PLANTS ECOTOXICOLOGY:

IMPLICATIONS FOR BIOLOGICAL MONITORING AND ECOLOGICAL RISK ASSESSMENT

GERAS'KIN S.A.

Russian Institute of Agricultural Radiology and Agroecology, Obninsk, Russia

Methods for assessing the quality of the environment

To take samples of air, water and soil and analyze them in laboratory using routine chemical-physical techniques

recognizing just a specific compound or its metabolites

a part of the knowledge necessary to evaluate the harmful potential of pollutants

To score the biological effects in animals or plants that could be exposed in their natural habitat

integrating the impacts of all the harmful agents, including synergistic and antagonistic effects

particularly useful for assessing unknown contaminants, complex mixtures, or hazardous wastes

Interaction of contaminants with plants takes place at the cellular level

Cellular responses is

a) the first manifestation of harmful effects, and

b) suitable tools for the early detection of pollution

Genetic test-systems should be used for an early and reliable displaying of the alterations in agroecosystems resulting from the human industrial activity

What changes on cytogenetic level can be induced by low concentrations of persistent pollutants under conditions of separate and combined exposure?

The frequency of aberrant cells in intercalary meristem of barley growing at soil pollution with ^{137}Cs, Cd, Pb and 2,4-D pesticide

	Treat ra	
Control	-	
^{137}Cs, MBq/ м 2	1. 7 14	
Cd, mg/kg	2 1 5	
Pb, mg/kg	3 15 30	
Pesticide 2,4-D, l/ha	1 2	

Significant increases in the frequency of aberrant cells were observed at the concentrations of lead and cadmium, which are close to the values adopted in Russia as the maximal permissible levels, and also at the 2,4-D herbicide dose recommended for agricultural application in the immediate past.

The observed cytogenetic effect was comparable with that induced by the maximum level of radioactive soil contamination tested (14.8 MBq/ м 2). Such radioactive contamination exceeds by 10 fold the maximum level permitted in radionuclides - contaminated areas where people are resident.

Comparison of the data approximations by three regression models

Substance	Model	R^2	*Hayek*	p
^{137}Cs	Linear	78.0	6.0	<0.01
	Logarithmic	87.2	4.4	<0.05
	Power	93.3	☼	☼
Cd	Linear	60.7	21.6	<0.001
	Logarithmic	94.3	8.1	<0.01
	Power	99.8	☼	☼
Pb, mg/kg	Linear	78.4	18.0	<0.001
	Logarithmic	87.7	13.9	<0.001
	Power	99.8	☼	☼
Pesticide 2,4-D, l/ha	Linear	87.5	50.0	<0.001
	Logarithmic	98.8	15.6	<0.01
	Power	99.99	☼	☼

☼ - the best regression model

Soil contamination with single agent

The empirical dependences are of an over-linear nature, so the cytogenetic disturbance yield per unit of examined agent's concentration is higher at small doses, than at higher doses. This may, in part, be due to the fact that the uptake of essential compounds increased linearly, whereas the nonessential heavy-metal ions, lead and cadmium, were taken up more efficiently at low concentrations than at higher ones.

The non-linear character of empirical dependences emphasizes an importance of taking greater care at the choice of maximum permissible levels of soil contamination with the examined chemicals, because in the range of small concentrations, even a small excess of the current standards can result in a disproportionately high increment of cytogenetic disturbances

Combined soil contamination: Cd + ^{137}Cs

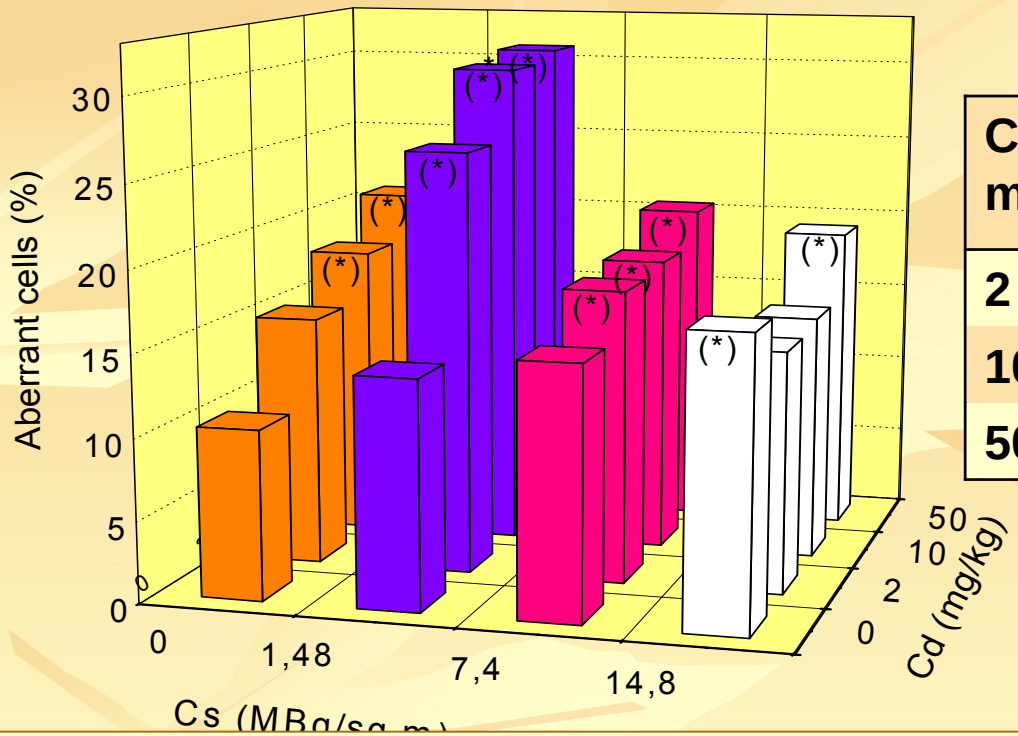

Table. Interaction coefficient

Cd, mg/kg	^{137}Cs, MBq/ м ^{2}		
	1.48	**7.4**	**14.8**
2	1.84*	0.76*	0.36**
10	1.74**	0.63**	0.32**
50	1.46**	0.65	0.50*

There are significant synergistic effects for combinations of the lowest ^{137}Cs-contamination density with all the tested cadmium concentrations.

^{137}Cs-contamination of 1.48 MBq/sq.m still occurs in the territories affected by the Chernobyl accident.

When the ^{137}Cs contamination of the soil increases at constant cadmium concentration, the synergistic effect changes to antagonistic.

Combined soil contamination: Pb + ^{137}Cs

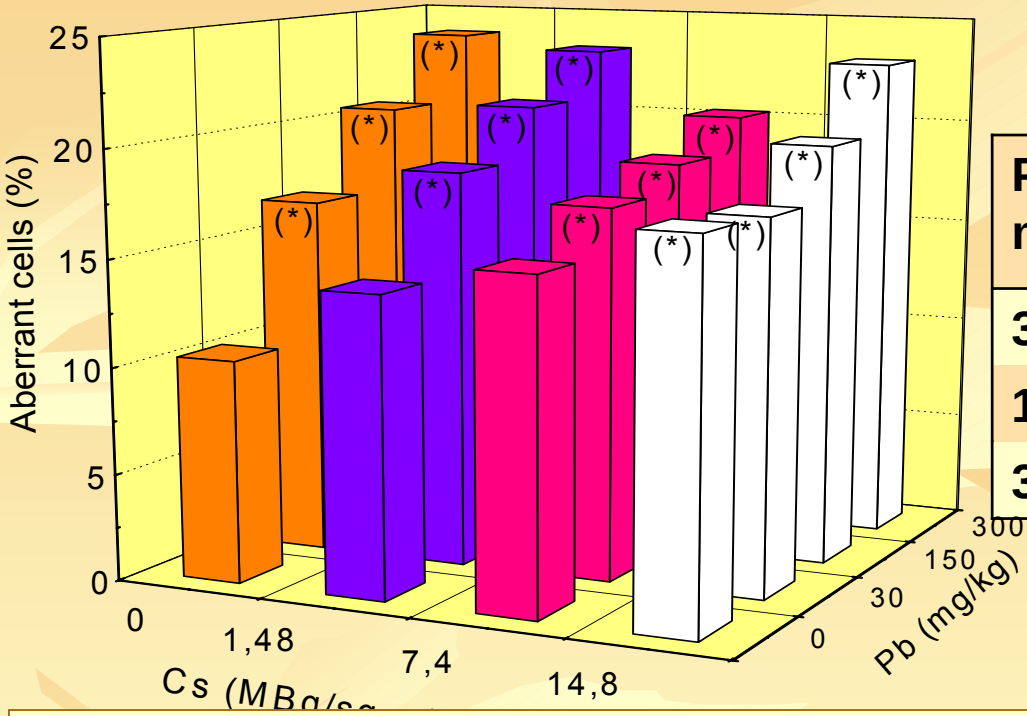

Table. Interaction coefficient

Pb, mg/kg	^{137}Cs, MBq/ м ^{2}		
	1.48	**7.4**	**14.8**
30	0.82	0.61	0.52*
150	0.74	0.54*	0.54**
300	0.75	0.53*	0.61*

The aberrant cell frequency under combined contamination differs little from that caused by lead alone.

Maximum effect occurs for combinations of every examined concentration of lead with the lowest ^{137}Cs contamination.

In contrast to the ^{137}Cs + Cd combined exposure, the interaction in the ^{137}Cs-Pb combination is either additive or antagonistic. The significant antagonistic effects are registered when the contaminants are applied at high concentrations.

Combined soil contamination: 2,4-D + ^{137}Cs

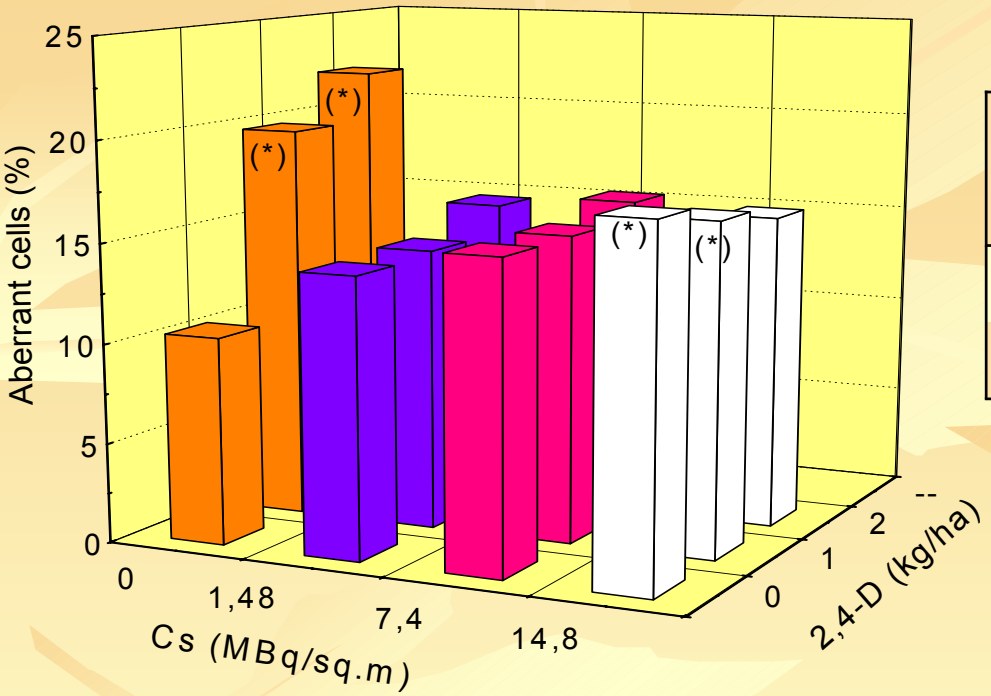

Table. Interaction coefficient

2,4-D, kg/ha	^{137}Cs, MBq/ м ^{2}		
	1.48	**7.4**	**14.8**
1	0.29**	0.35**	0.37**
2	0.34**	0.35**	0.28**

For individual treatments, the herbicide was a strong mutagenic agent, whereas the ^{137}Cs soil contamination only resulted in a significant cytogenetic effect at the maximum density treatment.

For the combined ^{137}Cs and herbicide treatments, a decrease in cytogenetic disturbance in comparison to the separate exposures occurred almost in all cases.

Interaction coefficient values indicated statistically significant antagonistic effects for all the combinations of the contaminants.

The results described suggest that the bioindication approach based on an analysis of the frequency of cytogenetic disturbances in intercalar meristem of spring barley give the tools for an efficient diagnostics of different types man-caused contaminations in agroecosytems.

Further studies are clearly needed

- to extend the test from being a research approach to a biomonitoring tool, and
- to validate the test results.

Overall, the findings described here along with results of our studies of combined action 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,

show that in most cases, **the experimentally observed effects differed from those expected from an additive hypothesis**.

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.

Therefore, **an application of findings from separate action to predict biological effects of combined exposure is unacceptable and causes essential deviations from experimentally observed data**.

CONCLUSIONS

The results presented here indicate that environmental factors are able of mutually intensifying their biological effect in situations of low-level contamination of the biosphere.

This emphasizes the necessity of taking into account the possible effects of synergetic and antagonistic types induced by combined exposure to different stressors when estimating consequences of a man made influence on natural and agricultural ecosystems.

Finally, the results presented here taken together with our previous findings, provide evidence that plants ecotoxicology can play an important role in improving environmental monitoring and risk assessment.