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A POSSIBLE APPROACH TO ASSESS COMPLIANCE WITH A LIMIT BY MEASUREMENTS *

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ABSTRACT

A proposal is made to permit compliance with a limit by radioactivity measurements, taking into account the statistical nature of radioactivy. The proposal has also some influence to the quality of the measurement under given conditions.

PROBLEM

Very frequently, figures are set in standards /IAEA 1994/ or by authorities with the objective to control doses. These figures are intended to be used in emergency cases, but also for chronic exposure situations and for routine releases. Such figures might be called guidelines, reference levels, action levels, limits etc., and have to be conceptually in terms of dose. For practical reasons and therefore more frequently, however, derived quantities are used as activity concentration for a given radionuclide i in a given material, e.g. in foodstuffs or in air. In the following, the activity concentration $A_{c,i}$ is denoted as A. Further it is assumed that the uncertainty of the sample mass or volume is negligible.

In any case, an apparently very precise figure is established, and the compliance with this number is achieved by checking whether the assessed activity concentration is below or above this figure. This can be done by calculations and by measurements.

When **calculations** are the basis for checking compliance with a limit, a deterministic model leads to a figure with the same properties. Applying stochastic models, a probability distribution results.

In the most frequent case, the assessment of the activity concentration by **measurement**, a statistical quantity results.

In the latter cases, unfortunately two different kind of figures have to be compared: a

- deterministic and a
- statistical quantity.

When measurements are the basis of decision, some problems obviously arise. This is because legal issues have to be compared with an statistical quantity.

The figures are:

a) a preset limit, indicated by a singular figure, usually expressed with one or two significant digits, e.g. 0,2 kBq/kg

b) a statistical quantity, to be expressed by a mean and a variance.

The following consideration is limited to the case that measurements of activity are the basis of judgement.

When samples are subject of measurements, a question as

" can you assure (or even guarantee) that the sample complies with..... "

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* concept developed and discussed in working group " Low Level Measurements" in committee " Radiation Protection" of the Austrian Standards Institute (ÖNORM):
H. Friedmann, E. Henrich, C. Hübsch (secretary), P. Kindl, A. Leitner,
F.J. Maringer, F. Steger, M. Tschurlovits (chairman), E. Unfried, G. Winkler.

is raised by authorities, by media and by the public. From a scientific point of view, striktly spoken, a positive answer can not be given at all. This is because radioactive decay does not behave to fulfil the properties of a deterministic quantity. However, the question is still asked frequently, although being an unscientific one by definition. Although a foolish question usually deserves a foolish answer, a realistic approach which might satisfy nonscientific formalists and being acceptable from scientists is presented below.

BASIC CONSIDERATIONS

The fulfilment of the condition, say

$$A < L \tag{1}$$

where: A... activity, L... limit

can be stated only with an additional information, namely the confidence interval of the assessment. Therefore, the correct statement is

$$A < L, \quad \textit{with a given probability} \tag{2}$$

linking three values:

a) mean A (estimated from the measurements)
b) uncertainty σ (estimated from the measurements)
c) limit L (constant)

Taking into account the well known properties of statistical distributions, a statement:

$$A < L, \textit{ with 100 \% probability}$$

can not be achieved by definition, although being required by some groups who think that the setting of limits solves all problems.

PROPOSAL

In the following, a possible solution of the question raised above is presented.

In order to obtain a resonable answer, the question on the purpose of the assay of radioactivity has to be formulated in a more precise form.

1. Formulation of the questions

There are three possible questions, which have to be clearly expressed in advance:

a) what is the activity concentration?
b) is the activity concentration of the sample lower than a given value and hence in compliance with an upper limit (e.g. a possibly contaminated food sample)?
c) is the activity concentration of the sample higher than a given value and hence in compliance with a lower limit? (not considered in detail here)

2. Answers

ad a) The first question is answered by measurements, the answer being an activity (concentration) A and a standard deviation σ expressing the statistical uncertainty:

$$A \pm \sigma$$

This formulation of the question is not associated with compliance with limits, but rather with the assessment of the activity as such.

ad b) This is the most frequent case, namely to check whether an activity in a sample is less than or equal to a preselected figure.

It is proposed to consider a sample in compliance with the limit when the following condition is fulfilled:

$$A + n \cdot \sigma \leq L \tag{3}$$

The choice of the number of standard deviations **n** is subject of discussion and by definition somewhat arbitrary. When **n** is chosen too small, the measurement is uncertain. When n is large, a lowering of the limit is associated with. To obtain a compromise, it seems therefore reasonable to adopt n = 1, leading to:

$$A + \sigma \leq L \tag{4}$$

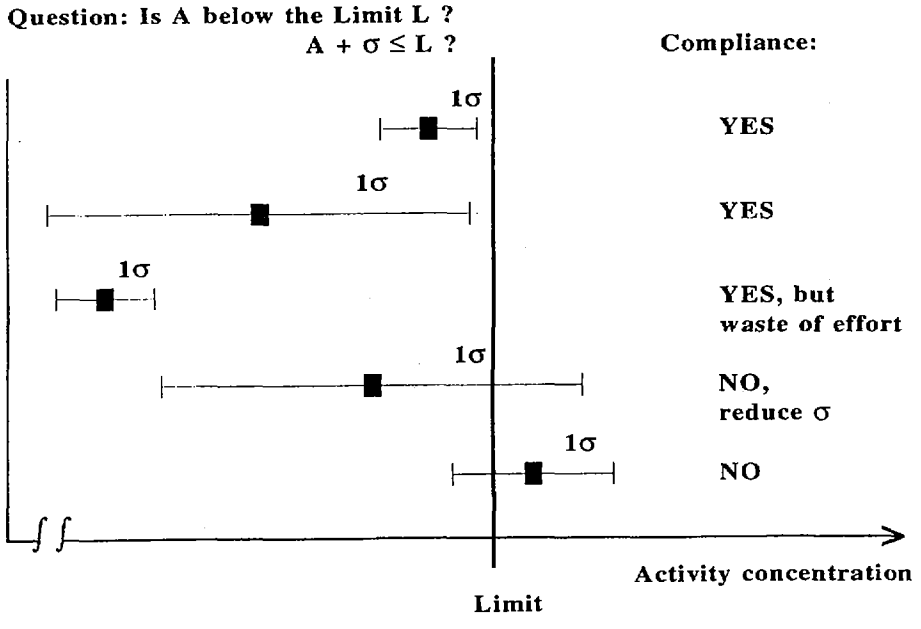
DISCUSSION

This concept presented above has the following properties:

i) the activity of the sample is by definition less than the limit. Hence, a possible blame of a hidden increase of the limit is unfounded.

ii) The definition has an inherent property which might be even more important than the condition i) above: The acceptable uncertainty of the measurement in a given case depends on the activity level and the quality of the measurement, i.e. on the variance and the detection limit. This implies that an inexpensive measurement with a large variance is sufficient to prove compliance with the limit for samples well below the limit. On the other hand, when the activity approaches the limit, an accurate measurement permits the confirmation of the compliance of samples with the limits with almost arbitrary accuracy.

Some examples are shown in the figure.



Details can be found in /ÖN94/

REFERENCES

/ÖN 94/ ÖNORM S 5250-1 : Zählstatistische Aspekte bei Radioaktivitätsmessungen.
/IAEA 94/ Safety Series 115-I (1994) FAO/ IAEA/ ILO/ OECD/ PAHO/ WHO International Basic Safety Standards.