicity when inhaled (Thorium 230 dose coefficient ( $\mu\text{Sv/Bq}$ ) is close to plutonium 239 one)
- Permanent production of a radioactive gas : radon 222
- Fine grained mud, easily dispersable by wind or water
- Chemical toxicity (heavy metals and acid) : about 100 kg / ton.

# 5-2 / Disposal of tailings (France)

- Tailings in France

- 8 former uranium mills in France
- 50 million tons of tailings have been produced
- Radioactive tailings are « stored » at 20 different places
- Different disposal concepts :
  - Dry storage in former open pits or basins
  - Wet storage under water



FRANCE / COGEMA sites with tailings

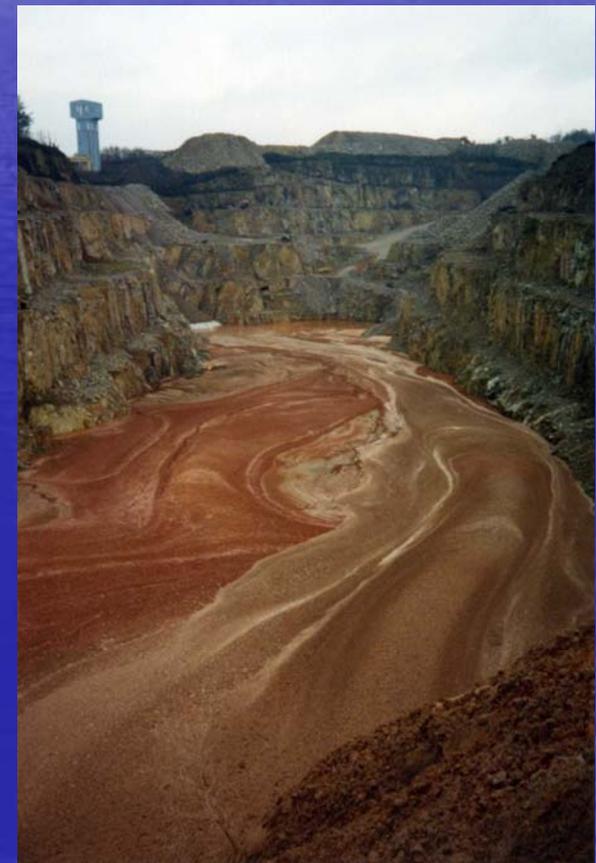
● Ancienne usine de traitement de minerais, avec résidus miniers.

Bessines sur Gartempe (Limousin area, 1993)

Tailings were transported from the mill to the disposal place by truck.  
The radioactive mud was falling down on the streets of the village.  
Local NGO sent a sample of mud to the CRIIRAD laboratory.



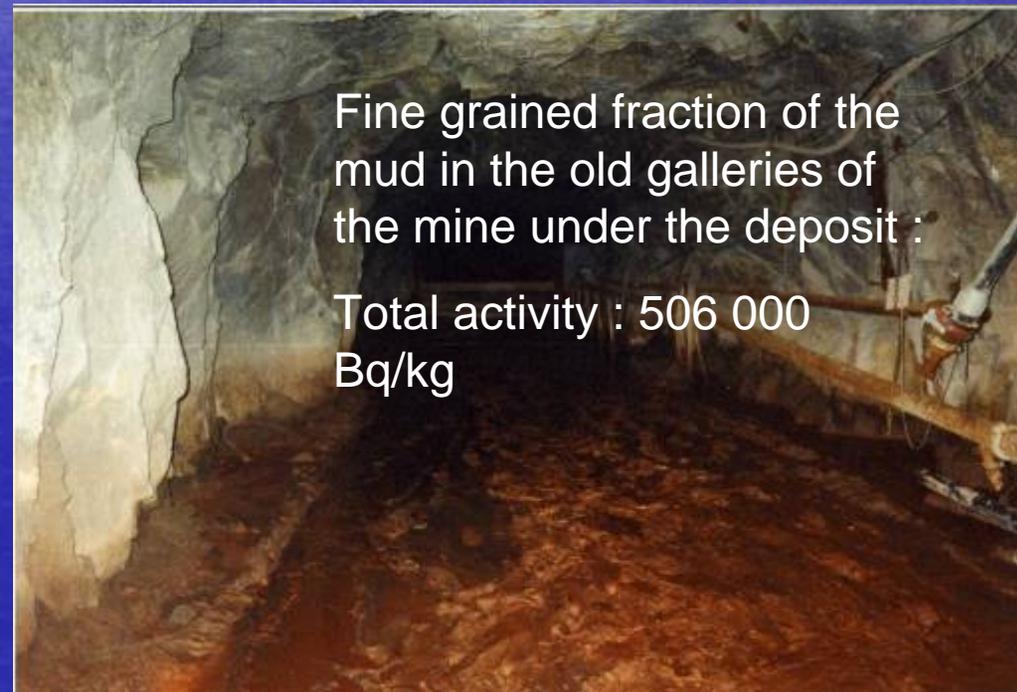
Bellezane disposal place (COGEMA open pit, Limousin area).  
1.3 million tons of tailings stored by the end of 1991.  
CRIIRAD made a survey for the local authorities (Conseil Régional and  
Conseil Général).



# CRIIRAD measurements (1993) / disposal of tailings Bellezane



Mud in the open pit :  
total activity : 256 000 Bq/kg



Fine grained fraction of the  
mud in the old galleries of  
the mine under the deposit :  
Total activity : 506 000  
Bq/kg

The Bellezane open pit (disposal of tailings) is rehabilitated ?



Saint-Priest-La-Prugne (COGEMA site)  
1.3 million tons of tailings are stored under water.  
Artificial dam (18 hectares).

Who will guarantee the dam stability on the very long term ?



# 5-2 / Disposal of tailings (Niger)

## Uranium mill / AREVA-COGEMA / Niger



Radioactive tailings from COMINAK mill  
50 hectares / 10.5 million tons. : Activity above 500,000 Bq/kg  
Tailings are « stored » in the open air :  
What about radon and dust transfer to the atmosphere ?



Twice a day a « cloud » of dust falls upon Arlit streets



CRIIRAD technician is trying to get a sample of dust in Arlit city



# 5-3 / Disposal of tailings (Gabon)

- Gabon (COMUF : subsidiary of CEA-COGEMA)

- From 1961 to 1975, more than 2 million tons of radioactive tailings have been simply discharged into the river

- CRIIRAD comments

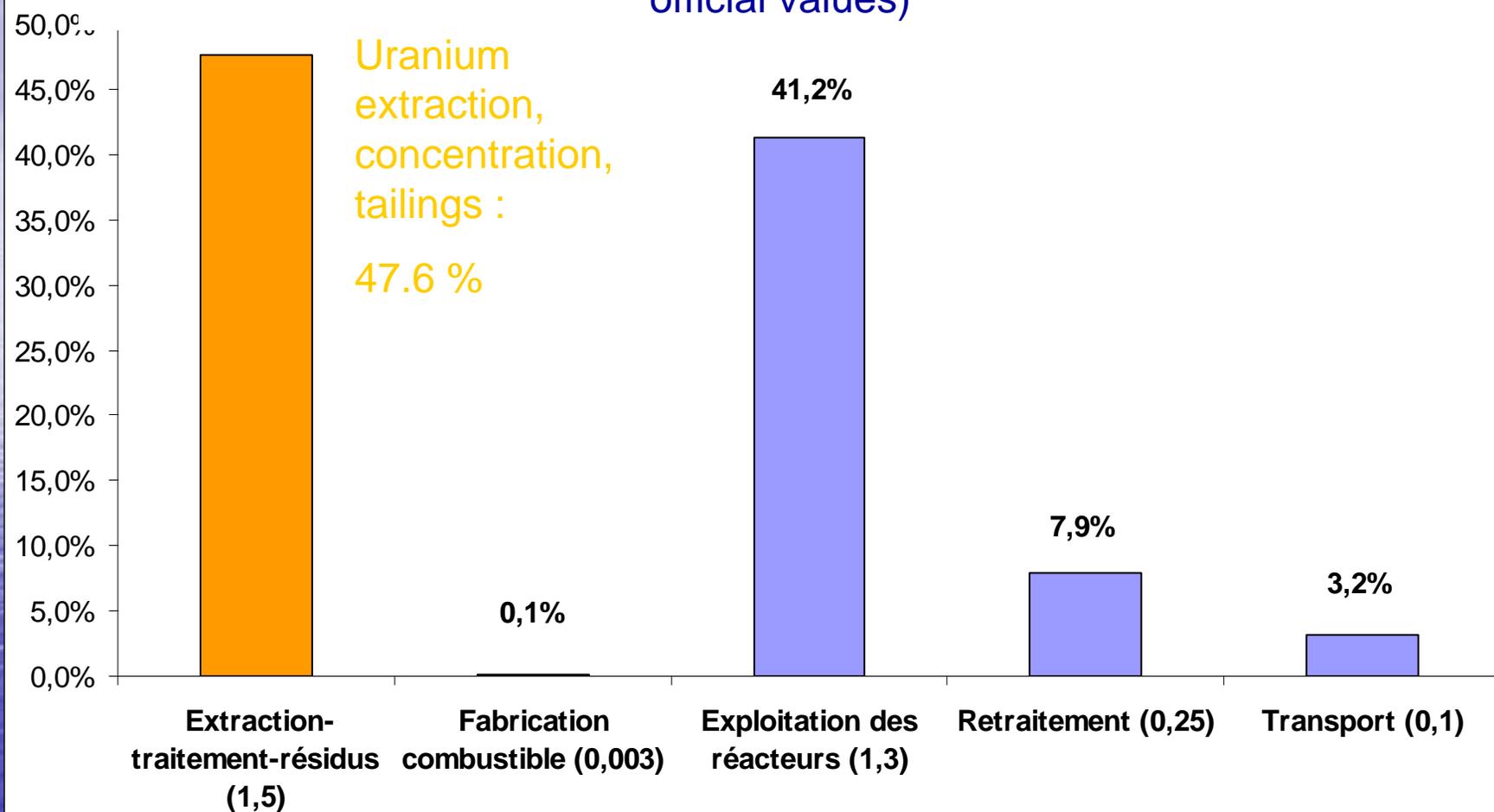
- Improvement of regulatory status of tailings
- Disposal techniques to be improved
- Monetary provisions for long term surveillance
- Improvement of radiological impact studies (hydrogeology)
- Intermediate storage of tailings without proper cover should be forbidden.

## • Conclusions

- Uranium extraction implies a long term contamination of the environment (water, soil, fauna and flora)
- It creates huge amounts of radioactive waste and nobody knows how to manage it on the long term
- Weak and scientifically unsound regulations have been designed to enable uranium extraction at low cost
- In France the main improvements have been obtained after long fights involving local NGO's and CRIIRAD independent laboratory
- Citizens are more efficient if they are in a position to make their own assessments and radiological checks

PS : It is easy to use a Geiger Muller and at each place with uranium resources people should have one in order to check radiation

Global radiological impact of nuclear electricity : local and regional collective dose (man-Sievert per Gigawatt per year : UNSCEAR 1993 official values)



Source: UNSCEAR 1993 (avec coefficients de dose officiels)

## Examples of CRIIRAD laboratory studies in the area of uranium mining impact (1992 à 2004)

- Division minière de Vendée / Site de l'Écarpière / Pour la municipalité de Gétigné / Étude Juridique (1991) et Étude radioécologique (1992-1993)
- Division minière de Vendée / Site de l'Écarpière, La Baconnière, Le Chardon / Pour l'association Moine et Sèvre pour l'Avenir / Étude ponctuelle (1998-1999)
- Division minière de la Crouzille / Pour le Conseil Régional du Limousin et le Conseil Général de la Haute Vienne / Contre-expertise (1993 – 1994)
- Division minière du Forez / site des Bois Noirs Limouzat / Pour le Collectif des Bois Noirs (1996) et la municipalité de Saint-Priest-La-Prugne (2000 – 2003)
- Division minière de l'Hérault (Lodévois) / Étude préliminaire / Sur fonds propres (2003)
- Site de Saint-Pierre (Cantal) / Étude préliminaire / Pour l'association Nos Enfants et leur Sécurité (2003-2004)