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INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Site-Specific Cancer Risk and Occupational Exposure to Uranium

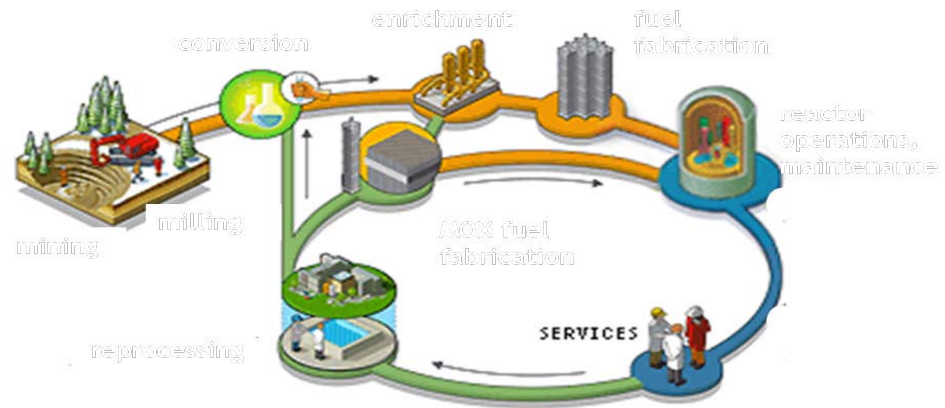
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Introduction

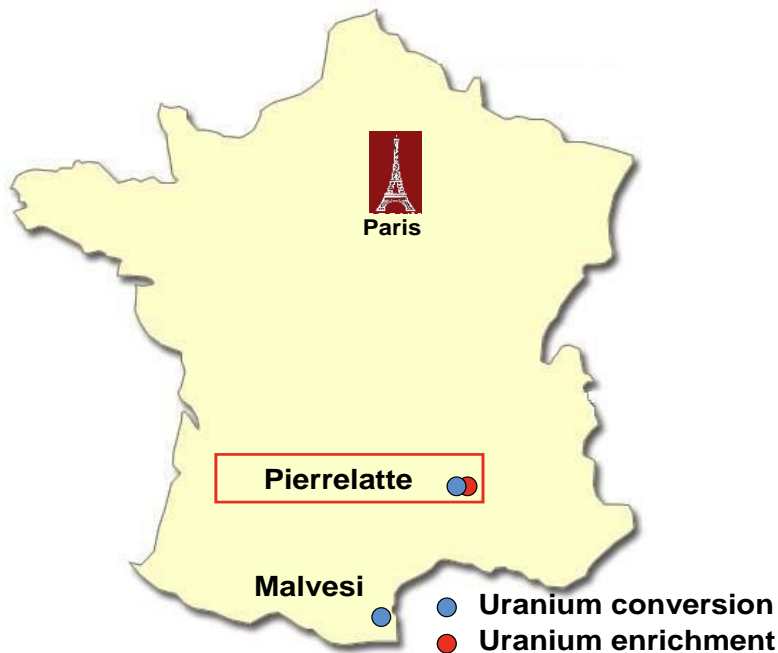


- Due to its fission property Uranium is a key element of the nuclear fuel cycle
- Uranium presents a triple toxicity: chemical, particular, and radiological (as emitter of alpha radiation)
- In occupational conditions, internal radiation exposure occurs from inhalation of airborne radioactive particles (5 μm) and dusts
- Uranium chemical conversion, fuel fabrication, and maintenance are operations at increased risk of internal radiation exposure (*UNSCEAR, 2000*)
- Epidemiological evidence on cancer effect of uranium is limited (*Guseva Canu et al. Health Phys, 2008*)

Objective

To assess the effect of uranium exposure on site-specific cancer mortality among workers potentially exposed to uranium

- AREVA NC Pierrelatte Plant is one of the main uranium conversion plants in France
- It also operated uranium enrichment (1960-1996) and dismantling of enrichment facilities (since 1996)



Uranium target organs:

- lung
- lymphatic and hematopoietic tissue
- soft tissue, upper aero-digestive tract, bone, kidney, liver



Material and methods (1)

Data collection and mortality follow-up definition

Sources of data

- *AREVA NC personnel records*
- *Central archive of dosimetry records*
- *Vital records office of the municipality of birth*
- *National Institute of Statistics and Economic Evaluation*
- *National causes of death registry*

Start of follow-up : 01/01/1968 or date of hire + 6 months

End of follow-up: date of death or 31/12/2005



Material and methods (2)

Exposure assessment

- *AREVA NC plant specific job-exposure matrix* (Guseva Canu et al. *RESP*, 2008; Guseva Canu et al. *IJHEH*, 2008)
- *Exposure agents: 6 categories of uranium compounds and 16 categories of pollutants known as being carcinogenic, mutagenic or toxic that have been ever in used at the plant between 1960 and 2006*

Description of the Pierrelatte cohort: 1968-2005 follow-up

Characteristics	N (%)
Number of employees	2709 (100)
Number of person-years	72786.82
Number of deaths	411 (15.17)
Number of deaths from cancer	193 (7.12)
Socio economic status	n (%)
Managerial/professional	310 (11.44)
Skilled technical	1340 (49.46)
Manual and unskilled	812 (29.97)
Clerical	144 (5.32)
Undefined	103 (3.80)

Characteristics	N (%)
Duration of (years):	(mean \pm SD)
Employment	19.52 \pm 9.86
Follow-up	28.00 \pm 11.18
Average age (years):	(mean \pm SD)
At recruitment	29.72 \pm 7.37
At entry into cohort	32.65 \pm 8.19
At study end-point (31/12/2005)	59.51 \pm 15.04
Monitored for external radiation	1455 (53.71)
Mean cumulative X+ γ dose	6 mSv

Description of the uranium exposure

Type of Uranium*	Detail	Exposed workers n (%)
<i>Natural uranium compounds</i>		
soluble (type F)	UF ₆ , UF ₄ , UO ₂ (NO ₃) ₂ , (UO ₄ , nH ₂ O)	2253 (83.23)
moderately soluble (type M)	(U ₂ O ₇)(NH ₄) ₂ , U ₃ O ₈ , UO ₂ F ₂ , UO ₃	1815 (67.05)
insoluble (type S)	UO ₂	992 (36.65)
<i>Reprocessed uranium compounds</i>		
soluble (type F)	UF ₆ , UF ₄ , UO ₂ (NO ₃) ₂ , (UO ₄ , nH ₂ O)	851 (31.44)
moderately soluble (type M)	(U ₂ O ₇)(NH ₄) ₂ , U ₃ O ₈ , UO ₂ F ₂ , UO ₃	656 (24.23)
insoluble (type S)	UO ₂	475 (17.55)



Material and methods (3)

Statistical analyses

Cox proportional hazards regression model was used to estimate hazard ratios (HR) and 95% confidence intervals (CIs)

- *adjusted for age by the timescale in the model*
- *+ adjusted for the socioeconomic status and calendar period*
- *+ adjusted for the associated chemical exposure*
- *Stata 10 (Stata Corporation, Texas)*

Results (1)

Lung cancer (n=48)	Unexposed		Exposed		HR* (95%-CI)	HR** (95%-CI)
	PYR	D	PYR	D		
<i>Natural uranium compounds</i>						
soluble (type F)	16032.45	12	56754.36	36	0.49 (0.26-0.95)	0.54 (0.28-1.07)
moderately soluble (type M)	31813.84	25	40972.98	23	0.58 (0.33-1.02)	0.69 (0.38-1.24)
insoluble (type S)	53242.75	36	19544.07	12	0.98 (0.51-1.88)	0.98 (0.51-1.90)
<i>Reprocessed uranium compounds</i>						
soluble (type F)	60279.18	42	12507.63	6	0.73 (0.31-1.71)	0.89 (0.37-2.14)
moderately soluble (type M)	64528.84	44	8257.98	4	0.99 (0.36-2.78)	2.01 (0.69-5.86)
insoluble (type S)	65907.59	45	6879.23	3	1.05 (0.33-3.42)	2.12 (0.63-7.12)

* Age-adjusted

** Multivariable-adjusted

Results (2)

Lymphatic and haematopoietic tissue (n=18)	Unexposed		Exposed		HR* (95%-CI)	HR** (95%-CI)
	PYR	D	PYR	D		
<i>Natural uranium compounds</i>						
soluble (type F)	16032.45	3	56754.36	15	0.95 (0.27-3.31)	0.89 (0.25-3.17)
moderately soluble (type M)	31813.84	7	40972.98	11	1.07 (0.41-2.76)	1.12 (0.42- 2.97)
insoluble (type S)	53242.75	12	19544.07	6	1.44 (0.54-3.84)	1.40 (0.52-3.76)
<i>Reprocessed uranium compounds</i>						
soluble (type F)	60279.18	15	12507.63	3	1.07 (0.31-3.72)	1.16 (0.33-4.14)
moderately soluble (type M)	64528.84	17	8257.98	1	0.56 (0.08-4.53)	0.96 (0.12-7.75)
insoluble (type S)	65907.59	15	6879.23	3	2.89 (0.81-10.40)	5.48 (1.33-22.61)

* Age-adjusted

** Multivariable-adjusted

Discussion

Reprocessed uranium: which particularity?

■ Undesirable isotopic contaminants

- ^{232}U , an alpha emitter (half-life 72 years), which rapidly produces descendents that emit alpha, beta, and gamma radiation, notably ^{212}Bi and ^{208}Tl , emitters of hard and intense gamma and beta radiation;
- ^{234}U , an alpha emitter (half-life 24×10^4 years)
- ^{236}U , which implies a higher degree of ^{235}U enrichment than equivalent natural uranium bearing compounds
- transuranians, such as highly radioactive ^{237}Np , ^{241}Am , and the various isotopes of plutonium

Discussion

Limitations and strong points

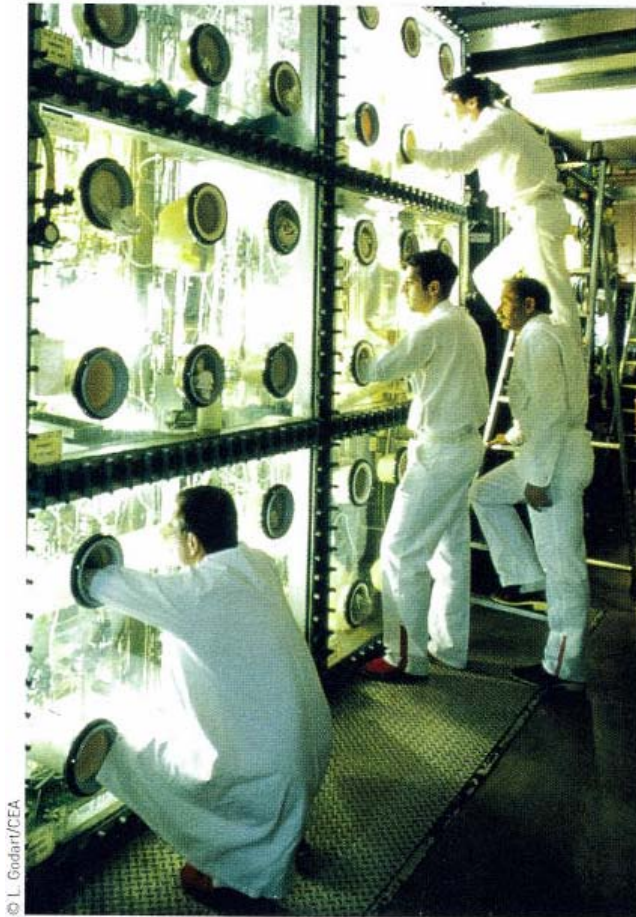
■ Limitations:

- Limited statistical power
- No dose-response analyses
- No accounting for ^{235}U % of enrichment for uranium compounds

■ Strong points:

- Uranium compounds classified through the validated specific and sensitive JEM
- Consistency with experimental studies (solubility and radioactivity)
- Accounting for associated chemical exposure
- Possibility of the cohort extension to other plants in France and UK and Belgium (*PCRD 6, «Alpha risk» project*)

Thank you for your attention



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