PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT
2010, vol. 5, no 1, 53-58

Model of Permanent Eco-chemical Education of Employees of Chemical Industry in the Function of Ecological Development

Model trwałej eko-chemicznej edukacji pracowników przemysłu chemicznego

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Streszczenie
Pracownicy przemysłu chemicznego odgrywają istotną rolę w ochronie środowiska. Aby rozwiązać problemy środowiskowe jest koniecznym, aby poprawić ich wiedzę na temat wpływu na środowisko substancji chemicznych, z którymi mają oni styczność. Celem badań jest analiza wiedzy eko-chemicznej pracowników przemysłu nawozów mineralnych w regionie Nowego Sadu (Serbia) i określenie zakresu wiedzy, który powinien zostać przez nich przyswojony w przyszłości. Użyto metod analitycznych i deskryptywnych. Zastosowanym narzędziem był oryginalny kwestionariusz. Rezultaty badań pokazują, że pracownicy posiadają wprawdzie pewną wiedzę o wpływie na środowisko związków chemicznych, jednak nie jest ona wystarczająca. W celu poprawy sytuacji zaproponowano model zróżnicowanej eko-chemicznej edukacji przygotowany dla osób dorosłych, pracujących zawodowo.

Słowa kluczowe: wpływ substancji chemicznych na środowisko, przemysł nawozów mineralnych, pracownicy, środowisko, wiedza

Abstract
Employees of chemical industry play a significant role in environmental protection. In order to solve environmental problems it is necessary for them to improve knowledge on environmental impact of chemicals which they come in contact with. The aim of research is the analysis of the ecochemical knowledge in employees of the fertilizer industry in the Novi Sad region (Serbia), and structuring of chemical contents for further increase of their knowledge. Analytical and descriptive methods were used. The research instrument was a questionnairre, specially designed for the purpose of this research. Techniques of research were: field investigation, action investigation and combined techniques. It was shown that workers have certain, but insufficient knowledge of environmental effect of chemical pollutants. They should improve the existing and acquire new knowledge. A model of differentiated eco-chemical education was created for permanent adult professional education.

Key words: effect of chemicals on the environemnt, mineral fertilizer industry, employees, environment, knowledge

Introduction

Development of chemical industry is followed by the incresed environmental pollution (Djukanović, 1996). Thus improvement of technical and technological processes must be accompanied by the adequate protection measures (Markovic, 1995).

One of the most significant factors in pollution, but also in environmental protection, are workers employed in various branches of chemical industry.

Most employees of the fertilizer plants in Serbia have completed secondary education, lasting three or four years. Ecochemical content in three-year program in secondary professional schools comprizes environmental protection, pollution sources and damage sanation, and are being studied through the course *Ecology and environmental protection* (1 class per week during one school year). These topics are also studied within one educational theme in a *Chemistry* course. Ecochemical content in four-year program comprizes very few classes within *Biology* course and, indirectly, through *Geography* and *Chemistry* courses. In high schools, ecochemical content is not studied as the separate course, but are incorporated in Biology course.

Modern technology, as well as new scientific discoveries in the field of ecochemistry, require the workers to possess additional knowledge (Andevski, 1997), which includes improvement of ecochemical knowledge of effects of chemicals on living organisms, environment, objects etc. (White, 2004). Industry of mineral fertilizers is one of the most important branches of chemical industry in Novi Sad (Vojvodina, Serbia). It has a great impact on the level of environmental pollution and the quality of life. Production of fertilizers is a source of significant environmental pollution (Markovic, 1996), which imposes the need to additionaly educate workers employed in this branch of chemical industry (Matijevic, 2008). Motivation of workers for continuing education is greatly influenced by previous knowledge, age, working conditions, possibilities to them for further education and numerous other factors (Schmidt, 2007).

In the Republic of Serbia, there is an ongoing reform of education at all levels. It also includes development of new programs for continual professional development of workers. Mechanisms of accreditation of the programs of professional development are still being created in all educational fileds, including improvement and development of courses in the field of environmental protection. The industry of mineral fertilizers imposes the need to design programs for specialized courses, and the purpose of this investigation is to analyze the existing level of ecochemical knowledge in workers with secondary education, with an aim to create models for permanent ecochemical education of workers in chemical industry.

Experimental Section

Object of research

The object of this research is developed from the need to analyze the level and quality of knowledge in workers employed by the fertilizer industry on environmental impact of chemicals, especially mineral fertilizers, in order to suggest a model for their further professional development.

Aims and tasks of the research

The aim of this research is the analysis of the ecochemical knowledge in workers employed by the fertilizer industry in the region of Novi Sad, as well as structuring of chemical contents for further increase of their knowledge. This content should become a vital part of the model of differentiated adult ecochemical education.

The following tasks were set for this investigation:

- Analysis of workers' knowledge on environmental impact of pollutants,
- Analysis of knowledge level of employees on effects of mineral fertilizers on the environment.

Research hypotheses

The main hypothesis is defined as follows: Employees of the mineral fertilizer industry in region of Novi Sad have certain, but insufficient knowledge on environmental impact of chemical pollutants.

Specific hypotheses:

- Workers with high school/university education are more familiar with environmental impact of chemical pollutants in general than workers with secondary education.
- Workers with high school/university education are more familiar with environmental impact of mineral fertilizers than workers with secondary education.

Research methods and techniques

In this investigation, analytical and descriptive methods were used. The research instrument was a questionnairre which was specially designed for the purpose of this research. Techniques of research were: field investigation, action investigation and combined techniques.

Table 1. Level of knowledge of chemical workers on averse environmental effects of chemical contaminants.

	High school/university education			Secondary education		
	Completely (%)	Partially (%)	No (%)	Completely (%)	Partially (%)	No (%)
Do you know which the adverse environmental effects of pesticides are?	66.67	33.33	0	91.3	8.7	0
Do you know which the adverse environmental effects of solvents are?	66.67	33.33	0	82.61	17.39	0
Do you know which the adverse environmental effects of aldehydes and ketones are?	44.44	44.44	11.11	30.43	60.87	8.7
Do you know which the adverse environmental effects of aromatic compounds are?	44.44	44.44	11.11	26.09	65.21	8.70
Do you know which the adverse environmental effects of heavy metals are?	66.67	11.11	22.22	69.57	30.43	0
Do you know which the adverse environmental effects of nitrogen compounds are?	77.78	22.22	0	73.91	26.09	0
Do you know which the adverse effects of chemicals on objects are?	77.78	22.22	0	60.87	39.13	0

Sample

Investigation included 141 workers, employed in the mineral fertilizer plant in Novi Sad, of which 89 workers had secondary education and 52 workers had high school or university education.

Results and discussion

Most workers of all education levels believe that they know the environmental impact of pesticides, solvents, heavy metals, and nitrogen compounds. However, the percentage of workers who think that they know these facts only partially

Table 2. Level of knowledge of chemical workers on adverse environmental effects of mineral fertilizers

ARE THESE STATEMENTS CORRECT?						
	High school/university education			Secondary education		
	Yes (%)	No (%)	I don't know (%)	Yes (%)	No (%)	I don't know (%)
Ammonia, accumulated in soil, and its salts formed in transformation of nitrogen fertilizers, increase pH of soil.	100	0	0	73.91	17.39	8.70
Nitric acid is formed in soil by oxidation of ammonium salts, thus reducing pH of soil.	77,78	22.22	0	69.56	30.44	0
Phosphates from phosphoric fertilizers penetrate deeper layers of soil and are transformed into thermodinamically most stable compounds with low solubility products, which plants can't absorb.	77.78	22.22	0	69.56	8.70	21.74
Diffusion of phosphates into deeper layers of soil causes increased concentrations of phosphates in soil and environmental pollution.	88.89	11.11	0	69.56	8.70	21.75
Transformation of phosphates into insoluble compounds and their reaction with soil components (which yields more soluble compounds) causes their low mobility.	100	0	0	60.87	4.35	34.78
Nitrogen fertilizers contributes to the natural water pollution more than phosphoric fertilizers.	77.78	11.11	11.11	26.09	43.48	30.43
Content of nitrogen fertilizers in surface and groundwater is increased with the increased application of these fertilizers in soil.	100	0	0	100	0	0
Increased application of nitrates as mineral fertilizers leads to their increased content in water.	88.89	11.11	0	69.56	8.70	21.74
Nitrates in water cause the disease called methemoglobinaemia ?	44.44	0	55.56	34.78	0	65.22
Components of mineral fertilizers are accumulated in plants and agricultural products.	100	0	0	61.40	38.6	0

cannot be neglected (Table 1). According to the obtained results, workers with secondary education have better knowledge of effects of pesticides, solvents, heavy metals, and nitrogen compounds on the environment, then workers with higher education. Adverse health and environmental effects of aldehydes, ketones and aromatic compounds is not very well known to most workers. All workers claim that they have a complete knowledge of impact of chemicals on objects.

When asked to specify the specific knowledge of effects of mineral fertilizers (Table 2), workers stated that they are completely acquainted with the adverse effects of the following:

1. Effects of ammonia and ammonium salts, which are produced in transformation of nitrogen fertilizers in soil on pH of soil;
2. Production of nitric acid in soil in reaction of oxidation of ammonium salts and its effect on pH of soil;
3. Transformation of phosphoric fertilizers in deeper soil layers into thermodynamically most stable compounds with low solubility products, which plants cannot absorb; Diffusion process of phosphoric fertilizers, which causes the increase in phosphorous content in soil, and their environmental impact;
4. Transformation of phosphates into insoluble compounds and their reaction with soil components;
5. Transformation of phosphates into insoluble compounds and their reaction with soil components;
6. Consequences of increased content of nitrates in water as a result of frequent application of mineral fertilizers that contain nitrate ion as a basic component;

Table 3. Proposal of content for additional education of workers with high/school/university diploma

I General content 1.1. Basic consequences of chemical pollution of atmosphere, hydrosphere and soil 1.2. Basic consequences of effects of chemicals on living organisms 1.3. Effects of pesticides on organisms and the environment 1.4. Effects of polychlorinated biphenyls 1.5. Effects of contaminants on aquatic biocenose 1.5.1. Effects of heavy metals 1.5.1.1. Effects of silver 1.5.1.2. Effects of cadmium 1.5.1.3. Effects of chromium 1.5.1.4. Effects of copper 1.5.1.5. Effects of lead 1.5.1.6. Effects of mercury 1.5.1.7. Effects of nickel 1.5.1.8. Effects of iron 1.5.1.9. Effects of manganese 1.5.2. Effects of oil 1.5.3. Effects of surfactants 1.5.4. Effects of pesticides 1.5.5. Effects of phenol 1.5.6. Effects of chlorine 1.5.7. Effects of ammonia	1.6. Contamination of food pollution by chemicals 1.6.1. Mycotoxins 1.6.2. Toxic metals 1.6.3. Halogen compounds 1.6.4. Pesticides 1.6.5. Antibiotics, hormones and additives 1.6.6. Synthetic substances 1.7. Environmental effects of chemical contaminants originated from agricultural production 1.8. Effects of acidic oxides 1.8.1 Oxides of sulfur 1.8.2. Nitric oxides 1.9. Effects of fluorides 1.10.Environmental effects of aerial precipitation 1.11. Pollution of troposphere with oxidants 1.12. Environmental effects of emissions of basic pollutants 1.13. Greenhouse effect 1.14. Environmental effects of pollutants on objects 1.15. Effects of reduced content of stratospheric ozone **II Special content** 2. Mineral fertilizers as pollutants 2.1. Effects of mineral fertilizers on water pollution 2.1.1. Effects of nitrogen fertilizers 2.1.2. Effects of phosphoric fertilizers	2.2. Effects of mineral fertilizers on soil pollution 2.3. Effects of mineral fertilizers on air pollution 2.4. Application of fertilizers that contain microelements 2.5. Transformation of mineral fertilizers in soil 2.5.1. Transformation of nitrogen fertilizers 2.5.2. Transformation of phosphoric fertilizers 2.5.3. «Big nitrogen pump» 2.6. Effects of mineral fertilizers on pH of soil 2.7. Pathways for reducing mineral fertilizer content in soil 2.8. Environmental effects of nitrates as fertilizers 2.9. Accumulation of fertilizers in plants 2.9.1. Transformations in plants caused by fertilizers 2.10. Problem of partial exhaustion of fertilizers 2.11. Effects of mineral fertilizers on humans and animals 3. Environmental effects of pesticides 3.1. Accumulation of pesticides in plants 3.2. Effects of pesticides on flora and fauna

7. Accumulation of mineral fertilizers in plants and their implementation into trophical chains.

It should be emphasized the significant percentage of workers who think that they have insufficient knowledge of the following facts:

- processes of transformation and diffusion of phosphates in soil and their environmental impact;
- effects of nitrates in fertilizers on their increased content in water.

Participants have exhibited excellent knowledge on relationship between content of nitrogen fertilizers in soil and in water, but most of them don't know the adverse health effects of nitrates, such as methemoglobinaemia. In contrast to workers with university education, most workers with

Table 4. Proposal of content for additional education of workers with secondary school diploma

I General content	**II Special content**
1.1. Basic consequences of chemical pollution of atmosphere, hydrosphere and soil	2. Mineral fertilizers as pollutants
1.2. Basic consequences of effects of chemicals on living organisms	2.1. Application of fertilizers that contain microelements
1.3. Effects of pesticides on organisms and the environment	2.2. Transformation of mineral fertilizers in soil
1.4. Effects of phenols and polychlorinated biphenyls	2.2.1. «Big nitrogen pump»
1.5. Effects of contaminants on aquatic biocenose	2.3. Effects of mineral fertilizers on pH of soil
1.6. Environmental effects of chemical contaminants	2.4. Pathways for reducing mineral fertilizer content in soil
1.7. Environmental effects of chemical contaminants originated from agricultural production	2.5. Effects of mineral fertilizers on water pollution
1.8. Effects of acidic oxides	2.6. Effects of mineral fertilizers on soil pollution
1.8.1 Oxides of sulfur	2.7. Effects of mineral fertilizers on air pollution
1.8.2. Nitric oxides	3. Environmental effects fertilizers
1.9. Effects of fluorides	3.1. Environmental effects of nitrates as fertilizers
1.10.Environmental effects of aerial precipitation	3.2. Accumulation of fertilizers in plants
1.11. Pollution of troposphere with oxidants	3.3. Problem of partial exhaustion of fertilizers
1.12. Environmental effects of emissions of basic pollutants	3.4. Effects of mineral fertilizers on humans and animals
1.13. Greenhouse effect	4. Environmental effects of pesticides
1.14. Environmental effects of pollutants on objects	4.1. Accumulation of pesticides in plants
1.15. Effects of reduced content of stratospheric ozone	4.2. Effects of pesticides on flora and fauna

secondary education don't have sufficient knowledge on effects of nitrogen and phosphoric fertilizers on pollution of natural waters.

Model of additional education of workers in mineral fertilizers industry in the field of environmental effect of chemicals

Analysis of the questionaire has revealed the fact that present knowledge of participants should be improved and that workers should be further educated on effects of chemical substances on the environment, and especially of mineral fertilizers which they come in contact with. Educational content is differentiated according to the previous academic level of workers:

- content for additional education of workers with high school/university education (Table3),
- content for additional education of workers with secondary education (Table 4).

Content is also divided into general and specific. General content includes knowledge on environmental impact of different chemical contaminants, while specific content includes knowledge on effects of mineral fertilizers and pesticides on the environment.

Workers with high shool/university education should be offered wider ecochemical content since they are more interested in learning than workers with secondary education. Educational process should include various teaching methods: monologue and dialogue, discussion, textual method, demonstration, method of written essays and graphics, film projections, laboratory method, projects, case-study etc. (Oljaca, 1997)

On the basis of the obtained results it can be concluded that the workers who participated in the survey, employed in the industry of mineral fertilizers in the region of Novi Sad (Vojvodina, Serbia) have sufficient knowledge on environmental effect of various chemical pollutants, including mineral fertilizers, but they also should improve the existing and acquire new knowledge, which confirms the main research hypothesis.

Workers with high school/university diploma have in many fields better knowledge than workers with secondary education, except in case of environmental effects of pesticides, solvents, heavy metals and nitrogen compounds. This means that the specific hypothesis of this research has been only partially confirmed.

In order to provide workers with additional ecochemical knowledge, it is necessary to design the model of permanent ecochemical education of workers in mineral fertilizer industry, in which the important part would be information on environmental impact of various chemical contaminants, and especially effects of mineral fertilizers and pesticides. This content should be differentiated according to the academic level of employees and should be divided into general content (data on environmental effects of various pollutants) and specific content (data on imact of fertilizers and pesticides).

Additional knowledge of these facts not only improves the professional position of workers, but also develops their correct attitude towards the

environment, which reduces the risk of further environmental pollution. Permanent ecochemical education of the workers in chemical industry is of a great significance in prevention of further pollution and sanation of existing environmental problems.

Acknowledgement

Research presented in this paper was supported by the Ministry of Science and Environmental Protection of the Republic of Serbia (Project No. 149009).

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