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Studies Identifying Contaminants of Emerging Concern in Groundwater and Surface Water

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Northwestern Water Planning Alliance
Executive Committee

May 14, 2020

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

OVERVIEW

- Pharmaceuticals
- Perfluoroalkanes
- Microplastics

USGS

The Hydrologic Cycle and Groundwater Vulnerability

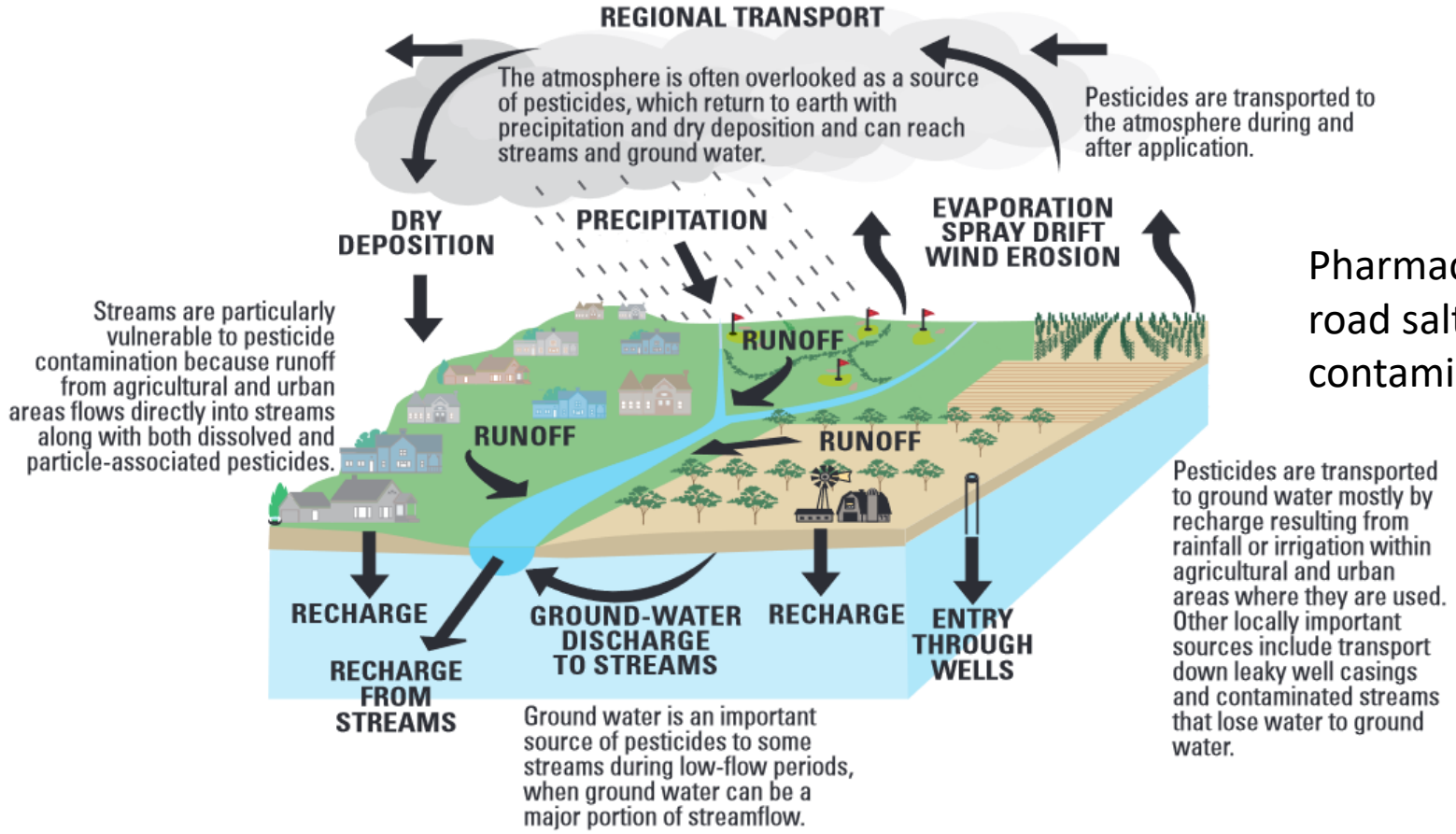

Figure 2–4. Pesticides are transported to streams and ground water primarily by runoff and recharge. Nonpoint sources of pesticides originating from areas where they were applied—rather than point sources such as wastewater discharges—are the most widespread causes of pesticide occurrence in streams and ground water. (Modified from Majewski and Capel, 1995.)

Pharmaceuticals, road salt, land use contaminants

Source: Water Science School, Pesticides in Groundwater, https://www.usgs.gov/special-topic/water-science-school/science/pesticides-groundwater?qt-science_center_objects=0#qt-science_center_objects

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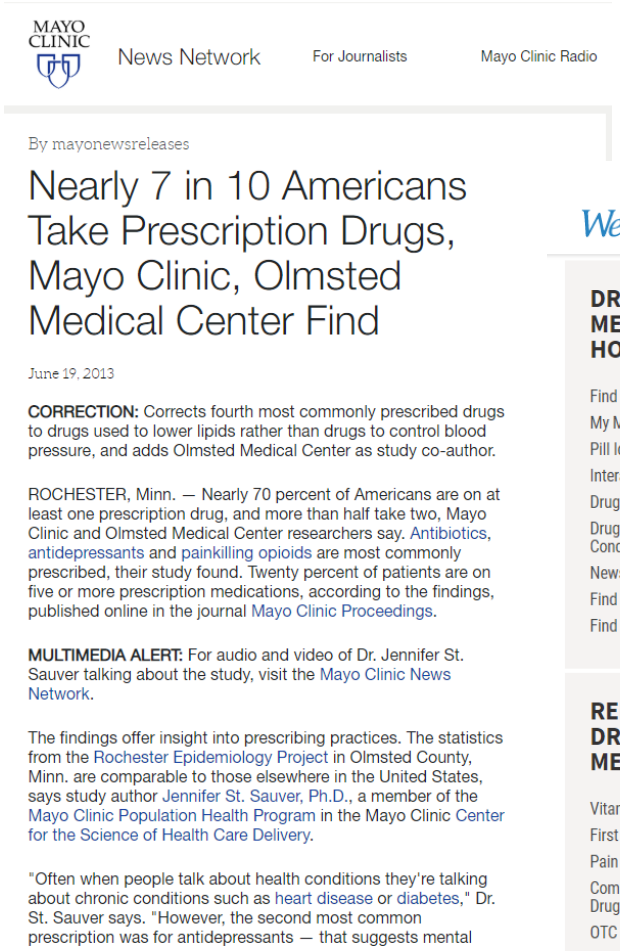
Pharmaceuticals



MAYO CLINIC News Network For Journalists Mayo Clinic Radio

By mayonewsreleases

Nearly 7 in 10 Americans Take Prescription Drugs, Mayo Clinic, Olmsted Medical Center Find

June 19, 2013

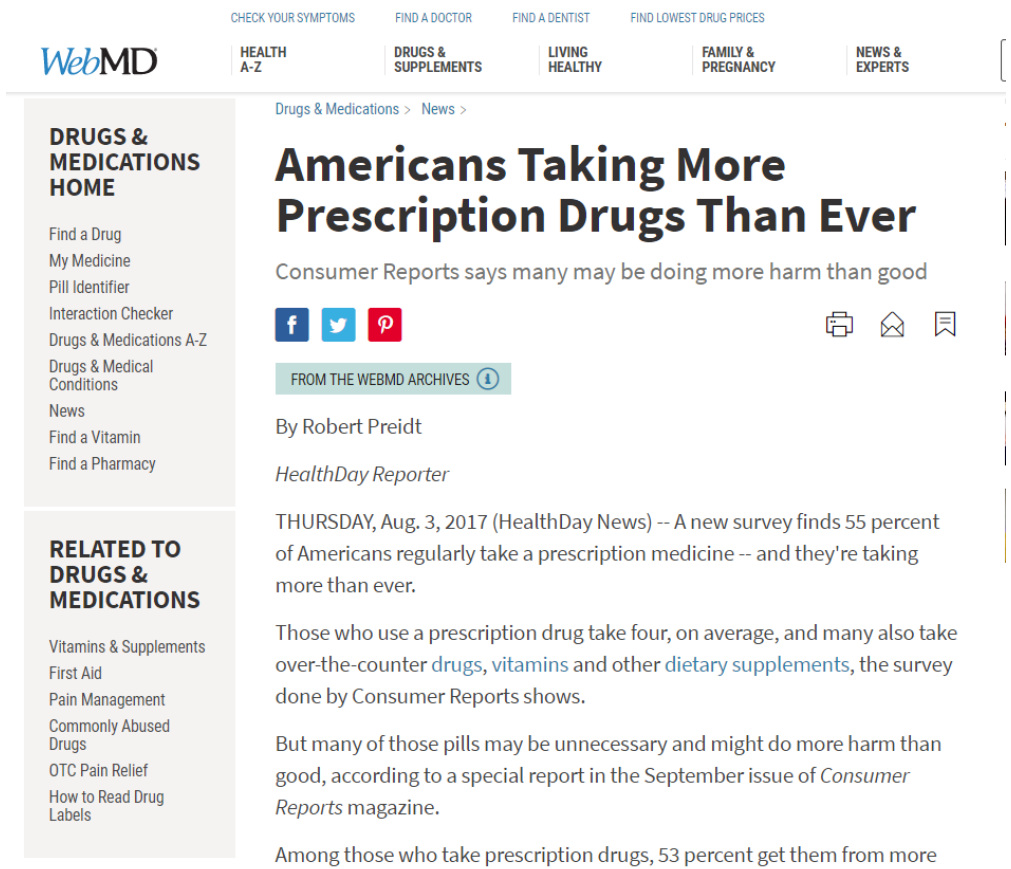
CORRECTION: Corrects fourth most commonly prescribed drugs to drugs used to lower lipids rather than drugs to control blood pressure, and adds Olmsted Medical Center as study co-author.

ROCHESTER, Minn. — Nearly 70 percent of Americans are on at least one prescription drug, and more than half take two, Mayo Clinic and Olmsted Medical Center researchers say. Antibiotics, antidepressants and painkilling opioids are most commonly prescribed, their study found. Twenty percent of patients are on five or more prescription medications, according to the findings, published online in the journal Mayo Clinic Proceedings.

MULTIMEDIA ALERT: For audio and video of Dr. Jennifer St. Sauver talking about the study, visit the Mayo Clinic News Network.

The findings offer insight into prescribing practices. The statistics from the Rochester Epidemiology Project in Olmsted County, Minn. are comparable to those elsewhere in the United States, says study author Jennifer St. Sauver, Ph.D., a member of the Mayo Clinic Population Health Program in the Mayo Clinic Center for the Science of Health Care Delivery.

"Often when people talk about health conditions they're talking about chronic conditions such as heart disease or diabetes," Dr. St. Sauver says. "However, the second most common prescription was for antidepressants — that suggests mental



CHECK YOUR SYMPTOMS FIND A DOCTOR FIND A DENTIST FIND LOWEST DRUG PRICES

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Americans Taking More Prescription Drugs Than Ever

Consumer Reports says many may be doing more harm than good

FROM THE WEBMD ARCHIVES

By Robert Preidt

HealthDay Reporter

THURSDAY, Aug. 3, 2017 (HealthDay News) -- A new survey finds 55 percent of Americans regularly take a prescription medicine -- and they're taking more than ever.

Those who use a prescription drug take four, on average, and many also take over-the-counter drugs, vitamins and other dietary supplements, the survey done by Consumer Reports shows.

But many of those pills may be unnecessary and might do more harm than good, according to a special report in the September issue of *Consumer Reports* magazine.

Among those who take prescription drugs, 53 percent get them from more than one health care provider, which increases the risk of adverse drug effects. More than a third say no provider has reviewed their medicines to see if all are necessary.

1. Vicodin
2. Simvastatin
3. Lisinopril
4. Levothyroxine
5. Azithromycin
6. Metformin
7. Lipitor
8. Amlodipine
9. Amoxicillin
10. Hydrochlorothiazide

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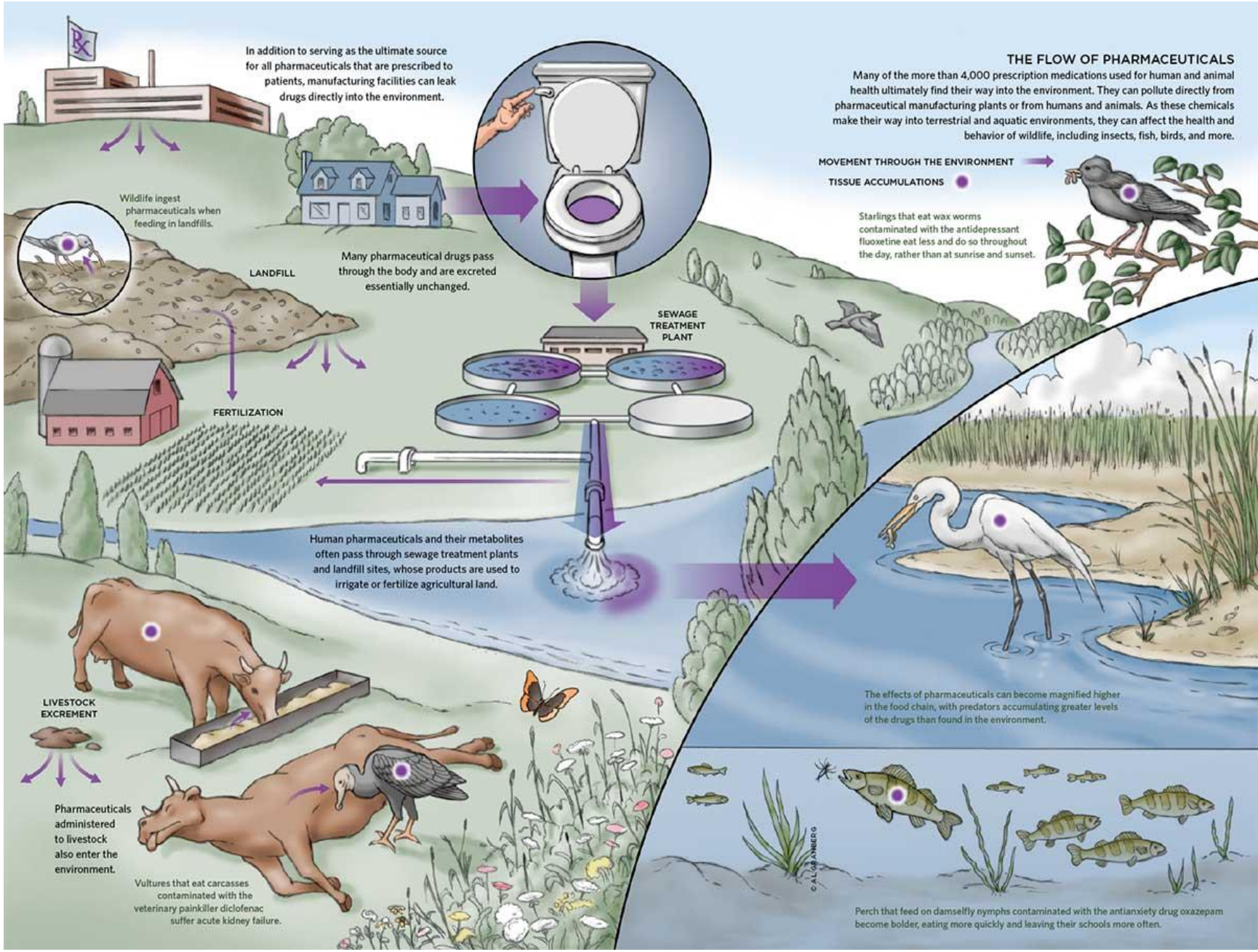
https://www.medicinenet.com/top_drugs_prescribed_in_the_us/views.htm

Cycling of Pharmaceuticals in the Environment



Source: Granberg, https://www.usgs.gov/media/images/pharmaceuticals-move-throughout-aquatic-environment

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Pharmaceuticals Detected in Private Drinking Water Supplies in Shallow Aquifers

- Tested 20 domestic drinking water wells for 117 organic wastewater compounds
- PFASs, pharmaceuticals, and artificial sweetener detected most frequently
- Nitrate, boron, and well depth correlate with PFAS and pharmaceutical detections
- Septic Systems are likely main source, but landfills also

SOURCE: Laurel A. Schaider, Janet M. Ackerman, Ruthann A. Rudel
Septic systems as sources of organic wastewater compounds in domestic drinking water wells in a shallow sand and gravel aquifer
Science of The Total Environment, Volume 547, 2016, pp. 470-481
Source: Laurel A. Schaider, Ruthann A. Rudel, Janet M. Ackerman, Sarah C. Dunagan, Julia Green Brody
Pharmaceuticals, perfluorosurfactants, and other organic wastewater compounds in public drinking water wells in a shallow sand and gravel aquifer
Science of The Total Environment, Volumes 468–469, 2014, pp. 384-393

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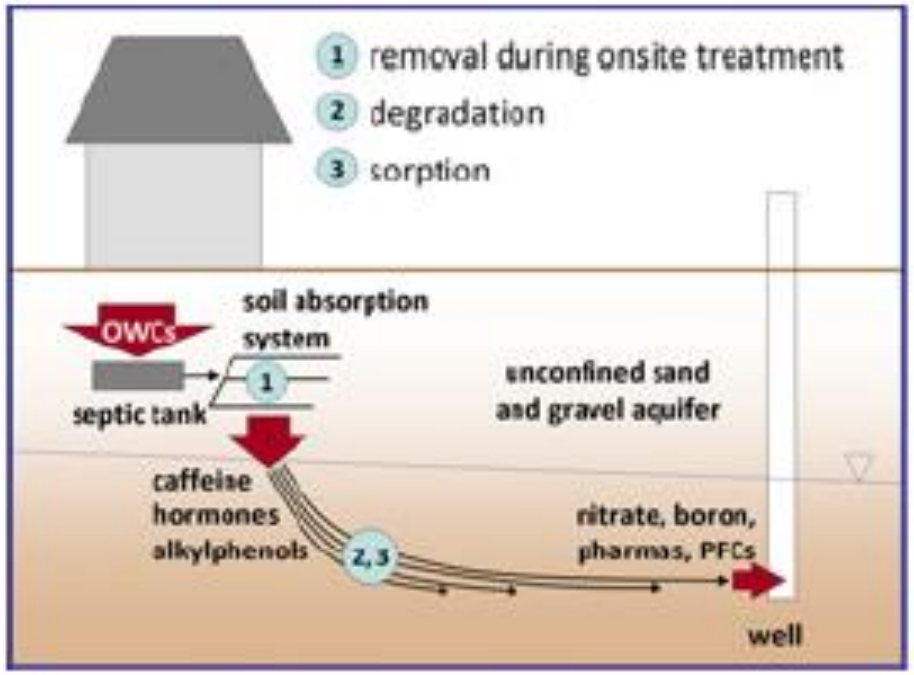
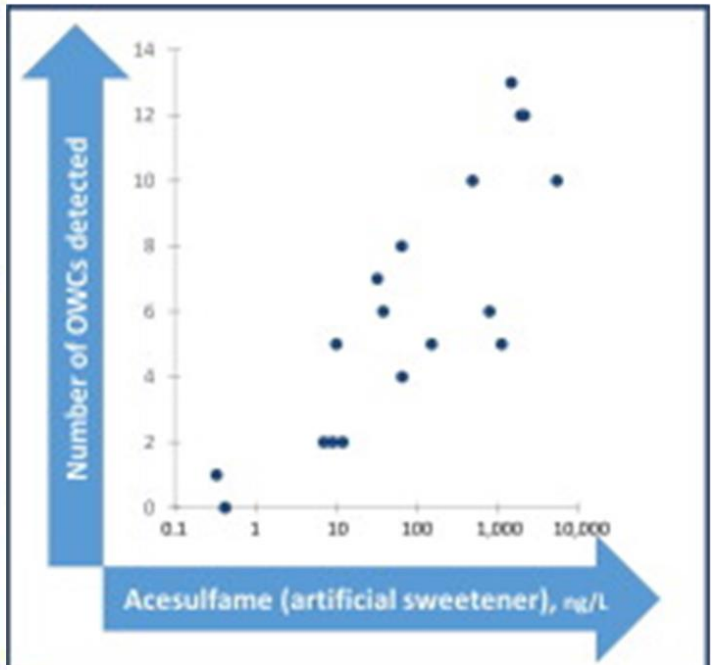
Pharmaceuticals and other Organic Waste Compounds Detected in Private Drinking Water Supplies in Shallow Aquifers





- 17 wells, (85%) contained detectable concentrations of at least one Organic Waste Compounds (OWC)
- Acesulfame- a marker for waste water contamination
- Detections are in parts per trillion

SOURCE: Laurel A. Schaider, Janet M. Ackerman, Ruthann A. Rudel
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Pharmaceuticals and other OWC Detected in Public Drinking Water Supplies in Shallow Aquifers

- Tested 20 Public wells (raw water) in sand and gravel for 92 OWC
- Pharmaceuticals and PFAS most frequently detected
- Septic systems primary source into aquifer
- Nitrate, boron, and extent of unsewered development correlate with OWC presence.
  - Boron is surrogate for waster water tracer (present in soaps/detergents)

SOURCE: Laurel A. Schaider, Janet M. Ackerman, Ruthann A. Rudel
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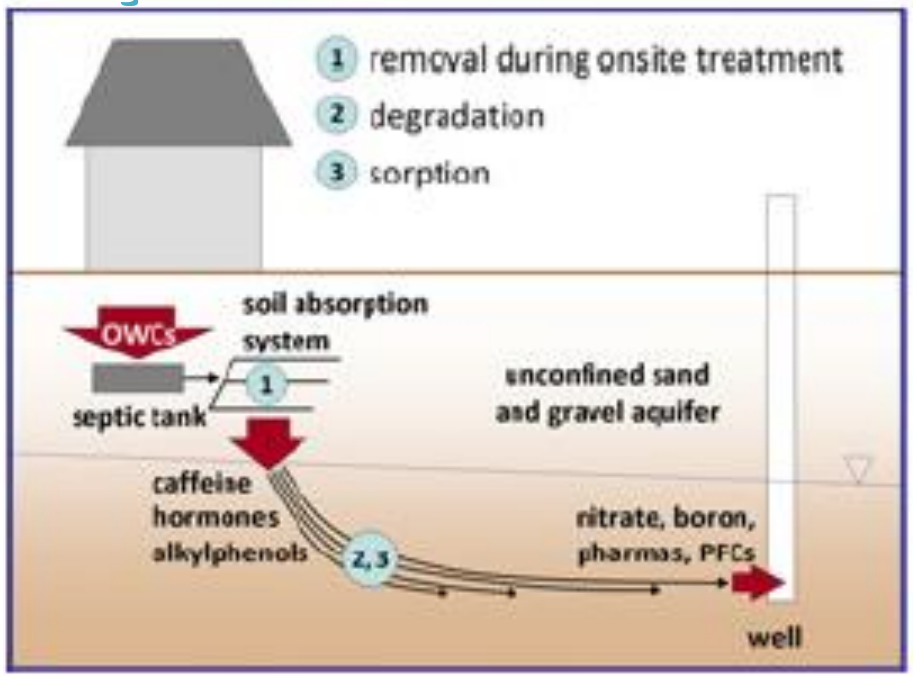

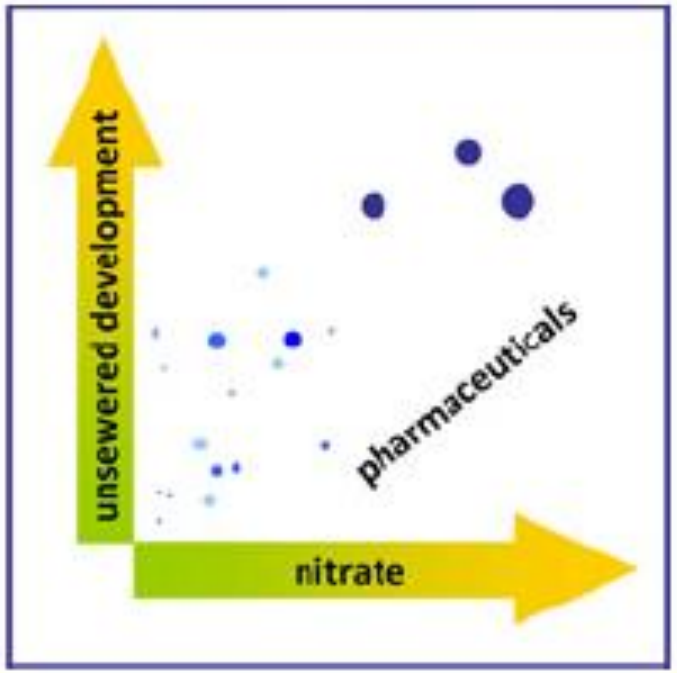

- 15 wells, (75%) contained least one Organic Waste Compounds (OWC)
- 60% antibiotics
- 40% PFAS
- boron as markers for waste water

- Detections are in parts per trillion

SOURCE: Laurel A. Schaider, Janet M. Ackerman, Ruthann A. Rudel
Septic systems as sources of organic wastewater compounds in domestic drinking water wells in a shallow sand and gravel aquifer
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Pharmaceuticals and Other Chemicals in Landfill Waste

- Sampled fresh (before storage or treatment) landfill leachate from 19 landfills across the United States
  - 12 municipal
  - 7 private

- Tested for 202 contaminants of emerging concern (CEC)
- Industrial chemical, prescription pharmaceuticals, household chemicals, and nonprescription pharmaceuticals most frequently detected
- Landfills receiving greater precipitation had greater frequency of CEC detections

SOURCE: Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States: Environmental Science--Processes and Impacts, 2014, v. 16, no. 10, p. 2335-2354, doi:10.1039/C4EM00124A. https://toxics.usgs.gov/highlights/2014-08-12-leachate_pharm.html

USGS

Pharmaceuticals and Other Chemicals in Landfill Waste

Max Concentration	Percent Frequency of Detection	Chemical
7,020,000 ppt	55	para-cresol (plasticizer and flame-retardant, antioxidant in oils, rubber, polymers, and wood preservative)
4,080,000 ppt	95	bisphenol A (used in plastics, thermal paper, and epoxy resins)
705,000 ppt	65	ibuprofen (analgesic, antipyretic)
254,000 ppt	95	DEET (insect repellent)
147,000 ppt	90	lidocaine (local anesthetic, topical anti-itch treatment)
97,200 ppt	84	camphor (natural compound with medicinal uses and embalming)
51,200 ppt	95	cotinine (transformation product of nicotine)
2,590 ppt	75	carbamazepine (anticonvulsant and mood stabilizer)
168 ppt	55	estrone (natural estrogenic hormone)

SOURCE: Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States: Environmental Science--Processes and Impacts, 2014, v. 16, no. 10, p. 2335-2354, doi:10.1039/C4EM00124A. https://toxics.usgs.gov/highlights/2014-08-12-leachate_pharm.html

USGS

Pharmaceuticals in Landfill Leachate Disposed to Wastewater Treatment Plants

- Sampled final (after storage or treatment processes) landfill leachate from 22 landfills across the United States

- Tested for 190 contaminants of emerging concern (CEC)
- All samples detected CECs
- Detected 101 different CECs: 43, prescription pharmaceuticals, 22 industrial chemicals, 15 household chemicals, and 12 nonprescription pharmaceuticals most frequently detected
- Final leachate from active landfills had significantly greater CEC concentrations from modern lined landfills than unlined, closed landfills.

SOURCE: https://toxics.usgs.gov/highlights/2015-11-13-leachate_pathways.html

SOURCE: Masoner, J.R., Kolpin, D.W., Furlong, E.T., Cozzarelli, I.M., and Gray, J.L., 2015, Landfill leachate as a mirror of today's disposable society--Pharmaceuticals and other contaminants of emerging concern in final leachate from landfills in the conterminous United States: Environmental Toxicology and Chemistry, doi:10.1002/etc.3219 (Advanced Web release).

Masoner, J.R., Kolpin, D.W., Furlong, E.T., Cozzarelli, I.M., Gray, J.L., and Schwab, E.A., 2014, Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States: Environmental Science--Processes and Impacts, v. 16, no. 10, p. 2335-2354, doi:10.1039/C4EM00124A.

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Pharmaceuticals in Landfill Leachate Disposed to Wastewater Treatment Plants

Most Frequent Detections:	
Lidocaine	Local anesthetic
Cotinine	Nicotine breakdown products
Carisoprodol	Muscle relaxant
Bisphenol A	Plastics component
carbamazepine	Anticonvulsant
DEET	Insect repellent

SOURCE: https://toxics.usgs.gov/highlights/2015-11-13-leachate_pathways.html

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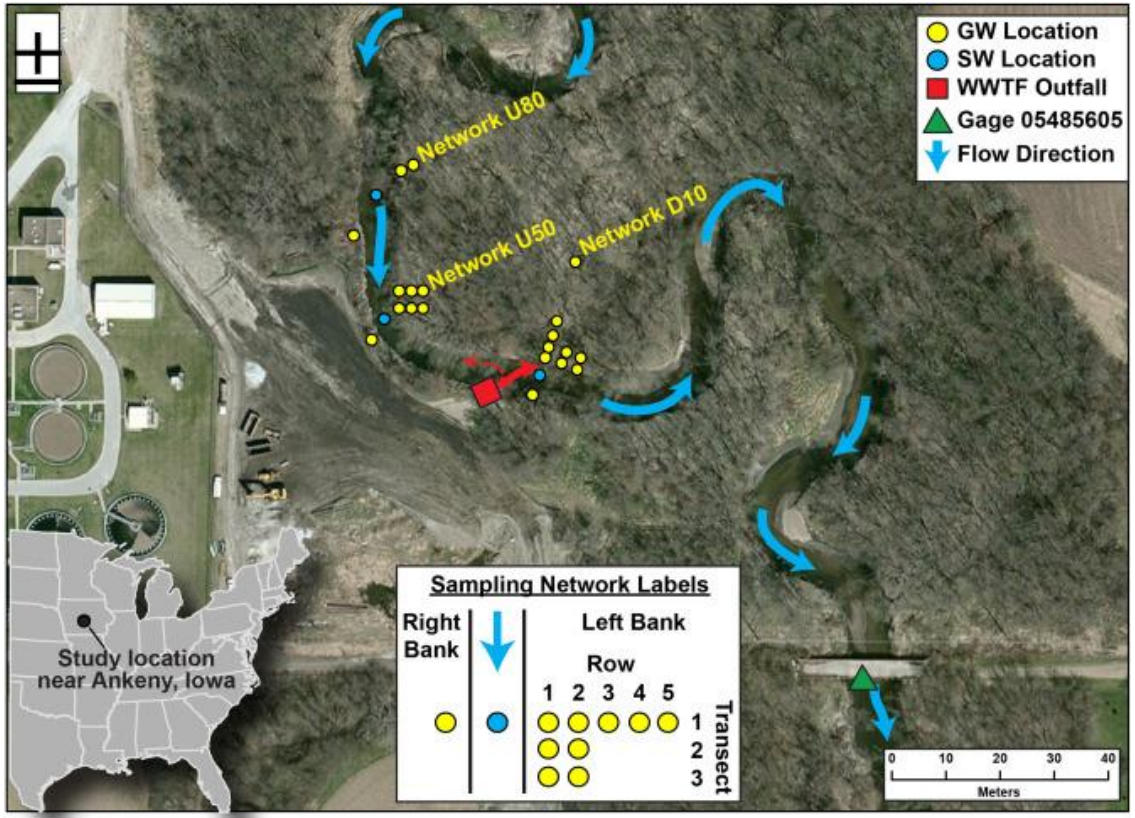
Pharmaceuticals Found in Treated Wastewater can be Transported from Surface Water to Groundwater

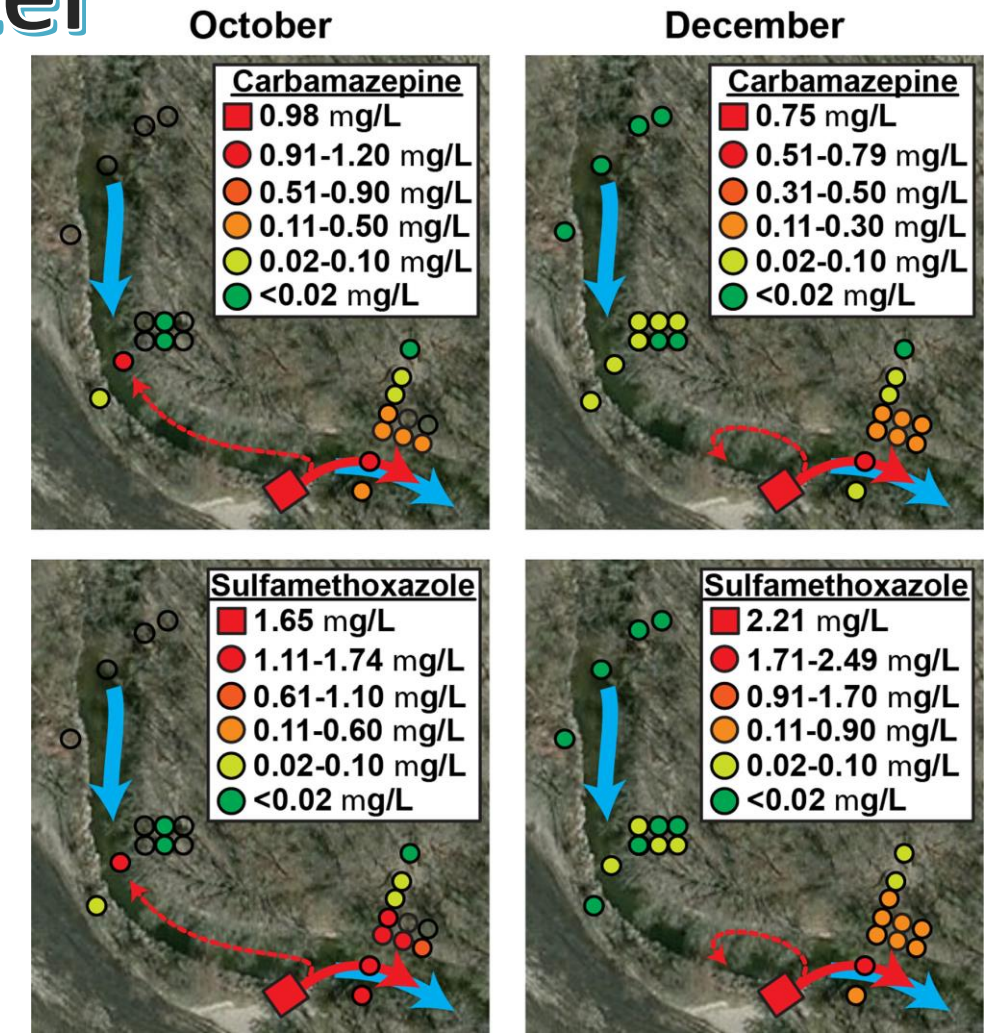
- Wastewater effluent contributing 99 and 71 percent of the flow within creek sampled two periods, October and December of 2012
- Stream and shallow groundwater samples collected and analyzed for 110 pharmaceuticals.
- 42 (Oct.) and 55 (Dec.) percent of samples detected pharmaceuticals

USGS

USGS study: Riverbank filtration potential of pharmaceuticals in a wastewater-impacted stream: Environmental Pollution, 2014, v. 193, p. 173-180, doi:10.1016/j.envpol.2014.06.028.

Pharmaceuticals Found in Treated Wastewater can be Transported from Surface Water to Groundwater





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PerfluoroWhat?

- PFAS is a broad name for man-made industrial chemicals
  - Nonstick cookware, firefighting foams, food wrappers, stain and water resistant fabrics, household cleaners
- These chemicals are
  - Oil and water repellent
  - Extremely persistent
  - Bioaccumulate

Photo sources:
https://www.rnz.co.nz/news/environment/397591/banned-firefighting-foam-found-at-port-taranaki-dunedin-airport
https://chemicalwatch.com/76146/precise-genx-mechanism-of-toxicity-eludes-epa-scientists

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Potential Health Effects

- Studies associate PFOS and PFOA in exposure with high cholesterol, thyroid disorders, preeclampsia, and testicular and kidney cancer, reproductive and developmental effects.

- Confirmed animal carcinogen at parts per trillion level
  - That is equivalent to 1 ounce in 7.5 billion gallons of water

- In blood of general human and wildlife population

USEPA Fact Sheet: https://www.epa.gov/sites/production/files/2017-12/documents/ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf

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Are PFOS and PFOAs regulated?

Federally NOT regulated:
NO Maximum Contaminant Level (MCL) established by USEPA

Some States have established drinking water standards

State	Guideline (µg/L)		Source
	PFOA	PFOS	
Delaware	0.4	0.2	DNREC 2016
Maine	0.13	0.56	MDEP 2016
Michigan	0.42	0.011	MDEQ 2015
Minnesota	0.035	0.027	MDH 2017b
New Jersey	0.04	NA	NJDEP 2016
North Carolina	2	NA	NCDEQ 2013
Texas	0.3	0.6	TCEQ 2016
Vermont	0.02	NA	VTDEC 2016

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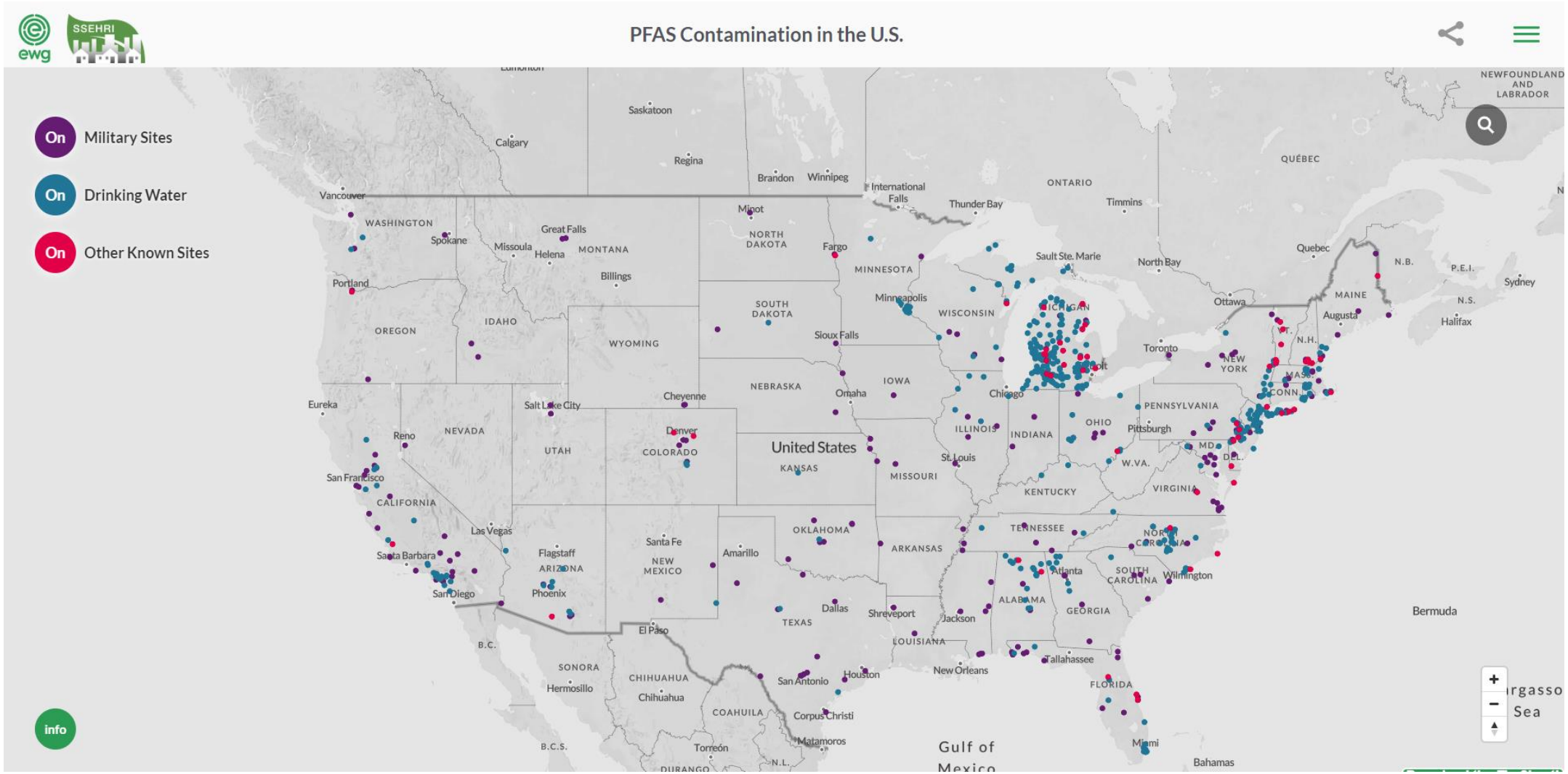
PFAS Detected in Drinking Water and Groundwater



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Source: https://www.ewg.org/interactive-maps/2019_pfas_contamination/map/

Illinois PFAS Study

- Illinois Environmental Protection Agency is testing municipal water supplies for PFAS compounds throughout the State (2020-2021).
- Illinois has not established a standard.
- Defer to USEPA Lifetime Health Advisory of 70 nanograms per liter (ng/L) or parts per trillion (ppt).

Source: https://pfas-1.itrcweb.org/wp-content/uploads/2018/01/pfas_fact_sheet_regulations__1_4_18.pdf

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Microplastics are Everywhere!

- Plastic does not biodegrade or breakdown into simple, digestible components.
- Plastic simply breaks down into smaller and smaller plastic pieces, creating microplastics.
- Samples collected from the St. Croix and Mississippi Rivers from water, sediment, fish, and mussels ALL contained microplastics.
- Fibers were most abundant, 86 to 93 percent in the samples.

USGS

Microplastic Types and Sources

Microbeads
Soaps, scrubs, toothpastes, deodorants, sunscreen, lipstick, eye shadow, shaving cream, medical uses (drug delivery)

Pellets
Pre-production pellets and powders, bead blasting (boat hulls and engine parts)

Fibers/Lines
Synthetic clothing and textiles, cigarette butts, nets

Fragments
Degraded pieces of plastic litter such as bottles, manufacturing waste material (shavings), tire particles

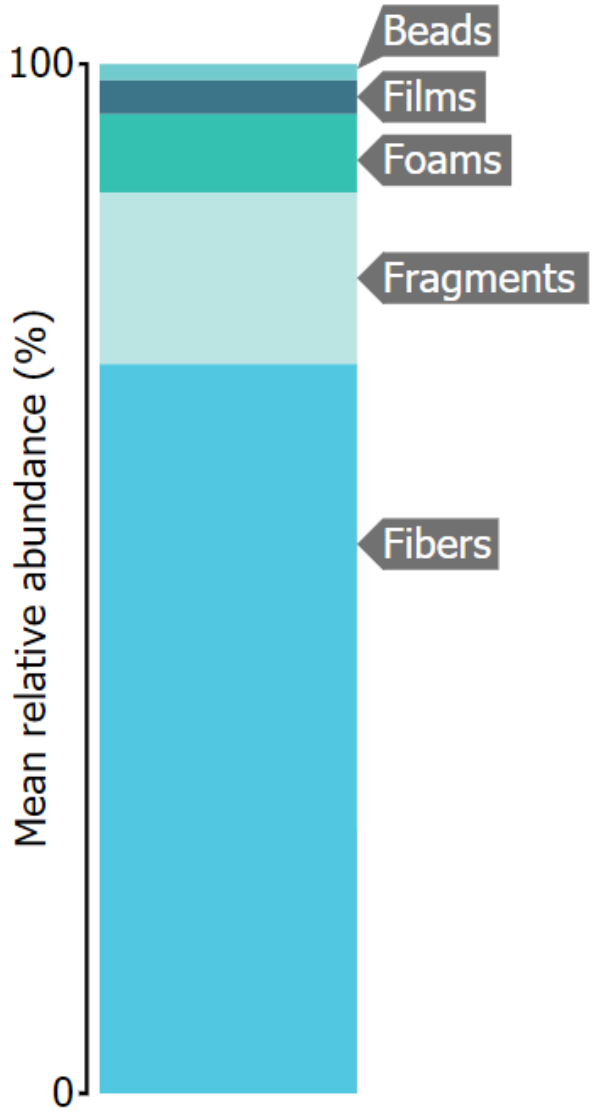
Films
Bags and wrappers

Foams
Styrofoam™, rubber

https://irma.nps.gov/DataStore/DownloadFile/577360
https://www.sciencebase.gov/catalog/item/58e7d00ae4b09da6799c0f8a

Microplastics in our Nation's Surface Water

- 12% of freshwater fish have ingested plastic particles
- 50 – 90 particles per serving of oysters and mussels
- Hazards are physical, carcinogenic, and endocrine disruption



Source: https://owi.usgs.gov/vizlab/microplastics/

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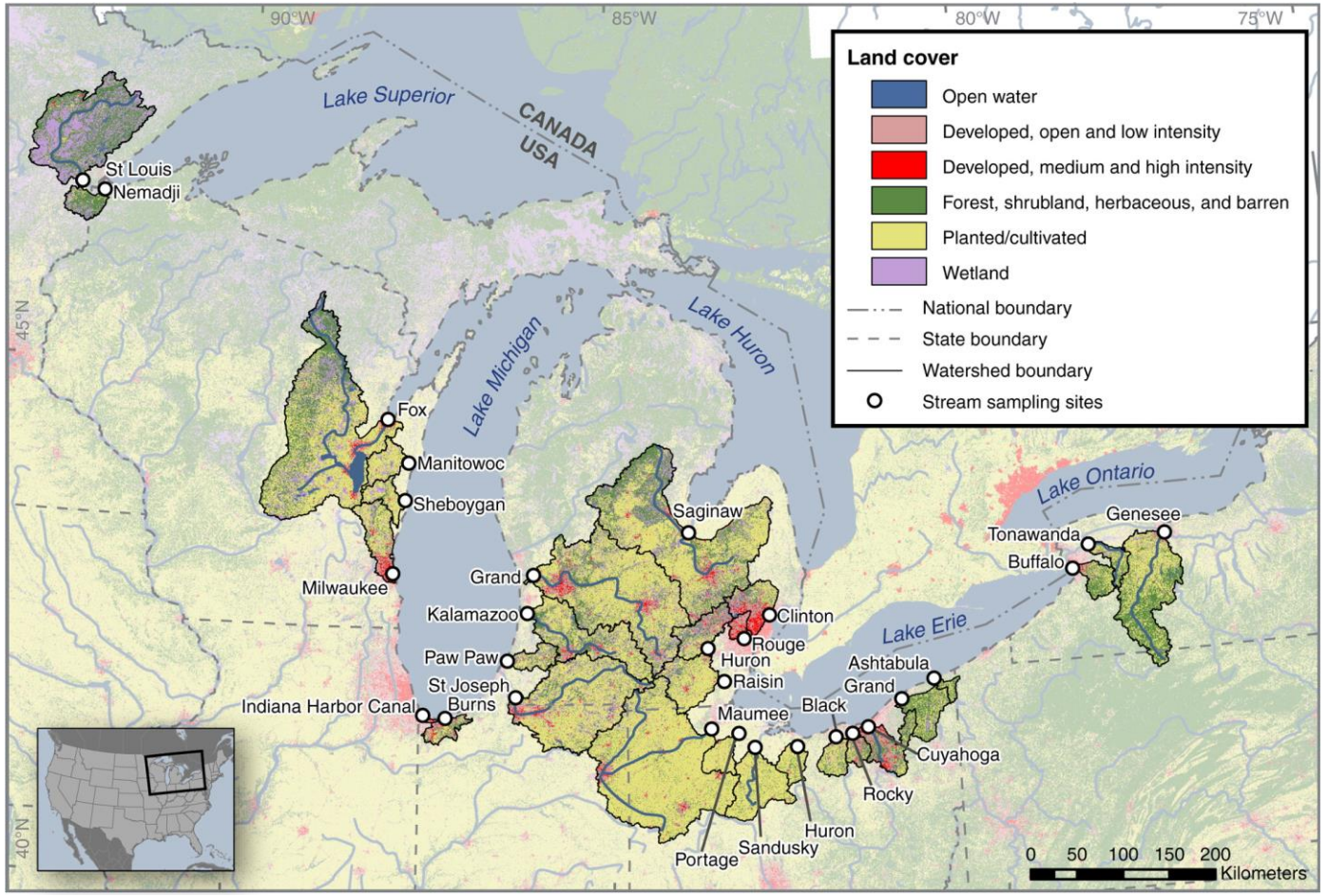
Plastic Debris in 29 Tributaries to the Great Lakes

- 107 samples analyzed
- 100% detection of plastic particles
- 71% fibers
- 17% fragments



Sampling locations, watershed boundaries, and watershed land uses.

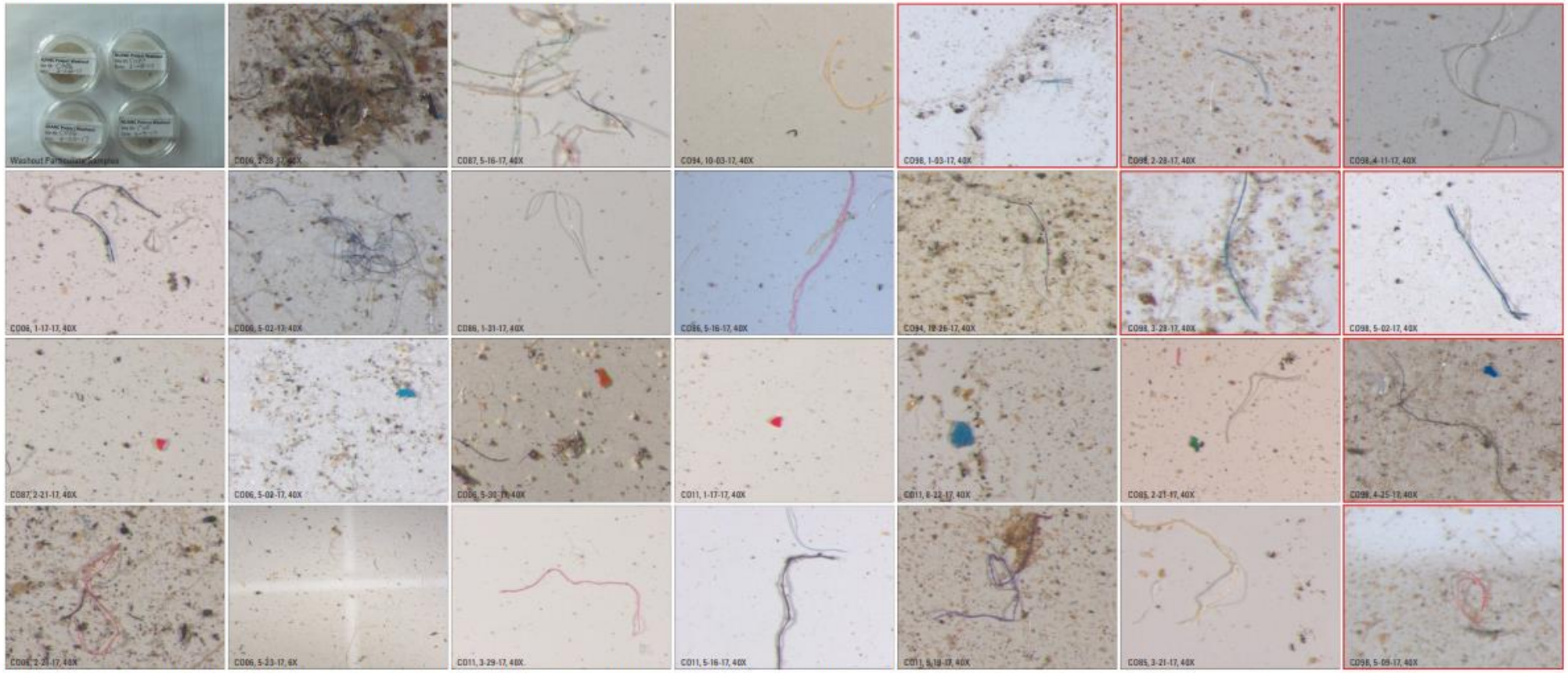
USGS

Published in: Austin K. Baldwin; Steven R. Corsi; Sherri A. Mason; *Environ. Sci. Technol.* **2016,** 50, 10377-10385.
DOI: 10.1021/acs.est.6b02917

Microplastics in the Rain

- Colorado Front Range peppered with microfibers and microparticles in >90 percent of samples

Photomicrographs of plastics collected at the NUANC NTN subnetwork, Sugarloaf, and Loch Vale sites in Colorado



(Explanation of labels: CO06, site identification; 2-28-17, month-day-year; 40X, magnification; Red outline indicates Loch Vale samples.)

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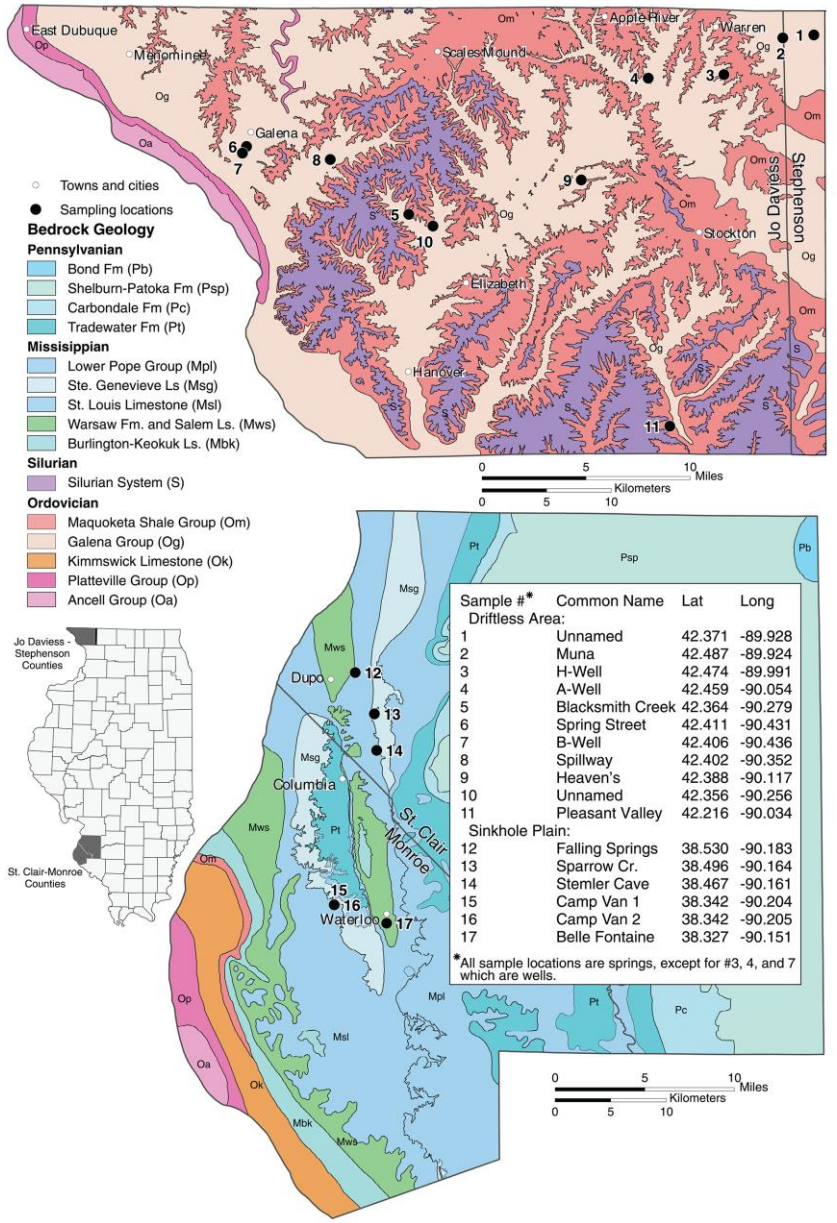
https://pubs.usgs.gov/of/2019/1048/ofr20191048.pdf

Microplastic in Groundwater

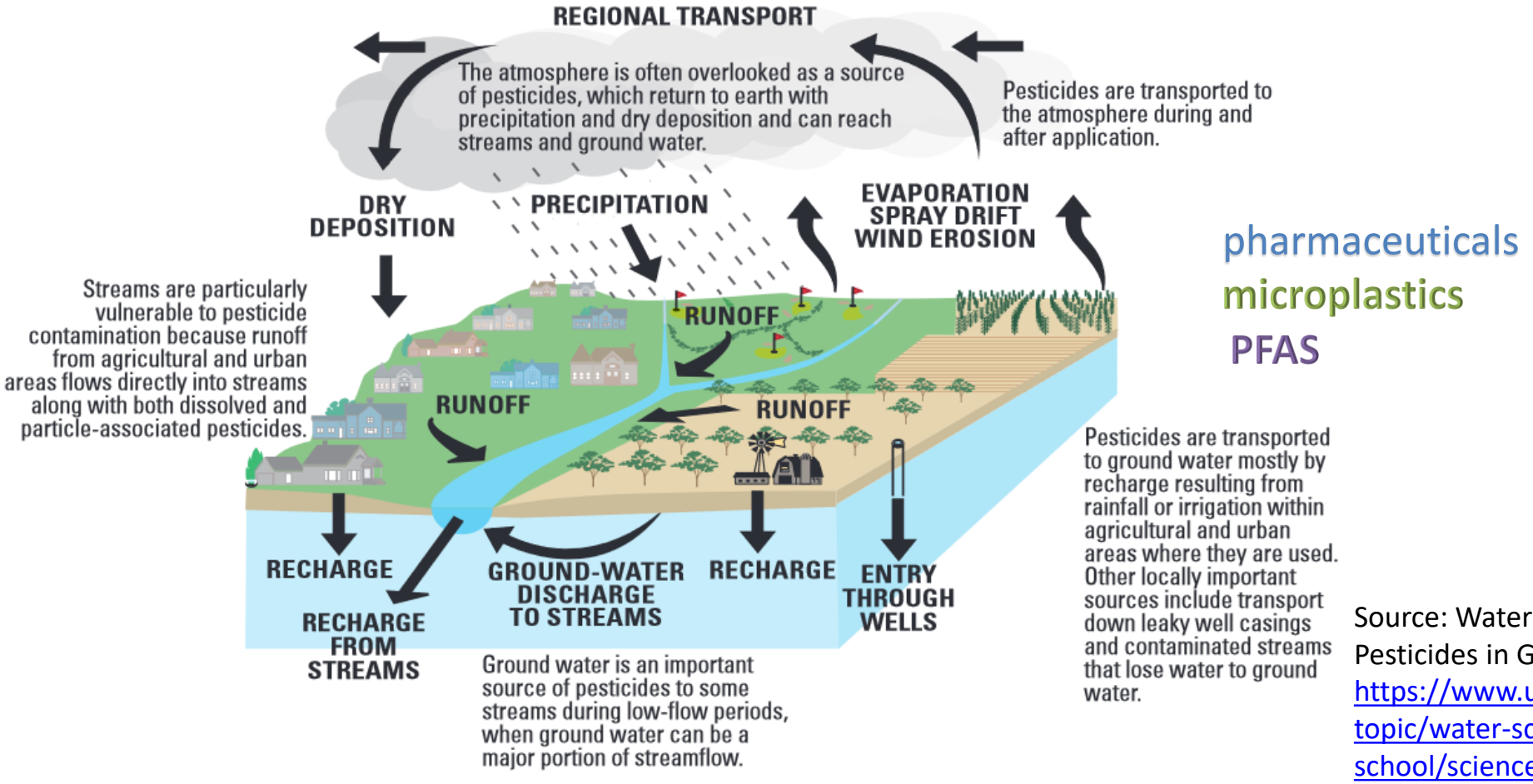
- Primarily in karst aquifers which have large voids
- Scientists have only just begun to explore microplastics in groundwater systems



USGS

Source: Samuel V. Panno, Walton R. Kelly, John Scott, Wei Zheng, Rachael E. McNeish, Nancy Holm, Timothy J. Hoellein, Elizabeth L. Baranski. **Microplastic Contamination in Karst Groundwater Systems**. *Groundwater*, 2019; DOI: 10.1111/gwat.12862

Groundwater and Surface Waters are Vulnerable



pharmaceuticals
microplastics
PFAS

Figure 2–4. Pesticides are transported to streams and ground water primarily by runoff and recharge. Nonpoint sources of pesticides originating from areas where they were applied—rather than point sources such as wastewater discharges—are the most widespread causes of pesticide occurrence in streams and ground water. (Modified from Majewski and Capel, 1995.)

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