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Abstract

Concerns about nitrates in private drinking water supplies in the older poultry growing areas of Arkansas prompted soil and water testing in the early 1990's. Exposed poultry house pads were recognized as a potential source of nitrates in the groundwater. Soils beneath nine different poultry house pads in five counties were sampled in 10-30 cm increments to bedrock or to a maximum sampling depth of 90 cm. The nine sites had been exposed to natural weathering conditions ranging from never to for more than 20 years. Routine soil tests were conducted by the University of Arkansas Soil Testing Lab at Marianna according to standard methods (Mehlich III extractant). The relatively immobile elements P, Ca, Mg, Fe, Mn, Cu, and Zn were mainly concentrated in the upper part of the soil profiles (0-30 cm). The more leachable NO_3-N, K, and SO_4-S were generally found throughout the soil profile. Sodium was found in high concentrations throughout the soil profile at two sites. This study shows that nitrate-N, potassium, and sulfate-S from exposed poultry house pads and manure storage areas have the potential of leaching into groundwater. The other eight elements tested do not pose a threat of leaching, but are possible surface water contaminants.

Introduction

Concerns about nitrates in private drinking water supplies in the older poultry growing areas of Arkansas prompted soil and water testing in the early 1990's (Austin and Steele, 1990; Daniel et al., 1991; Daniel et al., 1992; Edwards and Daniel, 1992; Gilmour et al., 1987; and Smith and Steele, 1990). Exposed poultry house pads were recognized as a potential source of nitrate contamination of the groundwater. (Teague et al., 1993).

Poultry houses are typically built by cutting and filling the soil to form a level base for construction. Wood chips, rice hulls, or other carbonaceous materials are placed on the dirt floor as bedding to absorb the wet poultry droppings (Boles et al., 1995a; Boles et al., 1995b). The resulting by-product called "chicken litter" is removed generally on a yearly basis and land applied as fertilizer (Chapman, 1996). In many cases the litter is left on the floor when the poultry house is torn down or destroyed by natural forces. The remaining litter, which may be 10-20 cm deep, contains a high concentration of chemical elements some of which may be subject to leaching into the groundwater.

Information on the contribution of exposed poultry house pads to groundwater contamination is lacking. Ritter (1991) showed that both nitrate-N and NH_4-N concentrations were at or above 300 mg/kg in the surface 30 cm of soil beneath the litter in producing broiler houses in Delaware. The concentrations declined to less than 100 mg/kg at about 60 cm of soil depth in 25 year-old houses, but remained above 50mg/kg to the maximum sampling depth of 135 cm.

Materials and Methods

Soils beneath nine different poultry house pads in five counties in Arkansas were sampled by auger in increments ranging from 10 to 30 centimeters (cm) in thickness to bedrock or to a maximum sampling depth of 90 cm. The poultry house pads were sampled because water in nearby wells used for drinking tested above the health advisory level of 10 mg/l of nitrate-nitrogen (Tacker, 1991; Teague, et al., 1993). The nine sites had been exposed to natural weathering conditions ranging from never to for more than 20 years. Routine soil tests were conducted by the University of Arkansas Soil Testing Lab at Marianna according to standard methods (Mehlich III extractant). Soil pH was reported in standard units using distilled water for dispersion (Chapman, 1998). The other 11 elements were reported in milligrams per kilogram (mg/kg) of soil.

Results and Discussion

The nine sample location sites are numbered in perceived weathering sequence based on historical records from non- or freshly-exposed (site number 1) to long-term exposure of more than 20 years (site number 9). Relative values (Chapman et al., 1997; Chapman et al., 1998) for individual elements are shown in Table 1 along with max-

imum depths at which high concentrations were detected. The relative element concentrations are based on the results of 60,000 to 100,000 routine soil samples tested annually by the University of Arkansas Soil Testing Lab at Marianna.

The relatively immobile elements P, Ca, Mg, Fe, Mn, Cu, and Zn were mainly concentrated in the upper part of the soil profiles (0-30 cm). The more leachable NO_3-N, K, and SO_4-S were generally found throughout the soil profile. Sodium was found in high concentrations throughout the soil profile at two sites.

The following is a discussion of each of the individual sites.

Site 1 - Covered Poultry House Pad, Coastal Plains, Pike County, Arkansas.

The poultry house was empty of chickens. Dry litter remained on the floor from the last batch grown. Soil samples were collected in 15 cm increments beneath the dry litter to a depth of 90 cm.

Soil test results showed extremely acid pH throughout the profile and high or very high concentrations of most elements in the upper 15 cm (Table 2). Even though the pad had not been exposed to the weather, the more mobile sulfates and nitrates showed evidence of downward movement to the greatest depth sampled (90 cm). Potassium concentrations indicated downward movement to at least 60 cm. The other elements showed little evidence of moving below the upper 15 cm of soil.

Table 1. Maximum Depth (cm) of High Element Concentration in Soil Beneath Poultry House Pads

Soil Test Element	Highest Observed Concentration (mg/kg)	Site Number								
		1	2	3	4	5	6	7	8	9
NO_3-N	50+	90*	90*	90*	0	45*	15	90*	0	0
P	150+	15	15	30	40	10	15	15	30	30
K	300+	60	90*	90*	60*	45*	60*	60	90*	90*
Ca	1000+	15	15	30	20	10	0	0	0	0
Mg	250+	15	15	30	0	0	0	0	0	0
Na	200+	30	90*	0	0	0	60*	60	0	0
SO_4-S	50+	90*	90*	90*	60*	45*	60*	90*	90*	90*
Fe	100+	0	15	90*	20	10	15	0	45	30
Mn	100+	0	0	0	0	0	15	0	0	0
Cu	3+	15	15	30	20	0	0	0	0	30
Zn	9+	15	15	30	20	10	0	15	45	30

*Maximum soil depth sampled.

Site 2 - Freshly Exposed Poultry House Pad, Ozark Highlands, Benton County, Arkansas.

Litter present from the last batch of broilers grown had been exposed to rainfall for several months. Soil samples were collected in 15- to 30-cm increments beneath the litter surface.

The soil was extremely acid (pH below 4.5) throughout the profile with high or very high concentrations of most elements in the upper 15 cm (Table 3). In addition to the sulfates and nitrates, potassium and sodium showed evidence of leaching to a depth of 90 cm.

Site 3 - Poultry Manure Storage Area Exposed to the Weather, Coastal Plains, Columbia County, Arkansas.

Soil samples were collected in 30 cm increments to a depth of 90 cm. Previously stockpiled litter had been removed prior to sampling.

There was a high concentration of most elements (P, K, Ca, Mg, nitrates, Cu, and Zn) in the upper 30 cm of soil. There was a higher than expected (but not high) concentration of potassium, sulfates, and nitrates throughout the soil profile.

Site 4 - Exposed Poultry House Pad (five years), Ozark Highlands, Washington County, Arkansas.

Soil test results were similar to those from site three

Table 2. Chemical Analysis of Soil Beneath a Covered Poultry House Pad - Site 1, Coastal Plains, Pike County, Arkansas.

Soil Depth (cm)	Observed Element Concentration											
	pH	P	K	Ca	Mg	Na	SO_4-S	NO^3-N	Fe	Mn	Cu	Zn
		mg/kg										
0-15	4.3	650	6364	1065	395	1520	566	499*	63	15	3.2	26.2
15-30	3.8	13	1904	114	28	257	278	499*	40	0	0.5	3.4
30-45	3.1	2	742	69	16	106	206	227	46	0	0.7	3.1
45-60	3.0	5	489	67	14	95	178	140	41	0	0.9	4.1
60-75	3.1	11	297	84	14	117	142	108	37	0	0.8	4.1
75-90	3.1	5	241	104	15	95	93	107	50	1	0.8	2.1

*Upper reporting limit for the element.

except that nitrate concentrations remained low throughout the soil profile. Soil pH dropped from 6.6 in the upper 20 cm to 4.3 at the 40-60 cm depth.

Site 5 - Exposed Poultry House Pad (five years), Ozark Highlands, Washington County, Arkansas.

Soil test results indicated a buildup of P, K, Ca, sulfates, nitrates, and zinc in the upper 10 cm of soil (Table 4). Soil pH was acidic throughout the profile (5.2 to 3.9). Sulfate, nitrate, and potassium concentrations varied from low to high with depths to 45 cm.

Site 6 - Exposed Poultry House Pad (five years), Ozark Highlands, Washington County, Arkansas.

Soil test results indicated a buildup of P, K, sulfates and nitrates in the upper 15 cm of soil. In addition, potassium and sulfate were high throughout the soil profile. The other elements tested in the normal range.

Site 7 - Exposed Poultry House Pad (10 years), Ouachita Mountains, Sevier County, Arkansas.

Soil test results indicated a large buildup of potassium, sulfates and nitrates throughout the soil profile (Table 5). Extremely high potassium concentrations decreased with depth, whereas sulfate concentrations increased with depth.

Site 8 - Exposed Poultry House Pad (15 years), Coastal Plains, Sevier County, Arkansas.

The entire soil profile was acidic (pH 5.1-4.6). Phosphorus was high (above 150 mg/kg) in the upper 30 cm of soil.

Potassium was high (above 300 mg/kg) in the lower third of the soil profile (60-90 cm). All other elements were in normal ranges throughout the soil profile. Nitrate con-

Table 3. Chemical Analysis of Soil Beneath a Freshly Exposed Poultry House Pad - Site 2, Ozark Highlands, Benton County, Arkansas.

Soil Depth (cm)	Observed Element Concentration											
	pH	P	K	Ca	Mg	Na	SO_4-S	NO_3-N	Fe	Mn	Cu	Zn
		mg/kg										
0-15	4.4	1401	8080	3812	911	499*	492	499*	175	65	4.2	48.9
15-30	4.4	81	3122	535	173	446	406	406	65	10	0.7	5.8
30-60	4.2	11	2220	266	96	351	401	375	41	4	0.5	2.1
60-90	3.9	7	2544	292	109	543	350	456	33	4	0.3	1.4

*Upper reporting limit for the element.

Table 4. Chemical Analysis of Soil Beneath Exposed Poultry House Pad - Site 5, Ozark Highlands, Washington County, Arkansas.

Soil Depth (cm)	Observed Element Concentration											
	pH	P	K	Ca	Mg	Na	SO_4-S	NO_3-N	Fe	Mn	Cu	Zn
		mg/kg										
0-10	5.2	1430	948	1632	144	144	220	85	118	63	1.7	24.4
10-30	4.2	61	140	856	116	60	19	183	69	82	2.7	6.5
30-45	3.9	52	572	233	45	80	83	62	58	7	0.8	1.9

Table 5. Chemical Analysis of Soil Beneath Exposed Poultry House Pad - Site 7, Ouachita Mountains, Sevier County, Arkansas.

Soil Depth (cm)	Observed Element Concentration											
	pH	P	K	Ca	Mg	Na	SO_4-S	NO_3-N	Fe	Mn	Cu	Zn
		mg/kg										
0-15	5.0	227	499	492	175	212	67	252	27	12	2.0	14.7
15-30	3.7	10	499*	219	116	202	72	272	21	2	0.5	6.3
30-45	3.4	10	499*	257	142	207	141	325	22	2	0.6	4.9
45-60	3.2	43	399	223	128	217	180	291	30	1	0.8	3.3
60-75	3.3	28	281	170	108	164	130	231	27	1	0.8	2.7
75-90	3.3	10	202	154	117	166	143	191	25	1	0.8	2.7

*Upper reporting limit for the element.

Table 6. Chemical Analysis of Soil Beneath Exposed Poultry House Pad - Site 9, Coastal Plains, Columbia County, Arkansas.

Soil Depth (cm)	Observed Element Concentration											
	pH	P	K	Ca	Mg	Na	SO_4-S	NO_3-N	Fe	Mn	Cu	Zn
		mg/kg										
0-15	6.1	336	117	384	53	84	1	3	176	17	5.1	47.3
15-30	5.5	417	250	507	91	71	13	2	100	3	3.4	18.2
30-60	4.6	113	345	237	69	71	33	4	67	1	1.6	7.8
60-90	4.4	9	302	91	23	60	70	3	26	1	1.1	4.7

centrations were extremely low throughout the profile. Sulfates were low in the upper two thirds of the profile (060 cm) but were high in the lower third (60-90 cm).

Site 9 - Exposed Poultry House Pad (20 years), Coastal Plains, Columbia County, Arkansas.

Phosphorus, copper and zinc concentrations were high in the upper third (0-30 cm) of the soil profile (Table 6). The other elements were in the normal concentration range. Potassium concentrations increased from normal in the 0-30 cm depth to high (above 300 mg/kg) in the lower two thirds of the soil profile.

Our observations suggest that nitrate-N, potassium and sulfate-S from exposed poultry house pads and manure storage areas have the potential of leaching into groundwater. The other eight elements tested do not pose a threat of leaching, but are possible surface water contaminants.

One of the most practical ways of protecting groundwater and nearby water wells from nitrate contamination from abandoned poultry houses is to remove and land-apply the accumulated poultry manure immediately after the final growout. Exposed poultry house pads should be planted to forages or other vegetation to take up excess plant nutrients and reduce the potential for additional loss by leaching and surface runoff.

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