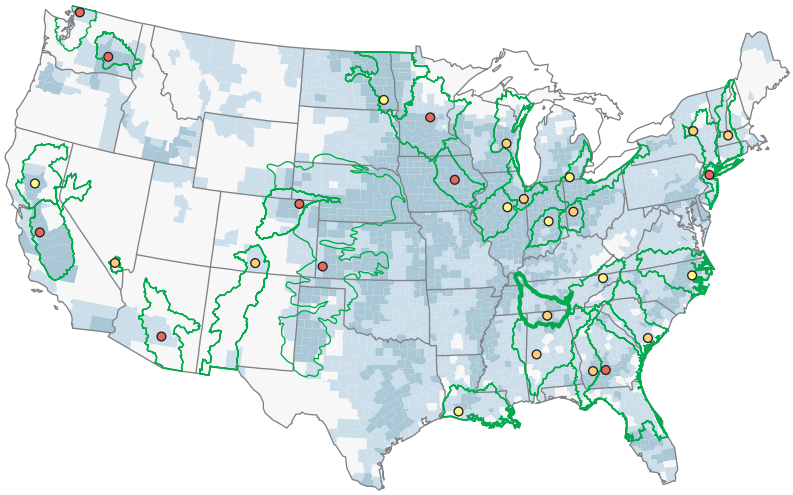


EXPLANATION

AVERAGE ANNUAL TOTAL NITROGEN INPUT— in pounds per acre, by county, for 1995-98. Inputs are from fertilizer, manure, and the atmosphere

- Greater than 25 pounds per acre
- 6 to 25 pounds per acre
- Less than 6 pounds per acre

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM AGRICULTURAL LAND-USE STUDY-AREA BOUNDARY

MEDIAN CONCENTRATION OF NITRATE, IN MILLIGRAMS PER LITER

- Less than 1
- 1 to 5
- Greater than 5

Figure 9. Distribution of selected National Water-Quality Assessment Program agricultural land-use study areas, median nitrate concentration, and estimated average annual nitrogen input across the Nation. (Modified from U.S. Geological Survey, 1999.)

had c m a able e ima ed e fl me n and al i ed n c n, a n de ec ed, and i deg ada e e e de ec ed le f e en l and a l e c ncen a- i n han fl me n (able 5). The h ical and chemical e ie f he e e icide a e imila ; h e e , he field di i a i n half-life f fl me n i ab ice a l ng a ha f aldica b (Wa ch e and he , 1992). Gl h a e, he e ce i n he ela i n be een e and de ec i n f e enc , had he highe e ima ed e and a a lied i hin he b ffe a ea f all f he ell b a n de ec ed (able 5). The anal ical me h d f gl h a e had a highe MRL (0.1 µg/L) han man f he he e i- cide (able 5), b ha babl d e n acc n f he lack f de ec i n . Median c ncen a i n f fl me n and a a ine de ec i n e e 0.41 and 0.12 µg/L, e ec i el (g ea e han he MRL f gl h a e), e en h gh fl me n and a a ine a lica i n e e ab a hi d f he e ima ed am n f gl h a e a lied. Gl h a e ha a il i n c efficien de f magni de highe han a a ine and fl me n, and he ae bic il half-life f gl h - a e i 47 da c m a ed 146 and 189 da f a a ine and fl me n, e ec i el (U.S. De a men f Ag i- c l e, 2002). Deg ada e f gl h - a e e e n anal ed in hi d .

Fl me n and a a ine gene - all e e de ec ed in am le f m ell he e he e e icide e e a lied in he b ffe a ea (fig. 12). Fl me n a de ec ed in am le f m 83 e cen f ell i h b ffe a ea ha had e ima ed e d ing 2000 (fig. 12). Th ee f he f am- le in hich fl me n a n de ec ed had l DO c ncen a i n (le han 1.5 mg/L), indica ing l ng a e age g nd- a e e idence ime a he e ell , l a e f echa ge, me deg ee f c nfinemen in he eg li h (he f h ell c ld n be m ed c n in l and did n ha e a DO mea emen). A a ine a de ec ed in ab 70 e cen f he ell he e i a a lied in he b ffe a ea in 2000; and, like fl me n, fi e f he i am le f m ell i h e ima ed e in hich a a ine a n de ec ed had DO c ncen a- i n le han 1.5 mg/L (he i h am le did n ha e a DO mea emen). Fl me n a de ec ed nl in am le f m ell he e i a a lied in he b ffe a ea d ing he 2000 g ing ea n; h e e , a a ine a de ec ed a c ncen a i n be een 0.014 and 0.21 µg/L in am le f m i m ni ing ell he e n a a ine a a lied in he b ffe a ea d ing he 2000 g ing ea n (fig. 12). The e l -le el de ec i n f a a ine indica e ei he ha e id e e - i in he b face f e i d g ea e han a ea , ha he c n ib ing a ea f he e ell incl de a ea n acc n ed f b he b ffe a ea .

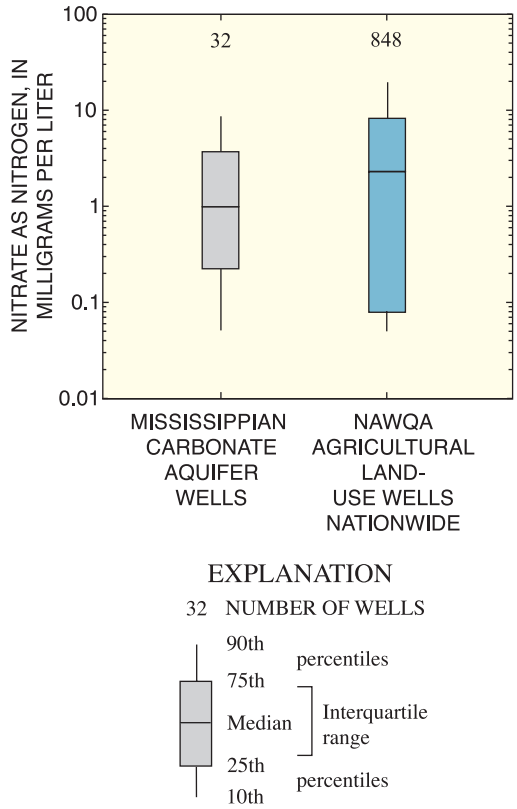
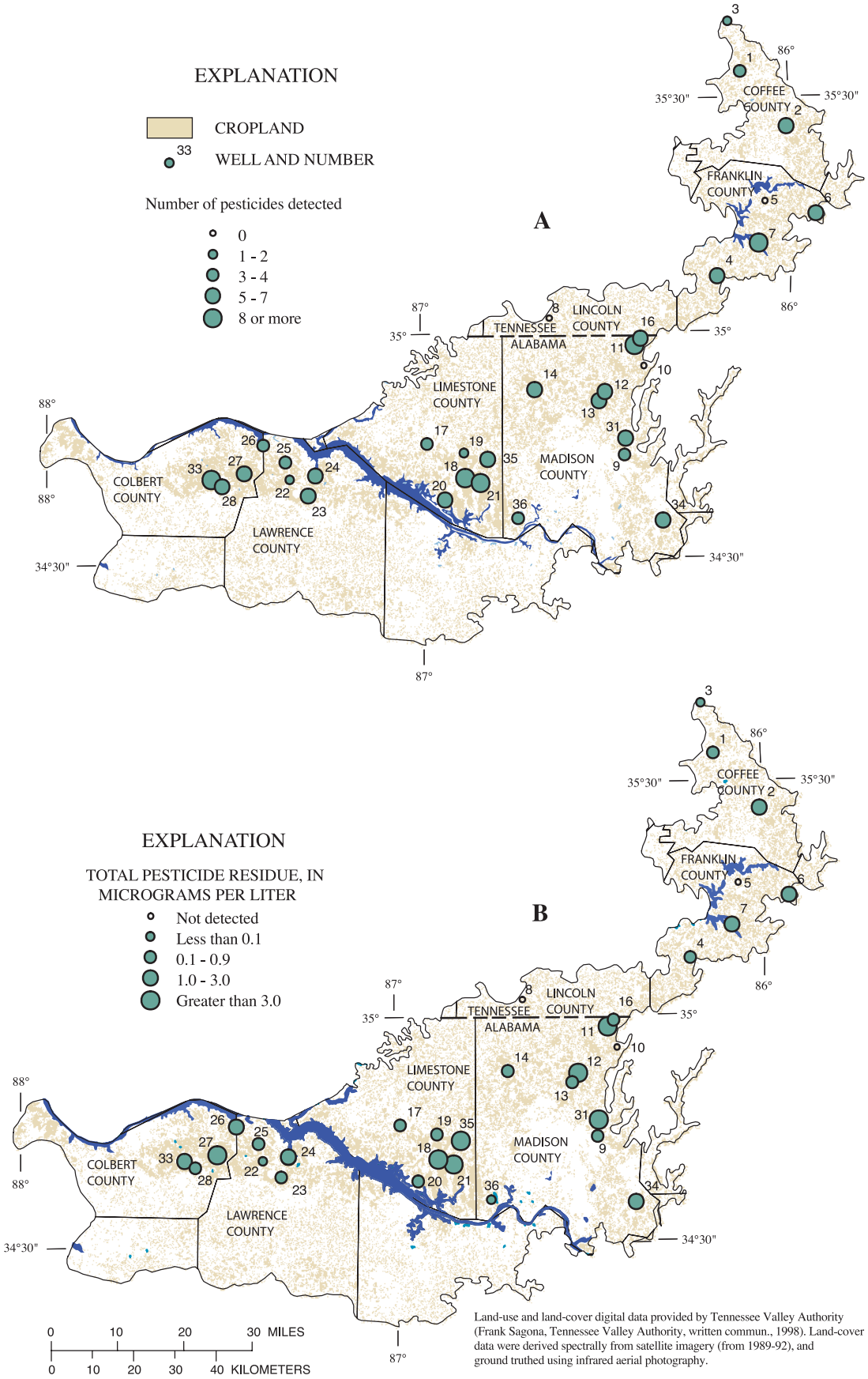


Figure 10. Nitrate concentrations in samples from the Mississippian carbonate aquifer and from National Water-Quality Assessment Program agricultural land-use wells across the Nation.

Pe icide deg ada e e en ed 38 e cen f he e icide de ec ed a c ncen a i n g ea e han 0.01 µg/L; h e e , deg ada e acc n ed f nl 17 e cen f he e icide anal ed. Nine f he 12 m f e en l de ec ed e icide e e deg ada e (able 5). The cc ence f deg ada e gene all c in- cided i h de ec i n f he a en e icide. A a ine, fl me n, and n fl a n deg ada e e e c m- m nl de ec ed a c ncen a i n c m a able g ea e han he a en e icide (able 5 and fig. 13). In me am le , he a en e icide a n de ec ed. Aldica b lf ne and lf ide (deg ada e f he c n in ec icide aldica b) e e de ec ed a c ncen a i n le han 0.2 µg/L (able 5) in ab 22 e cen f he am le , b aldica b a de ec ed nl nce a a c ncen a i n f 0.004 µg/L. N all deg ada e anal ed e e de ec ed. Al h gh ca b f - an a de ec ed in am le a l c ncen a i n (le han 0.03 µg/L), deg ada e anal ed (3-ke ca b f an and 3-h d ca b f an) e e n de ec ed. The MRL f he e deg ada e a e 0.072 and 0.062 µg/L, e ec i el .

C ncen a i n f he deg ada e f fl me n gene all e e le han he fl me n c ncen a- i n, in c n a n fl a n and a a ine deg a- da e , hich icall e e de ec ed a highe c ncen a i n han n fl a n and a a ine (fig. 13). The l e ela i e c ncen a i n f fl me n deg- ada e c m a ed i h a a ine and n fl a n ma be he e l f addi i nal a lica i n f fl me n la e in he g ing ea n ma eflec l e a e f deg ada i n f fl me n. The inci al deg a- da e f fl me n de ec ed a deme h lfl me - n (41 e cen f am le , able 5). The deg ada e 3- (ifl me h l) aniline (TFMA) f m f m deg ada- i n f fl me n deme h lfl me n and a de ec ed in 19 e cen f he am le ; 3- hen l ea, he deg ada e f deme h lfl me n a n de ec ed. TFMA c ncen a i n icall e e l (median a 0.07 µg/L) and e e le han deme h- lfl me n c ncen a i n ; h e e , in he am le f m ell 33, TFMA c ncen a i n e e c n ide abl highe (0.24 and 0.42 µg/L), and deme h- lfl me n c ncen a i n e e le han TFMA c ncen a i n (< 0.05 and 0.18 µg/L). Sam le f m hi ell had a calci e a a i n inde nea e (able 4), indica ing a l nge a e age g nd- a e e idence ime han f he am le . E ima ed echa ge da e f m CFC da a f hi ell e e in he mid- la e-1970 . The ela i el high TFMA c ncen- a i n ma be he e l f he l nge a e age e i- dence ime f g nd a e a hi ell, all ing m e deg ada i n cc han a he he ell .

The dee h la a ine a a ine a i (DAR) ha been ed a a ali a i e indica f he a h a h gh hich a e and a a ine m e in he b- face (Adam and Th man, 1991). Dee h la a ine f m f m he b eakd n f a a ine b mic be in he il en i nmen . A DAR le han 1 ma indica e a id an he b face i h h e idence ime f a e and a a ine in he il ne. In he Ea e n Highland Rim, inkh le in addi i n il mac e c ld ide a h a f a id m e- men f a e and e icide in he g nd a e . The maj i f a a ine c ncen a i n e e le han 0.25 µg/L. The fi e am le i h a a ine c ncen a- i n g ea e han 0.75 µg/L had DAR le han 1 (fig. 14), gge ing ha he e high a a ine c ncen- a i n a e he e l f a id echa ge he a ife i h a h e idence ime in he il ne. The fe de ec i n f me lachl , hich ha a h e ae bic il half-life han a a ine (U.S. De a men f



Land-use and land-cover digital data provided by Tennessee Valley Authority (Frank Sagona, Tennessee Valley Authority, written commun., 1998). Land-cover data were derived spectrally from satellite imagery (from 1989-92), and ground truthed using infrared aerial photography.

Figure 11. (A) Number of pesticides detected and (B) total pesticide concentration in samples from the Mississippian carbonate aquifer.

Table 5. Summary statistics for pesticides detected at concentrations equal to or greater than 0.01 microgram per liter in samples from the Mississippian carbonate aquifer and estimated use of selected pesticides in buffer areas around wells

[F, f ngicide; H, he bicide; I, in ec icide; Deg ., e icide deg ada e; E, e ima ed al e; --, n da a; NA, n a licable; MRL, minim m e ing le el; µg/L, mic g am e li e ; lb , nd]

Pesticide	Detection frequency (percent)	Number of detections	Maximum concentration (µg/L)	Median detection (µg/L)	MRL	Pesticide type	Median estimated use (lbs)	Number of buffer areas with use during 2000
A a ine	62	20	1.83	0.12	0.007	H	36	21
Fl me n	59	19	2.13	0.41	0.062	H	27	24
Dee h ldei la a ine	59	19	0.071 E	.022 E	0.06	Deg .	NA	NA
N fl a n	53	17	0.71	0.081	0.077	H	8	24
H d a a ine	50	16	0.168 E	.035 E	0.193	Deg .	NA	NA
Deme h ln fl a n	47	15	3.21	0.41	0.05	Deg .	NA	NA
Dee h la a ine	47	15	0.71 E	.19 E	0.002	Deg .	NA	NA
Dei la a ine	47	15	0.1 E	.034 E	0.074	Deg .	NA	NA
Deme h lfl me n	41	13	1.85	0.39	0.05	Deg .	NA	NA
Aldica b lf ne	22	7	0.16 E	.12 E	0.160	Deg .	NA	NA
3-(ifl me h l) aniline (TFMA)	19	6	0.42	0.07	0.05	Deg .	NA	NA
Aldica b lf ide	16	5	0.085 E	.029 E	0.027	Deg .	NA	NA
Me lachl	12	4	0.92	0.19	0.002	H	5	22
P me n	9	3	0.17	0.02	0.018	H	--	--
Di n	9	3	0.14	.016 E	0.079	H	11	24
Ima e ha [1]	7	2	0.056 E	NA	0.088	H	< 0.5	15
Me ala l	6	2	0.022 E	NA	0.057	F	4.3	24
Ca b f an	6	2	0.028	NA	0.003	I	0.8	21
Sima ine	6	2	0.021	NA	0.005	H	0.5	21
Ace chl	3	1	0.057	NA	0.002	H	5	21
Me ib in	3	1	0.015	NA	0.004	H	3	24
Pendime halin	3	1	0.059	NA	0.004	H	3.5	21
2,4-D me h l e e	3	1	0.025 E	NA	0.086	H	--	--
Di henamid	3	1	0.014 E	NA	0.058	H	--	--
Gl h a e[2]	0	0	--	NA	0.1	H	127	32
Aldica b	0	0	--	NA	0.082	I	28	24
Ca ba l	0	0	--	NA	0.003	I	2.7	21
P me n	0	0	--	NA	0.05	H	4.7	24

[1]Anal ed in 28 am le

[2]Anal ed in 17 am le

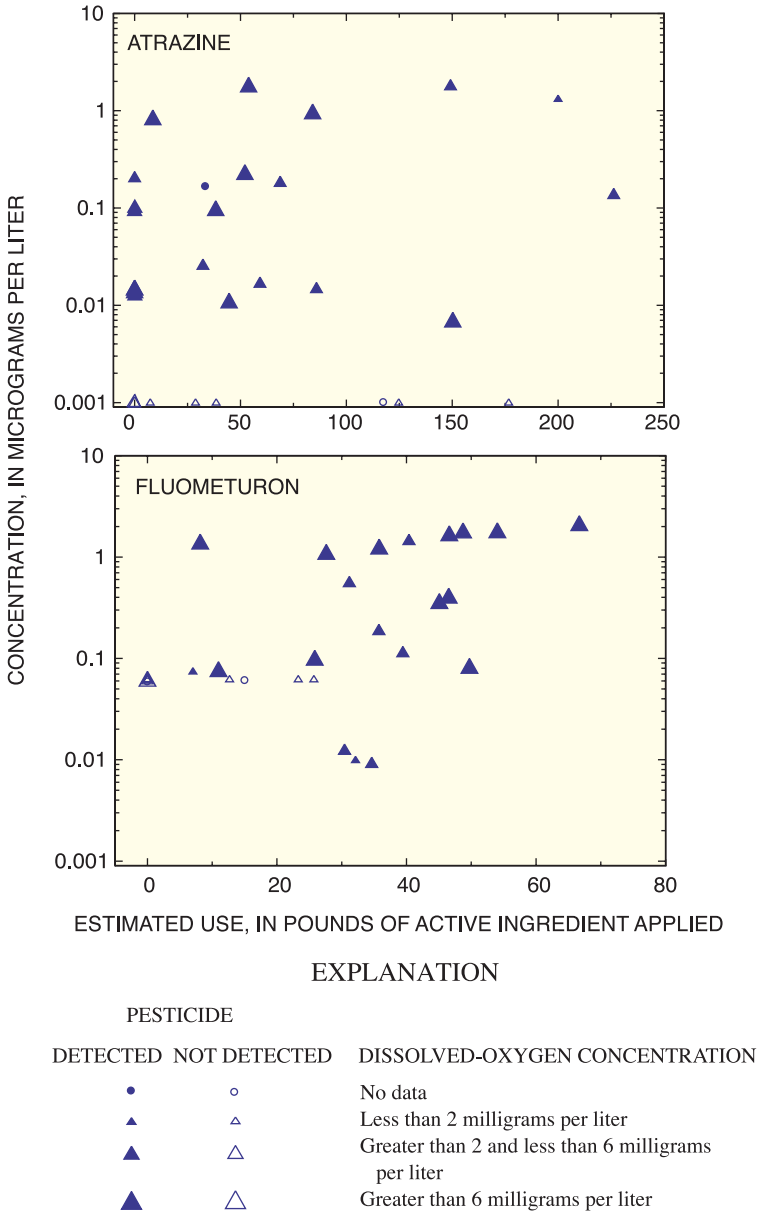


Figure 12. Concentrations of atrazine, fluometuron, and dissolved oxygen and estimated use of atrazine and fluometuron in buffer areas around wells in the Mississippian carbonate aquifer.

Ag ic l e, 2002), a high c ncen a i n ed mi- nan l in am le i h DAR le han 1 (fig. 14), - he in e e a i n ha high c ncen a i n f a a ine e l f m a id infil a i n f echa ge.

Gi en ha e icide ed in b ffe a ea f ell diffe ed, he al e icide c ncen a i n (m f all e icide and e icide deg ada e in a am le), in addi i n he am n f c land nea a ell, a ed e al a e hich fac e e ela ed e i- cide cc ence. Beca e il e ie a e di ec l c ela ed land e, di ce ning he infl ence f dif- fe ence in il e ie n he cc ence f e icide in hi e ing i n ible. The al e icide c ncen a i n a c ela ed DO c ncen a i n and, in n, ela ed fac c ela ed DO c ncen a i n . Al h gh DO i i i el c ela ed ni a e c ncen a i n, a ial c ela i n anal i indica e ha ni a e and DO acc n f me f he a ia i n in al e icide c ncen a i n. Gi en he e- d minance f c land nea he e ell and he ela i n be een al e icide and ni a e c n- cen a i n , fe ili e a lica i n c land i he bable ce f ni a e he e ell . The ela i n be een DO and al e icide c ncen a i n indica e ha e icide a e m e likel be de ec ed a high c ncen a i n he e g nd- a e e idence ime i h and he a e f echa ge i fa . Al h gh he ela- i n be een al e icide c ncen a i n and he calci e a a i n inde a n a i icall ignifican , am le i h he highe al e i- cide c ncen a i n e e a cia ed i h ell ha ing g nd a e i h a h e idence ime ba ed n DO and he a a i n inde (fig. 15).

Pe icide e e de ec ed m e f e en l in am le f m m ni ing ell in hi d han in am le f m he ag ic l al a ea ac he Na i n. A a ine and i deg ada e, dee h la a ine, e e de ec ed in 62 and 47 e cen , e ec i el , f am le c llec ed f m he Mi i i ian ca b na e a ife (fig. 16). A a ine and dee h la a ine e e de ec ed in ab 25 e cen f he m ni ing ell am led be een 1991 and 2001 a a f ag ic l al land- e die c nd c ed b he NAWQA P g am (U.S. Ge l gical S e , 2002a) and e e he m f e en l de ec ed e icide na i n ide. The g ea e f e enc f de ec i n in hi d c ld eflec g ea e a a ine e in he LTEN han in he a ea am led in he na i nal da a e ; h e e , ab half f he ell in he na i nal da a e e e in a ea ha had g ea e e i- ma ed e f a a ine han in he LTEN (Thelin and Giane i, 2000) (fig. 17). The a e age de ec i n f e- enc f a a ine in am le f m a ea na i n ide i h a a ine e g ea e han he LTEN a ab 30 e cen , m ch l e han he 62 e cen de ec i n f e enc in am le c llec ed f hi d . Me l- achl a he hi d m f e en l de ec ed e icide

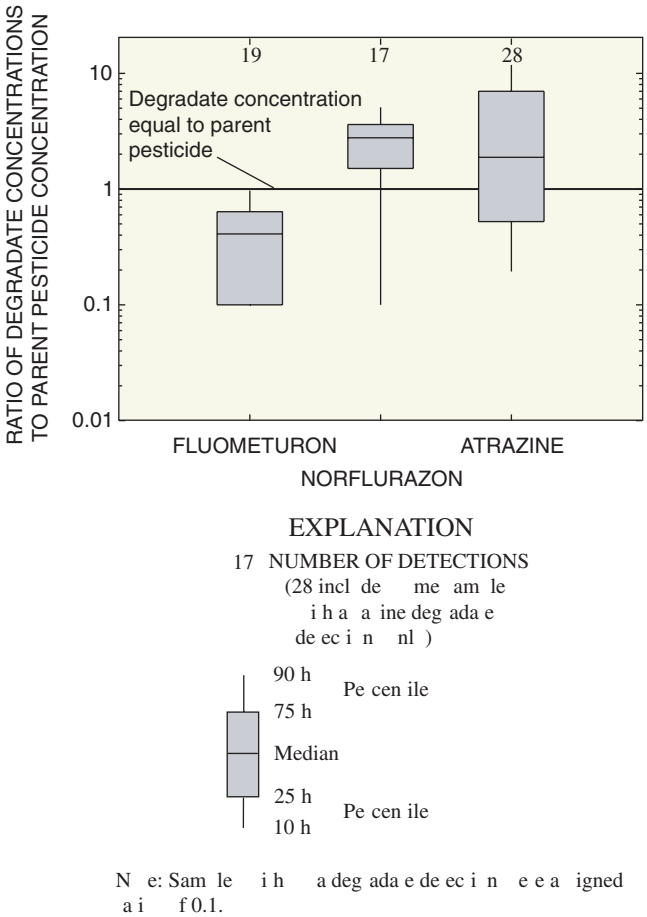


Figure 13. Ratios of degradate to parent pesticide concentration for fluometuron, norflurazon, and atrazine in samples from the Mississippian carbonate aquifer.

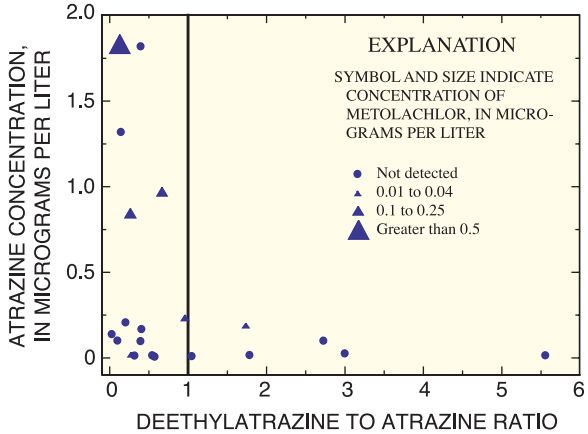


Figure 14. Relation between deethylatrazine to atrazine ratios (less than 1) and concentrations of atrazine and metolachlor in water samples from the Mississippian carbonate aquifer.

na i n ide and a he f h m f e en l de ec ed e icide in hi d (n incl ding deg a- da e). Median c ncen a i n f a a ine, dee h la a- ine, and me lachl e e n a i icall diffe en be een he da a e , b ended be ligh l highe in am le c llec ed f hi d han in am le c l- lec ed na i n ide (fig. 16).

The c n he bicide fl me n and n fl a- n al e e de ec ed m e f e en l in hi d han in am le f m ag ic l al land- e die ac he Na i n (fig. 16). Fl me n and n fl a- n e e de ec ed in 59 and 53 e cen , e ec i el , f am le in hi d c m a ed 2 and 1 e cen , e ec i el , f am le f m he he d a ea . The e he bicide had limi ed e in he a ea f he c n e e en ed b he na i nal da a (fig. 17, The- lin and Giane i, 2000), hich ma e lain he l e de ec i n f e enc . Median c ncen a i n f fl me n and n fl a n e e 0.41 and 0.08 µg/L, e ec i el , in hi d , c m a ed median c n- cen a i n f 0.1 and 0.07 µg/L, e ec i el , f he na i nal da a (fig. 16).

Implications for Drinking-Water Quality of the Mississippian Carbonate Aquifer

Wa e - ali da a c llec ed f hi land- e d and f m a e i d f d inking- a e ell l ca ed in he Ea e n Highland Rim (King b and Shel n, 2002) indica e ha he Mi i i ian ca - b na e a ife i ce ible c n amina i n f m n n in ce and ha he a e ali h gh m ch f he a ife ha been affec ed b ac i i ie a cia ed i h c d c i n. In he mme f 1999, a e am le f m a ne k f d inking- a e ell (ed minan l d me ic ell c m le ed in bed ck) e e anal ed f a b ad ange f c n i - en cha ac e i e he ali f a e in he a ife (King b and Shel n, 2002). D me ic and blic- l ell in he Ea e n Highland Rim icall i hd a g nd a e f m he bed ck in he Mi i - i ian ca b na e a ife . The a e - ali da a c l- lec ed f m he hall m ni ing ell in hi d e e en a e in he a ife ha h ld be m affec ed b ac i i ie a cia ed i h ag ic l al land e. M ch f he echa ge he bed ck a f he a ife i f m a e m ing h gh he eg li h. The m ni ing ell da a a e c m a ed da a c llec ed f m 25 f he d inking- a e ell ha a e c m le ed in he F Pa ne Che , T c mbia Lime ne, and

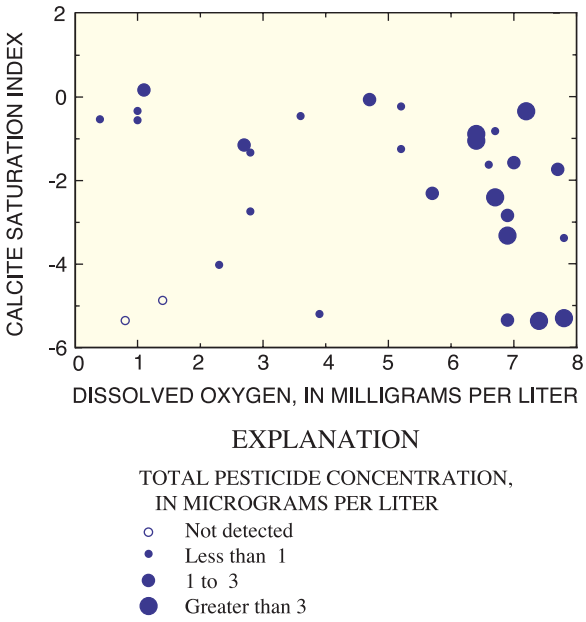


Figure 15. Relation between dissolved-oxygen concentration, calcite saturation index, and total pesticide concentration for samples from the Mississippian carbonate aquifer.

M n eagle Lime ne cha ac e i e he effec f c land n a f he Mi i i ian ca b na e a i- fe ed f a e l . The e d inking- a e ell anged f m 44 157 f dee , i h a median de h f 87 f (King b and Shel n, 2002).

C ncen a i n f in ganic c n i en in he ag ic l al land- e m ni ing ell a e imila c ncen a i n in he d inking- a e ell f m he e i d . Al h gh d inking- a e ell a e c m le ed in bed ck and gene all a e dee e han he m ni ing ell , b h g f ell ha e imi- la ange in DO, H, and ecific c nd c ance (fig. 18). Wi h he e ce i n f a ligh l highe median c ncen a i n f a i m in am le f m he land- e m ni ing ell , he land- e m ni ing ell and he d inking- a e ell a e n a i icall diffe en i h e ec maj in ganic c n i en c ncen a i n . P a i m i a lan n ien and i a lied ag ic l al land , hich ma acc n f he ligh l highe median c ncen a i n f am le f m he land- e m ni ing ell .

Ni a e c ncen a i n gene all e e l in b h ell ne k ; he median ni a e c ncen a i n f he d inking- a e ell a ab 1.5 mg/L c m- a ed 1 mg/L f he m ni ing ell (fig. 19). Ni a e c ncen a i n g ea e han 5 mg/L e e inf e- en in b h ne k (fig. 19). The d inking- a e ell had am le ha e ceeded he ma im m

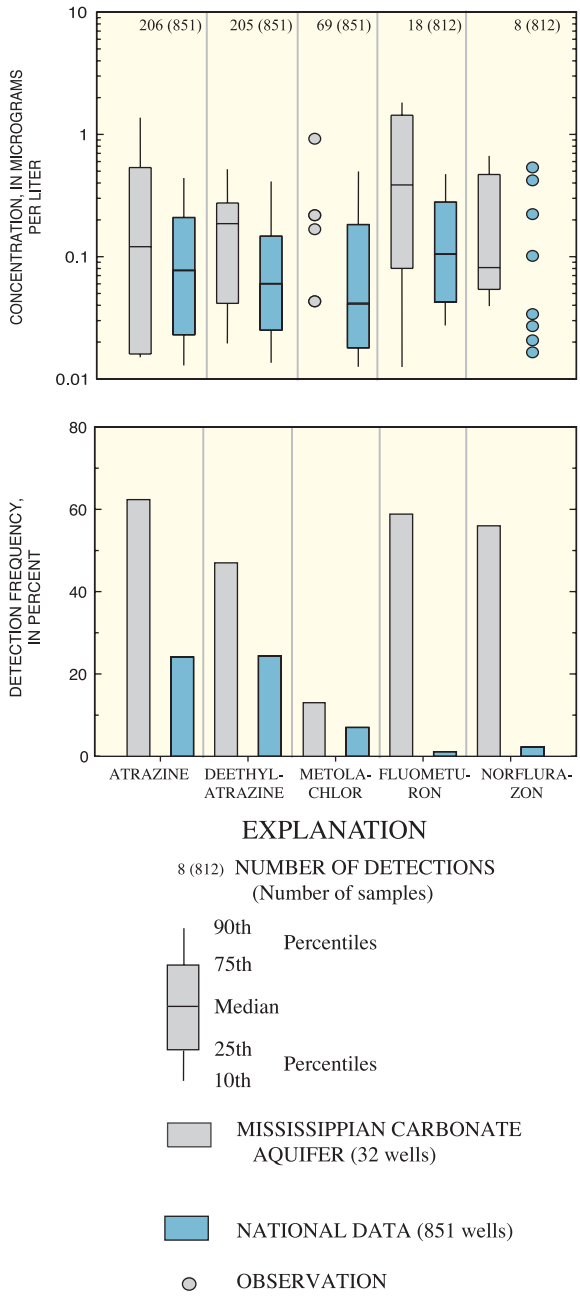


Figure 16. Detection frequencies and concentrations of selected pesticides at or above 0.01 microgram per liter in samples collected from the Mississippian carbonate aquifer and from selected National Water-Quality Assessment Program agricultural land-use wells across the Nation.

c n aminan le el f 10 mg/L. P in ce f ni a e (an animal feedl and a mall c e a i e fe ili e age facili) nea he e ell ma ha e c n ib ed he e high c ncen a i n (King b and Shel n, 2002). The gene all l c ncen a i n f ni a e in am le f m he land- e m ni ing ell