Soil properties affecting pesticide leaching - application in groundwater vulnerability mapping in the Czech Republic

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Abstract
Various pesticide and soil properties affect pesticide leaching into groundwater. In order to assess the risk of pesticide leaching, specific groundwater vulnerability maps were constructed for selected pesticides based on modified DRASTIC methodology with emphasis on soil cover that plays a key role in pesticide leaching due to adsorption of pesticides on soil particles. The Freundlich equation was used to fit experimental data points of the adsorption isotherms for each pesticide and soil using the average n parameter for each pesticide. The multiple linear regressions were used to define pedotransfer rules for the determination of the K_F parameter from the other physical and chemical soil properties. Resulting pedotransfer rules, the soil map of the Czech Republic and the Czech soil information system PUGIS were applied for the estimation of the adsorption properties of soils of the Czech Republic. The adsorption parameters K_F represents only one soil factor affecting the contaminant transport through the soil cover. The properties of selected pesticides represent wide range of used pesticides from those with none leaching potential to those with very good leaching potential. Specific groundwater vulnerability maps reflect those properties.

Key Words
Pesticides, adsorption, pedotransfer rules, groundwater vulnerability.

Introduction
Application of pesticides as a common farming practice can have an adverse effect on groundwater quality. Assessment of specific groundwater vulnerability can help to protect the groundwater by implementing best management practices in areas with increased groundwater vulnerability. Specific groundwater vulnerability can vary depending on pesticide properties, hydrogeologic settings and soil cover properties unlike the intrinsic groundwater vulnerability that does not account for the properties of a contaminant.

Methods
In order to assess the risk of pesticide leaching, specific groundwater vulnerability maps were constructed for selected pesticides based on modified DRASTIC methodology (Aller *et al.* 1987) with emphasis on soil cover that plays a key role in pesticides leaching due to adsorption of pesticides on soil particles.
The adsorption isotherms for selected pesticides and 13 representative soils of the Czech Republic (Table 1) were obtained using a standard laboratory procedure. Pesticides were selected based on following properties: water solubility, soil half-life and K_{oc}. The calculation of GUS index (Gustafson 1989) was also used for determination of a leaching potential. The Freundlich equation (relating adsorbed concentration of solute on soil particles, s, and solution concentration, c, $s = K_F \, . \, c^{1/n}$) was used to fit experimental data points of the adsorption isotherms for each pesticide and soil using the average n parameter for each pesticide. The multiple linear regressions were used to define pedotransfer rules (Table 2) for the determination of the K_F parameter from the other physical and chemical soil properties such as organic matter content (OM), pH_{KCl}, cation exchange capacity (CEC) and clay content. Resulting pedotransfer rules, the soil map of the Czech Republic (Němeček *et al.* 2001) and the Czech soil information system PUGIS (Kozák *et al.* 1996) were applied for the estimation of the adsorption properties of soils of the Czech Republic.

Results
Here we show only results of adsorption study and pesticide adsorption predictions. Properties of studied soils are given in the Table 1. It is evident that, soil properties of selected soils varied in wide range. Those properties determine adsorption characteristics of each soil. Pedotransfer rules, shown in the Table 2, were used for construction of K_F distribution maps for selected pesticides for whole territory of the Czech Republic. The maps for terbuthylazine and chlorotoluron are presented on Figure 1 and 2.

Table 1. Properties of soils

Soil type	Location	OM (%)	pH_{KCl} (-)	CEC (mmol/kg)	Clay (%)
Stagnic Chernozem Siltic	Milčice	5.03	7.43	403.8	15.8
Haplic Chernozem	Ivanovice na Hané	3.05	6.28	271.3	11.4
Haplic Chernozem	Praha Suchdol	3.47	7.21	263.8	19.3
Chernozem Arenic	Velké Chvalovice	1.59	6.94	141.3	6.40
Greyic Phaeozem	Čáslav	2.33	6.53	297.5	13.4
Haplic Luvisol	Hněvčeves	1.78	5.63	240.0	13.9
Haplic Cambisol	Humpolec	2.82	4.37	260.0	9.9
Haplic Cambisol	Předbořice	2.95	5.03	228.8	4.8
Haplic Cambisol	Jince	2.78	4.99	236.3	20.3
Dystric Cambisol	Vysoké nad Jizerou	3.99	4.79	284.2	16.9
Arenozem Epioutric	Semice	1.14	5.74	91.3	3.50
Loess	Praha Suchdol	0.76	7.40	241.3	24.5
Sand	Písková Lhota	0.04	8.11	56.3	3.30

Table 2. Pedotransfer rules

Pesticide	Regression equations
Terbuthylazine	$K_F = 4.36 + 1.16$ OM [%] – $0.38\ pH_{KCl}$ – 0.006 CEC [mmol/kg]
Chlorotoluron	$K_F = -0.91 + 2.01$ OM [%]
Metolachlor	$K_F = 3.76 + 0.79$ OM [%] – $0.5\ pH_{KCl}$
Fipronil	$K_F = 2.40 + 1.62$ OM [%] – 0.07 clay [%]
Trifluralin	$K_F = 839.7 + 80.6$ OM [%] – $97.9\ pH_{KCl}$
Metribuzin	$K_F = 1.74 + 0.28$ OM [%] – $0.24\ pH_{KCl}$
Hexazinone	$K_F = 0.83 - 0.119$ OM [%] + 0.0033 CEC [mmol/kg] – 0.05 clay [%]

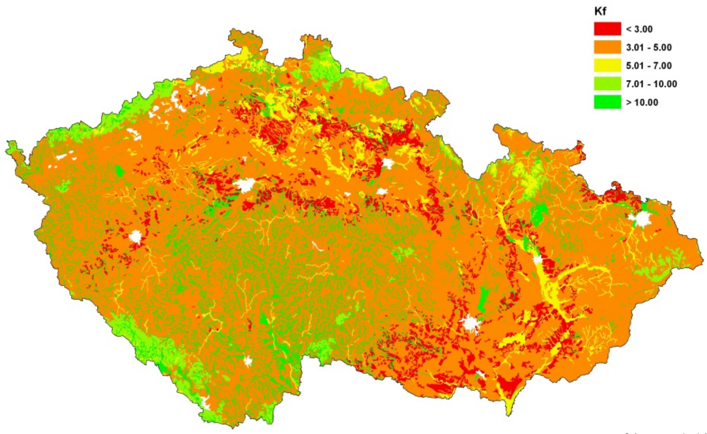

Figure 1. K_F parameter of the Freundlich equation [$cm^{3/n}\ \mu g^{1-1/n/g}$] for terbuthylazine.

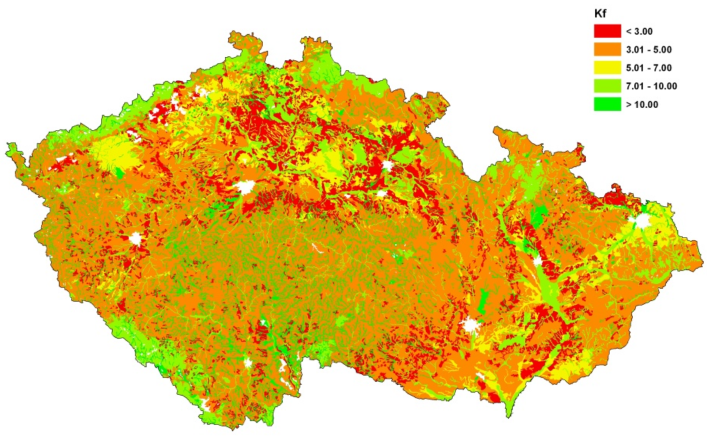

Figure 2. K_F parameter of the Freundlich equation [$cm^{3/n}\ \mu g^{1-1/n/g}$] for chlorotoluron.

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Conclusion

The maps of the predicted adsorption K_F parameters representing adsorption ability of studied soils were evaluated for each pesticide. Regression analysis showed that the K_F parameter mainly depends on organic matter content, pH_{KCL}, cation exchange capacity (CEC) and clay content. Application of pedotransfer rules enables effective assessment of soil adsorption parameters specific for individual pesticide allowing better groundwater vulnerability assessment. Resulting specific pesticide groundwater vulnerability varies considerably with soil adsorption parameters.

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