ISSN 0101-3084

CNEN/SP

ipen Instituto de Pesquisas Energéticas e Nucleares

STATISTICAL CONSIDERATIONS ON WASTE PACKAGES

Achilles Alfonso Suarez and Demerval Leonidas Rodrigues

PUBLICAÇÃO IPEN 202 SETEMBRO/1988

SÃO PAULO

PUBLICAÇÃO IPEN 202 SETEMBRO/1988

STATISTICAL CONSIDERATIONS ON WASTE PACKAGES

Achilles Alfonso Suarez and Demerval Leonidas Rodrigues

DEPARTAMENTO DO CICLO DO COMBUSTÍVEL

CNEN/SP
INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES
SÃO PAULO - BRASIL

Série PUBLICAÇÃO IPEN

INIS Categories and Descriptors

E52.00

INTERMEDIATE-LEVEL RADIOACTIVE WASTES
LOW-LEVEL RADIOACTIVE WASTES
PACKAGING
STATISTICS
WASTE TRANSPORTATION

IPEN - Doc - 3070

Aprovado para publicação em 04/08/88.

STATISTICAL CONSIDERATIONS ON WASTE PACKAGES*

Achilles Alfonso Suarez and Demerval Leonidas Rodrigues

ABSTRACT

The requirements of the optimization component of the system of dose limitation establishes that planning, designing, using or operating sources and practices at any level of the nuclear fuel cycle or outside of it shall be performed in such a manner that exposures are as low as reasonably achievable, economic and social factor being taken into account.

Statistical criteria to guarantee some aspects of the packaging and transport process of the low-and intermediate-level radioactive wastes are proposed and discussed.

CONSIDERAÇÕES ESTATÍSTICAS SOBRE EMBALAGENS DE REJEITOS*

RESUMO

As exigências de optimização do sistema de limitação de doses estabelece que o planejamento, projeto, uso ou operação de fontes e práticas em qualquer nível do ciclo de combustível nuclear ou fora dele deve ser feito de tal forma que as exposições sejam tão baixas quanto razoavelmente exequíveis, levando-se em conta fatores econômicos e sociais.

Critérios estatísticos para garantir alguns aspectos do processo de embalagem e transporte dos rejeitos de nível baixo e médio são propostos.

INTRODUCTION

Until the final repository be available waste producers are re-

(*) Trabalho apresentado no VI Simpósio Nipo-Brasileiro de Ciência e Tecnologia, realizado em São Paulo, de 10 a 12 de agosto de 1988.

quired to package their wastes (where necessary) and to store them. It is essential that the packaging meets the requirements for eventual transport, handling and disposal as well as those for long term storage.

The regulations concerning the transport of waste in Brazil which relate to the radioactive nature of the material are all based on the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material[1]. The IAEA regulations aim to protect the public and transport workers. This is to be achieved by ensuring adequate containment of the radioactive material, controlling the external radiation level and assuring the dissipation of any heat generated, and for fissible materials, ensuring the prevention of criticallity.

These requirements are realized by the specification of an adequate level of packaging, appropriate to the quantity and nature of the radioactive material to be transported. The intention is to allow the package to be dealt with by the carrier, as far as possible, in the same way as any other potentially hazardous goods in transit.

Packages must conform with general transport requirements and also pass a number of tests designed to simulate normal transport conditions, including minor accidents. The nature of these tests depends upon the package contents, but may include a short free drop onto as unyielding surface, a stacking test, a water spray test and a penetration test. Severe restrictions on the loss of radioactive material and shielding following these tests are imposed.

In order to guarantee a low risk level of accident and a minimal radiation exposure to transport workers and to the general public the IAEA standard restricts the maximum activity content of the package as well the surface radiation level. Assurance of these properties for the packaged wastes will form an essential component of a quality assurance program.

However, to be sure that those critical values are not exceded

defined statistical criteria have to be applied. Discussions are made concerning the highest activity content of the package, the highest surface radiation level and their relationship with the shielding design.

STATISTICAL CRITERIA

The discussions and evaluations which follows are based on the assumption that the measurements of the activity of sources (A) and the radiation level ($\dot{X}$) at the surface of the waste packages obey a normal distribution, that is, its density function is given by

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma} \exp\left[-(x-\mu)^2/2\,\sigma^2\right] \qquad (1)$$

where x is the quantity measured, μ its mean and σ^2 its variance. Also will be assumed that σ^2 include all kind of errors which could affect the observed value. Thus, σ/μ represents the fractional standard deviation which is related to the equipment accuracy.

The basic problem of test a hypothesis $\mu < \mu_o$, where μ_o is a given value, is to find a rejection region with a significance level α chosen in advance.

Applying statistical tests relative to the normal distribution[2] for the hypothesis $\mu < \mu_o$ results in a confidence region given by

$$\frac{\mu - \mu_o}{\sigma/\sqrt{n}} < -Z_\alpha \qquad (2)$$

where Z_α is the upper 100 α % point of the standard normal distribution and n is the size of a random sample of the measured quantity.

From this relation it is possible to deduce that

$$\frac{\mu}{\mu_o} < \frac{1}{1 + \frac{\sigma \sqrt{n}}{\mu} Z_\alpha} \qquad (3)$$

If the test hypothesis is to be observed.

This statistical property of distributions is shown in figure 1 where curves for three values of accuracy are displayed. All of them have 2 x 10^{-2} TBq (= 500 mCi) as their 95% upper level of confidence interval. Thus, depending of the accuracy of the measurement equipment available the maximum activity allowed to be packaged, in order to comply with the IAEA standards within a confidence level, is reduced.

In figure 2 is shown the activity fractions permitted to be packaged according the equipment accuracy and the accepted confidence interval. That figure is useful for any radioisotope with maximum activity per package equal to A_{MAX}.

For those waste packages which complies with the activity limits the next question is concerned with the transport index and the surface radiation level. The same kind of curves applies to decide which maximum surface radiation level is allowed for a package, with a given confidence interval, and for a given equipment accuracy. For that purpose ordinate represents $\hat{X}/\hat{X}_{MAX}$ and abscissa the fractional accuracy of the surface radiation level measurement $\sigma_{\hat{X}}/\hat{X}$.

During the shielding design the maximum activity content and surface radiation level as well the transport index of the waste package are correlated. This happens in such a way that those statistical aspects discussed here concerning the accuracy of measurement equipments attainable or available have to be taken into consideration if economic and social factor are taken into account.

CONCLUDING REMARKS

In order to comply with the safety regulations for packaging and transport of radioactive materials careful design of packages and

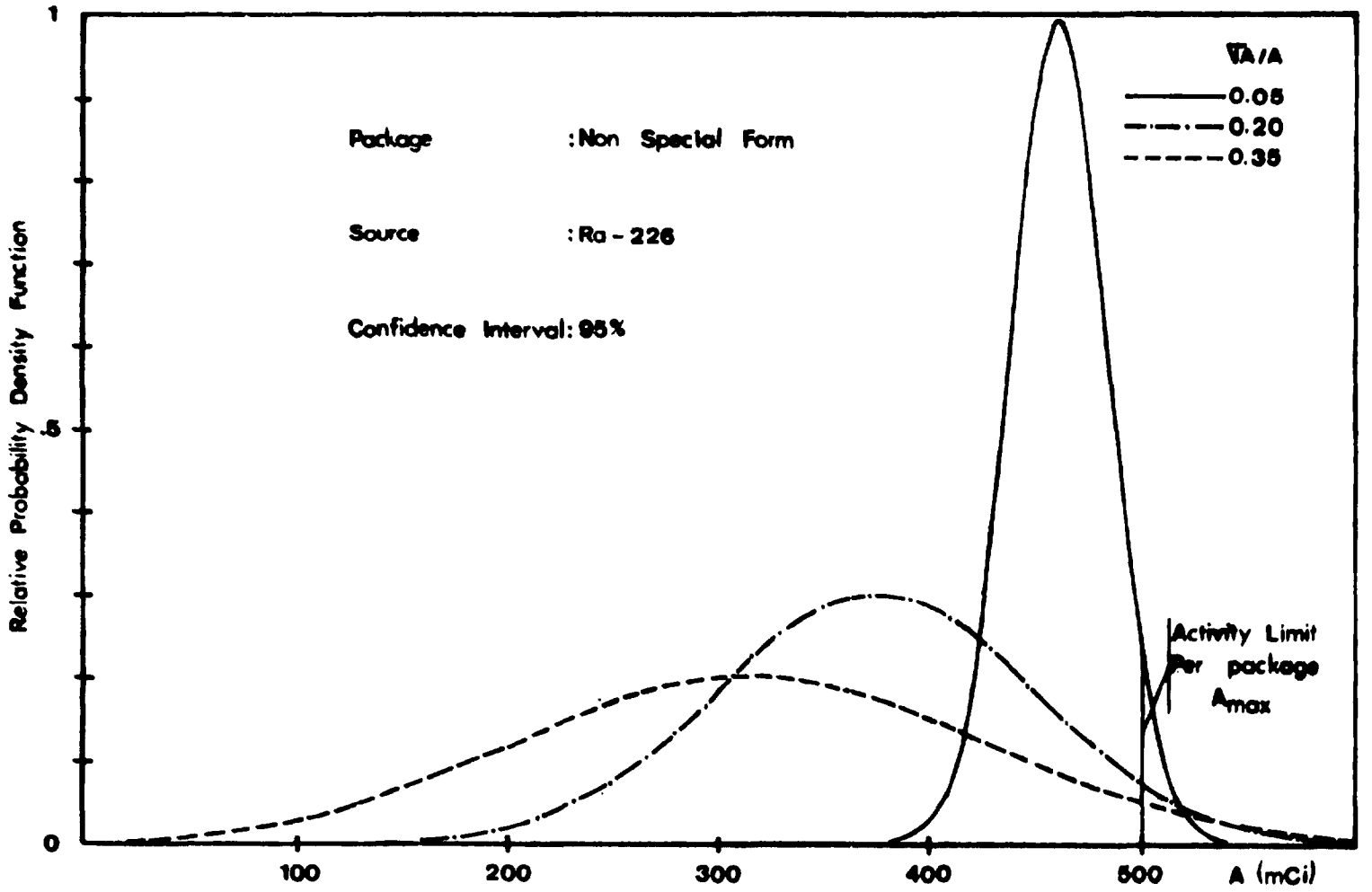

Figure 1 - Probability density functions for radium sources of 500 mCi measured with different equipment accuracies

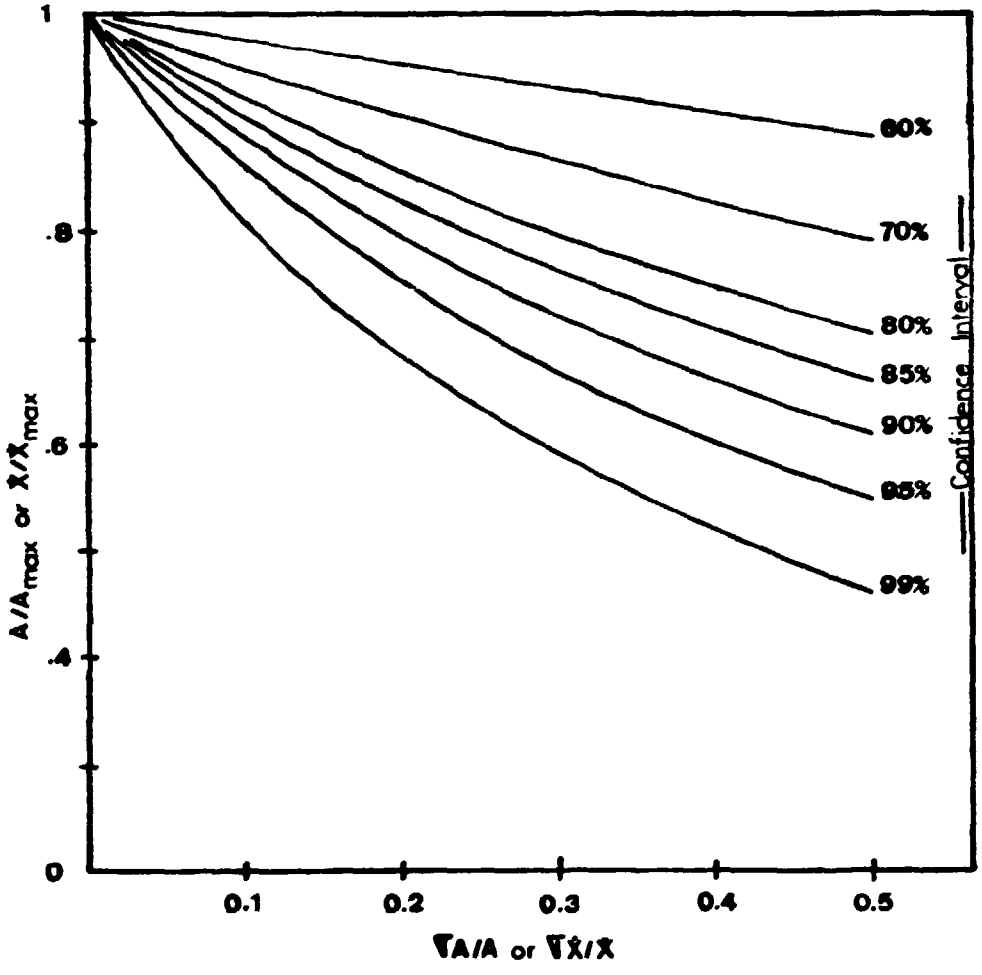

Figure 2 - Activity fractions or exposure fractions as functions of equipment accuracy and confidence interval

measurements supported by statistical criteria have to be applied.

The statistical criteria presented here will in turn form an integral part of the quality assurance and checking program to guarantee both compliance with regulatory standards and a safe and efficient operation.

ACKNOWLEDGEMENTS

The help given in the preparation of this paper by Dr. Barbara M. Rzyski is gratefully acknowledged.

REFERENCES

(1) INTERNATIONAL ATOMIC ENERGY AGENCY. Regulations for the Safe Transport of Radioactive Material. Vienna, 1985. (Safety Series no.6).

(2) CHOI, Sung C., Introductory Applied Statistics in Science. Prentice Hall, Inc., 1978.