



Impact of soil water regime on degradation and plant uptake behaviour of the herbicide isoproturon in different soil types

Sabine Grundmann, Ulrike Doerfler, Jean Charles Munch, Bernhard Ruth, Reiner Schroll *

Helmholtz Zentrum München, German Research Center for Environmental Health (GmbH), Institute of Soil Ecology, 85764 Neuherberg, Germany

ARTICLE INFO

Article history:

Received 18 August 2010
Received in revised form 11 November 2010
Accepted 12 November 2010
Available online 7 December 2010

Keywords:

Isoproturon
Lysimeter
Soil–plant–system
Water potential

ABSTRACT

The environmental fate of the worldwide used herbicide isoproturon was studied in four different, undisturbed lysimeters in the temperate zone of Middle Europe. To exclude climatic effects due to location, soils were collected at different regions in southern Germany and analyzed at a lysimeter station under identical environmental conditions. ^{14}C -isoproturon mineralization varied between 2.59% and 57.95% in the different soils. Barley plants grown on these lysimeters accumulated ^{14}C -pesticide residues from soil in partially high amounts and emitted $^{14}\text{CO}_2$ in an extent between 2.01% and 13.65% of the applied ^{14}C -pesticide. Plant uptake and $^{14}\text{CO}_2$ emissions from plants were inversely linked to the mineralization of the pesticide in the various soils: High isoproturon mineralization in soil resulted in low plant uptake whereas low isoproturon mineralization in soil resulted in high uptake of isoproturon residues in crop plants and high $^{14}\text{CO}_2$ emission from plant surfaces. The soil water regime was identified as an essential factor that regulates degradation and plant uptake of isoproturon whereby the intensity of the impact of this factor is strongly dependent on the soil type.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

During past decades, numerous lysimeter studies addressing the behaviour of chemicals in soil monoliths under field-like environmental conditions have been conducted (Schroll and Kühn, 2004) due to the near field environmental conditions afforded by this experimental approach (Führ et al., 1991). The leaching of chemicals from soil surfaces to the groundwater zone can be easily assessed and with assistance of mathematical modeling, the risk for contamination of ground and drinking water may be estimated. With this process it is therefore feasible to advice farmers on the appropriate time points for pesticide application, as well as also determining on which soils application of a particular pesticide should be either reduced or omitted. In order to be able to interpret both quantity and quality of pesticide residues being transported and distributed in soil cores, it is of fundamental importance to first elucidate pesticide degradation in upper soils destined for agricultural usage.

New lysimeter test systems (Stork et al., 1994, 1997; Schroll and Kühn, 2004) allow not only determination of pesticide leaching in soil monoliths but also quantification of chemical mineralization and volatilization from lysimeter surfaces following application of ^{14}C -labeled substances, subsequently achieving a complete mass balance of the applied ^{14}C -chemicals. Using the so-called two-

chamber system (Schroll and Kühn, 2004), various gaseous ^{14}C -labeled emissions from separate soil and plant surfaces may be distinguished leading to quantification of different chemical pathways from soil–plant-systems.

The German pesticide registration authority (BBA, 1990) has recommended the use of special soil types in lysimeter studies, comprising loamy or silty sands having low levels of organic matter (<1.5% org. C) all-over the soil profile, and a cumulative maximum of clay and silt at 30% (with clay not exceeding 10%). Thus, most lysimeter studies up to date addressing behaviour of chemicals have been conducted using either this soil type (Fettweis et al., 2001) or soil monoliths with similar soil characteristics (e.g. Bura-uel and Führ, 2000; Doick et al., 2005). By contrast, we were not interested to study pesticide behaviour in these “standard soils”, but our goal was to study the fate of a single pesticide in very different types of agricultural soils in order to determine the variability of pesticide behaviour in soil–plant-systems. Since the temperate zone of southern Germany is characterized by large variations of soil types (Scheffer and Schachtschabel, 2002) – often also occurring in small geographical areas – we therefore selected to analyze four different agricultural soil types representing a wide range of soil conditions in this region. Further, although soils were formed by an almost identical global climate, soil monoliths in our study are of very different composition, reflecting their differing origin. However, since the micro-climate (e.g., time point of precipitation; periods of sunlight) at their respective native location varies such a direct comparison of pesticide behaviour and fate

* Corresponding author. Tel.: +49 89 3187 3319; fax: +49 89 3187 3376.

E-mail address: schroll@helmholtz-muenchen.de (R. Schroll).

between soil monoliths would not be possible if studied at each native location. However, this drawback is circumvented by carrying out such comparisons at a lysimeter station, where both precipitation and sunlight parameters are the same for the various lysimeters. This enables to analyze the behaviour of chemicals in all soil–plant-systems under identical climatic conditions.

For the present lysimeter study we selected the herbicide isoproturon as it is widely used against annual grasses and broad-leaf weeds in the cereal production across Europe. The objectives of the study were: (i) to investigate the different behaviour of isoproturon in various soils under outdoor conditions, including transport (in the upper soil), degradation, volatilization and mineralization, (ii) to evaluate the role of plants within the pesticide behaviour, and (iii) to elucidate the factors (e.g. climate, native ability of soils) which exert the strongest effects on the environmental fate of isoproturon in the various soil–plant-systems. The leaching behaviour of isoproturon in these soils was already published earlier (Dörfler et al., 2006).

2. Materials and methods

2.1. Pesticide and chemicals

Uniformly ^{14}C -ring-labeled-isoproturon [3-(4-isopropylphenyl)-1,1-dimethylurea] was obtained from International Isotope, Munich, Germany (radioactive purity >98%). Non-labeled isoproturon (IPU, purity 99.9%) and the metabolites 3-(4-isopropylphenyl)-1-methylurea and 3-(4-isopropylphenyl)-urea (purity 99.5%) were purchased from Dr. Ehrenstorfer, Augsburg, Germany. Arelon as well as the formulation components of the commercially available product Arelon and the metabolite 3-[4-(2-hydroxyisopropylphenyl)]-1-methylurea (purity 99.5%) were provided by Agrevo, Frankfurt-Hoechst, Germany. The solvents were HPLC grade and purchased from Sigma–Aldrich, St. Louis, MO, USA. The scintillation cocktails were obtained from Perkin Elmer, Waltham, MA, USA.

2.2. Soils and plants

Four different agricultural soils from southern Germany were sampled as undisturbed soil cores from their respective native sites and located at the lysimeter station of the Helmholtz Research

Center (latitude: 48.250, longitude: 11.567, elevation 472 m, average annual temperature 7.5 °C, average annual rainfall 875 mm). The main soil characteristics are shown in Table 1. The crop rotation was as follows: barley, corn, wheat. The present study was conducted with barley plants (*Hordeum vulgare* L.) which were sowed in a density of 300 seeds per lysimeter.

2.3. Lysimeter test system

The lysimeter test system is described in detail by Schroll and Kühn (2004). The undisturbed soil columns in the lysimeters had a height of 2 m and a surface area of 1 m². For each of the four soils one single lysimeter was used. Considering the size of the lysimeters it can be assumed that the measured data are representative for the respective soils (Führ et al., 1991). Two different chambers – a soil chamber and a plant chamber – were placed on the surfaces of all lysimeters to quantify ^{14}C -gaseous losses from soil and plant surfaces. Air was sucked continuously through the chambers and subsequently washed out in a trapping system to fix volatile pesticide residues and $^{14}\text{CO}_2$. The trapping solutions were sampled three times per week to measure the radioactivity. Newly constructed soil humidity (Ruth and Munch, 2005) and temperature sensors (AD 590, Analog Devices GmbH, Munich, Germany) were installed 1.0 cm below the soil surface inside and outside the soil chambers in two of the four lysimeters. Aric Anthrosol and Mollic Gleysol were selected for humidity and temperature measurements since these soils showed very different soil characteristics and different isoproturon mineralization behaviour in laboratory experiments (Grundmann et al., 2008). A special equipment allowed simulation of natural rainfall within the soil chambers.

2.4. Application of isoproturon

On each lysimeter surface one soil chamber with open top was placed shortly before barley was sown and the soil humidity and temperature sensors were installed. The pesticide was applied when the barley plants were in the growing stage 29–30 (Zadoks et al., 1974). ^{14}C labeled isoproturon was mixed with Arelon and Arelon formulation components according to the instructions of the manufacturer (Agrevo, Frankfurt-Hoechst, Germany): The resulting ^{14}C -labeled Arelon had a final concentration of 0.5 kg L⁻¹ isoproturon and a final specific radioactivity of 686 Bq μg⁻¹. The

Table 1
Soil characteristics and native geographical position of the four lysimeter soils and native average climate at their original sites.

Name of soil (place of origin)	Calcaric Regosol (Feldkirchen)		Humic Cambisol (Kelheim)			Mollic Gleysol (Scheyern)			Aric Anthrosol (Hohenwart)		
	0–30	30–200	0–25	25–80	80–200	0–38	38–90	90–200	0–30	30–70	70–200
<i>Texture</i>											
<2 μm clay %	33	Gravel	11	12	6	22	29	28	13	9	1
2–63 μm silt %	34	–	19	13	46	60	61	65	19	21	4
63–2000 μm sand (%)	33	–	70	75	48	18	10	7	68	70	95
WHC % ^a	51.3	–	33.3	–	–	37.0	–	–	34.3	–	–
pH CaCl ₂	7.2	–	6.9	6.6	7.8	5.4	5.9	6.7	6.7	6.7	6.1
org. C (%)	2.7	–	1.3	0.17	0.2	1.5	0.35	0.25	0.99	0.87	0.06
Total N (%)	0.27	–	0.1	0.02	0.02	0.17	0.07	0.05	0.1	0.1	<0.01
CaCO ₃ (%)	5.1	–	0.5	<0.2	24.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
IPU–Kd-value (cm ³ g ⁻¹) ^b	1.83	n.d. ^c	0.86	n.d. ^c	n.d. ^c	1.06	n.d. ^c	n.d. ^c	0.71	n.d. ^c	n.d. ^c
<i>Native geographical position</i>											
Latitude	48.150		48.917			48.500			48.600		
Longitude	11.733		11.867			11.467			11.383		
Elevation (m)	521		348			478			392		
<i>Native average climate</i>											
Annual temperature (°C)	7.5		7.5			7.4			7.5		
Annual rainfall (mm)	900		750			843			775		

^a WHC = water holding capacity at a soil density of 1.3 g cm⁻³.

^b Kd values were determined according to OECD Guideline 106 (OECD, 2000).

^c n.d. = not determined.

Download English Version:

<https://daneshyari.com/en/article/4411354>

Download Persian Version:

<https://daneshyari.com/article/4411354>

[Daneshyari.com](https://daneshyari.com)