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Original Contribution

THE POSSIBILITY OF USING A CHEMICAL DOSIMETER KIT TO MEASURE THE ABSORBED DOSE IN NON-UNIFORM GAMMA-NEUTRON FIELDS

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ABSTRACT

PURPOSE: The purpose of this study was to assess the possibility of using different chemical dosimeters to measure the absorbed dose and to select a number of them for a kit, which can then be used to assess the radiation situation. This involved analysing the dosimetric characteristics of existing chemical dosimeters, discovering and inventing new chemical detectors of ionising radiation and optimising their dosimetric characteristics. METHODS: Relative and comparative methods were used to analyse the results of tests and colorimetric method to register the different types of radiation. RESULTS AND CONCLUSIONS: The tests were carried out for four dosimeter systems which were all found suitable for radiometric studies, for determining the absorbed dose in non-uniform radiation fields and assessing the equivalent dose.

Key words: *dosimetric characteristics, detectors*

INTRODUCTION

Chemical ionising-radiation detectors are used to measure the absorption of different kinds of radiation

The need for such detectors has been confirmed by a wide range of experimental and technical studies in the fields of missile construction, materials development and radiation chemistry and technology, as well as by the risk of industrial and radiation accidents, where the use of express methods of radiation measurement is essential. In this respect, chemical dosimeters have well-known advantages.

In the above-mentioned circumstances it is most often necessary to work in high-intensity non-uniform radiation fields, where the absorbed dose is over 10^6 Gy.

The chemical method in dosimetry has been known for a long time (1). Detectors have different dosimetric characteristics according to the fields in which they have been used, but most often what matters is the radiation output and their sensitivity to energy transmitted in a linear way.

Theoretical studies show that it is possible to select solutions of substances which, when exposed to ionising radiation, visibly change their colour or viscosity for absorbed dose of over 10^6 Gy. This means using solution groups from different substances where each different solution has a definite reaction to radiation with a given energy.

The purpose of these studies was to assess the possibility of determining the absorbed dose in a non-uniform gamma-neutron field through a selection of different chemical dosimeters, which give information about the type of radiation and assess its intensity.

It is possible to determine the absorbed dose with a certain degree of precision by comparing the colour of the solutions to a standard. In addition to this, the detector kit contains solutions, which change their viscosity and also allow for comparative measurement. This change is the basis for an assessment of the type of radiation and its intensity.

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MATERIALS AND METHODS

The selected solutions meet the requirement of easy preparation have a radiation output of absorbed doses from 0.1 to 10^6 Gy (10-1000 R). These requirements limited the choice of substances, which could be used to prepare chemical detectors as the most commonly used chemical dosimeters (ferrisulphate and cerium) measure an absorbed dose of 10^3 Gy and more (2).

In terms of the way in which the absorbed dose is registered (spectrophotometric, luminescent, polarimetric, etc.), there are a number of chemical dosimeters, which do not meet the requirement for fast measurement of doses within the above-mentioned range. The use of colorimetry and viscosity measurement for the solutions meets the requirements, and this determined the final content of the solution kit for assessment of the absorbed dose in non-uniform radiation fields.

Studies carried out at the School of Chemistry at St Kliment Ochridski University, the Organic Chemistry Department, showed that it is possible to visualize radioactive contamination using a system, which consists of a polymer and a dye with changing colour.
Some highly sensitive detectors for fast and continuous radiation registration have been in use and they include the following:

A polymer film with certain built-in organic compounds, which are sensitive to different types of radiation;
Dry organic mixtures, which change when exposed to ionising radiation;
Inks and veneers in an organic mixture, which react in different ways to different doses.

Two polymers have been used, polyvinylchloride and polymethylmetacrylate, with two of their main polymeric properties, namely:

They change their main characteristics, spectrum and colour according to the pH of the environment.

When exposed to radiation, they can change their structure, which leads to a change in their optic properties.

Detectors were exposed to gamma-, X-, and beta-radiation as follows:

- Gamma-radiation with 1,25 MeV energy produced by a Luch-1 therapy unit using a Co^{60} source of activity of $3{,}7.10^{13}$ Bq;
- X-radiation with 0,08 MeV effective energy produced by a THX therapy unit at voltage of 200 kV and current strength of 15 mA using a 1 mm copper filter for a 10x15 cm field and exposure rate of 10^4 A/kg;
- Beta-radiation of ^{90}Sr and ^{90}Y with particle density of 10 particles per cm² per second using a suitable polyethylene film.

RESULTS

The impact of alpha- and neutron radiation is analysed theoretically on the grounds of certain known reactions these types of radiation cause with certain substances (3).

The results of the tests carried out were assessed using the relative method.

The system of solutions selected for chemical dosimeters is presented on **Table 1**. The solutions were placed in 10 ml plastic syringes. Dosimeters D have an opening covered with polyethylene film. Viscosity was measured using the drop method (Oswald viscosimeter). The registration of nitrite ions took place with the help of indicators, which colour the solution from pale pink to crimson.

Table 1: *System of solutions for selected chemical dosimeters*

Dosimeter denominatio n	***Composition***	***Type of radiation registered***	***Method of dose determination***
A	Water solution of an ammonium salt; Acid environment; Nitrate-nitrate system.	Gamma-radiation	Colorimetric
B	Nitrate-nitrate, ^{6}Li-enriched system	Gamma- and neutron radiation	Colorimetric
C	0,04 % polyacrylamide solution	Gamma-radiation	Viscosity change measurement
D	0,04 % polyacrylamide solution covered with polyethylene film	Gamma- and X-radiation; Alpha- and beta-radiation	Viscosity change measurement

Comparative measurements were carried out using TFD-102 with thermoluminescsent dosimeters 101P and 101PM. The latter two measure gamma- and neutron radiation.

The solutions are prepared immediately before irradiation and are placed at a certain

point of the source's radiation field.

There is a visible change in the colour of system A at 0,17 Gy (17R); it becomes faintly crimson at 8,9 Gy (890 R). In Dosimeters C and D viscosity starts changing at 0,2 Gy (30 R) in a non-linear fashion; the changes start following a linear pattern for absorbed doses of up to 12,3 Gy (1230 R) (**Figure 1**). There was a marked difference in the System D results in tests using alpha-radiation of polonium sources and beta-radiation.

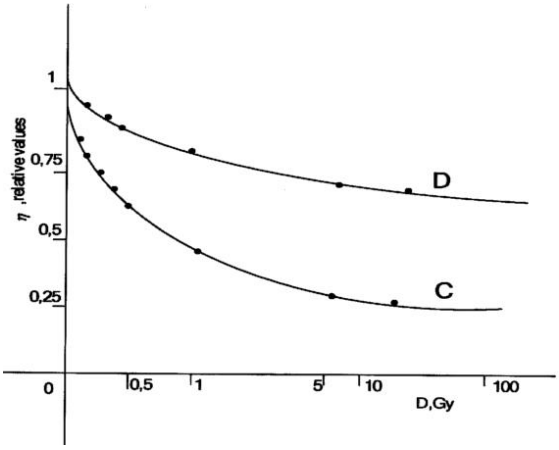

Figure 1 *Viscosity change in Dosimeters C and D in relation to the absorbed dose*

These differences are due to certain mistakes in the comparative analysis of the results, where to register alpha-radiation the surface distribution of particles is measured. The other cause is to do with the low intensity of the alpha-source. Subsequent measurements with the same solutions but with a different contribution of the absorbed dose of gamma-, beta- and alpha radiation have led to smaller differences in the indicated dose than in the presence of X-radiation.

These results are a sound basis for further determination of the dosimetric characteristics of detectors. Each of these systems can be studied in different directions: in terms of energy, dose, dose power, temperature range, as well as the system's ability to register the dose correctly. It is possible to determine with a certain degree of precision what the possible mistakes are for each system, as well as for the detector kit as a whole.

The results of the comparative measurements made with thermoluminescent dosimeters 101P and 101PM allow for an assessment of the chemical system's sensitivity to a greater energy range of photon radiation. At exposition of over $2{,}5.10^{-1}$ C/kg (2500 R), Dosimeter A changes proportionately to $6{,}25.10^{-1}$ C/kg (2500 R) (Figure. 2).

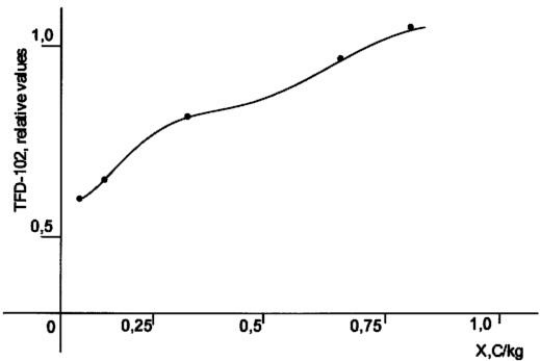

Figure 2 *Changes of colour in Dosimeter A in relation to the exposition*

The systems under consideration allow for other ingredients and components to be added to the solutions. With systems C and D it is possible to choose suitable thermal neutron covers and openings for alpha- and beta-radiation.

Separate measurement of the absorbed dose of different types of radiation, with a different quality quotient, makes it possible to determine the characteristics of the equivalent dose. Once the dosimetric characteristics are determined, the proposed system can be used to measure the dose in a certain radiation situation.

CONCLUSIONS

The chemical dosimeter kit enables the assessment of an absorbed dose of 0,1 to 10 Gy.

It is necessary to study the dosimetric characteristics of detectors and their ability to show the same results over time.

Once the dosimetric characteristics are optimised, it will also be possible to use polymer-dye detectors for neutron radiation fields in addition to the above-mentioned ones.

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