A Radiological Protection Study in a French Uranium Refinement Plant

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Introduction

The COMURHEX site of Malvési, belonging to the COGEMA group, is located in the south of France, near Narbonne. This plant converts uranium mining concentrates of natural isotopic composition (uranates and U_3O_8 oxides) into UF_4 through the successive steps of sample-taking, dissolution, precipitation, reduction, fluoration, and reprocessing.

A study has been conducted in 1995 to estimate the annual external and internal exposure of the 170 exposed workers. Internal exposure by inhalation has been derived, on the one hand, from the data of daily averaged activity concentration measured by 26 Fixed Air Sampling (FAS) devices distributed among the several production units and, on the other hand, from an annual estimate of the time spent by each operator at the different workstations, together with the use of the ICRP 68 [1] dose coefficients the most adapted to the solubility (moderate for uranates and slow for oxides) and the granulometry (AMAD=5_m) of the considered compounds. The results of this study showed that the annual collective effective dose (external+internal) of these 170 workers was 350 men.mSv, corresponding to an average annual individual effective dose of 2 mSv with an average contribution of the external exposure of 70%.

A more thorough study of these results showed that, when 60% of the exposed workers were exposed to an annual individual dose below 2 mSv and the most part of annual individual doses were below 5 mSv, 6 workers of the sample-taking workplace (representing only 3% of the 170 exposed workers) were exposed four times more than the average and received 12% of the plant collective dose, with corresponding annual individual doses between 6 and 12 mSv. As far as only internal exposure was analysed, those 6 workers were exposed seven times more than the average and received about 25% of the plant annual internal collective dose, with corresponding annual individual doses between 1.5 and 6 mSv.

Finally, interpretation of the monthly urinary excreta as well as the yearly lung counting results of the sample-taking station workers for 1993 (with use of the ICRP 66 [2], 54 [3] et 68 [1] models as well as the LUDEP 2.0 code [4] for slow, 5_m AMAD compounds) showed that the annual dose estimates based on workplace air sampling could possibly underestimate the annual effective internal dose, for annual individual doses derived from urinary excreta ranged from 10 to 40 mSv while doses derived from the yearly lung counting results - all below the detection limit – could nevertheless be compatible with annual doses as high as 50 mSv.

The results of this first study leaded to pursue efforts to better assess the dose of the workers of the sample-taking station as well as to study the principal characteristics of their exposure, in order to identify possible corrective actions and optimise the radiological protection of these workers. A comparison of the adequacy of various dose assessment methods for the optimisation of radiological protection in the case of exposure by inhalation to natural uranium compounds was then conducted in 1997. The best-adapted dose assessment methods were then used to conduct several measurement campaigns in 1997 and 1998 at the sample-taking workplace.

This paper will present the results of those two studies.

1. Adequacy of measurement methods to radiological protection optimisation

The optimisation of protection implies a realistic, sensitive and analytical assessment of individual and collective exposures in order to allow the identification of the main sources of exposure and the selection of the optimal protection options, for individual dose levels by far lower than annual limits [5].

The assessment of internal exposure by inhalation relies on the measurement of physical indicators which describe the exposure as well as on the application of a sequence of models [6]. The exposure model allows to estimate the inhaled activity on the basis of the measured indicator and of every characteristics of the exposure (identification of inhaled compounds, spatial and time profile of the exposure…) and the considered individual (ventilation rate, excretion, retention…). The dosimetric model allows then to evaluate the effective committed dose, most often by the simple use of default, or on purpose calculated, dose coefficients.

The realism of the dose assessment (i.e. minimal bias and uncertainty) will thus rely as well on the realism of the exposure model as on the realism of the different dosimetric (pulmonary, digestive and excretion, biokinetic and excretion, irradiation and weighting) sub-models. An essential point there is the great sensitivity of the pulmonary sub-model to the solubility and granulometry of the inhaled compounds [7].

Finally, the analysis of the exposures implies the identification of the principal sources of contamination, of the tasks giving rise to the highest exposure, of the most exposed workers, as well as a high enough sensitivity for measurement intervals compatible with the tasks analysis.

1.1 Realism of measurement methods

The analysis of the different parameters and models used in turn to assess the dose allows to propose the following description (see Figure 1) of the most obvious sources of uncertainty in the dose assessment for each of the considered measurement method:

OBSTACLES TO REALISM	Air sampling			Bioassays	
	Collective	Individual		Urinary excreta	Lung retention
		5 l/h	120 l/h		
Atmospheric activity non representative of inhaled air					
Estimation of ventilation rate					
Estimation of time spent at the workstations					
Hypothesis of a given time profile exposure					
Urinary concentration non representative of daily excretion					
Use of a urinary excretion model					
Use of a pulmonary model					
Use of a dosimetric model (dose factors)					

Unimportant	Some important	Important	Very important

Figure 1. Realism of measurement methods

- For collective air sampling, the uncertainty relies essentially in the representativeness of the sampled air compared to the inhaled air, as well as on the quality of the estimates of the ventilation rate and of the time spent by the workers at the different work stations being sampled.

- For individual air sampling, the uncertainty depends essentially on the possible difference between the measured and inhaled activity concentrations as well as on the estimate of the ventilation rate of the considered individual. This uncertainty is much lower than the one associated with the collective air sampling as long as the sampling is made close enough to the respiratory tract entrance and the sampling rate is high enough to permit a representative sampling of the ambient particles.

- For urinary excreta measurements, beyond the problem of the representativeness of the urinary samples which may be greatly reduced by the normalisation of the samples to their creatinine content [8], the most part of the uncertainty relies on the adequacy of the systemic urinary excretion function to the considered individual and, above all, on the determination of a realistic exposure time-profile, for the dose associated with a given measurement will depend heavily on the time elapsed between the intake and the measurement. However, one could imagine using the results of frequent enough personal air sampling measurements to help in the determination of a realistic incorporation time-profile.

- For lung retention measurements, the uncertainty relies principally in the determination of a realistic exposure time profile. Moreover, as well as for urinary excreta measurements, a higher measurement frequency, as well as the consideration in the dose estimation (for the most insoluble compounds) of the activity inhaled during preceding measurements allows to increase the realism of the dose assessment.

1.2 Sensitivity of measurement methods

Generic calculation (see Table 1) have been made for each measurement method in order to evaluate the dose distribution (detectable dose distribution) corresponding to a measurement equal to the detection limit, as well as the yearly dose distribution (yearly detectable dose distribution) corresponding to a sequence of measurements equal to the detection limit.

Table 1. Sensitivity of measurement methods

Measurement characteristics					
	Air sampling			Bioassays	
	Collective	Individual		Urinary excreta	Lung retention
Sampling rate	1 200 l/h	5 l/h	120 l/h		
Periodicity	1 day	30days / 1 day	30days / 1 day	30 days	180 days
Detection limits	220 mBq UNAT filter	9 mBq UNAT filter	9 mBq UNAT filter	0,1 µg U/l urine	150 Bq UNAT lung
Detectable doses for one single measurement					
Fast solubility	0.2 µSv	2 µSv	0.07 µSv	1 µSv IC95 (0.2-2 µSv)	-
Moderate solubility	0.5 µSv	5 µSv	0.2 µSv	10 µSv IC95 (3.6 -18 µSv)	13 mSv IC95 (5-20 mSv)
Slow solubility	2 µSv	20 µSv	0.7 µSv	1.5 mSv IC95 (0.5-2.4 mSv)	24 mSv IC95 (16-28 mSv)
Detectable doses per year for measurements equal to the detection limit					
	1 measurement/ day	1 measurement/ month/day	1 measurement/ month/day	1 measurement/ month	2 measurements /year
Fast solubility	30 µSv	20 µSv 0.3 mSv	0.7 µSv 10 µSv	9 µSv IC95 (6-11 µSv)	-
Moderate solubility	100 µSv	50 µSv 1 mSv	2 µSv 40 µSv	59 µSv IC95 (50-66 µSv)	21 mSv IC95 (11-31 mSv)
Slow solubility	300 µSv	200 µSv 3 mSv	7 µSv 100 µSv	6 mSv IC95 (5.7-6.7 mSv)	30 mSv IC95 (25-32 mSv)

For air sampling methods, the detectable doses have been estimated by the simple application of the ICRP 68 [1] dose coefficients. For bioassays, the detectable dose corresponding to a given time after a single intake has been estimated by calculating the corresponding inhaled quantity with the LUDEP 2.0 software [4], which applies the ICRP 66 [2] and ICRP 54 [3] pulmonary and biokinetic models, and by applying the ICRP 68 dose coefficients. The detectable dose distributions have been then estimated by the use of a monte-carlo technique based on a uniform distribution of the time elapsed since intake between a 3 days exclusion time and the measurement interval.

- For a Fixed Air Sampler (FAS) sampling 1200 l/h, a detection limit (5 mn counting) of 220 mBq of natural uranium (Unat) on the filter, a particle collection fraction for 5µm AMAD particles of 80% and a ventilation rate of 1.2 m^3/h, the doses associated with the detection limit (detectable dose) are around 0.2, 0.5 and 2 µSv/measurement for compounds of fast, moderate and slow solubility, corresponding to an average yearly dose of 30, 100 and 300 µSv/year for a sequence of measurements equal to the detection limit.

- For a Personal Air Sampler (PAS) sampling 5 l/h, a detection limit (1 h counting) of 9 mBq Unat on the filter, the same particles collection fraction and ventilation rate, the detectable doses are around 2, 5 and 20 µSv/measurement for compounds of fast, moderate and slow solubility, corresponding to an average yearly dose of 20, 50 and 200 µSv/year for a sequence of monthly measurements equal to the detection limit and 0.3, 1 and 3 mSv/year for a similar sequence of daily measurements.

- For a High Sampling Rate Personal Air Sampler (HSR-PAS) sampling 120 l/h, the same detection limit (1 h counting) of 9 mBq Unat on the filter, the same particles collection fraction and ventilation rate, the detectable doses vary in proportion with the sampling rate and are thus 24 times lower than those of the PAS. These doses are around 0.07, 0.2 and 0.7 µSv/measurement for compounds of fast, moderate and

slow solubility, corresponding to an average yearly dose of 0.7, 2 and 7 µSv/year for a sequence of monthly measurements equal to the detection limit and 10, 40 and 100 µSv/year for a similar sequence of daily measurements.

- For a detection limit in urine of 0,1 µg U/l (i.e. 2,5 mBq/l Unat), a daily urinary excretion of 1.4 l/j, a measurement period of 30 days and an exclusion duration of 3 days, the average detectable doses received between two measurements are around 1µSv, 10µSv and 1.5 mSv/measurement (with 95% confidence intervals (CI) of 0.2-2 µSv, 3.6-18 µSv, and 0.5-2.4 mSv) for compounds of fast, moderate and slow solubility, corresponding to an average yearly dose of 9 µSv/year, 59 µSv/year and 6 mSv/year (with 95% CI of 6-11 µSv/year, 50-66 µSv/year and 5.7-6.7 mSv/year) for a sequence of monthly measurements equal to the detection limit.

- For a detection limit of lung activity of 150 Bq Unat, a measurement period of 180 j and an exclusion duration of one day, the average detectable doses received between two measurements are around 13 and 24 mSv/measurement (with 95% CI of 5-20 mSv and 16-28 mSv) for compounds of moderate and slow solubility, corresponding to an average yearly dose of 21 and 30 mSv/year (with 95% CI of 11-31 mSv/year and 25-32 mSv/year) for a sequence of two measurements equal to the detection limit.

1.3 Analytical capabilities of the measurement methods

As shown on Figure 3, the main interest of FAS for the analysis of the exposures is that they allow (with a high enough sensitivity in the case of natural uranium compounds) daily measurements of activity concentration close to the contamination sources and the workstations which may give first indications on the most important sources of contamination as well as on the workstations being the most at risk. However, the main difficulty in the use of this measurement method for such an analysis is the lack of realism in the assessment of workers exposure [9].

The main interest of PAS and HSR-PAS is the realism in the evaluation of workers individual exposures as well as the possibility of identifying the tasks where the workers are the most exposed, through the use of dedicated measurement campaigns where such a sampling system is allocated to each task. However, the PAS with the lowest sampling rate do not allow a sensitive and representative assessment of exposures to natural uranium for sampling duration below one week. Finally, the use of FAS seems to be more appropriate for identification and daily control of possible sources of contamination.

The principal interest of urinary excreta measurements is their ease of use and the realism in the assessment of workers exposure, as long as one may dispose of representative samples, a realistic estimation of the incorporation time-profile, and a high enough measurement frequency. However, one must note the low sensitivity of monthly (or bi-monthly) measurements for the least soluble natural uranium compounds, and the difficulties that more frequent measurements could raise. Nevertheless, such measurements may help to validate the dosimetric estimations based on air sampling systems.

The main interest of lung retention measurements is the realism (even more important than the one of urinary excreta) in the assessment of workers exposure. However, beyond the inadequacy of such measurements for the most soluble compounds, their very low sensitivity for natural uranium compounds as well as the difficulties of their use seem to remove any interest of this method for the optimisation of radiological protection.

	Air sampling				Bioassays	
	Collective	Individual			Urinary excreta	Lung retention
		5 l/h	120 l/h			
Measurement periodicity	1 j	5 j	5 j	1 j	30 j	180 j
Sources						
Tasks						
Operators						

Very good	Good	Average	Insufficient	Very insufficient

Figure 3. Adequacy of measurement methods to optimisation

1.3 Conclusion

For exposure by inhalation to natural uranium compounds, the study of the realism, sensitivity and analytical capabilities of the various measurement methods showed that:

- Collective air sampling methods (FAS) are a good mean of first identification of the principal sources of contamination and the most exposed workers.

- Individual air sampling systems (PAS) and particularly those with a high sampling rate (HSR-PAS) are the most adapted to the assessment of individual doses as well as to the identification of the tasks the most at risk.

- Measurements of urinary excreta are an interesting mean of validating the individual exposure estimates based on air sampling methods.

- The optimisation of radiological protection in such a context should be done by the simultaneous use of those complementary measurement methods.

2. Exposure analysis and measurement methods comparison in the sample-taking workplace

The workers of the sample-taking workplace take systematic samples of every drums of mining concentrate in order to analyse and record their uranium and impurities content. The successive steps of the process are the manual unbanding of the drum (unbanding stations), the - fully automated and confined - lid removal, drum emptying, primary (1%) and secondary sampling (1%) of the drum content, the automated filling and lid replacement of the drum (filling station), the manual removing of the secondary samples (secondary sampling station), the drum rebanding (rebanding station), and finally the preparation of samples in a laboratory.

The study carried out attempted to identify, through a number of measurement campaigns using personal and fixed air sampling apparatus, the operations which contribute the most to the exposure of operators at the sample-taking workplace. The study also included a comparison and analysis of the results of the different air sampling measurement methods used to determine which were, in this particular situation, the most suitable for analytical (task by task) estimation of individual doses with a view to optimisation of exposures.

2.1 Estimation of exposures per task with collective air sampling

Determination of per-task exposures by the combined use of fixed air sampling apparatus (FAS) (for the evaluation of daily average activity concentrations) and personal air sampling systems (PAS) assigned to each task (for evaluation of the daily work times at each station of a reference operator) has shown (see Table 2 on next page) that the workstations with the highest exposure in the months of May and June 1997 (excluding cleaning operations) were the rebanding stations (53%) and the unbanding stations (18%) (platform function) as well as the laboratory (14%) and the secondary sample-taking stations (8%) (laboratory function). It is interesting

to note that the platform function which represents only 49% of the time spent, makes a 77% contribution to total exposure, which shows the more than average activity concentrations encountered at the corresponding workstations. Conversely, the laboratory function, which represents 51% of the time spent, represents only 23% of the total exposure excluding cleaning, which shows the less than average activity concentrations encountered there.

2.2 Estimation of exposures per task with individual air sampling

Comparison of the results of these exposure calculations with those of evaluations based on the one-month accumulated exposure readings of the PAS assigned to each of the tasks has shown (see Table 3 on next page) that the latter indicated a similar ranking of the stations in terms of relative contribution to exposure with 77% of exposure for the unbanding and rebanding stations, and 13% for the secondary sample-taking station, which were the only two working stations for which the one-month integrated activity was greater than the detection limit.

However, it was found that the exposure estimates for May and June 1997 based on the PAS results for those two tasks were greater by a factor of 30 to 100 (45 to 70 for both months combined) than the corresponding estimates made using the FAS. Thus, the annual individual doses corresponding to exposure during these two months of the reference operator (calculated using a 1.2 m^3/h ventilation rate and a dose factor derived from ICRP Publication 68 [1] with the help of the LUDEP 2.0 software [4] for a compound of low solubility and an AMAD of 10 _ m^1) were 0.43 mSv/year and 18 mSv/year respectively, depending on whether they were determined using FAS or PAS.

Table 2. Contributions of tasks to total operation time and exposure

	Contribution to total operation time	Contribution to total exposure	
		(FAS)	*(PAS)*
Platform function			
Unbanding	**26%**	**18%**	**77%**
Rebanding	**17%**	**54%**	
Lid unsticking	3%	2%	*2% **
Empty drums	1%	2%	*2% **
Computer room	4%	1%	*2% **
Laboratory function			
Computer room	3%	1%	*2% **
Laboratory grinding	**5%**	**3%**	*2% **
Laboratory heating	**36%**	**11%**	
Secondary sampling	**5%**	**8%**	**13%**
Total	100%	100%	100%
Platform function	**51%**	**77%**	**83%**
Laboratory function	**49%**	**23%**	**17%**

(*) One month integrated activity below detection limit

[1] Standard value close to the mean aerodynamic diameter of 9 _ m measured at the workstations.

Table 3. Dose estimates per task (2 months) by FAS and PAS

	Effective dose (Sv)		PAS / FAS
	FAS	PAS	
Platform function			
Unbanding	**6.1E-05**		**44**
Rebanding		2.7E-03	
Lid unsticking	2.1E-06	7.0E-05*	33*
Empty drums	1.5E-06	6.9E-05*	46*
Computer room	1.1E-06	8.2E-05*	73*
Laboratory function			
Computer room	5.8E-07	7.3E-05*	278*
Laboratory grinding	1.2E-05	8.4E-05*	7*
Laboratory heating			
Secondary sampling	**6.6E-06**	**4.6E-04**	**69**
Total	**8.6E-05**	**3.6E-03**	
Total annual dose	**4.3E-04**	**318E-03**	

(*) One month integrated activity below detection limit

The study then tried to determine the reasons for the significant difference between the measurements made by FAS and PAS, seeking to establish whether these differences result from the existence of contamination peaks during operations (whose contribution is correctly integrated by the PAS but underestimated in the daily average of the FAS), the presence of systematic bias in the activity concentration measurement of either method, or the different sampling positions (distance and height) of both apparatus in relation to the sources of contamination.

2.3 Testing for the existence of contamination peaks during operations

To determine whether any concentration peaks generated by the operations themselves could explain the disparity between the exposure evaluations made with FAS and PAS, the best approach appeared to be to study the correlation between the daily averaged activity concentrations measured with the FAS at the different workstations and the amount of time spent there by the operators.

This study showed a significant positive correlation between the daily average concentration at the unbanding station and the time spent by the reference operator at this place, as well as a significant negative correlation between the daily average concentration at the secondary sampling station and the time spent by the reference operator at this place. No significant correlation between the average concentration and the time spent by the operator were found for the other stations.

In order to interpret the observed correlations, we may try to formulate as follows the relation existing, at a given workstation, between average activity concentration measured by a FAS and activity concentrations existing at this station during and outside the operations conducted at this station:

$$C_{FAS} = (T_{work} C_{work} + (T - T_{work}) . C_{T - T_{work}}) / T$$

with:

C_{FAS}	Daily averaged activity concentration measured by the Fixed Air Sampler (FAS)
C_{work}	Daily averaged activity concentration during operations
$C_{T-T_{work}}$	Daily averaged activity concentration outside operations
T	Daily measurement duration of the FAS
T_{work}	Daily operation duration

Similarly, activity inhaled during operations at a given workstation may be expressed as follows:

$$A = V_R \cdot T_{work} \cdot C_{work}$$

with:

A	Daily activity inhaled during operations
V_R	Ventilation rate

We may then test the impact on these formulations of three simple categories of activity concentration time profile during operations:

1. Operations at a given workstation have no impact on the contamination of this workstation ($C_{FAS} = C_{work}$).

The average activity concentration and the operation duration are then independent and activity inhaled during operations at a given workstation may then be expressed as:

$$A = V_R \cdot T_{work} \cdot C_{FAS}$$

2. Operations at the workstation are the only source of contamination of this workstation ($C_{T-T_{work}} = 0$)

The average activity concentration and the operation duration are then positively correlated and activity inhaled during operations at a given workstation may then be expressed as:

$$A = V_R \cdot T \cdot C_{FAS}$$

3. The contamination of the workstation is null during operations ($C_{work} = 0$)

The average activity concentration and the operation duration are then negatively correlated for

$$C_{FAS} = (1 - T_{work} / T)\, C_{T-T_{work}}$$

and activity inhaled during operations at a given workstation may then be expressed as:

$$A = V_R \cdot T_{work} \cdot C_{work} = 0$$

This formulation, together with the observed correlations between activity concentrations measured by the FAS and total duration of operations, allowed us to divide the workstations into three types:

1. The rebanding workstation is characterised by the fact that the operations carried out there appear to be the main source of contamination of the station. The estimation of the exposure there using FAS could be thus carried out by simply multiplying the daily average activity concentrations measured by the sampling time per day. However, an exposure estimate of this type still remains lower by a factor of 10 than one using PAS.

2. The secondary sample-taking station exhibits contamination which appears to diminish while operations are carried out there. The use of FAS measurements would appear to be ill suited for estimating the exposure received in such a station.

3. Finally, it would appear that the operations carried out in all the other workstations have little impact on the contamination prevailing there and that the method consisting of multiplying the average daily activity concentration measured using FAS by the daily work duration appears to be the best suited for determining exposure on the basis of FAS measurements.

2.4 Testing for the existence of systematic bias in the activity concentration measurement methods

To detect systematic bias in FAS and PAS exposure estimates, two measurement campaigns were carried out (December 1997 and March 1998) to compare the monthly activity accumulated over eight hours per day by

PAS and FAS placed at a distance of less than 30 cm and operated simultaneously. The results of these measurements have made it possible to observe differences of up to a factor of three (on one side or another) in exposure estimates made using FAS and PAS. In the light of these results, there is assumed to be no systematic overestimation of the measurement of activity concentration by PAS compared to FAS but an important variability which may be possibly due to high activity concentration gradients.

2.5 Testing for the importance of sampling position

Finally, the importance of the sampling point position relative to the sources of contamination and the operator's respiratory tract entrance was evaluated during a March 1998 measurement campaign to compare simultaneous estimations of exposure carried out using a PAS worn at the waist and a HSR-PAS, offering greater exposure estimation reliability, due to its higher sampling rate and its sampling point as close as possible to the entrance of the operator's respiratory tract. The results of this campaign have shown that for both platform and laboratory tasks, monthly exposure estimates made using PAS exceeded those made using monthly totals of the daily HSR-PAS measurements by a factor of two. That difference can be possibly explained by the greater proximity to the sources of contamination of the PAS, which is worn at the waist. These results confirmed thus the acceptable accuracy of the PAS measurements under these conditions and suggested the existence of important contamination gradients which may partly explain the still lower activity concentration measurements of FAS, which are further away from the sources of contamination and higher, compared to HSR-PAS.

3. Conclusion

The different results of this study have shown that although FAS may produce representative measurements of average daily activity concentrations at sampling points close to workstations, their use for the estimation of exposure (including the case where there is precise information on exposure times), is more uncertain and may result in substantial underestimation of exposure. This is because FAS measurements fail to properly reflect the dynamics of exposure, due to variation in contamination over time and space in the workstations and to operator movement.

As PAS are worn by operators, a more representative estimation of exposure is obtained, but their low sampling rate can provide, for reason of sensitivity, only monthly exposure estimates. Moreover, when this type of device is worn at the waist, a representative sample of the air inhaled cannot be obtained in the presence of high activity concentration gradients.

Due to their high sampling rate and their sampling point which is representative of the air inhaled, HSR-PAS make it possible to make sensitive estimates that are highly representative of daily exposure and appear to be the most suitable for analysis of exposures. The possibility of making daily measurements means that this device not only constitutes an operational dosimetry system but also a tool for analysing the causes and implementing corrective action in the event of abnormally high individual exposure. Its daily measurements could also be used to determine a realistic incorporation time-profile for the dosimetric interpretation of bioassays. Finally, the measuring campaigns carried out have demonstrated the feasibility of on-site daily measurement of the activity of the filters of the HSR-PAS. The main drawback of this system remains the fact that it is relatively heavy, weighing approximately one kilogram. However, the possibility of placing the filter at a distance from the main part of the equipment makes it possible to envisage a suitable carrying system.

The different measurements made with FAS and PAS have made it possible to establish the substantial contribution (more than half) of the rebanding station to the sampling workplace operators exposure. The study of correlation between activity concentration and operation duration permitted to postulate that most of the exposure at the rebanding station result from contamination peaks generated by the operations carried out there. A real-time contamination measurement campaign conducted latter, confirmed the existence of these peaks and proved the capability of such a correlation analysis to provide valuable information on the contamination time-profile at the different workstations.

On the basis of this radiological protection study, protection actions related to the rebanding station (automation, confinement…) have been searched for and an optimisation study will be soon conducted to choose the most cost-effective radiological protection option.

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