RADIATION PROTECTION - SELECTED TOPICS
Paper presented at Int. Symposium
Dubrovnik, 2-6 October 1989

ON SISTEMATIC AND STATISTIC ERRORS IN RADIONUCLIDE MASS ACTIVITY ESTIMATION PROCEDURE

Smelcerovic M.*, Djuric G.**, Popovic D.**
* "Boris Kidric", Institute of Nuclear Sciencies, Beograd, Yugoslavia
** Faculty of Veterinary Medicine, Beograd, Yugoslavia

ABSTRACT

One of the most important requirements during nuclear accidents is the fast estimation of the mass activity of the radionuclides that suddenly and without control reach the environment. The paper points to sistematic errors in the procedures of sampling, sample preparation and measurement itself, that in high degree contribute to total mass activity evaluation error. Statistic errors in gamma spectrometry as well as in total mass alfa and beta activity evaluation are also discussed. Beside, some of the possible sources of errors in the partial mass activity evaluation for some of the radionuclides are presented. The contribution of the errors in the total mass activity evaluation error is estimated and procedures that could posibly reduce it are discussed.
Keywords: Accidents, Calibration, Standards, Environmental

INTRODUCTION

Radionuclides mass activity evaluation methods for environmental samples enable identification and radionuclides partial activities estimation (alfa and gamma spectrometry, radiochemical separation procedures)as well as fast estimation of radiocontamination levels (total alfa and beta activity estimation methods) (4,5). The fast estimation procedures are inevitable in accidental situations due to large number of contaminated samples and lack of time, but only data on radionuclides partial activities present a complete information on the radiocontamination level on the whole.

An accidental situation requires an optimization of working conditions considering the total error of the applied method. But the specifity of the situation causes a number of sistematic errors not usually present in the regular working conditions that are often significantly higher than inevitable statistic ones.

The aim of this work is to point to the main sources of errors in accidental situations measurements and to discuss it.

MATERIALS AND METHODS

The total error in the radionuclides mass activities evaluation procedures is due both to statistic and sistematic errors. Sistematic errors emerge in sampling, sample trasportation and sample preparation procedures, as well as in the measuring procedure itself. On the other hand, statistic errors are mainly due to the statistic nature of the phenomenon of radioactivity, but the process of radioactive contamination could also be a statistic one, as it depends on many factors difficult to forsee: origin and physico-chemical characteristics of the radioactive material, microhydrometeorological conditions, configuration and geochemical composition of soil, planted cultures, cattle breeding conditions.

The sistematic errors most oftenly present in the radio-nuclides mass activities estimation procedures are presented in Table 1.

Table 1. Sistematic errors in radionuclides mass activity estimation procedures

Errors in:	Due to :	Estimated value:
CHOISE OF SAMPLE	sample nonrepresentative, as it should represent the totality (for instance, 1 l of milk per 10.000 l, or a number of soil samples proportional to surface area of specific configuration)	$\sigma_k \approx 1000-5000\%$
	A. Errors in S A M P L I N G	
SOIL SAMPLING	unadequately defined area of soil sampling considering configuration and chemical composition of soil, as well as difficulties in thickness and depth of soil layer estimation	$\sigma_{u1} \approx 50\%$
PLANTS SAMPLING	unadequately chosen part of plant,	$\sigma_{u2} \approx 20\%$
	highly contaminated soil deposited on root or radionuclides shaken off stem,	$\sigma_{u3} \approx 20\%$
	radionuclides shaken off leaves or fruits	$\sigma_{u4} \approx 10\%$
MILK SAMPLING	dirty wrapping material	$\sigma_{u5} \approx 5\%$

Table 1. continued

Errors in:	Due to:	Estimated value:
MEAT SAMPLING	unadequately defined tissue fatty meat	$\sigma_{u6} \approx 5\%$ $\sigma_{u7} \approx 5\%$
WATER SAMPLING	unadecuately sampling: surface, middle and bottom layer should be sampled, not before radioactive mamerial completely deposited	$\sigma_{u8} \approx 50\%$
B. Errors in SAMPLE TRANSPORTATION AND STORAGE		
WRAPPING MATERIAL AND DISHES	unadequately chosen dishes (PVC, teflon are required) that could result in radionuclides absorption on walls	$\sigma_{u9} \approx 20\%$
C. Errors in SAMPLE PREPARATION		
GAMMA SPECTROMETRY OR ABSOLUTE TOTAL BETA ACTIVITY ESTIMATION METHODS	native samples measured in non standard geometry, nonhomogenous samples(hay, grass): differencies in selfabsorption	$\sigma_{p1} \approx 10\%$ $\sigma_{p2} \approx 50\%$
ALFA MASS ACTIVITY ESTIMATION METHODS	small range of alfa particles (often necessary to concentrate radionuclides)	$\sigma_{p3} \approx 20\%$
RADIOCHEMICAL METHODS	mineralization: yield nonaccurately estimated, volatile radionuclides	$\sigma_{p4} \approx 10\%$ $\sigma_{p5} \approx 100\%$

As for statistic errors, the most significant are those in the counting rate as these determine the mesuring time intervals. The length of the intervals are inversal to the square root of the error that should not exceed 1 - 10%. Other statistic errors emerge in background spectrum measurement that is especially important in gamma spectrometry. This is strongly emphasized in accidental situations when background values could be significantly increased.

Therefore, the statistic error in sample counting rate is generally expressed as

$$\sigma_u = \sqrt{\left(\frac{R_o}{R_m - R_o}\right)^2 \sigma_o^2 + \left(\frac{R_m}{R_m - R_o}\right)^2 \sigma_m^2} \qquad (1)$$

where R_o is the background counting rate, R_m is the sample counting rate (together with background value) and σ_o and σ_m are the relative errors in the background and sample counting rates, respectively.

The next important contributors to the total error of the method are the errors in detector efficiency estimation. Therefore, the efficiency calibration should include all of the radionuclides carriers matrixes in the environment (water, soil, grass, milk, meat ecc). If not, one should expect an extra error of about 10% on high energies but very much increased in the low energies region.

In alfa spectrometry, the background counting rate is usually stable enough unless the counter itself has not been contaminated. The alfa counter also should be calibrated for accidental situations and concentration yield should be evaluated for all of the environmental samples together with the correction factors for all types of radionuclides carriers. That is especially important for dry mineralization (2)

The statistic errors in total beta activity absolute estimation method could reach 40%, but could be minimized if one knows the radionuclides mixture composition and type of carrier matrix. But as the corrections for selfabsorption require the counting rate determinations with an absorber, the total statistic error of the method is expressed as

$$\sigma \approx 2\ \sigma_u + \sigma_f \qquad (2)$$

where σ_f is an error introduced by using an absorber, that could be evaluated by Eq.(1), together with σ_u. This error could be kept under 20% (6).

RESULTS AND DISCUSSION

A nonhomogenous radiocontamination of soils results in ununiform contamination of plants, animals, foods and fodder. The distribution of Cs-137 in vegetables and fruit (Fig.1), pork (Fig.2) and lamb meat (Fig.3) after the nuclear accident in Chernobyl, in 1986 (3) is an illustration for this as the activity ratio between different samples of the same kind often exceeds 60. That confirms the assumption that statistic errors under a few tens of percentage do not significantly contribute to the total error of the method.

The activity distribution in lamb meat presented in Fig.2 could be a good example for the evaluation of maximum error in the activity estimation procedure. The total error in this case could be evaluated as

$$\sigma = \sigma_{u7} + \sigma_u \leq 60\% \qquad (3)$$

So it becomes obvious that the differencies in the activity level between different samples of meat are mainly due to the different contamination levels on different sampling localities and not to the errors in the measuring procedure.

The after Charnobyl results also pointed to rather high differencies in the activity levels in grass sampled within an area with the diameter smaller than 1 km (3). This leads to the conclusion that the maximum values were not good and accurate presentation of the radiocontamination level over a large area. Numerous scientific misunderstanding after the nuclear accident at Chernobyl were due to that fact.

Therefore, it can be concluded that with a proper choise of the representative sample, statistic errors could be decreased approximately for the square root from the number of samples investigated, what makes it neglectable compared to statistic errors due to sampling.

Also, as accidental situations produce a large number of samples, one should choose an optimum measuring time interval and it is the one that guarantees the statistic error less than 20%.

Finally, one should mention some of the errors that have not been discussed in this paper. Those are errors due to thin sources selfabsorbtion effect, to instabilities of spectrometers and accessoring electronics equipement, to uncontroled various disturbances, to necessary radionuclides half-lives corrections, to yields differencies among radionuclides within same series ecc. Calibration procedures with standard sources that very much differ in activity level and energies from the investigated samples, could be also a significant error source.

CONCLUSIONS

The fast and accurate estimation of the radiocontamination level in the environment during sudden nuclear accidents, demands the minimization of errors and the other measuring procedures optimization that should be performed in regular working conditions. Among the measures to be taken the most important are: the adequate and complete calibration of instruments, developement and standardization of different radiochemical procedures, planning of sampling, sample transportation and preparation procedures, training of teams for accidental working conditions and developement of adequate information system.

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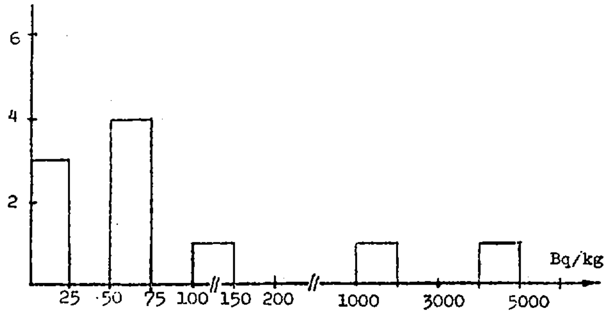

Fig.1 The distribution of ^{137}Cs contents in vegetables and fruits

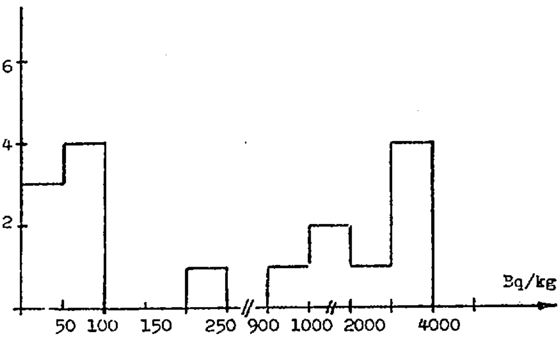

Fig.2 The distribution of ^{137}Cs contents in lamb meat

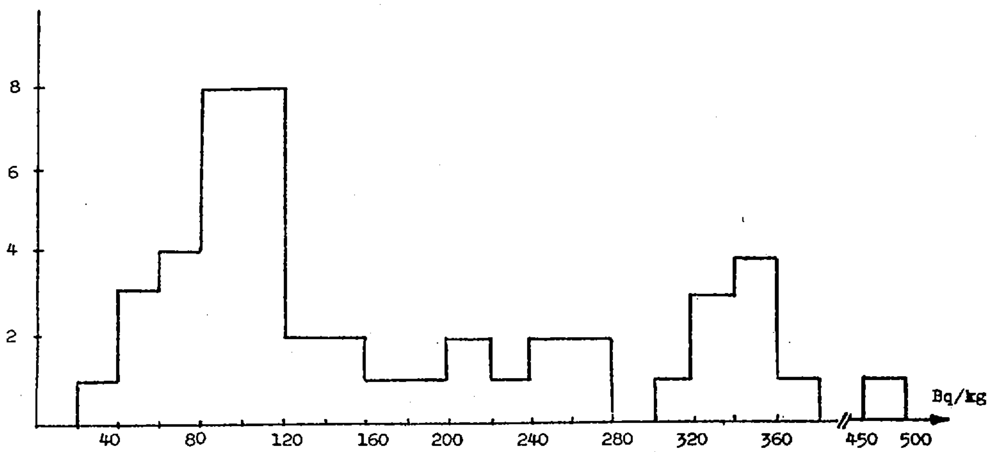

Fig.3 The distribution of ^{137}Cs contents in pork