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TRANSFORMATIONS OF 2,4-DICHLOROPHENOL IN THE SOIL

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Abstract. The experiment was carried out under laboratory conditions on sterile and nonsterile humus soil treated with ^{14}C-2,4-dichlorophenol (DCP). The disappearance dynamics of extractable residues, and formation of the bound ones, as well as diffusion of radioactive volatile substances to the air were observed during 112 days. The results showed that disappearance of extractable residues of 2,4-DCP and binding to the soil matter run much faster in the presence of soil microorganisms than under abiotic factors. It has been stated that soil microorganisms played an important role as the regulator of free residues level in soil solution, enhanced their mineralization process. Moreover, by participation in binding of 2,4-DCP to soil matrix microorganisms also limited the release of toxic substance into the air.

Key words: 2,4-dichlorophenol, soil, extractable residues, bound residues, mineralization

I. INTRODUCTION

The knowledge about the fate and possible transformations of pesticides and their toxic degradation products is important for environment, because they can pose potential hazard as a result of accumulation in the soil, and leaching down the soil profile to ground water. The xenobiotics often found in the soil are phenolic compounds. These compounds can be introduced into environment with industrial and municipal wastes, and by application of some pesticides with herbicidal action in agriculture. Chlorophenols are chemical analogues of aromatic substances that naturally occur in the soil which suggests that, likewise, can be incorporated into humus structure. One of these compounds often found in the soil on agriculture areas is 2,4-dichlorophenol (2,4-DCP), the main metabolite of 2,4-D herbicide and related compounds. The aim of presented studies was to recognize the role of soil microorganisms in real degradation of 2,4-DCP, as well as participation of abiotic factors in this process.

II. MATERIAL AND METHODS

The experiment was carried out under laboratory conditions on humus soil, without history of 2,4-D herbicide application. To observe and consider the influence of abiotic and biotic factors on 2,4-DCP degradation, the experiment was conducted in two factor variants. In the first variant the soil samples of 100 g were placed in Erlenmayer flasks, and then sterilized 3 times using Koch apparatus, each time at intervals of 24 hours. In the second variant the natural soil, without any previous treatment was used. Then all soil samples were

fortified at the level of 20 ppm with methanol-water mixture of ^{14}C-ring-labelled 2,4-dichlorophenol and "cool" compound. Afterwards the treated soil samples were brought up to 60% of maximum water capacity with distilled water. The Erlenmayer flasks supplied with NaOH traps for radioactive compounds evolved from the soil, were incubated for 112 days at 23°C. During this period the disappearance of extractable residues, formation of the bound ones and volatile ^{14}C products of 2,4-DCP degradation were observed. Soil samples were taken at established intervals, and then analyzed for extractable residues (by methanol exhaustive extraction method), and bound residues (by combustion of the previously extracted soil). The radioactivity of methanol extracts and trap solutions were determined using liquid-scintillation counter (LSC) Beckman 5000TD. The results obtained in radioactivity units [dpm] (disintegration per minute) on LSC have been expressed as residue units [mg/kg] or percent of total 2,4-DCP applied into 100g portion of soil.

III. RESULTS

The degradation of 2,4-DCP applied into natural soil advanced much faster than in sterile soil. In the presence of active soil microorganisms (Fig. 2) the disappearance of free ^{14}C residues (extractable) was as dynamic, so during 8 weeks the residue level decreased from 18.85 ppm to 4.24 ppm, whereas in sterilized soil extractable radioactivity decreased to about 9 ppm (Fig. 1).

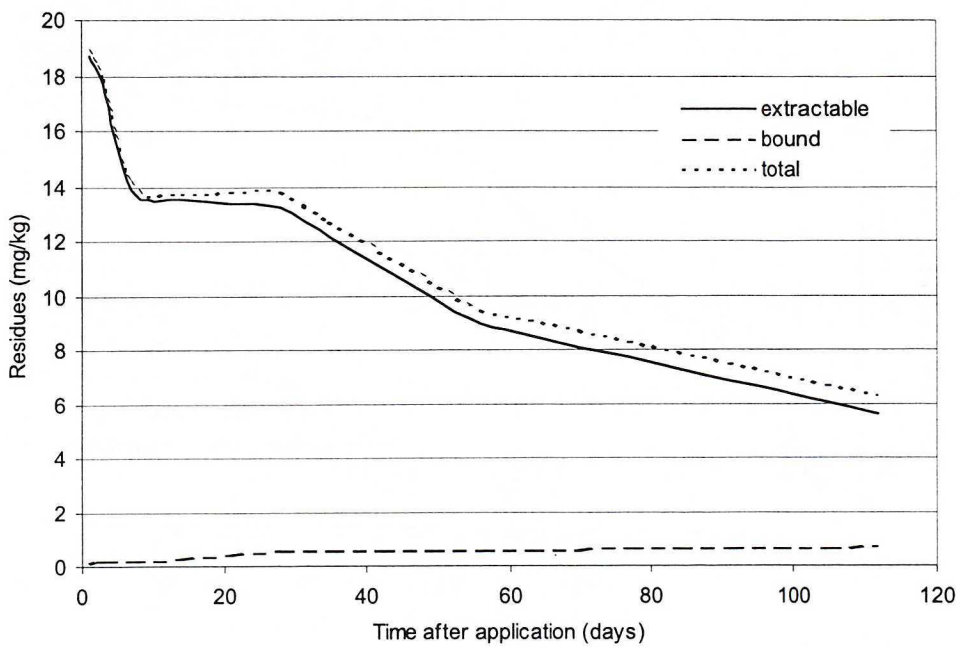

Fig. 1. Disappearance dynamic of 2,4-dichlorophenol residues in sterile soil

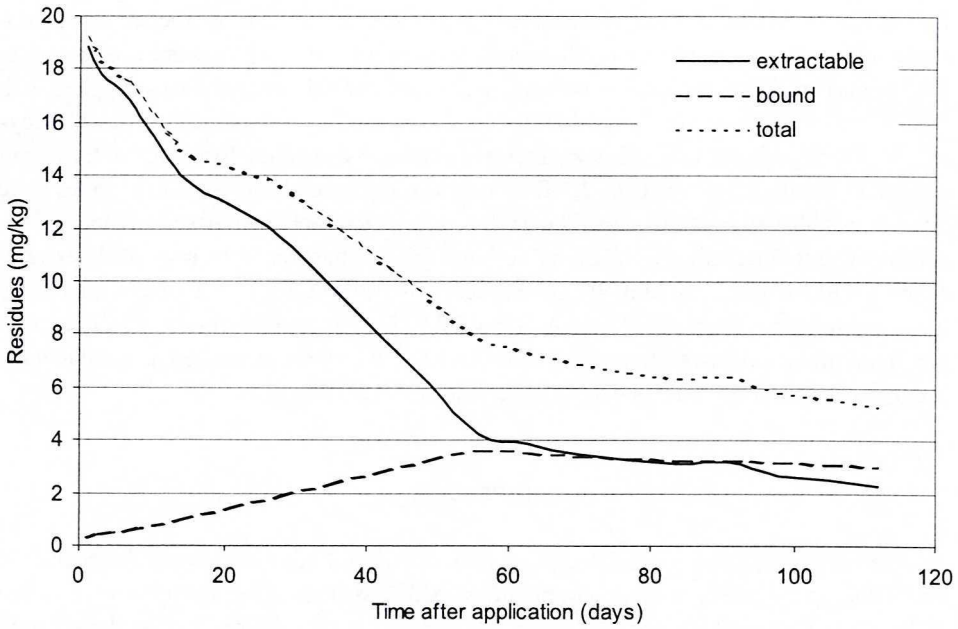

Fig. 2. Disappearance dynamic of 2,4-dichlorophenol residues in natural soil

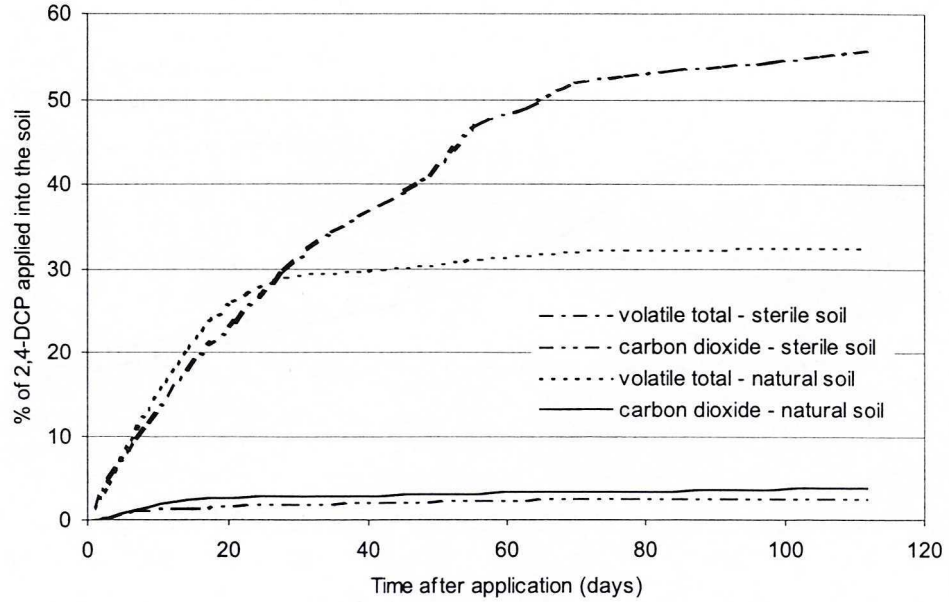

Fig. 3. Volatile compounds evolved from the soil treated with 2,4-dichlorophenol

In both variants, the disappearance of extractable residues was simultaneously accompanied by the increase of bound forms. You can observe that in the same period of 8 weeks, in natural soil bound residues reached to 3.65 ppm, but in sterile soil the bound ones were relatively low (0.56 ppm).

More differences between both variants appeared in the next 8 weeks. In sterile soil (Fig. 1) both processes were less dynamic, while in natural soil (Fig. 2) the disappearance of extractable and bound residues took place. Also the amounts of radioactive volatile compounds, including $^{14}CO_2$ which evolved from the soil prove favorable influence of soil microorganisms on release and mineralization of 2,4-DCP (Fig. 3). The total amount of volatile radioactive substances evolved from sterile soil was about 55.88% of applied compound, and 2.68% as $^{14}CO_2$, but from natural soil there evolved 32.54% and 3.82% respectively.

IV. DISCUSSION

The experiment confirmed the possibility of 2,4-DCP incorporating into soil matrix. The results showed that the disappearance of xenobiotics in the soil is a resultant of two simultaneously running processes; real degradation of residues and binding them to soil matter, which were in progress under biotic and as well as abiotic factors. It seems that the soil microflora has a dominant influence on these transformations.

The soil microorganisms mediated in binding 2,4-DCP to humus, thereby they performed the role of natural factor decreasing the concentration of extractable residues which are easily available for plants and living organisms. This also suggests that by binding and enhanced mineralization microflora prevented the evaporation of toxic substances from the soil to the air.

The results obtained in above mentioned investigations confirmed the trends observed in experiments with other pesticides and their metabolites, where the concentrations of bound residues were higher in the presence of natural soil microflora than without its participation (Dec at al. 1990; Lewandowska et al. 1991; Dec and Bollag 1998; Helling and Krivonak 1978).

It has been stated that mediation of microflora in binding toxic compounds to soil matrix simultaneously limited their release into the soil solution. Also its influence on mineralization process of residues is beneficial for environment, because these as free or released from the soil absorbing complex would be available for successive plants (Dec and Bollag 1988; Dec et al. 1990; Lewandowska 1991).

V. LITERATURE

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PRZEMIANY 2,4-DICHLOROFENOLU W GLEBIE

STRESZCZENIE

Badano wpływ mikroflory glebowej na rzeczywistą degradację 2,4-dichlorofenolu (DCP), jak też udział czynników abiotycznych w tym procesie. Doświadczenie w dwóch wariantach przeprowadzono w warunkach laboratoryjnych, gdzie śledzono zanikanie 2,4-DCP w glebie humusowej. Do gleby naturalnej, uprzednio niczym nie traktowanej (wariant I) oraz poddanej sterylizacji (wariant II), zaaplikowano roztwór metanolowo-wodny związku znakowanego w pierścieniu izotopem węgla ^{14}C w mieszaninie z preparatem „zimnym", w ilości odpowiadającej fortyfikacji na poziomie 20 ppm. W okresie 16 tygodni śledzono zanikanie ekstrahowalnych pozostałości 2,4-DCP i powstawanie form związanych oraz oznaczano ilości radioaktywnych związków lotnych, które oddyfundowały z traktowanej gleby.

Wyniki badań wykazały, że zanikanie 2,4-DCP w glebie jest wypadkową rzeczywistej degradacji i wiązania jego pozostałości z humusem. Oba procesy postępują pod wpływem czynników biotycznych i abiotycznych. Jednak w obecności naturalnej mikroflory proces zanikania 2,4-DCP był bardziej dynamiczny niż w glebie, w której przez sterylizację wyeliminowano czynnik biologiczny. Można sądzić, że mikroflora pośrednicząc w wiązaniu z materią gleby spełnia rolę naturalnego czynnika obniżającego poziom wolnych pozostałości w roztworze glebowym, przez co ogranicza możliwość ich poboru przez rośliny chronione i następcze. Stwierdzono również, że mikroorganizmy glebowe sprzyjają mineralizacji 2,4-DCP.