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PLANT PROTECTION PRODUCTS VERSUS CHANGES IN THE NATURAL ENVIRONMENT AND THEIR IMPACT ON THE HUMAN HEALTH

Summary

Farmers wanting to meet the global competition increasingly often use chemical agents to increase yields. However, more and more research confirms the assumptions of scientists on the negative impact of pesticides on life forms. Research points to a significant statistical linkage between the use of plant protection products and higher risk of developmental disorders, neurological disorders and certain forms of cancer. These disorders might be transferred to the next generations through changes in the gene expression, which are not connected to changes in the DNA sequence. The paper is to present the risks for the natural environment following from the use of pesticides in agriculture, which is also linked to human health.

Key words: agriculture, pesticides, changes in the environment, wildlife habitats, epigenetics, human health.

Introduction

Agriculture has always had impact on the natural environment. The initially undertaken extensive production affected the environment, but nature had time to recover. Changes were brought about by the Industrial Revolution and then Digital Revolution, started at the end of the first half of the 20th century. This disturbed the balance between the economy and the environment. So far it seemed that harmonious development can be ensured based on activities underlain by two principles: renewable resources should be used at a pace not exceeding the pace of their renewal, and inflow of pollution to the natural environment should not exceed the capacity of the environment to assimilate it (Woś and

Zegar, 2002). Today, adherence to the principles is not enough. On the one hand, changes that have taken place in the environment caused global climate change and, on the other, pesticides once used continue to have a negative impact on human organisms and are inherited by subsequent generations through change in epigenetic nature, although they had not been used for many years.

Agriculture in Poland uses over 60% of the total area of the country and is an important element of the pressure put on the environment. Synthetic plant protection products were used as of the 1950s without comprehensive knowledge on long-term effects of their impact on the environment and human health. It is especially important in case of products that have very long time of decay, e.g. DDT (half-life of DDT in human body fat is 5-7 years). Although it has been banned for over a decade, products of DDT decay are still detectible. The most often detected compounds from the group are p, p'-DDT and small quantities of Lindan. The major effects of contact with these compounds include pancreatic cancer, leukaemia and other serious diseases (Freinch et al., 2003). Pesticides partly solve some problems, but they cause others, e.g. they contribute to faster evolution of new species of pests making them resilient to most of the used insecticides.

Extension of industrial agriculture indeed solves the problem of malnutrition and hunger in rich communities by lowering production costs and increasing crops, but it, simultaneously, enhances the pressure on the environment by universal use of chemical products, whose negative impact is increasingly more visible. The environmental and social costs of industrial agriculture are high, causing for instance contamination of water and air, loss of biodiversity, lower soil fertility, dependence on non-renewable resources, deprivation of farmers.

Many researchers demonstrate the negative impact of agriculture and in particular pesticides on human health. According to the World Health Organization, presently over 13 million deaths and nearly one quarter of diseases are caused by environmental pollution (Bollati and Baccarelli, 2010). The research shows an important statistical connection between exposure to plant protection products and higher risk of both developmental disorders and many other diseases, including certain forms of cancer.

Today, many publications are devoted to agricultural model based on sustainable development. It is a socio-economic development philosophy considering respect for the environment. Sustainable development consists in harmonious matching of production, economic and environmental objectives. Agriculture based on this concept is to ensure long-lasting sustainable and self-supporting development. This concept is to enable better life for the contemporary as well as future generations via setting adequate proportions between the economic, human and natural capital.

Poland, upon accession to the European Union, was covered by the Common Agricultural Policy. The CAP evolution is targeted at minimising the sig-

nificance of production and income targets for more general targets linked also with preservation of biodiversity of the natural environment and sustainable development and preservation and protection of the landscape and unique natural values. Presently, the importance of agricultural production, which remains in accord with the natural environment, is increasingly more often highlighted. In response to the agriculture intensification process, broadly-conceived organic farming is being promoted (Twardy, Smoroń and Nadolna, 2013).

This paper aims at literature review concerning threats to the environment, life forms and humans following from overuse of industrial means of production. The paper uses also data from the Central Statistical Office (Polish: *Główny Urząd Statystyczny,* GUS).

The impact of agricultural activity on the natural environment

Impact of agriculture on the natural environment depends on its development stage. Today, the negative effects of the 2nd Agricultural Revolution, the so-called "Green Revolution", are clear. In the global agriculture there are still economies only starting their 1st Agricultural Revolution, while a growing number of countries enters the 3rd stage of the Agricultural Revolution, which is triggered by biotechnological revolution. Its impact on the natural environment cannot be entirely predicted, since it changes the approach of humans to nature in general (Halamska, 2014).

The use of chemical plant protection products contaminating food, air, soil and water is not the only factor co-creating the threat for the environment and human health. Other threats following from agricultural production intensification include:

- contamination of surface waters and groundwater environment caused by improper use of fertilisers, especially nitrogen and phosphorus fertilisers;
- improper sewage management at farms, including leaks in septic tanks for sewage or their incorrect treatment before discharge to water or ground;
- intensified soil erosion and consequently reduction in its fertility;
- emission to the air of methane, carbon dioxide and other gaseous substances originating from intensive livestock rearing or breeding, leading to unfavourable climate change;
- emission to the air of particulate matter originating from intensive livestock rearing or breeding (dust from litter, fodder mixing storages, cereal dryers or other livestock facilities);
- change in the landscape and in the climate, which results in extinction of some fauna and flora species (Kajdan-Zysnarska et al., 2010).

Data presented in Figure 1 point to an upward trend in the use of plant protection products in Poland. They become more and more popular, their use has grown over three-fold over the last 10 years. The upward trend wavered in 2009 and 2010, probably due to turbulences in the global markets and not increase

in the awareness of farmers as regards their negative impact on the natural environment and human health. Several times higher use of pesticides in the Polish agriculture brings about the risk not only for the consumers but also for the natural environment, primarily for the very farmers and their families exposed to the impact of much higher doses of substances harmful to their bodies.

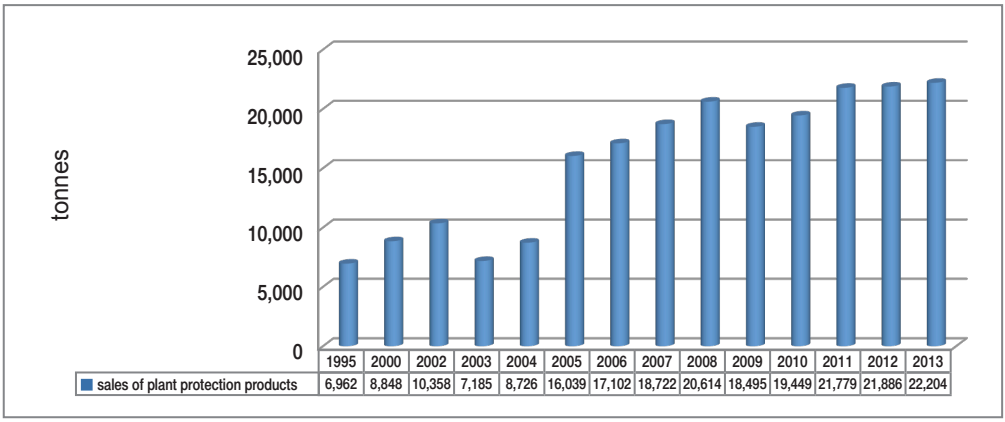

Fig. 1. Sales of plant protection products (in active substance) in Poland in 2000-2013.
Source: own study on the basis of: *Rocznik Statystyczny Rolnictwa* (2007-2014). GUS, Warszawa.

The impact of using pesticides in agriculture on wildlife habitats

The common practice of using pesticides from the middle of the 20th century was not indifferent to the environment, especially to wildlife. They affected animals via waters polluted with pesticides and by disrupting the food chain. In their research Köhler and Triebskorn (2013), indicated that the use of pesticides in the 1960s and 70s caused a major drop in the number of birds of prey. Pesticides build up in the bodies of predators that feed on other animals exposed to the effect of chemical agents contained in plant protection products. The use of pesticides caused not only a clear drop in the population of birds of prey but also that of bees, and major changes in the aquatic ecosystems. Research revealed that pesticides are present in the organisms of both land and marine mammals. As pointed out by Hallmann, Foppen, van Turnhout, de Kroon and Jongejans (2014), banned pesticides are replaced with new ones, which also contribute to unfavourable changes in the ecosystems.

Control of crop pests by pesticides also dwindles the populations of harmless invertebrates which form the basic source of food for many species of birds. Research by Brühl, Schmidlt, Pieper and Alscher (2013) showed, for instance, that amphibians are very sensitive to the toxic effects of pesticides, even when its concentration is permissible according to the international standards, thus this group of animals is now the most threatened with extinction.

Therefore, in a near future a failure to take firm actions can result in major changes in ecosystems and contribute to extinction of many species of animals from agricultural areas. Europe witnesses a clear drop in the number of wildlife habitats near farms, which is undoubtedly largely the effect of popularisation of the industrial methods of crop cultivation. Rapid changes caused by this method of crop cultivation do not allow animal species, adjusted to living in conditions created by traditional agriculture, to adapt to the newly created conditions.

The impact on human health of pesticides in agriculture

Literature demonstrates many mechanisms of negative impact of pesticides on human body. Undoubtedly, the epigenetic effect plays a crucial part in the development and aging of humans but also in pathogenesis of malignant tumours. The newest research shows that epigenetic abnormalities can be transferred to the next generations.

Proving that a given disease was caused by contact with a specific pesticide, is still a major challenge for scientists. As indicated by Meyer-Baron, Knapp, Schäper and van Thriel (2015), in the entire human population it is impossible to find a group of people that has never been in contact with pesticides. Many diseases are caused by the impact of varied factors which hinders unanimous definition of their cause. Apart from that most of the diseases have a complex aetiology because environmental and genetic factors are linked via epigenetic mechanisms. Their impact on the cells of living organisms is known for several years but only recently scientists started to understand how broad their range is. Epigenetics is a branch of science explaining the changes in the impact of gene expression that are not connected to changes in the DNA sequence. Epigenetic factors affect the gene activity, but the relations between the genome and epigenome are not fully explained. What is known, however, is that when a cell divides, the epigenetic markers in its chromosomes are passed on to daughter cell chromosome.

Humans can come in contact with pesticides by many ways, e.g.:

- directly at work or home,
- by food,
- by breathing with polluted air in agricultural areas during and after pesticide spraying,
- by drinking water contaminated with pesticides,
- by pesticides present in dust particles (Greenpeace, 2015).

It is impossible to totally eliminate artificial chemical compounds contained in food supplied to the consumer, thus permissible doses tolerated by organisms were set for specific pesticides (Potocki, 2006). The tolerated dose means the maximum pesticide residue left after the waiting period, which remains in raw materials and products. Nonetheless, it should be noted that not all producers and processors of agricultural raw materials aiming to increase yields and, consequently income, observe the applicable standards.

Substances included in plant protection products have different effects on animal organisms depending on their development period, the effects of pesticides are especially dangerous at foetal and infant stage of development. Research by Anway et al. (2006), confirmed the research results of other scientists, indicating that rat embryos exposed in utero to the effects of vinclozolin in adulthood showed congenital disorders of sexual organs. Moreover, one of the components of insecticides, methoxychlor – had a negative effect on the pregnancy, reproductive processes, and development of testes in males (Okazaki, Nishimura, Nakamura and Kitamura, 2001). Another pesticide known to increase methylation is DDT, commonly known as Azotox, which changes the genes responsible for obesity.

Table 1

Impact of pesticides on epigenetic changes

Pesticide name	Type of epigenetic modification	Disorder
Arsenic DDT Diazinon Methoxychlor Permethrin TCDD Vinclozolin	Changes in DNA methylation	Alcoholism Dementia Schizophrenia Brain tumours, lung cancer, liver cancer, kidney cancer, ovarian cancer, cervical cancer, prostate cancer
Dieldrin Paraquat Propoxur	Histone modification	Leukaemia
Dichlorvos Fipronil Fungicides	Change in miRNA expression profile	Heart diseases Prostate cancer

Source: own study on the basis of: (Rzeszutek et al., 2014).

Research by Sciandrello, Caradonna, Mauro and Barbata (2004), indicated malignant transformation after administration of arsenic to mouse embryos, which is one of the most often used components of plant protection products. Researchers also found changes in DNA methylation in case of diazinon, i.e. a well-known insecticide, which can also have its part in the development of different types of cancer (Zhang et al., 2012).

The negative impact of such compounds as dieldrin, paraquat, propoxur, which are components of commonly used insecticides, covers their impact on histone modification, which consequently resulted in their build up in the central nervous system. They also indicated a major endotoxicity for mammalian

cells (Wang, Chiou, Chang and Hu, 1998). Research was held under laboratory conditions, where animals were subject to much higher doses of pesticides than those commonly inhaled by humans due to environmental contamination.

Other research, presented by Skiner (2014), pointed to transgenerational effects caused by doses much closer to those that humans are exposed to. Moreover, there are groups of people especially at risk of the negative impact of pesticides, these include farmers and their families, in particular people conducting the spraying and employees in greenhouses. Italian research in people employed in agriculture showed an increased level of pesticides in their bodies. The level of harmful substances was higher in the organisms of farmers, regardless of the type of performed work, which could be the effect of long-term exposure to very persistent organochlorine pesticides (Schummer, Salquebre, Briand, Millet and Appenzeller, 2012). However, observance of the principles of safety linked to the use of plant protection products can limit the negative impact of characterised chemical products.

Pesticides can also have a negative impact on the future generations. From experimental research it follows that some substances contained in pesticides can cause inheritance of diseases through transgenerational epigenetic inheritance. Exposure of pregnant women to some pesticides can increase the probability of disease not only for them but also the next generations, even if they did not have direct contact with these substances. Laboratory research by Anway and Skinner (2006), proved that exposure of rats to vinclozolin has a major unfavourable impact on the offspring in four subsequent generations (e.g. for animals injected with DDT over 50% of their fourth generation was obese although the second generation was normal size). It is possible that the process is similar for people. In the US DDT was commonly used in the 1940s and 50s. The third generation after the use of DDT in the US now deals with obesity. The reasons for this phenomenon can be found in epigenetics.

Many synthetic plant protection products cause permanent and pervasive contamination of the natural environment, which in turn exposes every human to the impact of these substances. Data show that many of the used substances are in the form of mixtures, whose unfavourable effects are unknown, especially in a long term perspective (Reffstrup, Larsen and Meyer, 2010).

Conclusions

Initially, the negative impact of pesticides on the natural environment was not recognised. It was reckoned that they will solve the problem of deprivation. However, indiscriminate use of these substances contributed to irreversible changes in the environment and starts to have a negative impact on the health of the next generations.

Many chemical compounds used presently in agriculture have become persistent and pervasive contaminants of the environment. These components are both in water that we drink and food that we consume every day. This exposes

people to the mixtures of different substances, whose effect on the human population and the environment as a whole has not been examined. The effects of various substances can be seen only after several years. The future generations, although they will not be exposed to individual pesticides themselves, they will be threatened by diseases that they cause, because of the transgenerational epigenetic inheritance. The impact of pesticides leading to epigenetic abnormalities can disturb the proper functioning of the organism, which results in the development of many diseases.

Analysis shows that the use of plant protection products grows in Poland. Only in the last few years farmers, e.g. because of the increased demand for organic products – started to see the need to protect the environment. What also grows is the number of studies confirming the negative impact of chemical agents used in agriculture on the natural environment and directly or indirectly on human health. The common application of pesticides and little known long--term effects of their influence on the environment constitute a risk for all living organisms and future generations.

One might hope that higher level of social awareness will force the use of respective personal protection measures, especially by farmers and their families, who are most exposed to much higher doses of pesticides than the rest of the society.

Thus, it seems that the greatest challenge of today's agriculture is finding balance between the need to feed the increasingly growing population and releasing the population from the risks involved in the faults of the industrial model of agriculture. It is possible that this will happen not through increased chemicalisation of agriculture but through biological progress, targeted at the creation of new plant species resilient to diseases, pests and unfavourable climate conditions. Livestock production also needs biological progress consisting in the introduction of new animal breeds more resistant to diseases, characterised by pace of ontogenesis (height and weight), higher content of better quality proteins and abilities to adapt to the unfavourable environmental factors.

Bearing in mind the results of epigenetic research, it is expedient to consider far-reaching changes in the production technology in agriculture. The future of agriculture should be based on sustainable agriculture, which takes into account the basic needs of all people, at the same time, looking after the protection of the natural environment and its restoration possibilities, without the risk that it will not be possible to satisfy the needs of the future generations, because of the irreversible changes in the natural environment caused by improper human activity.

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ŚRODKI OCHRONY ROŚLIN A ZMIANY W ŚRODOWISKU NATURALNYM I ICH WPŁYW NA ZDROWIE CZŁOWIEKA

Abstrakt

Rolnicy, chcąc sprostać globalnej konkurencji, w coraz większym stopniu wykorzystują środki chemiczne w celu zwiększenia plonów. Coraz więcej badań potwierdza jednak przypuszczenia naukowców o negatywnym wpływie pestycydów na organizmy żywe. Badania wskazują bowiem na znaczący statystyczny związek pomiędzy stosowaniem środków ochrony roślin a wzrostem ryzyka występowania zaburzeń rozwojowych, chorób neurologicznych oraz niektórych nowotworów. Choroby te mogą być przenoszone na kolejne pokolenia poprzez zmiany ekspresji genów, które nie łączą się ze zmianami sekwencji DNA. Celem artykułu jest przedstawienie zagrożeń wynikających ze stosowania pestycydów w rolnictwie dla środowiska naturalnego, a z tym wiąże się również zdrowie ludzi.

Słowa kluczowe: rolnictwo, pestycydy, zmiany w środowisku, siedliska dzikich zwierząt, epigenetyka, zdrowie człowieka.

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