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## Herbicide and Insecticide Residues in Tailwater Pits: Water and Pit Bottom Soil from Irrigated Corn and Sorghum Fields

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Water and soil sediment samples from tailwater pits used to collect irrigation runoff were analyzed for herbicide and insecticide residue. Herbicide residues were more frequently found and generally more persistent than were insecticide residues. Atrazine residue occurred more frequently than other pesticides in both pit bottom soil and water samples. Propazine and fonofos residues were also common. The maximum amount of atrazine detected was 1068.3 ppb in bottom soil and 1074.1 ppb in water. Propazine also was detected at a high level, 429.0 ppb in bottom soil and 153 ppb in water. Insecticides such as fonofos were found at 771.2 ppb in bottom soil and 5.9 ppb in water. Analyses detected residues of 11 additional pesticides: alachlor, carbofuran, cyanazine, dimethoate, disulfoton, EPN, EPTC, parathion, phorate, R25788, and terbutryn. In general, pesticide residues were small enough that water from irrigation tailwater pits could be reused to irrigate crops in the same or other fields. In a few cases, however, herbicide residues were concentrated sufficiently that particularly sensitive crops might be damaged if irrigated with water from the pits. Insecticide residues were usually not detected at the end of the growing season. Residues of fonofos were sufficient in five pits (1974) to kill fish if the pit bottom soil had been roiled and to be a potential hazard to birds and mammals.

In the development of irrigation systems for farm land, collecting basins are excavated to impound runoff from fields during irrigation (Hay and Pope, 1977). They also may collect water during and after heavy rainfall. These basins, called tailwater pits, collect water which may be pumped back to the high end of the field, or onto another field, and reused for irrigation (Figure 1). Tailwater pits provide drinking water for pheasants, doves, rabbits, coyotes, and occasional deer and are resting sites for waterfowl. (Vegetation is discouraged from growing in the water or on the shore of well-managed pits. Thus, they are relatively unimportant as feeding and nesting sites). Consideration has also been given to the use of tailwater pits for fish rearing, livestock drinking water, and for swimming.

Pesticides are utilized extensively in the production of corn and grain sorghum, and other crops, on irrigated land in southwest Kansas. One would expect irrigation water and silt to carry measurable pesticide residues into the tailwater pits. Farmers have asked if herbicide residues may accumulate and cause crop damage when tailwater is reused for irrigation. Those contemplating other uses for the water are also concerned.

In 1973 and 1974 we conducted the study reported herein to help answer such questions. Extraction-cleanup methods and gas chromatographic procedures were adapted for analyses of water and soil for pesticide residues.

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### MATERIALS AND METHODS

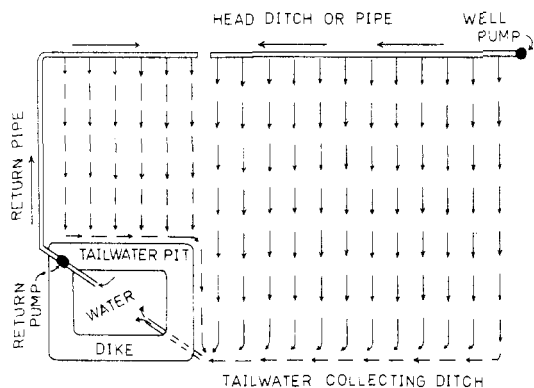
Thirty-six tailwater pits in Haskell County, Kansas, each receiving water from one or more fields of corn or grain sorghum, were sampled. Most fields were 160 acres (65 ha) in size. The surface soils of all the fields were Richfield, Ulysses, or Richfield-Ulysses silt loam, and all fields had from 0 to 3% slope (Hamilton et al., 1968).

The fields and pits were managed by 28 different farmers. Our purpose was to determine the occurrence of pesticide residues under actual agricultural conditions. Therefore, the investigators did not try to influence tillage and irrigation practices nor to coordinate pesticide use. Information about pesticide use in fields draining into the tailwater pits was obtained in June or July of each year by questionnaires and interviews. Additional information was added to each record after pesticide applications were made.

For 1973, our plan included sampling each pit before the first runoff of the growing season, immediately after the first runoff, at midseason, in late summer, and during autumn. However, we could not visit all pits daily and irregular patterns of rainfall and irrigation upset the timing of our first two samplings. In 1974 we sampled each pit in May, June, July, August, and November without regard to dates of runoff into specific pits.

Although the closest field associated with each pit was recorded as either corn or sorghum, in 1973 it was not known what crops were grown in nonadjacent fields which drained into some of the pits. In 1974 we attempted to identify all of the fields which drained into each pit and to record the crops grown in them. Thus, some pits were known to have received runoff from both corn and sorghum.

Water samples (3.8 L) were collected into clean glass jugs from the edges of pits near their inlets. At each sampling we took 1 gal (3.8 L) of tailwater and 1 qt (0.95 L) of



**Figure 1.** Diagram of an irrigated field, tailwater pit, and tailwater reuse system. This pit is drawn disproportionately large. Typically a 160-acre (65-ha) field 0.5 mile (0.8 km) long on each side is served by a pit 6 to 10 ft (2 or 3 m) deep, 75 to 125 ft (23 to 38 m) wide, and 125 to 200 ft (38 to 61 m) long. The part of the field irrigated by tailwater can usually be irrigated alternately by fresh well water. Most irrigation systems are not designed for controlled mixing of fresh water and tailwater for simultaneous use on any one part of the field.

muddy bottom soil from each pit. This soil was primarily sediment, but in some pits it included original pit bottom soil. Pit bottom soil (primarily sediment) was collected ca. 20 to 25 ft (6 to 8 m) from the shore near the inlet. Exceptions occurred when water was depleted from pits and the body of water was less than 40 ft (12 m) wide. A collecting device, to obtain pit bottom soil, was made from a 2-in. (5.08 cm) i.d. iron pipe 13 in. (33 cm) long, which was threaded and capped on one end. A chain link welded to the lip of the open end was used to attach a 25-ft (ca. 8 m) rope.

For collecting the samples, the rope was coiled (loose end secured to the collector's wrist), and the device and coil were thrown into the pit for retrieval. Bottom soil was poured from the device into wide-mouth Mason jars (Kerr Glass Mfg. Corp., Sand Springs, Okla.) until a 1-qt (0.95 L) sample was obtained. Aluminum foil was used to line the jar lids.

Many of the 1973 samples were stored 2 weeks or longer at ca. 22 °C before extraction of residues for analysis. Extractions were made from the 1974 samples within 2.7 ± 1.7 days after collection.

**Extraction of Sediment.** Stones and other large objects were removed from the sample of pit bottom soil, and the sample was thoroughly mixed with a spatula on a sheet of aluminum foil. A portion of the soil sample (150 g) was weighed and placed in a quart jar with 100 mL of acetone. The mixture was then mixed vigorously for 5 min on a mechanical shaker. The slurry (mixture of sediment and acetone) was then reextracted with three successive portions of ethyl acetate (100 mL each), and the total extract of acetone and ethyl acetate was decanted. The combined extract was placed in a 1000-mL round-bottom flask and was evaporated to dryness with vacuum in a 45 °C water bath. The extract residue was then dissolved in 5 mL of benzene.

**Extraction of Water.** Water samples were collected in clean 1-gal jars for transport to the laboratory. Two liters of a sample was placed in a separate 1-gal jar for extraction with 200 mL of 50% ethyl acetate in hexane. The jar was shaken vigorously for at least 1 min. After the phases separated, the ethyl acetate-hexane (upper) layer was decanted into a 1-L round-bottom flask. A second extraction was then completed, and the upper layers were combined. The sample was then reextracted with 400 mL of chloroform, and the extracts were com-

bined and evaporated to dryness with vacuum in a 45 °C water bath. The extract residue was dissolved in 5 mL of benzene.

**Cleanup Procedure.** Kontes K420280 chromaflex minicolumn, size 10.5 mm i.d., was packed with a mixture of 24 g of Celite 545, 12 g of MgO, and 15 g of Norit SG 1. The column was capped with a 5-mm glass-wool plug and the column then flushed with acetone. The extract in 5 mL of benzene was added to the column and eluted with 75 mL of 25% ethyl acetate in benzene with the eluent being collected in a 250-mL round-bottom flask. The column was flushed dry with nitrogen gas. The eluent was evaporated to dryness with vacuum in a 45 °C water bath. The residue was then dissolved in benzene for injection into the gas chromatograph.

**Gas Chromatographic Analysis.** The nitrogen compounds were gas chromatographed on a dual-column Tracor 550 with a Coulson conductivity detector in the nitrogen mode. Both columns were 3 ft × 0.25 in. (91 cm × 6 mm) Pyrex packed with Chromosorb W HP, 60/80 mesh. One column used a 3% OV-25 liquid phase, the other, a 1.1% Carbowax 20M. Hydrogen was the carrier gas at a flow rate of 58 mL/min. Temperatures for the inlets were 200 °C; outlets, 210 °C; transfer line, 215 °C; furnace valve block, 220 °C; and the furnace was operated at 900 °C.

Atrazine and carbofuran (retention times 680 and 1053 s, respectively) were separated on OV-25 at an oven temperature of 140 °C and a carrier flow of 80 mL/min. The much larger atrazine peak was vented off before switching the column onto the detector, to allow the carbofuran to be observed on the recorder without prior disturbance.

Propazine and atrazine (retention times of 197 and 275 s, respectively) were separated on the Carbowax column at an oven temperature of 140 °C and a carrier flow of 58 mL/min. Sensitivity of the detector to nitrogen was 1.2 ng at a peak size equal to twice baseline noise. An Autolab 6300 digital integrator assisted in quantitating peak values.

Organophosphate compounds were determined on a Bendix 2110X gas chromatograph equipped with a Bendix flame photometric detector and a 6 ft × 0.25 in. (1.8 m × 6 mm) Pyrex column; 3% OV-1 on 60/80 mesh Gas-Chrom Q was the packing material. The detector temperature was 150 °C, and the nitrogen carrier flow was 135 mL/min. The detector gas flows were: hydrogen, 300 mL/min; air, 80 mL/min; and oxygen 10 mL/min. Oven temperature was set at 185 °C and the inlet was maintained at 215 °C.

Sensitivity to phosphorus was 25 pg at a peak size equal to twice baseline noise. Preliminary results from the recovery studies using pure standards of all tested pesticides yielded average recoveries of 99 ± 3% of all pesticides found in tailwater pits. The percentages of the recoveries from fortified soil and water samples are shown in Table I.

## RESULTS AND DISCUSSION

Pesticide residue data from the samples collected in 1973 were published previously (Kadoum et al., 1975).

Herbicide and insecticide residues found in tailwater pit samples (Tables II-VII) indicate some residue movement from fields. Various rates and timing of pesticide applications, soil pH and organic matter, amount of runoff water, and tillage and cultivation methods undoubtedly affected the amounts of residues in the pits.

Residues of seven herbicides and seven insecticides were detected. The mean number of different pesticides detected in tailwater pits in 1974 alone was 2.3 for pits receiving runoff from sorghum fields, 3.4 from those serving

Table I

Pesticide	Recovery <sup>a</sup>	Pesticide	Recovery <sup>a</sup>
Carbofuran	98 ± 3	Alachlor	98 ± 3
Dimethoate	95 ± 5	Atrazine	103 ± 2
Disulfoton	101 ± 2	Cyanazine	96 ± 4
EPN	95 ± 4	EPTC	96 ± 5
Fonofos	101 ± 2	Propachlor	100 ± 2
Parathion	100 ± 2	Propazine	103 ± 2
Phorate	101 ± 2	Terbutryn	99 ± 3
		R25788	96 ± 4

<sup>a</sup> Standard deviation calculated from four replicates.

corn fields, and 4.4 from pits serving both corn and sorghum. Potential hazard to crops and animals, due to summary or synergistic effects of different pesticide residues in the same tailwater pit, should be considered.

Residues of the triazine herbicides, atrazine and propazine, occurred in both water and bottom soil with far greater frequency than did other pesticides. Both persisted throughout the year (Table VII). Atrazine occurred in greater concentrations than all other residues (Table IV).

Seasonal uses of specific pesticides are reflected in the chronology of peak concentrations of residues in the tailwater pits (Table VII). All of the herbicides in this study were used most heavily as preplant, planting time, and early postemergent applications in Haskell County.

All were detected in highest concentrations in May or June. The insecticides carbofuran, fonofos, and phorate were used mostly in planting time applications against corn rootworms in corn. Concentrations of their residues peaked from 4 to 6 weeks later in June and July. Dimethoate, disulfoton, EPN, and parathion were used mostly as foliar applications against a complex of sorghum and corn insects in late July and in August and September. Residues of all these peaked in August, except for parathion for which a low peak appeared unaccountably in May of 1974.

Many pesticides were aerially applied to crops in the locale of our study. Resultant drift, or even direct application over tailwater pits, may account for some of the pesticide residues detected.

The pesticides most likely to have entered tailwater pits aerially were atrazine, dimethoate, and EPN applied to corn fields, propazine to sorghum fields, and disulfoton and parathion applied to both corn and sorghum. Some runoff occasionally occurred in the study area after heavy rains. However, rainfall is generally a minor contributor to field runoff in southwest Kansas. We believe that irrigation runoff is the primary carrier of pesticide residues into tailwater pits in the study area.

We may calculate the amount of pesticide which is applied to a crop when residue-bearing tailwater is reused

Table II. Frequency and Concentrations of Pesticide Residues in Samples from 12 Tailwater Pits Serving Sorghum Fields in Haskell County, Kansas, 1973

Pesticide <sup>c</sup>	Frequency of detection <sup>a</sup>		Concentration of residues, <sup>b</sup> ppb		
	No. of samples	No. of pits implicated	Median	Mean	Maximum
Pit Bottom Soil (40 Samples)					
Alachlor	1	1		121.0	
Atrazine	13	6	29.2	47.1	132.5
Phorate	1	1		2.3	
Propazine	22	7	71.6	106.2	429.0
Terbutryn	2	1	128.1	128.1	218.5
Tailwater (46 Samples)					
Atrazine	22	7	4.7	20.4	128.0
Cyanazine	3	2	47.5	34.2	50.7
Parathion	2	2	0.7	0.7	1.0
Phorate	3	2	1.5	1.6	2.2
Propazine	25	7	16.3	36.2	153.0
Terbutryn	1	1		4.4	

<sup>a</sup> Some samples contained no residues, others contained several kinds. The sum of residue frequencies is therefore not equal to the number of samples analyzed. <sup>b</sup> Medians and means were calculated from detectable residue data only. Statistics based on all samples analyzed, including those with no detectable residues of a given pesticide, would be much lower. <sup>c</sup> Analyses showed no detectable residues (<0.1 ppb) for cyanazine and parathion in bottom soil and for alachlor in water.

Table III. Frequency and Concentrations of Pesticide Residues in Samples from 24 Tailwater Pits Serving Corn Fields in Haskell County, Kansas, 1973

Pesticide	Frequency of detection <sup>a</sup>		Concentration of residues, <sup>b</sup> ppb		
	No. of samples	No. of pits implicated	Median	Mean	Maximum
Pit Bottom Soil (96 Samples)					
Atrazine	81	23	27.2	42.9	369.0
Cyanazine	1	1		21.6	
Fonofos	4	1	4.0	4.4	8.4
Phorate	4	2	1.7	2.1	4.6
Tailwater (108 Samples)					
Atrazine	98	24	3.5	13.9	250.0
Cyanazine	4	1	5.7	21.1	73.0
Fonofos	2	1		0.4	
Phorate	7	6	0.8	1.8	8.7

<sup>a</sup> Some samples contained no residues, others contained several kinds. The sum of residue frequencies is therefore not equal to the number of samples analyzed. <sup>b</sup> Medians and means were calculated from detectable residue data only. Statistics based on all samples analyzed, including those with no detectable residues of a given pesticide, would be much lower.

Table IV. Frequency and Concentrations of Pesticide Residues in Samples from 26 Tailwater Pits Serving Corn Fields in Haskell County, Kansas, 1974

Pesticide <sup>c</sup>	Frequency of detection <sup>a</sup>		Concentration of residues, <sup>b</sup> ppb		
	No. of samples	No. of pits implicated	Median	Mean	Maximum
Pit Bottom Soil (129 Samples)					
Alachlor	1	1		188.6	
Atrazine	109	23	35.1	90.8	1068.3
Carbofuran	2	2	50.0	50.0	75.9
Cyanazine	6	3	8.7	16.9	46.6
Disulfoton	6	5	11.4	13.8	32.7
EPN	2	2	33.5	33.5	58.2
EPTC	11	7	38.1	40.8	102.3
Fonofos	22	6	15.6	130.9	771.2
Phorate	7	5	1.6	9.6	56.9
Tailwater (129 Samples)					
Alachlor	5	3	8.6	30.3	98.8
Atrazine	14	24	6.1	56.2	1074.1
Carbofuran	12	10	31.1	35.2	88.9
Cyanazine	5	3	46.0	37.7	54.0
Dimethoate	10	10	1.5	1.9	4.3
EPN	3	3	1.0	1.4	2.2
EPTC	17	11	0.3	1.7	11.4
Fonofos	12	6	0.4	1.8	5.9
Parathion	1	1		6.2	
R25788	6	5	1.9	1.6	2.8

<sup>a</sup> Some samples contained no residues, others contained several kinds. The sum of residue frequencies is therefore not equal to the number of samples analyzed. <sup>b</sup> Medians and means were calculated from detectable residue data only. Statistics based on all samples analyzed, including those with no detectable residues of a given pesticide, would be much lower. <sup>c</sup> Analyses showed no detectable residues (<0.1 ppb) for dimethoate, parathion, and R25788 in bottom soil and for disulfoton and phorate in water.

Table V. Frequency and Concentrations of Pesticide Residues in Samples from Five Tailwater Pits Each Serving Both Corn and Sorghum Fields in Haskell County, Kansas, 1974

Pesticide <sup>c</sup>	Frequency of detection <sup>a</sup>		Concentration of residues, <sup>b</sup> ppb		
	No. of samples	No. of pits implicated	Median	Mean	Maximum
Bottom Soil (25 Samples)					
Atrazine	12	4	77.6	133.4	468.9
Carbofuran	2	2	30.6	30.6	42.4
Cyanazine	3	1	124.8	88.4	124.8
Disulfoton	1	1		11.0	
EPN	1	1		75.0	
Fonofos	4	1	48.4	136.2	428.9
Propazine	14	4	53.2	65.6	247.8
Terbutryn	3	1	30.5	39.1	72.0
Tailwater (25 Samples)					
Atrazine	15	5	6.1	81.7	766.7
Carbofuran	3	2	17.0	24.1	51.7
Cyanazine	4	1	24.1	24.1	45.9
Dimethoate	1	1		1.9	
EPTC	1	1		0.3	
Fonofos	3	1	0.2	0.2	0.3
Parathion	1	1		0.1	
Phorate	1	1		0.1	
Propazine	15	5	2.4	28.5	219.4
Terbutryn	3	1	5.7	9.5	19.0

<sup>a</sup> Some samples contained no residues, others contained several kinds. The sum of residue frequencies is therefore not equal to the number of samples analyzed. <sup>b</sup> Medians and means were calculated from detectable residue data only. Statistics based on all samples analyzed, including those with no detectable residues of a given pesticide would be much lower. <sup>c</sup> Analyses showed no detectable residues (<0.1 ppb) for dimethoate, EPTC, and parathion in bottom soil and for disulfoton and EPN in water.

for irrigation. On medium-textured soils such as the silt loams of our study area, a typical midsummer irrigation of corn requires 4 acre-inches of water/acre (Hay and Pope, 1976a). Sorghum and alfalfa have similar requirements for high production. Wheat fields may need irrigations of similar or greater quantity in the autumn before planting or in May (Hay and Pope, 1976b).

Relatively few of the pesticide residues in water were as great as 10 ppb although exceptions skewed the means upward (Tables II-VII). If tailwater containing 10 ppb

of a pesticide residue was reused to supply cropland with a 4-inch (10-cm) irrigation, this would equal a pesticide application of 0.009 lb/acre (0.001 kg/ha) (Table VIII). That is an inconsequential amount.

However, water from two pits carried exceptionally high concentrations of atrazine in 1974, one with 1074 ppb in May and the other with 739 ppb in June. Such exceptions may create problems. Again referring to Table VIII, a 4-inch (10-cm) irrigation with water from the pit carrying 1074 ppb atrazine delivers 0.98 lb/acre (0.18 kg/ha) of the

Table VI. Frequency and Concentrations of Pesticide Residues in Samples from Four Tailwater Pits Serving Sorghum Fields in Haskell County, Kansas, 1974

Pesticide <sup>c</sup>	Frequency of detection <sup>a</sup>		Concentration of residues, <sup>b</sup> ppb		
	No. of samples	No. of pits implicated	Median	Mean	Maximum
Bottom Soil (19 Samples)					
Atrazine	13	3	46.2	63.9	193.7
Disulfoton	2	1	117.2	117.2	227.8
Propazine	7	3	23.5	44.8	183.2
Tailwater (19 Samples)					
Atrazine	15	3	6.2	31.8	285.0
Parathion	1	1	0.1	0.1	0.1
Propazine	10	4	6.7	32.9	269.4

<sup>a</sup> Some samples contained no residues, others contained several kinds. The sum of residue frequencies is therefore not equal to the number of samples analyzed. <sup>b</sup> Medians and means were calculated from detectable residue data only. Statistics based on all samples analyzed, including those with no detectable residues of a given pesticide, would be much lower. <sup>c</sup> Analyses showed no detectable residues (<0.1 ppb) for parathion in bottom soil and for disulfoton in water.

Table VII. Concentrations (ppb) of Pesticide Residues Occurring in Tailwater Pits in Different Months (Data for Each Pesticide is the Mean of All Pits from Which Residues of that Specific Pesticide Were Detected. 1973 and 1974 Data Are Pooled)<sup>a</sup>

Pesticide	Soil					Water				
	May	June	July	Aug	Nov-Dec	May	June	July	Aug	Nov-Dec
Herbicides										
Alachlor	0	47	30	0	0	38	9	0	0	0
Atrazine	38	124	65	32	16	47	87	19	7	6
Cyanazine	0	32	21	2	0	18	30	21	1	T
EPTC	4	26	8	0	0	T	2	T	0	0
Propazine	43	90	81	20	1	25	60	24	5	1
R25788	0	0	0	0	0	1	1	0	0	0
Terbutryn	0	117	36	34	0	0	12	3	2	0
Insecticides										
Carbofuran	0	5	7	0	0	6	31	1	0	0
Dimethoate	0	0	0	0	0	0	0	0	2	0
Disulfoton	0	0	0	36	11	0	0	0	0	0
EPN	0	0	0	27	2	0	0	0	1	T
Fonofos	9	305	101	14	2	T	2	T	T	0
Parathion	0	0	0	0	0	1	T	0	T	0
Phorate	0	9	3	3	0	0	1	T	0	0

<sup>a</sup> Residue concentrations rounded off to nearest whole ppb, those less than 0.5 ppb are reported as T = trace.

herbicide. This is one-third to one-half the amount recommended to kill many broadleaved weeds and some grasses (Nilson et al., 1975) and could possibly kill or injure soybeans, sugarbeets, or wheat. Several irrigations are usually required each growing season in southwest Kansas. Multiple irrigations increase the danger of damage, although in our study residue concentrations decreased as the season progressed.

Evans and Duseja (1973) reported atrazine concentrations of up to 0.86 ppm (860 ppb) in a stream below experimental applications to stream side plots. They concluded, "The low concentrations that are observed following proper application of the herbicides would not likely be hazardous to crops or animals". Comparing their results to ours as discussed in the foregoing paragraph, we must disagree with their conclusion.

The danger of damage to crops can be minimized in the following ways: (1) using tailwater on less sensitive crops; (2) avoiding repeated irrigation of the same area with tailwater; (3) using tailwater only after several weeks' degradation time has elapsed; (4) mixing tailwater with uncontaminated irrigation water. The third method is of minimal value because the cost of high capacity pits is prohibitive. Efficiency in tailwater use systems depends upon rapid (even continuous) reuse (Hay and Pope, 1977). The fourth method is also of limited feasibility because most irrigation systems are not designed for controlled mixing of fresh water and tailwater for simultaneous use on any one part of a field (Figure 1).

Table VIII. Pounds of Pesticide in Irrigation Water from Tailwater Pits with Indicated Levels of Pesticide Residue<sup>a</sup>

Residue, ppb	Acre-inches of irrigation water <sup>b</sup>			
	2	4	6	12
10	0.005	0.009	0.014	0.027
50	0.02	0.05	0.07	0.14
100	0.05	0.09	0.14	0.27
200	0.09	0.18	0.27	0.54
300	0.14	0.27	0.41	0.82
400	0.18	0.36	0.55	1.09
500	0.23	0.45	0.68	1.36
600	0.27	0.54	0.82	1.63
700	0.32	0.63	0.95	1.90
800	0.36	0.72	1.09	2.17
900	0.41	0.82	1.23	2.45
1000	0.45	0.91	1.36	2.72

<sup>a</sup> One ft<sup>3</sup> = 62.4 lb of water; one acre-foot = 43560 ft<sup>3</sup>; therefore, one acre-foot = 2718144 lb. 2718144 lb/1 billion = x/1; therefore, one ppb = 0.002718 lb/acre-foot water. <sup>b</sup> One acre-foot = 12 acre-inches. One acre-inch = 102.6 m<sup>3</sup>. In using this table to calculate amounts of pesticides applied per unit area of land through irrigation with tailwater, note that 1 lb/acre = 0.184 kg/hectare.

Most residues in pit bottom soils were in concentrations between 10 and 50 ppb. Notable exceptions were atrazine and the insecticide fonofos.

Since atrazine is low in toxicity to fish, game birds, and mammals, its presence in the quantities found, either in tailwater or in pit bottom soils, should constitute no danger

to fish, wildfowl, livestock, or man.

Fonofos was found in only one tailwater pit in 1973 (Table III) and seven in 1974 (Tables IV and V) but is occurred in concentrations of up to 771 ppb in pit bottom soil. It was found only in very low concentrations in the water. Fonofos residues were more persistent throughout the year than were any of the other insecticides. Residues of this chemical should cause no damage to crops irrigated with tailwater. However, fonofos is toxic to fish (Stauffer Chemical Co., 1972), and where turbulence disturbs the bottom soil it could contaminate or kill fish in stocked pits.

Fonofos is highly toxic to mammals (Stauffer Chemical Co., 1972; Wiswesser, 1976). Tailwater pits in this study contained up to one-tenth the mammalian LD<sub>50</sub> of fonofos in bottom soil and one-thousandth the mammalian LD<sub>50</sub> in water.

Our findings suggest a public benefit from the farmer's use of tailwater pits. Such collection and reuse of water make a virtually closed system from which, except for leaching and evaporation, no water or associated pesticide residues escape. This minimizes potential hazard to the general public.

#### ACKNOWLEDGMENT

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## Distribution of Oxadiazon and Phosalone in an Aquatic Model Ecosystem

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Four species of aquatic organisms were exposed to the herbicide oxadiazon [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- $\Delta^2$ -1,3,4-oxadiazolin-5-one] and the organophosphate insecticide phosalone, [*O,O*-diethyl *S*-(6-chloro-2-oxobenzoxazolin-3-yl)methyl] phosphorodithioate, in a model ecosystem for 48 and 31 days, respectively. Oxadiazon was introduced into the ecosystem adsorbed to 400 g of soil at the rate of 1 and 10 ppm, where as soil treated with 10 ppm phosalone was aged for 84 days before introduction. The organisms accumulated oxadiazon and phosalone 30 to 300 times greater than the water content, which indicates a low bioaccumulation potential. Seven degradation products of oxadiazon were found, with snails degrading oxadiazon more extensively than did algae or fish. Phosalone was toxic to daphnids and fish in the 20 to 30 ppb range, and only two degradation products were obtained.

The extensive worldwide use of pesticides has dictated that their effect on the environment be thoroughly investigated. Possible contamination of the aquatic environment, through direct application or erosion of pesticide-treated soil into lentic or lotic waters, is a primary

concern. Such contamination could adversely affect aquatic organisms and/or result in biological accumulation eventually affecting higher tropic organisms. Thus, all pesticides that enter water must be evaluated to determine their potential behavior in and effect on the aquatic environment.

Oxadiazon [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- $\Delta^2$ -1,3,4-oxadiazolin-5-one] is a promising herbicide useful for weed control in annual crops, such as rice and soybeans, and perennial orchard and vineyard crops. Phosalone, [*O,O*-diethyl *S*-(6-chloro-2-oxobenzoxazolin-3-yl) methyl] phosphorodithioate, is a nonsystemic organophosphate insecticide and miticide used to control several major pests in potatoes, cotton, and orchards. Since

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