PURDEX IN FOCUS

Synthetic Organic Chemicals in the nation's tap water

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Our *Purdex In Focus* series highlights a particular contaminant found in tap water and presents a more detailed analysis of its occurrence in the nation's drinking water. These reports will include information on sources of contamination, potential health risks from exposure to the contaminant in drinking water, a state-by-state comparison of reported contaminant levels, the number of people impacted in each state, and the number of health violations issued. All of our analyses are supported by our database of millions of certified drinking water test data collected annually from thousands of community water systems throughout the country. (These are the same data that the U.S. EPA and state primacy agencies use to determine compliance with drinking water standards.)

Summary
Synthetic Organic Chemicals (SOCs) are a class of chemicals that are all man-made and do not occur naturally in the environment. SOCs can be found in a number of manufactured products like herbicides, pesticides, and many organic compounds widely used by commercial and industrial operations. The U.S. Environmental Protection Agency and the U.S. Food and Drug Administration have set health standards that regulate SOCs in tap and bottled water, respectively. During 2008-2012, an estimated 100 million Americans were exposed to one or more of these SOCs in tap water. Nationally, atrazine and di(2-ethylhexyl) phthalate were the two most common SOCs detected; they were detected in half of all positive SOC drinking water samples. Less than 20% of all community water systems that tested for SOCs during this period reported positive samples. Our analyses show that SOCs are more commonly found in tap water from a surface water source and are more often detected in larger community water systems than in smaller systems. SOC production and use seems to be state-specific, occurring more often in some states than in others, so national estimates of SOC occurrence in tap water should be weighted accordingly. Homeowners and business owners concerned about SOC levels in their tap water have several home-filtration options from which to choose that incorporate a variety of filtration technologies from simple carbon filters to more advanced reverse osmosis systems.

Synthetic Organic Chemicals
Organic chemicals (i.e., chemicals containing carbon) are widely synthesized in the U.S. by a number of laboratories and chemical companies. One group of chemicals called Synthetic Organic Chemicals (SOCs) are used in a variety of pesticides, herbicides, insecticides, plastics, synthetic fibers, dyes, and as ingredients in many other organic compounds. SOCs are all man-made and do not naturally occur in the environment. Some of the better-known SOCs are Atrazine, 2,4-D, Dioxin and Polychlorinated Biphenyls (PCBs).

SOCs most often enter the natural environment through the application of pesticides and herbicides (including runoff from areas where they are applied) from home or agricultural uses, as part of a legally discharged waste stream from commercial and industrial operations, improper or illegal waste disposal, accidental releases or as byproducts of incineration.

Some SOCs are very persistent in the environment and can exist for a long period of time in both soil and water. Traditionally, ground water has been assumed to be a relatively pristine source of water and better protected from contamination than surface water supplies. Over the past decade, however, a variety of SOCs have been discovered in the nation's ground water, often at concentrations far exceeding those in surface water supplies.

The Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Environmental Protection Agency (EPA) are required to prepare a list, in order of priority, of substances that are most commonly found at facilities on the National Priorities List (NPL) and which are determined to pose the most significant potential threat to human health due to their known or suspected toxicity and potential for human exposure at these NPL sites. A large number of SOCs have been added to this list over the past two decades and are typically ranked at the top of the list.

Currently, there are 30 SOCs that are regulated in drinking water by EPA. Even though EPA regulates each of these individual SOCs separately as contaminants of concern in drinking water, this paper analyzes the occurrence in the nation's tap water of all SOCs as a combined unit. Future editions of the *Purdex In Focus* series will examine the occurrence of individual SOCs in tap water on a state-by-state basis.

Health Effects
The toxicity of SOCs in drinking water is determined by the amount of contamination and how much is absorbed into the body from drinking, bathing and cooking with the contaminated tap water. When SOCs are found in water supplies, they normally are not present in high enough concentrations to cause acute health effects such as chemical burns, nausea, or convulsions. Instead, they typically occur in trace levels, and the concern is primarily for their potential for causing chronic health problems like cancer.

One of the complicating factors in setting drinking water standards for individual SOCs is that it generally is not known how a particular compound might interact with other chemicals present in the water to adversely affect human health. Often when one organic compound is found, others are there also, and their combined negative impact on health may be additive or possibly greater than (synergistic) or less than (antagonistic) what would be observed when any one is ingested individually. The number of possible interactions makes thorough analysis of them all as a class of chemicals an impossible task but with improved computational predictive modeling it is hoped that one day these interactions can be better defined.

Regulation of SOCs in Drinking Water
The Safe Drinking Water Act requires EPA to establish National Primary Drinking Water Regulations (NPDWRs) for contaminants in drinking water that may cause adverse health effects. There are 30 SOCs that are regulated in drinking water and each one has its own Maximum Contaminant Level (MCL). The U.S. Food and Drug Administration has set similar standards for bottled water.

The frequency of SOC monitoring by community water systems can vary between states because some SOCs are not used in certain areas of the country and because some water systems are not susceptible to SOC contamination. In these cases, a community water system can petition the EPA for a monitoring waiver, which allows them the opportunity to test less often (i.e., every 3, 6 or 9 years).

Data Source and Analysis
All of the water sample data used in this report come from the Purdex National Tap Water Database, which represents a collection of millions of drinking water sample test data from active, fully licensed community water systems throughout the nation. (State primacy agencies and EPA use the same data to determine compliance with drinking water standards.) Arithmetic means of treated drinking water sample data were used in this analysis, as calculated averages better represent estimated contaminant concentrations in a typical drinking water distribution system. Controling for the variability in sampling frequency and anlaytical detection limits were not part of this analysis. Raw water sample data from water sources not meant for human consumption were not used in this analysis.

Individual water system personnel managed sample collection activity and only state-certified laboratories were employed to analyze the samples using the same analytical methods for every sample as required by EPA. For purposes of this report, it is assumed that all related sample collection, handling, and analytical activity, as well as primacy agency reporting and record keeping, met all federal and state regulatory requirements and best-practices protocols. However, with the very large number of, and varied procedures for, manually recording sample analysis results, and since Purdex did not have oversight of any step in the process, it is expected that human error might have an (insignificant) impact on recorded values.

Some states are not part of this analysis because we were not able to obtain the necessary data from them. These include Michigan, New Hampshire, West Virginia, South Dakota, and Oklahoma.

Discussion

Table 1 lists all of the SOCs that are currently regulated by EPA. Pesticides, herbicides and insecticides make up the majority of the SOC grouping. About half of the contaminants on the list include the risk of cancer as one of the adverse health effects from exposure in drinking water.

Table 1. Synthetic Organic Contaminants Regulated in Drinking Water

Contaminant	Typical Source	Health Effects
2,4-D	Runoff from herbicide used on row crops	Kidney, liver, or adrenal gland problems
2,4,5-TP (Silvex)	Residue of banned herbicide	Liver problems
Alachlor	Runoff from herbicide used on row crops	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer
Atrazine	Runoff from herbicide used on row crops	Cardiovascular system or reproductive problems
Benzo(a)pyrene (PAH)	Leaching from linings of water storage tanks and distribution lines	Reproductive difficulties; risk of cancer
Carbofuran	Leaching of soil fumigant used on rice and alfalfa	Problems with blood, nervous system, or reproductive system
Chlordane	Residue of banned termiticide	Problems with liver or nervous system; increased risk of cancer
Dalapon	Runoff from herbicide used on rights of way	Minor kidney changes
Di(2-ethylhexyl) Adipate	Discharge from chemical factories	Weight loss, liver problems, or possible reproductive difficulties.
Di(2-ethylhexyl) Phthalate	Discharge from rubber and chemical factories	Reproductive difficulties; liver problems; increased risk of cancer
Dibromochloropropane (DBCP)	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	Reproductive problems; increased risk of cancer
Dinoseb	Runoff from herbicide used on soybeans and vegetables	Reproductive difficulties
Dioxin (2,3,7,8-TCDD)	Emissions from waste incineration and other combustion; discharge from chemical factories	Reproductive difficulties; increased risk of cancer
Diquat	Runoff from herbicide use	Cataracts
Endothall	Runoff from herbicide use	Stomach and intestinal problems
Endrin	Residue of banned insecticide	Liver problems
Ethylene Dibromide	Discharge from petroleum refineries	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer
Glyphosate	Runoff from herbicide use	Kidney problems; reproductive difficulties
Heptachlor	Residue of banned termiticide	Liver damage; increased risk of cancer
Heptachlor Epoxide	Breakdown of heptachlor	Liver damage; increased risk of cancer
Hexachlorobenzene	Discharge from metal refineries and agricultural chemical factories	Problems with liver or kidneys; adverse reproductive effects; increased risk of cancer
Hexachlorocyclopentadiene	Discharge from chemical factories	Kidney or stomach problems
Lindane	Runoff/leaching from insecticide used on cattle, lumber, gardens	Liver or kidney problems
Methoxychlor	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	Reproductive difficulties
Oxamyl (Vydate)	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	Slight nervous system effects
Polychlorinated Biphenyls (PCBs)	Runoff from landfills; discharge of waste chemicals	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer
Pentachlorophenol	Discharge from wood preserving factories	Liver or kidney problems; increased cancer risk
Picloram	Herbicide runoff	Liver problems
Simazine	Herbicide runoff	Problems with blood
Toxaphene	Runoff/leaching from insecticide used on cotton and cattle	Kidney, liver, or thyroid problems; increased risk of cancer

Table 2 ranks the individual regulated SOCs in order of how often they were detected in drinking water samples when compared to all SOC detections during 2008-2012. As indicated in the table, over half of all the positive SOC samples were for atrazine and Di(2-ethylhexyl) phthalate alone. Atrazine is a herbicide and Di(2-ethylhexyl) phthalate is a manufactured chemical that is commonly added to plastics to make them flexible. Encouragingly, some of the worst and most publicized chemicals appear at the bottom of the list (i.e., PCBs and dioxin). Most of the herbicides appear at the top of the list while the first listed pesticide, methoxychlor, appears down towards the bottom at number 17. This is expected as there are far more herbicides than pesticides that are regulated in drinking water by EPA. The percentage values shown in the table do not distinguish between which sources the drinking water came from (ground vs. surface) nor in which states they were more commonly found; we will examine these factors more closely in upcoming *Purdex In Focus* papers where we will highlight the occurrence of individual SOCs in tap water.

Table 2. Frequency of Positive SOC Detections in the Nation's Tap Water

Rank	Contaminant	As Percentage of All Positive Samples (%)
1	Atrazine	28.9
2	Di(2-ethylhexyl) Phthalate	28.1
3	Simazine	8.4
4	Dalapon	7.3
5	Dibromochloropropane (DBCP)	3.8
6	Di(2-ethylhexyl) Adipate	3.4
7	Hexachlorocyclopentadiene	2.6
8	Heptachlor Epoxide	2.3
9	2,4-D	2
10	Pentachlorophenol	1.8
11	Ethylene Dibromide	1.6
12	Benzo(a)pyrene (PAHs)	1.4
13	Picloram	1.2
14	Dinoseb	1.2
15	Diquat	0.9
16	Alachlor (Lasso)	0.8
17	2,4,5-TP (Silvex)	0.8
18	Heptachlor	0.6
19	Chlordane	0.6
20	Methoxychlor	0.4
21	Endrin	0.3
22	BHC-gamma (Lindane)	0.3
23	Polychlorinated biphenyls (PCBs)	0.2
24	Oxamyl (Vydate)	0.2
25	Carbofuran	0.2
26	Toxaphene	0.2
27	Hexachlorobenzene	0.2
28	Glyphosate	0.1
29	Endothall	0.1
30	Dioxin (2,3,7,8-TCDD)	0.1

Table 3 lists the percentage of community water systems in each state that tested for and detected SOCs in their drinking water during 2008-2012. As indicated, the top five states with the highest percentage of community water systems detecting SOCs are, in order, Louisiana, Maryland, Alabama, Delaware and Idaho while the bottom five on the list with the fewest systems detecting SOCs are Washington, California, New Jersey, Georgia and Alaska. (Surprisingly, Hawaii shows up ninth on the list.) Two-thirds of the states listed below show that less than 20% of their community water systems detected SOCs in their tap water during this period.

Table 3. Percentage of Community Water Systems (CWSs) Detecting SOCs in Drinking Water

State	Total CWS Count	CWSs Detecting SOCs		State	Total CWS Count	CWSs Detecting SOCs	
		Count	Percentage of Total (%)			Count	Percentage of Total (%)
LA	160	123	77	WI	564	62	11
MD	333	167	50	NM	459	50	11
AL	129	59	46	AK	10	1	10
DE	156	70	45	NY	1434	128	9
ID	50	18	36	CA	1011	89	9
KY	208	70	34	MN	815	65	8
RI	53	17	32	UT	43	3	7
KS	561	144	26	OH	960	65	7
HI	98	24	24	ND	143	8	6
IA	794	164	21	OR	796	44	6
TN	153	27	18	MO	1155	57	5
IN	661	111	17	MA	429	20	5
FL	1124	188	17	ME	267	12	4
NE	560	92	16	MT	632	28	4
PA	1457	237	16	VT	257	10	4
TX	4263	672	16	AR	424	16	4
IL	1099	170	15	CT	254	8	3
SC	159	24	15	WY	230	6	3
AZ	463	69	15	WA	1445	33	2
NC	1639	228	14	VA	705	13	2
NV	175	23	13	NJ	502	5	1
CO	720	94	13	GA	1671	7	>1
MS	17	2	12	*DC*	*1*	*1*	*100*

Table 4 compares the occurrence of SOCs in tap water from community water systems using either a ground water source or a surface water source (lakes, rivers, reservoirs, etc.) during 2008-2012. Eighty-percent of all community water systems in the U.S. use ground water as their drinking water source. As can be expected, Table 4 shows that there were about six-times the number of ground water systems than surface water systems that tested for SOCs in this time period. Our analysis shows that 29% of surface water systems detected SOCs in their tap water compared to only 9% of water systems on ground water. These data suggest that SOCs are more prevalent in tap water derived from surface water sources than from ground water sources.

Table 4. Community Water Systems (CWSs) Detecting SOCs in Tap Water Based on Water Source

Drinking Water Source	No. of CWSs Testing For SOCs	No. of CWSs Detecting SOCs	Percentage of CWSs Detecting SOCs (%)
Surface Water	4,307	1,264	**29**
Ground Water	24,540	2,208	**9**
Total	28,847	3,472	

Table 5 ranks the states based on number of people within each state using tap water with some detectable level of one or more SOCs during 2008-2012. As can be seen in the table, close to 100 million people consumed, bathed or cooked with SOC-tainted tap water during this time period.

Table 5. Populations With SOCs in Drinking Water

Rank	State	Affected Population*	Rank	State	Affected Population*
1	TX	12,724,723	24	MN	753,101
2	FL	11,082,460	25	DE	689,495
3	NY	10,038,646	26	RI	674,710
4	IL	4,607,939	27	OR	600,659
5	MD	4,522,036	28	NJ	522,703
6	PA	4,485,103	29	WI	472,241
7	AZ	4,406,907	30	NM	463,388
8	NC	3,835,323	31	CT	447,730
9	CA	3,525,768	32	WA	398,867
10	LA	2,802,604	33	ID	322,744
11	IN	2,508,304	34	MA	296,055
12	OH	2,504,378	35	SC	261,534
13	MO	2,306,617	36	MT	83,576
14	NV	2,019,625	37	ME	56,168
15	KS	1,903,391	38	AR	55,090
16	KY	1,868,943	39	AK	17,371
17	AL	1,392,883	40	WY	12,589
18	TN	1,314,521	41	VT	12,542
19	NE	1,126,022	42	UT	11,388
20	HI	1,054,351	43	ND	9,957
21	VA	1,009,473	44	MS	7,280
22	CO	999,288	45	GA	6,351
23	IA	946,627			

*Population counts in some states are estimates only due to how they are calculated and recorded by the state.

As a general rule, there are far more small community water systems in the U.S. that serve communities of less than 3,300 people than there are for medium, large and very large communities combined (serving > 3,300 people). Table 6 shows that there were about eight-times as many small systems testing for SOCs as there were for either of the other system size categories during 2008-2012. Our analysis shows that 22% of medium, and 30% of large, community water systems detected SOCs in their tap water compared to only about 9% of smaller systems. These data suggest that SOCs are more prevalent in medium and large community water systems, and, to a lesser extent, in smaller systems.

Note that this conclusion may vary within individual states so a general statement about the relationship between community size and SOC content in drinking water on a national level should not be made. We will examine state-to-state differences in individual SOC detections by community water systems in future *Purdex In Focus* papers.

Table 6. Community Water Systems (CWSs) Detecting SOCs in Tap Water Based on Community Size

System Size	No. of CWSs Testing For SOCs	No. of CWSs Detecting SOCs	Percentage of CWSs Detecting SOCs (%)
Small CWS (serving < 3,300 people)	23,608	2,043	**8.6**
Medium CWS (serving 3,300-10,000 people)	2,908	649	**22.3**
Large CWS (serving >10,000 people)	2,723	832	**30.5**
Total	29,239	3,524	

A community water system is in violation of EPA's health standard if a particular SOC is detected above its established MCL. As seen in Table 7, over half of all the MCL violations – for all SOCs combined – that were issued during 2008-2012 came from North Carolina, Florida and California. Note that these totals represent all SOC violations combined; we will examine in future *Purdex In Focus* papers, the number of MCL violations issued for each individual SOC compared to the total issued as a group.

Table 7. Maximum Contaminant Level Violations For All SOCs Issued by State

	Number of Violations By Year					
State	**2008**	**2009**	**2010**	**2011**	**2012**	**State Total**
NC	5	7	5	4		21
FL	9	6	4			19
CA	5	3			4	12
TX		6	1			7
PA		1	1	4		6
IA	2	2				4
IN			2	2		4
MA		3	1			4
MO			3	1		4
NJ					4	4
NY	3			1		4
ID				1	2	3
RI	3					3
AL				2		2
WI	2					2
KY					1	1
Total	**29**	**28**	**17**	**15**	**11**	**100**

Removing SOCs From Tap Water

SOCs can successfully be removed using a number of different types of filtration media. Granular activated carbon is generally used to remove organic compounds like SOCs from tap water. Also, reverse osmosis units are recommended as they typically remove over 98% of these compounds in the water. Manufacturers of home filtration systems vary widely in the amount and type of SOCs they remove so check carefully with the manufacturers' percentage removal claims. You can also check with third-party, independent organizations like NSF, WQA and UL for their certifications of specific filters.

There are many filtration products on the market so deciding on the best one for your tap water is an arduous task. To save you time, and to help in your search, we have analyzed a number of popular home filtration systems and put them through our scoring algorithm. Each filter is assigned an individual score (post-filter Purdex Score). To see which filter we recommend for your specific tap water's contaminant profile, visit our site at Purdex.com and check out the Filter Finder tab.

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About the Author

Thomas Keegan has been assisting public water systems for the past 16 years in meeting state and federal water quality reporting requirements. He recently co-founded Purdex LLC, which offers free public access to a variety of simple, consumer-oriented tools to objectively assess drinking water quality based on sample data collected from thousands of public water systems. Previously, he worked with the USEPA as a toxicologist studying the adverse health effects of drinking water contaminants. Tom has a BS in environmental science from the University of Massachusetts at Amherst and a MSPH from the University of North Carolina at Chapel Hill, Gillings School of Global Public Health. He can be reached at (508) 647-4874 or email: tkeegan@Purdex.com.