Cytogenetic consideration on plants exposed to low doses and multipollutants

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1. Introduction

A key question in dealing with contaminated sites is whether, and to what extent ecotoxical effects occur. At severely contaminated sites there are acute effects, but the core problem lies in possible long-term effects of chronic low dose-rate and multi-pollutant exposure. Interaction of contaminants with biota takes place first at the cellular level [1] making cellular responses not only the first manifestation of harmful effects, but also suitable tools for the early and sensitive detection of exposure. It is becoming increasingly clear [2] that cellular alterations may in the long run influence biological parameters important for populations such as growth, health and reproduction. These types of effects are of special concern because they can manifest themselves long after the source of contamination has been eliminated. Therefore, it is the genetic test-systems exactly should be used for an early displaying of the alterations resulting from the human industrial activity. From the practical point of view it is important to know what changes on cytogenetic level can be induced by low doses of ionizing radiation under conditions of single and combined with another factors exposure.

2. Methods and Results

2.1 Nonlinearity of Dose Response

The analysis of experimentally observed cells reactions on low-level irradiation showed [3] that the regularities of cytogenetic disturbances yield in this range are characterized by a sound nonlinearity. To corroborate this statement an experiment has been carried out on barley seedlings. From presented in Fig. 1 results it follows that the piecewise linear model fits the data much better than the linear one. It is important, that the improvement of the quality of approximation is not reached by means of the model complicating but achieving a mutual conformity between a biological phenomenon and its mathematical model [4].

2.2 . Synergetic and Antagonistic Effects of Combined Action

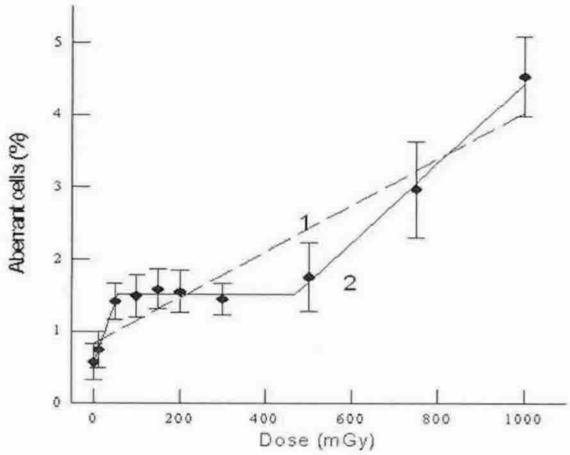

Figure 1. Aberrant cells frequency in barley germs exposed to low radiation doses and its approximation with linear (1) and piecewise linear (2) models

Contaminants present in nature as mixtures; therefore, interactions between individual compounds may be of importance. Ecotoxicological methods integrate the impacts of all the mutagenic activities in the environment, including synergistic and antagonistic effects. In our studies of combined effect of such frequently occurring agents as acute and chronic γ-radiation, heavy metals, pesticides, artificial and heavy natural radionuclides on spring barley, bulb onion, spiderwort and other plant species, it was shown that synergetic and antagonistic effects are most often registered at combinations of low doses and concentrations; moreover, these nonlinear effects make a governing contribution to a plant response under certain circumstances. For example, a study of cytogenetic disturbances induction in intercalar meristem cells of spring barley grown on soil contaminated with ^{137}Cs and Cd [5] has shown (Fig. 2) that the effect of combined exposure exceeds the sum of separate effects as much as 70%. On the contrary, the observed effect at soil pollution by ^{137}Cs, Pb and pesticides averaged only 50% from anticipated one proceeding from the additive model. Furthermore, our data [6] on genotoxicity assay of water samples from the natural reservoirs formed both in the nuclear explosion epicenter and located near the radium production industry storage cell suggest that substantial biological effects may be caused by metal and radionuclide combined exposure at concentrations below permissible exposure limits for human due to synergic response. Therefore, an application of findings on a separate action to a prediction of combined exposure biological effects is unacceptable and causes essential deviations from the experimentally obtained data.

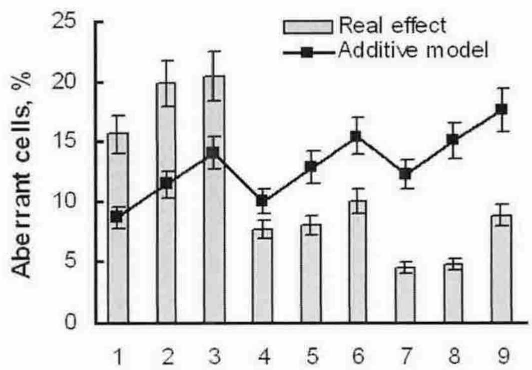

Figure 2. Cytogenetic disturbances yield in intercalar meristem of spring barley in conditions of combined soil pollution by Cs-137 and Cd
1 – 1.48 MBq/m^2 + 2 mg/kg; 2 – 1.48 MBq/m^2 + 10 mg/kg;
3 – 1.48 MBq/m^2 + 50 mg/kg; 4 – 7.4 MBq/m^2 + 2 mg/kg;
5 – 7.4 MBq/m^2 + 10 mg/kg;6 – 7.4 MBq/m^2 + 50 mg/kg;
7 – 14.8 MBq/m^2 + 2 mg/kg; 8 – 14.8 MBq/m^2 + 10 mg/kg;
9 – 14.8 MBq/m^2 + 50 mg/kg

3. Conclusion

Quantifying and reducing an impact of ionizing radiation on the environment require a comprehensive understanding of the ecological consequences of exposure. Therefore, the reality and severity of the ecotoxicological effects within areas of interest affected by low doses and multi-pollutant exposure are among key problems today. Genetic nature of such effects, as well as their dynamics in progeny remains inadequately explored up to now. It is a very important topic, but is also the most neglected one. Our findings suggest that the further evolution of investigations in ecotoxicology could shed light on the development of a theoretical bases and practical procedures for environmental protection against radioactivity, taking into account the new experimentally confirmed facts about the presence of such essentially important patterns of the biological effect of low doses of ionising radiation as the nonlinearity of a dose-effect relationship and increased probability of synergetic and antagonistic effects of the combined action of different factors. A development of a new concept of radiation protection for human and biota should be based on a clear understanding of these effects and their contribution to biological response.

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