National Water Quality Program

Multidecadal Change in Pesticide Concentrations Relative to Human Health Benchmarks in the Nation's Groundwater

Scientific Investigations Report 2025–5081

U.S. Department of the Interior
U.S. Geological Survey

Cover.

Upper left: Photograph of a South Platte agricultural land use well, Colorado. Photograph by Nancy Bauch, U.S. Geological Survey (former employee).

Upper right: Photograph of a South Platte agricultural land use well, Colorado. Photograph by Nancy Bauch, U.S. Geological Survey (former employee).

Bottom right: Photograph of drinking water in a glass. Photograph by Nancy Bauch, U.S. Geological Survey (former employee).

Bottom left: Photograph of an analytical chemist reviewing pesticide data at the U.S. Geological Survey National Water Quality Laboratory, Denver, Colorado. Photograph by Christoher Kanagy, U.S. Geological Survey.

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)

Supplemental Information

Concentrations of chemical constituents in water are in either milligrams per liter (mg/L) or micrograms per liter (μg/L).

Abbreviations

DBCP	1,2-dibromo-3-chloropropane
DEA	deethylatrazine
EPA	U.S. Environmental Protection Agency
ETN	Enhanced Trends Network
HHB	human health benchmark
HHBP	human health benchmarks for pesticides
LRL	laboratory reporting level
MCL	maximum contaminant level
NWQL	U.S. Geological Survey National Water Quality Laboratory
NWQN-GW	U.S. Geological Survey National Water Quality Network for Groundwater
QAQC	quality assurance and quality control
USGS	U.S. Geological Survey

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Abstract

Groundwater-quality trend assessments identify aquifers that are responding to changes in pesticide use and the compounds that may pose a threat to water availability. The U.S. Geological Survey has been monitoring pesticide concentrations in groundwater for 25 principal aquifers across the conterminous United States since 1993. The groundwater well locations represent a range of soils, climate, and landforms. The wells are used to monitor groundwater underlying selected agricultural and urban settings and groundwater used for domestic supply. This study examined changes in relative concentrations, defined here as the percentage of wells with pesticide concentrations exceeding a human health benchmark (HHB). HHBs used in this report are legally enforceable drinking-water standards and nonenforceable drinking water levels. Relative pesticide concentration increases may lead to decreased water availability, as restrictions may be put in place for groundwater used as a drinking-water source.

This study focused on concentration changes in 22 pesticides that were included in laboratory analysis from 1993 to 2023. The analysis and interpretation of these pesticide concentrations in groundwater have been separated into approximate decadal intervals (decade 1 (1993–2001), decade 2 (2002–12), and decade 3 (2013–22). For one pesticide, 1,2-dibromo-3-chloropropane (DBCP), concentration data were also collected in decade 4 (2023–onward).

Atrazine, deethylatrazine, alachlor, prometon, and simazine were 5 pesticides detected at moderate concentrations (greater than 10 percent of the HHB but less than or equal to the HHB). The percentage of wells that had groundwater pesticide concentrations in the moderate concentration category decreased from 7 percent in decade 1 to 2 percent in decade 3. The agricultural networks had the highest percentages of wells with moderate concentrations, and these percentages decreased from 13 percent in decade 1 to 4 percent in decade 3. Moderate concentrations in the urban networks decreased between decades 1 and 2 from 4 percent to 0 percent. No moderate concentrations occurred in the urban networks in decade 3. The percentage of wells with moderate concentrations in the domestic supply networks (1 percent) was the lowest of all the network types and did not change across the three decades. Moderate atrazine or deethylatrazine concentrations occurred across all three decades in aggregated ecoregions representing similar soils, climate, and landforms in the Semiarid West, Midcontinent, and Northeastern United States. Moderate concentrations of prometon, alachlor, and simazine also occurred in the Midcontinent, Arid West, Northeast, South Atlantic Gulf, and Semiarid West regions, but the moderate concentrations did not persist across all three decades.

DBCP was the only pesticide that exceeded its respective HHB, and the exceedances occurred across all four decades. In this report, the DBCP analysis was limited to one well network in the Central Valley, California. Agricultural use of DBCP was suspended in 1977. Forty-five years after being banned, DBCP concentrations were greater than the maximum contaminant level of 2 micrograms per liter (µg/L), but the number of exceedances decreased from 50 percent to 15 percent of the samples between 1993 and 2023.

This assessment of decadal groundwater pesticide concentrations provides a characterization of changes in water availability because of pesticide contamination in areas where groundwater is used as a drinking-water source. The results highlight the importance of continued long-term monitoring and assessment of groundwater pesticides to identify locations and specific compounds that may pose a potential risk to human health.

Introduction

The widespread use of pesticides in both agricultural and urban environments to protect crops, lawns, gardens, ornamental plants, and turf from diseases, weeds, and insect damage (Hoffman and others, 2000; Coupe and Capel, 2016) has led to the contamination of groundwater resources (Gilliom, 2007; DeSimone and others, 2014; Remigio and others, 2024). The time lag between use on the land surface and detection in groundwater can span years or decades, and the potential for increasing pesticide concentrations is of particular concern in areas where groundwater is heavily used as a drinking-water source. In the United States, groundwater from domestic supply wells is used as a drinking-water source for 13 percent of the U.S. population (Dieter and others, 2018; Johnson and others, 2019). Domestic-supply wells are not regulated by state or federal law, and homeowners are responsible for the maintenance and any monitoring of these drinking-water sources (Leistra and Boesten, 1989; DeSimone, 2009; Tesoriero and others, 2024). Pesticides in groundwater can become problematic from a human health perspective if concentrations are elevated relative to human health benchmarks (HHBs) and the groundwater source is used as a drinking-water source (Gilliom and others, 2006; McKnight and others, 2015; Hakoun and others, 2017; McGinley and others, 2023). Multidecadal analysis of trends in groundwater concentrations can demonstrate the time scales over which groundwater systems respond to changes in pesticide use and identify compounds that may pose a threat to water quality before large-scale problems occur.

Three decades ago, the U.S. Geological Survey (USGS) established a water quality monitoring network through the National Water-Quality Assessment (NAWQA) Program that is currently known as the National Water Quality Network (NWQN) (Gilliom and others, 2006; Rowe and others, 2013). The groundwater (GW) portion of the network was designed to provide an overview of water quality underlying areas of agricultural and urban land use and domestic drinking-water supply wells. The USGS monitors pesticide concentrations in 59 well networks that are distributed throughout eight aggregated ecoregions (Pacific Northwest, Pacific Coast, Arid West, Semiarid West, Mountain West, Midcontinent, South Atlantic Gulf, and Northeast). These aggregated ecoregions represent a range of soils, climate, and landforms in the conterminous United States. The NWQN-GW is the largest spatially distributed groundwater-quality monitoring network in the world (Lindsey and others, 2023). The land use networks (agricultural and urban) capture the quality of groundwater for the two different land use types, whereas the domestic supply wells capture the quality of groundwater used as a drinking-water source.

Groundwater pesticide concentration data from these monitoring locations supported a prior multidecadal pesticide assessment. The analysis of 80 pesticide concentrations in groundwater was separated into approximate decadal intervals (decade 1 [1993–2001], decade 2 [2002–12]). The prior study included an analysis of about 80 parent and degradate compounds; transformation of parent compounds by chemical, photochemical, or biological reactions in the environment produces degradate pesticide compounds in the environment. Groundwater pesticides were compared to HHBs to assess the potential risk to human health in locations where groundwater is used as a drinking-water source. HHBs used in this report are legally enforceable drinking-water standards and nonenforceable drinking water levels (U.S. Environmental Protection Agency, 2018, 2021; U.S. Geological Survey, 2024). More information about the HHBs is provided in the Methods Section, "Human health benchmarks for potential toxicity."

Ten years have passed since the previous national-scale analysis of changes in groundwater pesticide concentrations was completed. Given the potential risk of pesticides to reducing water availability, particularly in regions where groundwater is a drinking-water source, another analysis is warranted. The availability of additional data, from 2013 through 2024, provides an opportunity to do an updated assessment for the conterminous United States.

Purpose and Scope

Through the 2009 SECURE Water Act, the U.S. Congress tasked the USGS to perform regular, comprehensive water availability assessments (Alley and others, 2013; Evenson and others, 2018). The USGS completed an assessment of water supply, quality, and use for the period 2010–20 (Stets, 2025). The results from this assessment can be used to inform water resource managers about the availability of the Nation's freshwater, with respect to both quantity and quality, for human and environmental needs. Groundwater quality is a key water resources domain that can affect water availability trends (Stackpoole and others, 2023), and the purpose of this multi-decadal groundwater pesticide trends study is to assess changes in concentrations within the NWQN-GW. An analysis of groundwater pesticide concentrations over time can be used to identify which groundwater systems are responding to changes in pesticide use and transport. The results of 2 separate pesticide components in this report can also be used to determine which compounds may pose a threat to human health where groundwater is used as a drinking-water source.

The first component of this study assessed pesticide concentrations by network type and aggregated ecoregion and is referred to as the "National Groundwater Network Decadal Pesticide Analysis" in this document. Relative pesticide concentrations for pesticide compounds were estimated from 59 groundwater-quality monitoring networks distributed in the 25 principal aquifers of the conterminous United States. Relative concentrations are defined here as the percentage of wells with pesticide concentrations exceeding a HHB. The total number of pesticides included in this study is less than the previous national assessment (*n*=80) (Toccalino and others, 2014), because only 21 compounds were included in laboratory analysis from 1993 to 2023 and also had HHBs to evaluate potential risk to human health. Changes in the relative concentrations of groundwater pesticides were examined by network type (agricultural, urban, and domestic supply). In addition to the network type analysis, relative concentrations were examined across eight aggregated ecoregions (Pacific Northwest, Pacific Coast, Arid West, Semiarid West, Mountain West, Midcontinent, South Atlantic Gulf, and Northeast) with similar soils, climate, and landforms.

The second component of the study is referred to as the "DBCP in the Central Valley, Calif. change analysis" and focused on concentration changes for an additional pesticide, DBCP, in one well network in the Central Valley, California. The scope is limited to that network because prior USGS groundwater quality studies that focused on DBCP in the Central Valley found DBCP concentrations in groundwater above its HHB (Burow and others, 1998; Burow and others, 2007). This study serves as an update on DBCP trends for that location.

Methods

This study examined the proportion of pesticide concentrations relative to HHBs from 1993 to 2023. In this section, we describe the monitoring network for data collection, laboratory pesticide analysis, HHBs, and the analytical methods used for the "National Groundwater Network Decadal Pesticide Analysis" and the "DBCP in the Central Valley, Calif. change analysis."

Groundwater Pesticide Sampling—National Groundwater Network

The national groundwater network decadal pesticide analysis focused on samples collected from the USGS NWQN-GW. The current study presents pesticide data from 59 well networks (Lindsey and Kingsbury, 2024). The groundwater quality monitoring networks are defined as groups of wells with similar characteristics, and each network was originally designed with 20 to 30 wells using spatially distributed randomized sampling (Scott, 1990; fig. 1). Samples were collected from each network about every 10 years between 1993 and 2022. The alphanumeric network identifier is an abbreviation indicating the drainage basin name and the network type, such as ccptlusag2b for the Central Columbia Plateau (ccpt) land use study network (lus) focused on agricultural land use (ag) (table 1). The first decade of groundwater pesticide sampling was 1993–2001, the second was 2002–12, the third was 2013–22, and the fourth decade of sampling started in 2023. Herein, the term "decadal sampling" refers to the frequency of water quality sampling in this network. The "National Groundwater Network Decadal Pesticide Analysis" examines data from decades 1, 2, and 3, but the "DBCP in the Central Valley, Calif. change analysis" examines data from decades 1–4.

During each year in decades 1 and 2, pesticide samples were collected from 20 to 30 wells in 8 to 10 networks, resulting in all networks being sampled within a 10 year period. Because groundwater pesticide concentrations in exceedance of HHBs were not detected in the first two decades of monitoring and analysis (Toccalino and others, 2014), the number of monitored wells where groundwater pesticide samples were collected was reduced. In the third decade, the rotating schedule of network sampling was maintained, but the collection of pesticide samples was reduced to 8 wells within each network. Pesticide samples from groundwater were collected from these locations following protocols established by the USGS; raw samples were collected (before any treatment for domestic well water), and they were passed through 0.7-micrometer filters (Lapham and others, 1995; Koterba, 1998).

The objective of this monitoring framework was to evaluate the quality of groundwater underlying selected agricultural (number of well networks [*n*]=24) and urban (*n*=15) settings or groundwater used for domestic supply (*n*=20) within 25 principal aquifers of the United States (Gilliom and others, 1995). Wells in the agricultural and urban land use networks are typically shallower (average well depth, 6 meters [m] below surface) than wells in the domestic supply networks (average well depth, 43 m below surface), but well depths can vary by aquifers (Lindsey and Rupert, 2012) (table 1). For the purposes of discussion, wells in agricultural networks are referred to as "agricultural wells." Comparable language is used for wells in urban networks. Previous studies have referred to the well networks representing the depth zone used for domestic supply as major aquifer studies (Lindsey and others, 2023). Those networks are referred to herein as "the domestic supply network type."

The well networks are distributed across seven of the eight aggregated ecoregions (Pacific Northwest, Pacific Coast, Arid West, Semiarid West, Midcontinent, South Atlantic Gulf, and Northeast), which are regions of the conterminous United States with similar soils, climate, and landforms. There were no wells with pesticide monitoring in the Mountain West. These aggregated ecoregions have been used in prior groundwater-quality trend reports (Lindsey and others, 2023). The aggregated ecoregions combine multiple factors that affect groundwater quality such as soils, climate, and landforms into large, relatively homogenous units (Commission for Environmental Cooperation, 1997), with the latest ecoregions reflecting a regrouping of the EPA Level 3 ecoregions (Commission for Environmental Cooperation, 2021; Lindsey and others, 2023). The boundaries of the 59 well networks shown in figure 1 fall within the aggregated ecoregions. The boundaries of the aggregated ecoregions cross the boundaries of the principal aquifers shown in figure 1.

Groundwater Pesticide Sampling—1,2-Dibromo-3-Chloropropane (DBCP) in the Central Valley, California

The 1,2-dibromo-3-chloropropane (DBCP) in the Central Valley, Calif. change analysis relied on two sets of sampling data. Decadal samples of DBCP were collected from one well network in the San Joaquin-Tulare River Basin; refer to the sanjlusor1a network in figure 1 and table 1. The decadal concentration samples were collected from 36 wells in 1993, 2001, 2013, and 2023. The USGS also evaluated changes in DBCP concentrations at shorter time scales through a type of NWQN-GW well network known as an Enhanced Trends Network (ETN; Mathany and others, 2019). The ETN in the Central Valley aquifer of California collected bimonthly DBCP samples from a 98-m deep supply well and a 71-m deep monitoring well from 2014 to 2019 (Saraceno and others, 2018). Unfiltered DBCP samples were collected before any treatment for domestic well water (Lapham and others, 1995; Koterba, 1998).

Laboratory Pesticide Analysis

Water quality samples were analyzed for pesticide concentrations at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Water quality samples for the national groundwater network decadal pesticide analysis were analyzed using two different laboratory methods. Samples collected in decades 1 and 2 were analyzed using gas chromatography/mass spectrometry (Zaugg and others, 1995) or high-performance liquid chromatography (Werner and others, 1996; Furlong and others, 2001), also known as NWQL Laboratory Schedule 2033. Decade 3 samples were analyzed at the NWQL using a broad-spectrum liquid chromatography-tandem mass spectrometry method (Sandstrom and others, 2015), also known as NWQL Laboratory Schedule 2437. The change in laboratory analytical methods between decades 2 and 3 has the potential to introduce bias into the analysis of datasets that span all three decades. For this report, the relative comparability of the older and newer concentration data was confirmed based on the findings of a prior USGS report from Martin and others (2017), which compared the data from the 2033 method to the 2437 method. Martin and others (2017) focused on data collected from surface waters and incorporated adjustments for changes in laboratory recovery as assessed through laboratory spikes for 21 pesticide compounds included in this report. Martin and others (2017) found that the relation between the atrazine concentrations based on the older and newer NWQL methods was weak at concentrations below 0.01 micrograms per liter (μg/L). For concentrations greater than 0.1 μg/L, the relation between concentrations from both methods was close to a 1:1 line (fig. 2). The results of the two different analytical methods are comparable at concentrations relevant to

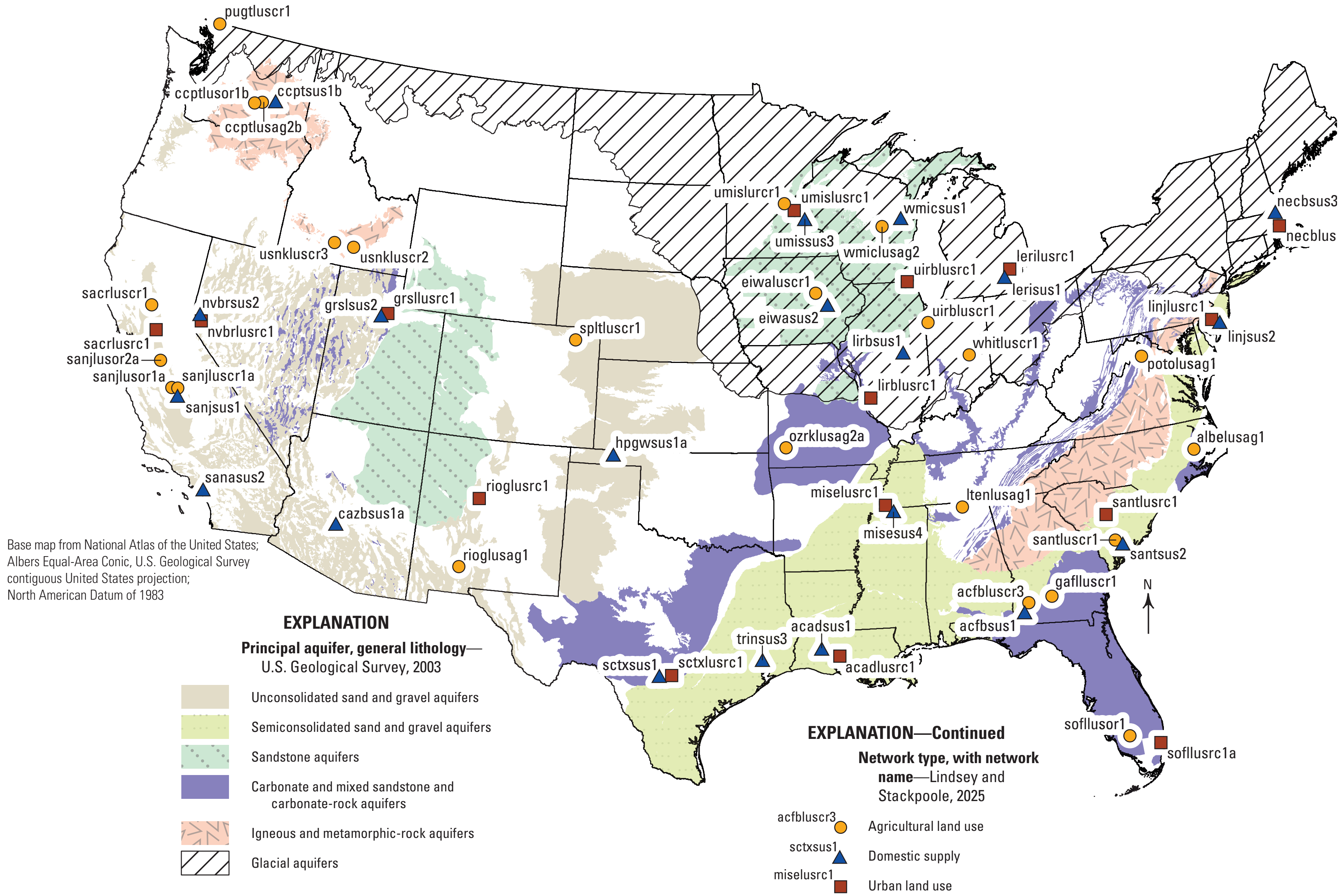

Figure 1. Map showing the U.S. Geological Survey National Water Quality Network for Groundwater and the associated principal aquifers and dominant lithology. Symbols are on the centroid of each network type.

Table 1. Overview of pesticide sampling across 59 well networks in the United States, including network identifiers, drainage basin-based study units, principal aquifer systems, network types, years sampled across three decades, the number of wells sampled, median well depth (meters), and aggregated ecoregion.

[ID, identifier]

Network ID	Drainage basin-based study unit	Principal aquifer system or aquifer	Network type	Year sampled, decade 1 (1993–2001)	Year sampled, decade 2 (2002–12)	Year sampled, decade 3 (2013–22)	Number of wells sampled across all three decades	Network median well depth (meters)	Aggregated ecoregion
acadlusrc1	Acadian-Pontchartrain Drainages	Coastal lowlands	Urban land use	2002	2011	2021	7	18	South Atlantic Gulf
acadsus1	Acadian-Pontchartrain Drainages	Coastal lowlands	Domestic supply	2000	2008	2020	4	44	South Atlantic Gulf
acfbluscr3	Apalachicola-Chattahoochee-Flint River Basin	Floridan and Surficial	Agricultural land use	1993	2002	2013	7	14	South Atlantic Gulf
acfbsus1	Apalachicola-Chattahoochee-Flint River Basin	Floridan	Domestic supply	1995	2002	2015	4	42	South Atlantic Gulf
albelusag1	Albemarle-Pamlico Drainage Basin	Northern Atlantic Coastal Plain	Agricultural land use	1994	2002	2014	1	6	South Atlantic Gulf
cazbsus1a	Central Arizona Basins	Basin and Range	Domestic supply	1997	2008	2018	4	148	Arid West
ccptlusag2b	Central Columbia Plateau	Columbia Plateau basin-fill and basaltic-rock	Agricultural land use	1994	2002	2014	6	13	Pacific Northwest
ccptlusor1b	Central Columbia Plateau	Columbia Plateau basin-fill and basaltic-rock	Agricultural land use	1995	2002	2015	6	9	Pacific Northwest
ccptsus1b	Central Columbia Plateau	Columbia Plateau basin-fill and basaltic-rock	Domestic supply	1994	2002	2014	7	68	Pacific Northwest
eiwaluscr1	Eastern Iowa Basins	Glacial	Agricultural land use	1997	2007	2017	8	5	Midcontinent
eiwasus2	Eastern Iowa Basins	Glacial	Domestic supply	1998	2007	2017	7	17	Midcontinent
gaflluscr1	Georgia-Florida Coastal Plain	Surficial	Agricultural land use	1994	2002	2015	5	9	South Atlantic Gulf
grsllusrc1	Great Salt Lake Basins	Basin and Range	Urban land use	1999	2012	2020	10	21	Arid West
grslsus2	Great Salt Lake Basins	Basin and Range	Domestic supply	2000	2008	2021	4	147	Arid West
hpgwsus1a	High Plains Regional Ground Water Study	High Plains	Domestic supply	1999	2010	2021	8	89	Semiarid West
lerilusrc1	Lake Erie-Lake Saint Clair Drainages	Glacial	Urban land use	1996	2006	2016	7	8	Midcontinent
lerisus1	Lake Erie-Lake Saint Clair Drainages	Glacial	Domestic supply	1998	2007	2016	8	27	Midcontinent
linjlusrc1	Long Island-New Jersey Coastal Drainages	Northern Atlantic Coastal Plain	Urban land use	1996	2005	2017	9	9	Northeast
linjsus2	Long Island-New Jersey Coastal Drainages	North Atlantic Coastal Plain	Domestic supply	1998	2006	2018	8	30	Northeast
lirbsus1	Lower Illinois River Basin	Glacial	Domestic supply	1996	2007	2018	8	77	Midcontinent
ltenlusag1	Lower Tennessee River Basin	Mississippian	Agricultural land use	2000	2012	2022	7	11	Midcontinent
miselusrc1	Mississippi Embayment	Miss. Embayment-TX Coastal Uplands	Urban land use	1997	2006	2017	7	20	South Atlantic Gulf
misesus4	Mississippi Embayment	Miss. Embayment-TX Coastal Uplands	Domestic supply		2007	2019	1	88	South Atlantic Gulf
necblusrc1	New England Coastal Basins	Glacial	Urban land use	1999	2010	2019	8	8	Northeast
necbsus3	New England Coastal Basins	Glacial	Domestic supply	2001	2011	2019	8	18	Northeast
nvbrlusrc1	Nevada Basin and Range	Basin and Range	Urban land use		2002	2013	4	12	Arid West
nvbrsus2	Nevada Basin and Range	Basin and Range	Domestic supply	1995	2003	2016	3	110	Arid West
ozrklusag2a	Ozark Plateaus	Ozark Plateaus	Agricultural land use	1995	2007	2017	6	55	Midcontinent
potolusag1	Potomac River Basin	Valley and Ridge	Agricultural land use	1993	2002	2014	19	47	Northeast
pugtluscr1	Puget Sound Basin	Glacial	Agricultural land use	1997	2006	2018	5	9	Pacific Northwest
rioglusag1	Rio Grande Valley	Rio Grande	Agricultural land use	1994	2006	2016	3	6	Arid West

Table 1. Overview of pesticide sampling across 59 well networks in the United States, including network identifiers, drainage basin-based study units, principal aquifer systems, network types, years sampled across three decades, the number of wells sampled, median well depth (meters), and aggregated ecoregion.—Continued

[ID, identifier]

Network ID	Drainage basin-based study unit	Principal aquifer system or aquifer	Network type	Year sampled, decade 1 (1993–2001)	Year sampled, decade 2 (2002–12)	Year sampled, decade 3 (2013–22)	Number of wells sampled across all three decades	Network median well depth (meters)	Aggregated ecoregion
rioglusrc1	Rio Grande Valley	Rio Grande	Urban land use	1993	2006	2016	2	7	Arid West
sacrluscr1	Sacramento River Basin	Central Valley	Agricultural land use	1997	2006	2017	7	11	Pacific
sacrlusrc1	Sacramento River Basin	Central Valley	Urban land use	1998	2005	2017	5	24	Pacific
sanasus1	Santa Ana Basin	California Coastal Basin	Domestic supply	2000	2011	2022	5	180	Pacific
sanasus2	Santa Ana Basin	California Coastal Basin	Domestic supply	1999	2009	2020	5	282	Pacific
sanjluscr1a	San Joaquin-Tulare Basins	Central Valley	Agricultural land use	1995	2002	2015	7	45	Pacific
sanjlusor1a	San Joaquin-Tulare Basins	Central Valley	Agricultural land use	1993	2001	2013	13	50	Pacific
sanjlusor2a	San Joaquin-Tulare Basins	Central Valley	Agricultural land use	1994	2001	2014	6	47	Pacific
sanjsus1	San Joaquin-Tulare Basins	Central Valley	Domestic supply	1995	2002	2015	8	47	Pacific
santluscr1	Santee River Basin and Coastal Drainages	Surficial	Agricultural land use	1997	2007	2018	5	5	South Atlantic Gulf
santlusrc1	Southeastern Coastal Plain aquifer system	Surficial	Urban land use	1996	2006	2016	6	6	South Atlantic Gulf
santsus2	Santee River Basin and Coastal Drainages	Floridan	Domestic supply	1998	2006	2018	7	55	South Atlantic Gulf
sctxlusrc1	South-Central Texas	Edwards-Trinity	Urban land use	1998	2006	2017	20	80	Semiarid West
sctxsus1	South-Central Texas	Edwards-Trinity	Urban land Use	1998	2006	2017	8	109	Semiarid West
sofllusor1	Southern Florida	Surficial	Agricultural land use	1998	2009	2019	3	4	South Atlantic Gulf
sofllusrc1a	Southern Florida	Biscayne	Urban land use	1996	2010	2021	1	5	South Atlantic Gulf
spltluscr1	South Platte River Basin	Alluvial	Agricultural land use	1994	2002	2013	26	7	Semiarid West
trinsus3	Trinity River Basin	Coastal lowlands	Domestic supply	1994	2002	2014	3	55	South Atlantic Gulf
uirbluscr1	Upper Illinois River Basin	Glacial	Agricultural land use	1999	2012	2021	7	5	Midcontinent
uirblusrc1	Upper Illinois River Basin	Glacial	Urban land use	2000	2010	2021	5	9	Midcontinent
umisluscr1	Upper Mississippi River Basin	Glacial	Agricultural land use	1998	2006	2018	6	8	Midcontinent
umislusrc1	Upper Mississippi River Basin	Glacial	Urban land use	1996	2006	2016	6	5	Midcontinent
umissus3	Upper Mississippi River Basin	Cambrian-Ordovician	Domestic supply	1996	2007	2018	6	55	Midcontinent
usnkluscr2	Upper Snake River Basin	Snake River Plain	Agricultural land use	1993	2005	2016	5	71	Arid West
usnkluscr3	Upper Snake River Basin	Snake River Plain	Agricultural land use	1994	2005	2017	6	62	Arid West
whitluscr1	White River Basin	Glacial	Agricultural land use	1994	2002	2014	8	8	Midcontinent
wmiclusag2	Western Lake Michigan Drainages	Glacial	Agricultural land use	1994	2002	2014	22	13	Midcontinent
wmicsus1	Western Lake Michigan Drainages	Cambrian-Ordovician	Domestic supply	1995	2002	2015	7	49	Midcontinent

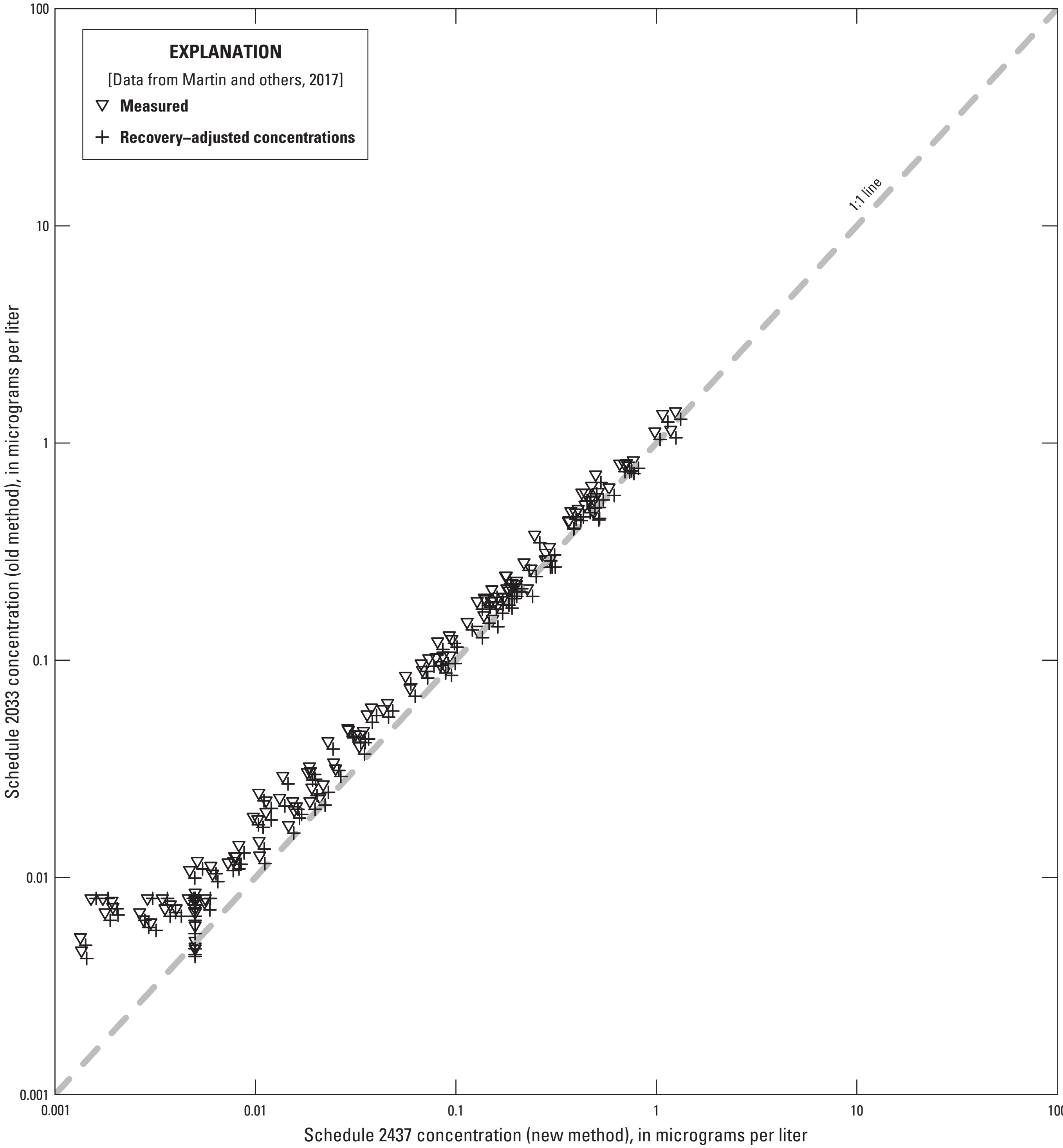

Figure 2. Graph showing the comparison of pesticide concentrations determined by two different analytical methods (2033 older and 2437 newer) during the period of study. This example plot shows that for atrazine, the results of the two different analytical methods are comparable at concentrations relevant to reporting on potential risk to human health, that is, at concentrations greater than 0.3 ug/L, which is the concentration that is 10 percent of the human health benchmark.

reporting on potential risk to human health, that is, at concentrations greater than 10 percent of the human-health benchmark. A relation similar to the one found for atrazine was also observed for the other pesticides that have been commonly detected in groundwater (metolachlor, prometon, and simazine). Therefore, for this report, we treat pesticide data from decades 1 and 2 as comparable to decade 3.

Water quality samples for the DBCP concentration change analysis in the Central Valley, Calif. relied on a different laboratory analysis because DBCP is a volatile organic compound. In decade 1, the USGS DBCP laboratory analysis method had a reporting level of 0.03 µg/L (Fishman, 1993). An enhanced method, to measure concentrations for more compounds, at lower concentrations, was implemented, which resulted in a lower reporting level of 0.02 µg/L (Rose and others, 2016).

Similar to prior USGS pesticide (Toccalino and others, 2014) and DBCP analysis (Rowe and others, 2007) studies, this report analyzed data across multiple laboratory schedules and laboratory reporting levels (LRL). Results that are greater than the LRL are reported, and results that are less the LRL are reported as nondetects (Bonn, 2008). The highest magnitude LRL for all decades was used in our analysis and this value is included in table 2.

Table 2. Characteristics of the 22 pesticides and their corresponding human health benchmarks (HHBs), including magnitude and type, in relation to multidecadal change in the Nation's groundwater.

[Reporting Level is the maximum reporting level present in the dataset for this report. Individual samples with raised reporting limits were removed if they were greater than 5 percent of the respective HHB. Samples with raised reporting limits were retained if the value was less than or equal to 5 percent of the HHB. µg/L, microgram per liter; HHB, human health benchmark; MCL, maximum contaminant level; HHBP-NC, Chronic, human health benchmark for pesticides noncancer chronic; HHBP-NC, Acute, human health benchmark for pesticides noncancer acute; HBSL-C, health based screening levels cancer; HBSL-NC, health based screening levels noncancer]

Compound name	Use group	Parent or degradate	Highest laboratory reporting level (µg/L)	HHB type	HHB (µg/L)	Category of highest concentration (high, moderate, low-moderate, and low) in decades 1, 2, or 3
Deethylatrazine (DEA)	Herbicide	Degradate	0.086	MCL	3	Moderate
Acetochlor	Herbicide	Parent	0.25	HHBP-NC, Chronic	100	Low
Alachlor	Herbicide	Parent	0.05	MCL	2	Moderate
Atrazine	Herbicide	Parent	0.05	MCL	3	Moderate
Azinphos-methyl	Insecticide	Parent	0.16	HHBP-NC, Chronic	8.9	Low
Carbaryl	Insecticide	Parent	0.25	HBSL-C	30 to 3,000[a]	Low
Chlorpyrifos	Insecticide	Parent	0.06	HBSL-NC	5	Low
cis-Permethrin	Insecticide	Parent	0.25	HHPB-NC, Acute[b]	2,900	Low
Diazinon	Insecticide	Parent	0.056	HBSL-NC	2	Low
Fonofos	Insecticide	Parent	0.022	HBSL-NC	10	Low
Malathion	Insecticide	Parent	0.25	HBSL-NC	60	Low
Methyl-parathion[c]	Insecticide	Parent	0.500	HBSL-NC	1[d]	Low
Metolachlor	Herbicide	Parent	0.18	HBSL-NC	2,000	Low
Metribuzin	Herbicide	Parent	0.4	HBSL-NC	8	Low
Pendimethalin	Herbicide	Parent	0.2	HHBP-NC	2,000	Low
Phorate	Insecticide	Parent	0.055	HHBP-NC	1	Low
Prometon	Herbicide	Parent	0.25	HBSL-NC	300	Moderate
Propyzamide	Herbicide	Parent	0.048	HHBP-NC	77	Low
Simazine	Herbicide	Parent	0.144	MCL	4	Moderate
Tebuthiuron	Herbicide	Parent	0.0767	HBSL-NC	800	Low
Terbufos	Insecticide	Parent	0.05	HBSL-NC	0.06[d]	Low
1,2-dibromo-3-chloropropane	Nematicide	Parent	0.03	MCL	0.2	High

[a]Cancer HBSLs are a range. The range represents a one-in-one million (10^{-6}) to one-in-ten thousand (10^{-4}) cancer risk range. The lower value of the range (30 ug/L) was used in this study's analysis.

[b]Reference for this benchmark is U.S. Geological Survey (2024). This value is the acute HHBP for children; the acute population adjusted dose adequately accounts for all chronic toxicity, including carcinogenicity.

[c]The name parathion-methyl is also used for this compound.

[d]Samples with raised reporting limits were retained if the value was less than or equal to 5 percent of the HHB.

Quality-assurance and quality-control (QAQC) samples were collected for all 22 pesticides. These QAQC field blank samples were used to evaluate the potential for sample collection, handling, and analysis to introduce contamination to water quality samples. The QAQC field replicate samples are used to characterize the variability of analytical results caused by random measurement error, and to estimate any positive or negative bias that might result from method performance. QAQC matrix spikes prepared in the field or laboratory samples were used to assess the effects of the sample matrix and (or) analyte degradation between sampling and analysis (Rowe and others, 2007, Toccalino and others, 2014). We did not identify any QAQC issues that would affect the results of our analysis. The accepted holding time for pesticide samples is 14 days (Sandstrom and others, 2015; Rose and others, 2016); we did not delete any data because of holding time issues. The quality of pesticide data collected in the third decade of sampling is summarized in Bexfield and others (2020), and QAQC of DBCP data for the public supply wells is the same as it is for other groundwater wells and is summarized in Bexfield and others (2022a; 2022b). The data analyzed in this study are available at Lindsey and Stackpoole (2025).

Human Health Benchmarks for Potential Toxicity

The national groundwater network and the DBCP in the Central Valley, Calif. change analyses examined pesticide concentrations relative to HHBs, defined here as relative concentrations. HHBs were used to classify groundwater pesticide concentrations into one of four categories. Pesticide concentrations above an HHB were defined as high. Concentrations that exceeded 0.10 of the HHB but were lower than or equal to the HHB were moderate. Concentrations that exceeded 0.05 of the HHB but were lower than or equal to 0.10 of the HHB were defined as low-moderate. Concentrations lower than or equal to 0.05 of the HHB were low (fig. 3*A*). These definitions are modified from the definitions used in prior USGS groundwater quality assessment studies (Belitz and others, 2022), with the addition of the low-moderate category.

The HHBs used for this study were the U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCLs) (U.S. Environmental Protection Agency, 2018). MCLs, established through the Safe Drinking Water Act of 1974 (42 U.S.C. 300(f)), are legally enforceable drinking-water standards for public water supplies. If MCLs were not available, then the EPA human health benchmarks for pesticides (HHBPs) (U.S. Environmental Protection Agency, 2021) or the USGS Health-Based Screening Levels (HBSLs) (U.S. Geological Survey, 2024) were used. HHBPs are nonenforceable drinking water levels that offer information about adverse health effects from drinking water exposure to contaminants that have no drinking water standards or health advisories, and they include noncancer benchmarks for acute (one-day) and chronic (lifetime) drinking water exposures. HBSLs are also nonenforceable guidelines for pesticides for which the EPA has not issued a drinking water health advisory or set an enforceable Federal drinking water standard. The HBSLs are determined only for those compounds that do not already have a MCL or a HHBP. HBSLs are typically determined using the same methodology that the EPA uses for chronic non-cancer HHBPs, with the exception of permethrin, for which the HHBP non cancer acute benchmark was used; the USEPA determined that there is no lower concentration level to protect against chronic or carcinogenic toxicity (U.S. Geological Survey, 2024).

Only pesticides with an HHB were included in the multidecadal pesticide change analysis. Similar to other groundwater pesticide assessments, the assumption of equimolar toxicity described in Bexfield and others (2021) was used for pesticide parent products and their degradates in this analysis. The results represent the number of wells with an exceedance for at least one pesticide; if multiple pesticides exceeded a HHB in a well, only one HHB exceedance was counted for that well. As a result, changes in the potential combined risk of mixtures of pesticides are not addressed in this study.

For most of the compounds analyzed in this study, the magnitude of the HHBs was at least 100 times the magnitude of the highest LRL; therefore, the changing LRLs over time did not affect the application of the method of reporting concentrations relative to HHBs for these compounds. However, for 2 compounds, terbufos and methyl-parathion, the highest LRL was greater than both 10 percent and 5 percent of the HHB. These two pesticides are less likely than the others to be quantified when they are present in groundwater at concentrations near their HHBs, meaning these compounds may be reported as nondetects, when they are actually in the sample (Bexfield and others, 2020). Terbufos and methyl-parathion were only evaluated for potentially exceeding a HHB, not the moderate or low-moderate categories. The highest LRL that we used for DBCP was greater than both 10 percent and 5 percent of the HHB, but not higher than the HHB. We only focused on reporting changes in concentration greater than the HHB for this compound.

National Groundwater Network Decadal Pesticide Analysis

The change in relative concentrations of 21 pesticides sampled across all 59 networks over three decades is presented by category (high, moderate, low-moderate, and low) for each network type and aggregated ecoregion. Toccalino and others (2014) used a different method, the Wilcoxon-Pratt signed-rank test, to determine changes in groundwater pesticide concentrations between decades 1 and 2. The Wilcoxon-Pratt signed-rank test (Pratt, 1959) is a nonparametric test that can be used for analysis of change between matched pairs of wells and two sampling periods. This test was used because 20 to 30 matched-pair trend tests within a well network were available for both decades 1 and 2. This study employed a more conservative, semi-quantitative approach because fewer wells were represented in decade 3, as compared to decades 1 and 2. In the third decade, the rotating schedule of network sampling was maintained, but the collection of pesticide samples was reduced to 8 wells within each network.

DBCP in the Central Valley, California Change Analysis

DBCP concentrations were obtained once per decade from 36 wells over four decades from one network in the Central Valley, Calif. The Wilcoxon-Pratt signed-rank test was used for the analysis

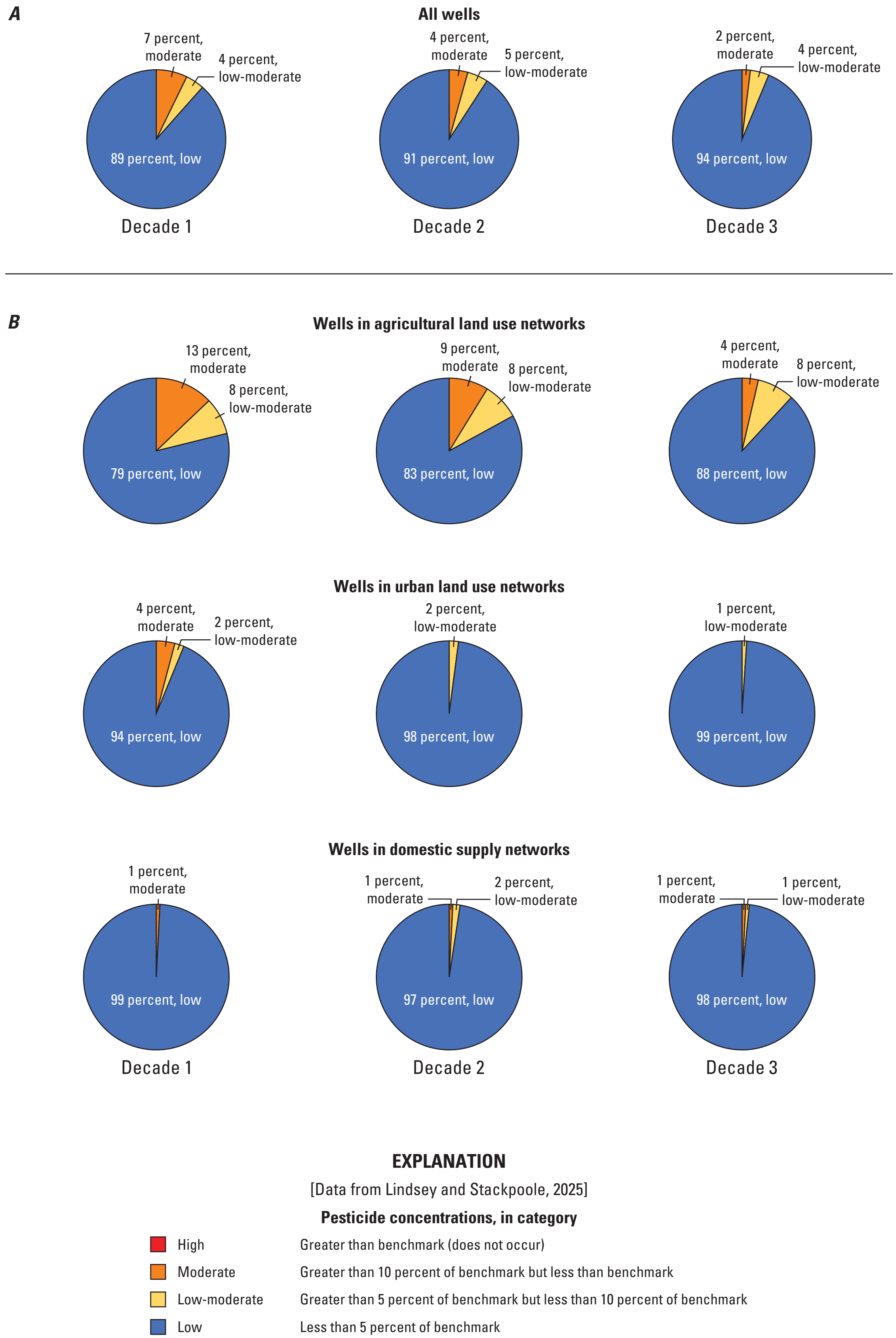

Figure 3. Graph showing the percentage of pesticide detections in each concentration category (high, moderate, low-moderate, and low) for each decade. *A*, all wells and *B*, wells separated out by network type: agricultural land use, urban land use, and domestic supply for the period 1993–2022.

of change between two sampling periods, and the Regional Kendall test was used to evaluate changes in DBCP concentration across all four sampling periods (Frans and Helsel, 2005; Helsel and others, 2006). The Regional Kendall test is an adaptation of the Seasonal Kendall test, where the wells were used instead of season of year as the “season” variable.

Bimonthly concentrations from two monitoring wells from 2014 to 2019 to the MCL (0.2 μg/L) were also collected. A Mann-Kendall trend test was used to evaluate temporal changes in these bimonthly data for the period 2014–19 (Helsel and others, 2020). The Mann-Kendall trend test can be used to test for monotonic trends, either a decrease or an increase in concentrations over time, and it does not assume that the data are normally distributed. The statistical analyses performed for this study were considered significant at a probability value (*p*-value) of less than or equal to 0.1.

Results

National Groundwater Network Decadal Pesticide Analysis

No pesticides were detected at high concentrations, and five pesticides were detected at moderate concentrations (alachlor, atrazine, deethylatrazine [DEA], prometon, and simazine). The percentage of all wells that had pesticide concentrations in the moderate category decreased each decade, from 7 percent in decade 1 to 2 percent in decade 3 (fig. 3*A*). Alachlor and prometon were detected at moderate concentrations in decade 1. Simazine was detected at moderate concentrations in decades 1 and 3. Atrazine or DEA were detected at moderate concentrations in decades 1, 2, and 3.

The agricultural wells were the well type that had the highest percentages of moderate concentrations, and these percentages decreased each decade (fig. 3*B*). Moderate concentrations were generally less frequent in the urban as compared to the agricultural wells. Moderate concentrations in the urban wells decreased between decades 1 and 2 from 4 percent to 0 percent and remained at 0 percent in decade 3. The percentage of domestic wells with moderate concentrations (1 percent) was the lowest of all the network types and did not change across the three decades.

Four pesticides (alachlor, atrazine, DEA, and simazine) were detected at low-moderate concentrations. The percentage of wells with detections in that category showed little change across all three decades (fig. 3*A*). The highest percentages of low-moderate concentrations occurred in the agricultural wells and remained at about 8 percent for each decade (fig. 3*B*). The percentage of wells with low-moderate concentrations also had little change across the decades in the urban and domestic supply wells.

Pesticides were detected at moderate or low-moderate concentrations during at least one decade in 6 of the 8 aggregated ecoregions. The Northeast, Midcontinent, and the Semiarid West aggregated ecoregions had wells with moderate concentrations in all three decades (figs. 4*A* and 4*B*). Atrazine or DEA occurred at moderate concentrations in 6 of the 8 aggregated ecoregions in at least one of the three decades. Moderate concentrations of alachlor, prometon, and simazine were also found in groundwater from some NWQN-GW wells in decades 1 and 3. The Pacific Coast was the only ecoregion where groundwater pesticide monitoring took place in all three decades, and no pesticides were detected in this ecoregion at moderate concentrations. No pesticide monitoring occurred in the Mountain West ecoregion.

DBCP in the Central Valley, California Change Analysis

One network in the Central Valley had DBCP concentrations that exceeded the 0.2 μg/L HHB in the first and second decades of sampling, so continued monitoring of DBCP concentrations in 20–30 wells in this network continued into the third and fourth decades of sampling. The results of the Wilcoxon-Pratt signed rank test indicated statistically significant decreases from the first to second decade (p=0.058) and the second to third decade (p=0.002), but there was no statistically significant change from the third to the fourth decade (p=0.34) (fig. 5). The Regional Kendall test for changes at the network level indicated a statistically significant decrease in DBCP concentrations from 1993 to 2024 (p=0.0006). The percentage of samples exceeding the HHB dropped from 50 percent to 15 percent, most concentrations were less than the MCL in the fourth decade of sampling.

The Mann-Kendall trend test for DBCP concentrations in seasonal samples from the two wells sampled from 2014 to 2019 in the ETN indicated a significant negative trend for each well (monitoring well, tau=−0.6061, and *p*-value=0.0061; supply well, tau=−0.6095, *p*-value=0.0001). In the shallower monitoring well, (71-m deep), DBCP concentrations were greater than the HHB for the entire sampling period. In the deeper supply well, (98-m deep), all measured DBCP concentrations were less than the HHB by 2016 and remained less than the HHB to the most recent sampling in 2019 (fig. 6).

Discussion

National Groundwater Network Decadal Pesticide Analysis

The proportion of pesticide concentrations in the moderate category (greater than 10 percent of the HHB but less than or equal to HHB) decreased over time. Five of the 21 pesticides were found at moderate concentrations: alachalor, atrazine, DEA, simazine, and prometon. These compounds had the highest pesticide concentrations found, and they are the focus of our discussion. In our study, atrazine was detected at moderate concentrations in 6 different ecoregions (Pacific Northwest, Arid West, Semiarid West, Midcontinent, South Atlantic Gulf, and Northeast) in decade 1, but by decade 3, it was only detected in 1, the Midcontinent ecoregion. We hypothesize that one of the processes that may have contributed to the reduction of pesticide concentrations in groundwater include degradation through abiotic or biotic processes in soils or groundwater (Fenner and others, 2013; Aisopou and others, 2015; Kundu and others, 2019). Alternative explanations for the decrease include

Figure 4. *A*, Map showing he conterminous United States with aggregated ecoregions: Pacific, Pacific Northwest, Arid West, Semiarid West, Midcontinent, South Atlantic Gulf, and Northeast. *B*, Graph showing changes in groundwater pesticide concentrations relative to a human health benchmark by aggregated ecoregion and land use for the period 1993–2022. Stacked bar charts are arranged from left to right according to their geographic location by aggregated ecoregions: Pacific, Pacific Northwest, Arid West, Semiarid West, Midcontinent, South Atlantic Gulf, and Northeast. There is no bar plot for the urban network in the Pacific Northwest ecoregion because there is no monitoring network for this land use type in that ecoregion. There are no bar plots for the Mountain West because there was no groundwater pesticide monitoring in that aggregated ecoregion.

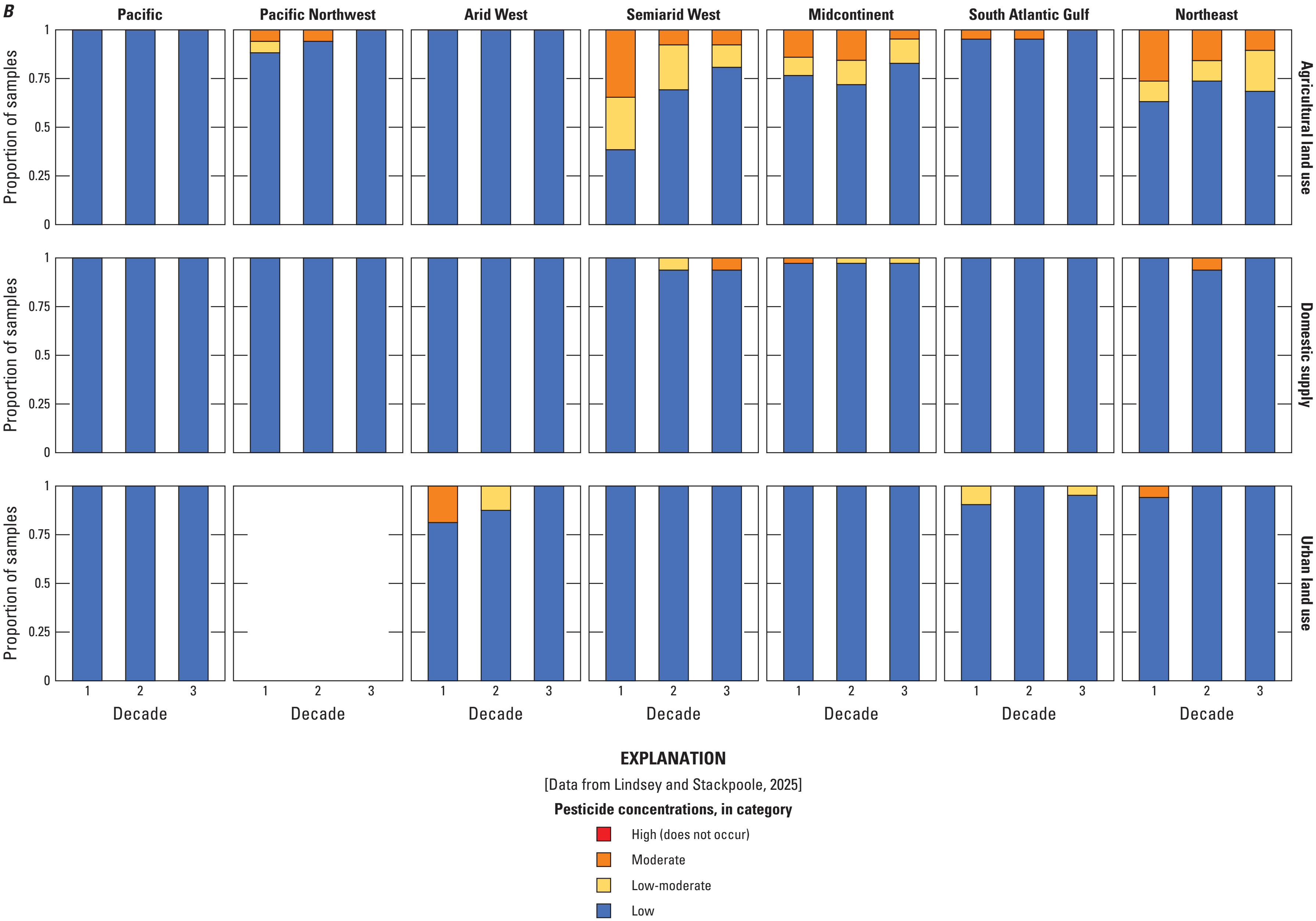

Figure 4.—Continued

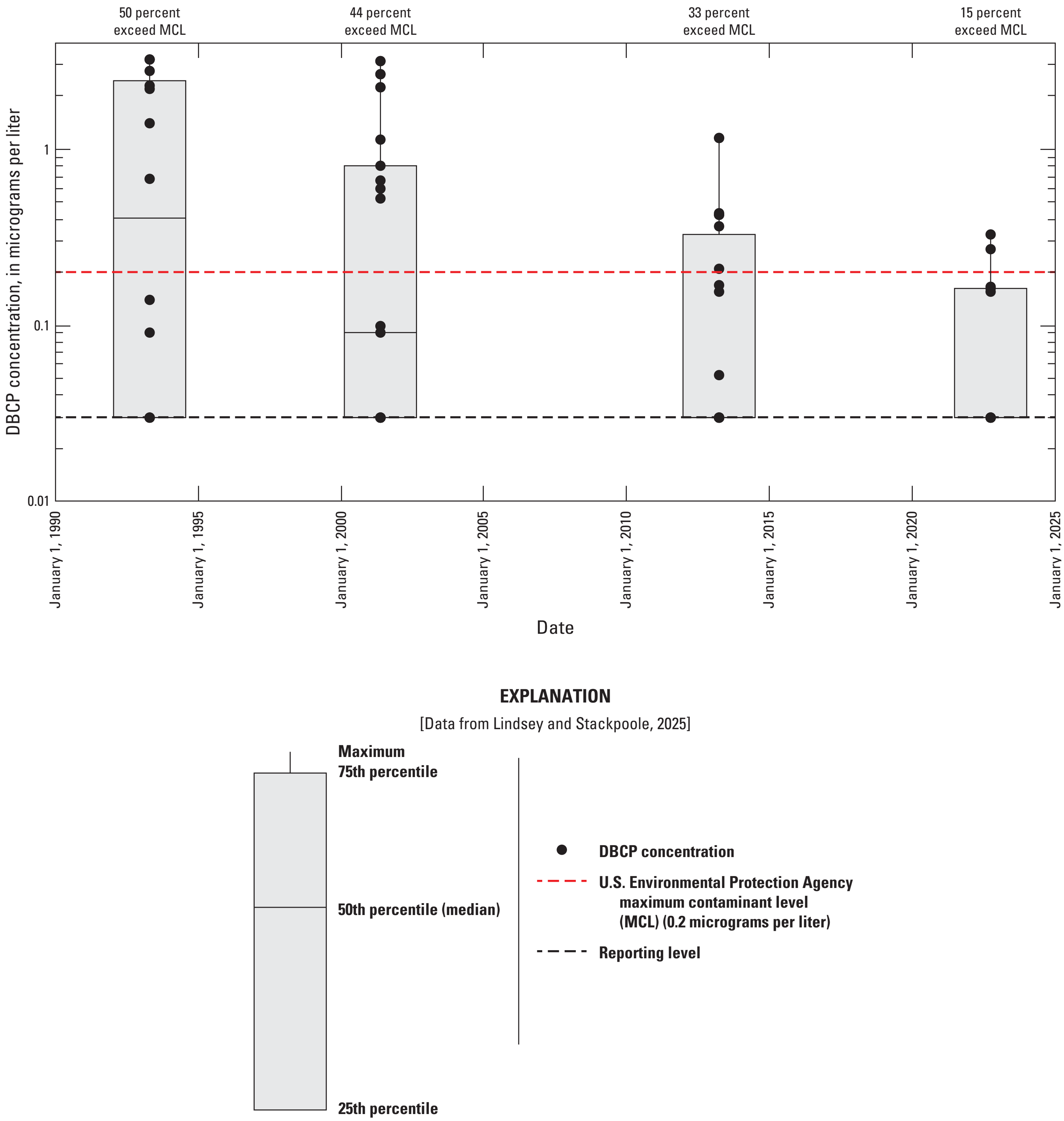

Figure 5. Graph showing 1,2-dibromo-3-chloropropane (DBCP) concentrations in groundwater from wells in the U.S. Geological Survey National Water Quality Network for Groundwater land use network in the Central Valley of California for the period from 1993 to 2024.

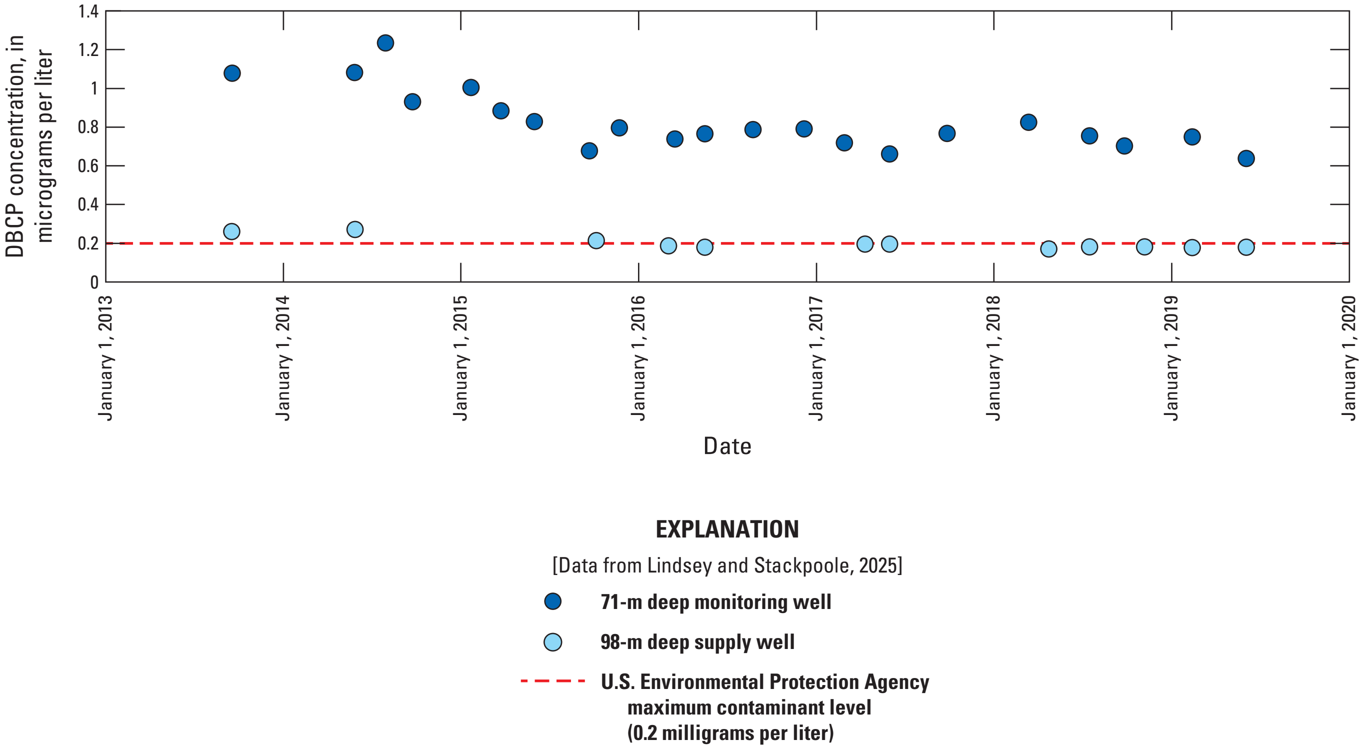

Figure 6. Graph showing 1,2-dibromo-3-chloropropane (DBCP) concentrations in two wells (98-meter [m] deep supply well and a 71-m deep monitoring well) sampled bimonthly for the period 2014 to 2019.

reduction in pesticide use or a change in the transport of pesticides to groundwater over time. Changes in pesticide use and soil management, coupled with changes in precipitation and temperature, can vary over time, affecting pesticide transport to groundwater (Arias-Estévez and others, 2008; Bexfield and others, 2021).

Atrazine and its degradate, DEA, were the pesticides that were most commonly observed at moderate concentrations across all three decades in the Semiarid West, Midcontinent, and Northeast aggregated ecoregions. In the United States, atrazine is still one of the most heavily used agricultural pesticides (Wieben, 2025). For roughly the same period of record encompassed in this report, atrazine and DEA were frequently detected at elevated concentrations in surface water for the period from 1993 to 2017, (Larson and others, 1999; Stone and others, 2014; Nowell and others, 2018; Stackpoole and others, 2021). In the prior NGWN-GW groundwater pesticide trends assessment, these two compounds were frequently detected in groundwater in decades 1 and 2. Atrazine concentrations decreased in agricultural wells, and DEA concentrations increased in the urban and domestic drinking water supply wells (Toccalino and others, 2014).

The specific aquifers where atrazine and DEA detections occurred across all three decades include the South Platte River Basin Alluvial aquifer in the Semiarid West, the Western Lake Michigan Drainages Glacial aquifer in the Midcontinent, and the Potomac River Basin Valley and Ridge aquifer in the Northeast. In these specific geographic locations, if atrazine or DEA were detected at moderate concentrations in decade 1, they were also detected at moderate concentrations in decades 2 and 3. We also found geographic locations where either atrazine or DEA were only found in decade 3; this occurred in the Midcontinent ecoregion, the Glacial Aquifer system in the Eastern Iowa Basin, and in the Semiarid West ecoregion, the Alluvial Aquifer system in the High Plains of Texas. Identification of these new locations with moderate concentrations of atrazine or DEA would not have been possible without continued monitoring of this pesticide and its degradate in the environment across all three decades. However, we are unable to determine the drivers of these decadal patterns in the groundwater pesticide concentration data because we lack information about pesticide use and management and the soil conditions and precipitation, key factors affecting transport and degradation rates of pesticides near these aquifer locations.

Moderate concentrations of alachlor, prometon, and simazine were also found in groundwater from some NWQN-GW wells in decades 1 and 3. In 1990, alachlor was a heavily used herbicide, especially where corn was commonly a dominant agricultural crop. However, because of the introduction of acetochlor for corn and glyphosate-resistant soybeans, the use of alachlor has steadily declined since 1994 (Vecchia and others, 2009). Alachlor is not a pesticide that has frequently been detected in prior USGS national-scale groundwater reports, which were focused on decades 1 and 2 of sampling (Kolpin and others, 1998; Toccalino and others, 2014). Prometon was detected at moderate concentrations in the Semiarid West ecoregion in decade 1. Simazine was detected in moderate concentrations in the Arid West and the Northeast in decades 1 and 3. In prior USGS studies prometon and simazine were commonly detected in groundwater (Kolpin and others, 1998; Toccalino and others, 2014).

There were differences in groundwater pesticide trend patterns across the different well types. The agricultural and urban networks capture the quality of recently recharged groundwater underlying selected agricultural land uses, whereas the domestic drinking-water supply wells are generally deeper than the land use networks and reflect a mixed land use signal. A larger number of moderate concentrations were detected in the agricultural as compared to the urban or domestic use networks, but the percentage of agricultural wells with moderate concentrations decreased. In contrast, the percentage of urban and domestic wells with moderate concentrations was lower than the agricultural wells. Moreover, the percentage of moderate pesticide concentrations in urban wells decreased over the three decades, but the percentage remained the same in the domestic supply wells.

Groundwater from individual wells in the domestic-well networks is generally used by rural residents as a primary drinking-water source (U.S. Environmental Protection Agency, 1977; Degnan and others, 2021; Lindsey and others, 2021). In our study, pesticides were detected at moderate concentrations in domestic supply wells in three aggregated ecoregions: the Arid West, Northeast, and Semiarid West. The domestic-well networks within the NWQN-GW cover areas that supply groundwater to more than 6 million people, or about 13 percent of the total number of people relying on domestic supply in the United States (Dieter and others, 2018; Johnson and others, 2019), and these networks cover at least part of the principal aquifers that together represent 99 percent of the withdrawals for domestic supply (Maupin and Arnold, 2010). Domestic-supply wells are not regulated by federal or state laws, and individuals are responsible for the maintenance and any monitoring of these drinking-water sources (Leistra and Boesten, 1989; DeSimone, 2009; Tesoriero and others, 2024).

The rarity of HHB exceedances and the national-scale decrease in moderate concentrations of pesticides can be viewed as encouraging results from a human-health standpoint. However, continued monitoring and assessment of groundwater pesticides is warranted, as many negative human-health effects have been linked to pesticide exposure (Montiel-León and others, 2019; de Souza and others, 2020; Stradtman and Freeman, 2021; McGinley and others, 2023), and these negative effects can occur when pesticide concentrations are below the human health benchmarks used in this study (Ackerman, 2007; Kim and others, 2017; Remigio and others, 2024). Additionally, multiple geogenic constituents (arsenic, lithium, and strontium), as well as nitrate and salt, are common and widely distributed at concentrations exceeding current regulatory thresholds in aquifers underlying the hydrologic regions across the United States (Lindsey and others, 2023; Erickson and others, 2024). Currently, groundwater contaminants from either geogenic or anthropogenic origin are very likely to coexist in groundwater, and there is a scientific gap in understanding about the combined effects of these groundwater contaminants on human health (Xie and others, 2023; Tesoriero and others, 2024).

DBCP in the Central Valley, California Change Analysis

In this study, DBCP was the only pesticide that was found at high concentrations (above the HHB) in groundwater, and this occurred in one well network in the Central Valley, California. Prior studies have documented that nonpoint, agricultural sources of DBCP were found to contribute to groundwater contamination in the Central Valley, Calif. (Loague and Abrams, 1999). The half-life of DBCP, which has been assessed at 6 years (Burow and others, 1998; Burow and others, 2007), is likely a factor contributing to its persistence in the environment. Our study documented that, even 45 years after being banned, DBCP continued to be present in groundwater from some NWQN-GW wells at concentrations greater than the MCL of 2 μg/L. However, samples collected from the decadal NQWN-GW network of 36 wells between 1993 and 2024 and bimonthly samples collected from two ETN wells from 2014 to 2019 indicated that concentrations of DBCP at the locations and depths represented by these wells are steadily decreasing over time, and most concentrations are now less than the MCL.

The analysis of change in groundwater DBCP concentrations in part of the Central Valley of California provided an opportunity to illustrate a localized example of the effects of a legacy pesticide on the environment. Legacy pesticides are those that have been banned or phased out of use and are detected in either surface or groundwater years to decades after application of active ingredients in the environment has ceased (Rasmussen and others, 2015; McManus and others, 2017). Legacy pesticides in groundwater can become problematic for human health if concentrations are elevated relative to human health benchmarks and the groundwater source is used as a drinking-water source (Gilliom and others, 2006; McKnight and others, 2015; Hakoun and others, 2017; McGinley and others, 2023). Agricultural application of DBCP was banned in the conterminous United States in 1979 (California State Water Resources Control Board, 2002). Forty-five years after being banned, groundwater DBCP concentrations were still greater than the maximum contaminant level of 2 micrograms per liter (μg/L). The long-term monitoring data did show that number of exceedances decreased from 50 percent to 15 percent of the samples between 1993 and 2024, indicating progress toward reducing the human health risks of this pesticide in groundwater.

Summary

Increases in contaminant concentrations over time, and contaminant concentrations that exceed or approach levels of human-health concern, could affect groundwater used as a drinking-water source. We evaluated 21 pesticides in the national groundwater network. The percentage of wells that had groundwater pesticide concentrations in the moderate concentration category decreased from 7 percent in decade 1 to 2 percent in decade 3. Five pesticides (atrazine, deethyatrazine, alachlor, prometon, and simazine) had concentrations within 0.10 and 0.05 of the human health benchmark (HHB). We examined one specific pesticide, 1,2-dibromo-3-chloropropane, in a groundwater network in the Central Valley, California. Across all three decades, 1,2-dibromo-3-chloropropane, exceeded its respective HHB, but exceedances decreased over time. Given that groundwater from domestic or public supply wells is used as a drinking-water source for roughly 13 percent of the U.S. population, and that negative human-health impacts can potentially occur from consuming water with contaminant

concentrations below HHBs, continued monitoring and evaluation of changes in pesticide concentrations in groundwater is important for the continued protection of human health.

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