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Neonicotinoids —transport in the aquatic environment

Contamination of surface and groundwater by neonicotinoids is a global problem and requires comprehensive action by individual countries (including Poland) in order to identify in detail the processes affecting the transport of these pesticides, their properties, and their harmfulness to the environment.

The aim of this study was to assess the transport of selected neonicotinoids in the aquatic environment. Five neonicotinoids were analyzed in detail: acetamiprid, clothianidin, imidacloprid, thiacloprid, and thiamethoxam. These are pesticides that have been or are most commonly used in agriculture and are on the EU's 1st and 2nd watch lists.

The research carried out for the purpose of the study included several stages: obtaining and reviewing literature data, planning experiments taking into account the uncertainty of results, laboratory tests, data development and analysis, and risk analysis for the aquatic environment.

The literature review was for gathering information on the studied neonicotinoids, including their basic characteristics, as well as processes influencing their fate in the aquatic environment (i.e. sorption, biodegradation, and chemical transformation).

Before planning the experiments, the main factors influencing the uncertainty of the obtained results were identified. These factors were then included in experiments for minimalization of their impact on the research results.

In order to determine the parameters of neonicotinoid transport, batch tests and column experiments were planned. Laboratory experiments consisted of four stages. The first stage was to conduct a pilot experiment of column studies using a conservative tracer (chloride) for three artificial soils. The purpose of this stage was to verify whether the prepared stand allows for obtaining reliable results. As part of the second stage of the column studies, the repeatability of the experiments was assessed by conducting imidacloprid migration studies simultaneously in two identical columns. Additionally, this stage included pilot studies of three selected neonicotinoids (acetamiprid, imidacloprid, and thiamethoxam) using two different artificial soil. The third stage of the research consisted of batch tests, performed in order to determine approximate values of the retardation factor, which facilitated the last stage of column experiments. In the last, the fourth stage of the research, column experiments for the migration of the studied neonicotinoids were carried out in two variants: 1) for acetamiprid individually and 2) for a mixture of five analyzed neonicotinoids on three selected natural soils and clean sand, treated as the reference material. The research was carried out on two levels of neonicotinoid concentrations in order to assess the effect of concentration on the rate of sorption of these pesticides. Transport parameters were determined using the CXTFIT–STANMOD software. It was observed that neonicotinoids sorb mainly on clay minerals and organic matter (the highest sorption was observed for soil, with the highest content of these components). In addition, it was found that individual neonicotinoids undergo sorption at a different rate — the highest sorption was observed for thiacloprid and the lowest for thiamethoxam.

The data obtained from the experiments were used in the analysis of the risk of groundwater intakes contamination related to the use of neonicotinoids. This analysis was performed for four out of five tested pesticides — acetamiprid, clothianidin, imidacloprid and thiamethoxam — currently approved for use in Poland. The considerations were carried out on the example of a hypothetical groundwater intake, near which there were two potential sources of contamination

— the expressway (chloride contamination) and the fruit orchard/greenhouses (neonicotinoid contamination). The risk analysis was performed assuming that the saturation zone consists entirely of multi-grained sand, and the characteristics of the aeration zone vary depending on the characteristic of this zone (four different soils) and its thickness (8, 4 or 2 m). Additionally, two variants of the initial concentration of pesticides were applied — higher, at the level of neonicotinoids solubility in water, and lower, estimated using the permissible dose of pesticides and the volume of infiltrating precipitation.

As a result of the analysis, it was shown that the use of acetamiprid and thiamethoxam for agricultural purposes is associated with acceptable risk, i.e. it does not pose a threat to the quality of water taken from the groundwater intake for food purposes. Two neonicotinoids — imidacloprid and clothianidin — pose a higher risk of contamination of the groundwater intake. A controlled or unacceptable risk occurs especially when the aeration zone is characterized by a small thickness (2 or 4 m) and consists of sandy soils with little or no clay minerals and organic matter content.

This dissertation, according to the author, is the first such extensive study on conducting column experiments taking into account the stage of research planning, including the analysis and minimization of factors affecting their uncertainty.

The data obtained as part of the experiments carried out for the purposes of the study allowed, among others, a better understanding of the processes influencing the transport of the analyzed neonicotinoids in the aquatic environment (1 thesis). These data were successfully used in the analysis of the risk of groundwater intakes contamination with neonicotinoids in agricultural areas. As a result of the analysis, the author of the dissertation proved that modeling the neonicotinoids transport in the aquatic environment in combination with risk analysis is a way to optimize their use in agriculture (thesis 2).