Accelerated Metolachlor Degradation in Soil by Zerovalent Iron and Compost

Jae E. Yang[1]*, Sung-Chul Kim[1], Yong-Sik Ok[1], Jeff Skousen[2], Dong-Kuk Kim[1], and Jin-Ho Joo[1]

1.Department of Biological Environment, Kangwon National University, Chuncheon, 200-701, Korea

2. Department of Plant & Soil Science, West Virginia University, Morgantown, WV, 26506

Introduction

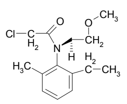
- Concerns over the presence of aromatic chlorinated compounds in surface and groundwater continue to increase.
- Metolachlor, chloroacetanilide herbicide, has been defined as a possible human carcinogen by WHO and ethylmethylanile, a metolachlor transformation product, shows genotoxic properties (Fava et al., 2000).
- Metolachlor dissipation in soil is affected by several factors including organic matter content, moisture levels, and redox potential etc.

Objective

1. Assess individual and combined effects of ZVI, organic matter, and moisture on the degradation of metolachlor in soil
2. Evaluate practical methods for field-scale remediation of metolachlor in soils

Materials and Methods

□ Metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide]



Molecular	$C_{15}H_{22}CNO_2$
Molar mass g mol^{-1}	283.79
Solubility (mg L^{-1})	530
Vapor pressure at 25℃	4.1 x 10^{-3} Pa
Sorption coefficient (K_d)	0.1 – 2.0 ml g^{-1}

□ Soil (Rice Paddy Soil in Central Korea)

Texture	pH	OM	CEC	Na	K	Ca	Mg	Fe	T-N
	1:5	%	-------------- cmol$_c$ kg^{-1}	--------------				-- mg kg^{-1} --	
Loam	5.75	1.26	12.16	0.84	1.76	3.18	0.66	13.75	945.7

□ Organic compost

pH (1:5)	EC µS cm^{-1}	Moisture contents %	Organic matter .... g kg-1	NaCl	C/N ratio
6.9	1,381.0	63.5	351.9	0.5	36.3

Degradation of Metolachlor in Contaminated Soil

□ Chemical treatments to degrade metolachlor in contaminated soil

- Zero-valent iron (ZVI, Fe^0) with organic matter (compost) and adjusted water content

□ Incubation test conditions : metolachlor concentration [200, 1,000 mg/kg] at 25ºC

- ZVI conc. : 5% (w/v)
- Water content : 10, 30% (w/v)
- Time : 0, 3, 7, 12, 19, 27, 40 days
- Organic matter: 10 ton/ha, 30 ton/ha

□ Extraction and analysis of metolachlor from the contaminated soil

- 20g of soil with 100ml acetone and 40ml water, shaking at 150rpm for 60 minutes
- Analyzed using GC with NPD detector (Hewlett packard 6890, USA)

Results

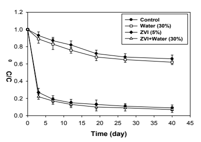


Fig. 1 Effects of soil moisture content on the metolachlor degradation in contaminated soil.

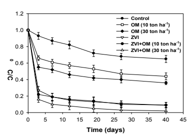


Fig. 2 Metolachlor degradation in contaminated soil by moisture, organic matter and ZVI treatment.

□ Rate constants and half-lives for metolachlor degradation by treatment of moisture, organic compost, and zerovalent iron

Treatments	Rate constants† (k or k_1 and k_2)	R^2‡	$t_{1/2}$ (day)§
Control	9.6 x 10^{-3}	0.90	72.2[a]
30% water	9.8 x 10^{-3}	0.90	70.7[a]
ZVI	4.4 x 10^{-1}, 2.2 x 10^{-2}	1.00, 0.89	1.6[c]
ZVI + 30% water	5.0 x 10^{-1}, 2.5 x 10^{-2}	1.00, 0.92	1.4[c]
Compost-10 ton ha^{-1} + 30% water	9.6 x 10^{-2}	0.96	63.0[b]
Compost-30 ton ha^{-1} + 30% water	9.6 x 10^{-2}	0.94	61.8[b]
ZVI + compost-10 ton ha^{-1} + 30% water	4.4 x 10^{-1}, 2.5 x 10^{-2}	1.00, 0.95	1.4[c]
ZVI + compost-10 ton ha^{-1} + 30% water	6.1 x 10^{-1}, 5.6 x 10^{-2}	1.00, 0.97	1.1[c]

† k for single first-order rate constant and k_1 and k_2 for bi-phasic rate constants

‡ All R^2 values are significant at $p < 0.01$

§ Same letters represent that half-life of each treatment is not statistically different at $p < 0.05$. In case of bi-phasic first order kinetics, half life was calculated based on first phase

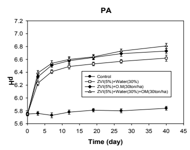


Fig. 3 Changes of pH in metolachlor contaminated soil by moisture, organic matter and ZVI treatment.

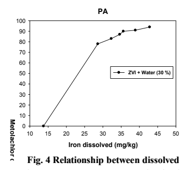


Fig. 4 Relationship between dissolved iron and metolachlor dechlorination in contaminated soil.

Fig. 5 Effects of ZVI treatment on the germination rate and growth of *Lactuca sativa* L. grown in the metolachor contaminated soil.

Fig. 6 Effects of ZVI treatment on the germination rate and growth of *Gigitaria adscendens* grown in the metolachor contaminated soil.

Conclusions

1. Most of the degradation by ZVI was occurred within 3 days followed by a slow degradation pattern which is described by bi-phasic kinetics .
2. The effect of moisture on metolachlor degradation was minimal when treated alone or combined with ZVI.
3. The efficiency of ZVI in metolachlor degradation was accelerated when ZVI was added in combination with compost and moisture, resulting in 98% degradation after 40 days.
4. Germination and growth of lettuce (*Lactuca sativa*) and crabgrass (*Digitaria sanguinalis* L. Scop.) were completely eliminated at 200 mg kg^{-1} metolachlor but were normal after remediation with ZVI.
5. The overall results suggest that the combined treatment of ZVI, compost and moisture might provide the maximum degradation efficiencies for field-scale remediation of metolachlor-contaminated soils.