A BETR Way to Track Toxic Pollutants

The continuing existence in recent years of significant toxaphene levels in the Great Lakes has been somewhat of a mystery, especially since the chemical had never been used very much in that watershed. First introduced in the 1940s, toxaphene was used primarily in Southeast cotton fields as an insecticide and herbicide. It was banned for use in the United States in 1986, but due to its persistent nature, detectable levels still exist in the environment today—and to an unusual degree they affect the Great Lakes, a thousand miles from the chemical's heaviest use.

Scientists have always suspected that the toxaphene was transported out of the southeastern United States, but it's been the stubbornness of the chemical's clearance from the Great Lakes watershed in the last 10 years that has been perplexing. Now, however, a new model developed by scientists in Canada and the United States purports to explain why. A joint product of Lawrence Berkeley National Laboratory in Berkeley, California, and the Canadian Environmental Modelling Centre at Trent University in Peterborough, Ontario, this so-called "mass balance contaminant fate model" may describe how chemicals move over long distances.

The model, known as BETR North America (for the two institutions involved), incorporates an enormous variety of meteorologic and toxic-release data, but it also factors in how a region's soil, water, and vegetation absorb and release pollutants; that is, it incorporates mass balance equations. While there are other continental models for evaluating the movement of contaminants, they focus on air transport patterns and don't address how pollutants interact with vegetation, soil, and water. As explained by codeveloper Tom McKone, a senior scientist at the Berkeley lab, the multimedia BETR North America model measures absorption traits of a region's soil, water, and vegetation against the solubility of specific contaminants. These differences in a region's ability to absorb contaminants determine the degree to which they get passed on.

"There's this sort of exchange that goes on," McKone says. "[Pollutants] partition into the soil and the vegetation, and then the wind changes, they go out, and they come back in. If you take a pollutant like toxaphene or dioxin and look at a cross-section of their partitioning, ninety-nine point nine percent of it is in the soil and vegetation. But it's the small fraction that's in the air that moves. It turns out that because there's enough vapor pressure to get some of it into the air, it'll redistribute itself—but it's going to redistribute itself with this real drag caused by the fact that it's trying to partition into the soil and vegetation. This is

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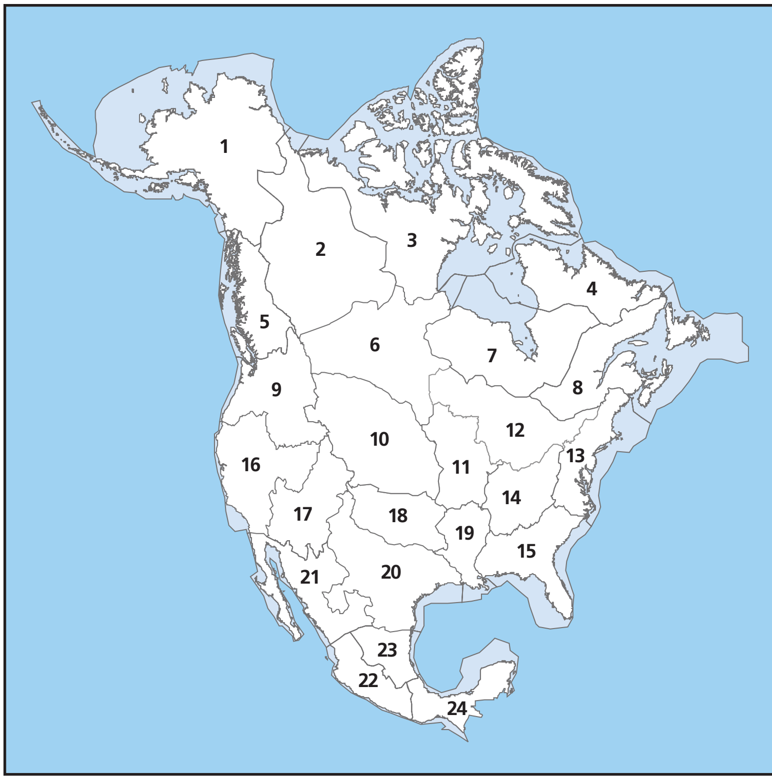


BETR North America Regions
(divided by watershed and soil type)

1. Yukon River–Aleutians
2. Mackenzie River
3. Arctic Archipelago
4. Ungava–Goose Bay
5. Fraser and Skeena Rivers
6. Saskatchewan River
7. James Bay–Canadian Shield
8. Gulf of St. Lawrence
9. Columbia River
10. Missouri and Cheyenne Rivers
11. Mississippi–Ozark
12. Great Lakes Basin
13. Appalachian–Atlantic Coast
14. Ohio River–Allegheny
15. Blue Ridge–Everglades
16. Sierra Nevada–Pacific Coast
17. Colorado River
18. Arkansas River–High Plains
19. Mississippi Delta
20. Rio Grande
21. Baja California
22. Sierra Madre Del Sud
23. Sierra Madre Oriental
24. Yucatán Peninsula

Matt MacLeod, Matt Ray/EHP

the process that has not been captured previously, this coupling between air, surface soil, and vegetation."

This attention to absorption rates is one characteristic that sets BETR North America apart from other models, McKone says. Another is its use of broad natural regions for measurement instead of the grids that are typical of other modeling methods. BETR North America divides Canada, the United States, and Mexico into 24 regions, largely based on watersheds and soil types. Each region is further divided into 7 compartments: upper atmosphere, lower atmosphere, freshwater, freshwater sediment, soil, coastal water, and vegetation. This configuration creates the 168 mass balance equations that define the model.

To date, the Berkeley–Trent scientists have applied the model to several chemicals, but the toxaphene examination has been the most detailed. Matt MacLeod, a graduate student at Trent University and the model's principal developer, says that study verified BETR North America's accuracy because its results agreed with previous measurements. That is, he says, the model correctly predicted that atmospheric conditions and regional pollution absorption rates would result in migration of toxaphene from the Mississippi Delta to the Great Lakes and a relative plateauing of its levels there over the last 10 or 15 years.

BETR North America's Genesis

According to MacLeod, BETR North America evolved from previous models. One notable predecessor is ChemCAN, to which it bears a close resemblance. The creation of Don Mackay, a Trent professor of environmental and resource studies who also worked on BETR North America, ChemCAN divides Canada into 24 regions with the capability of describing how those regions individually absorb pollutants into their water, soil, and vegetation. But with ChemCAN, the focus was on chemical properties and how they would interact with generic environmental conditions, MacLeod says. "There wasn't a focus on where the chemical was moving; it was just on how it partitioned between air and water or air and soil," he says. "What was missing was tracking where the chemical went when it left the region that you were working on."

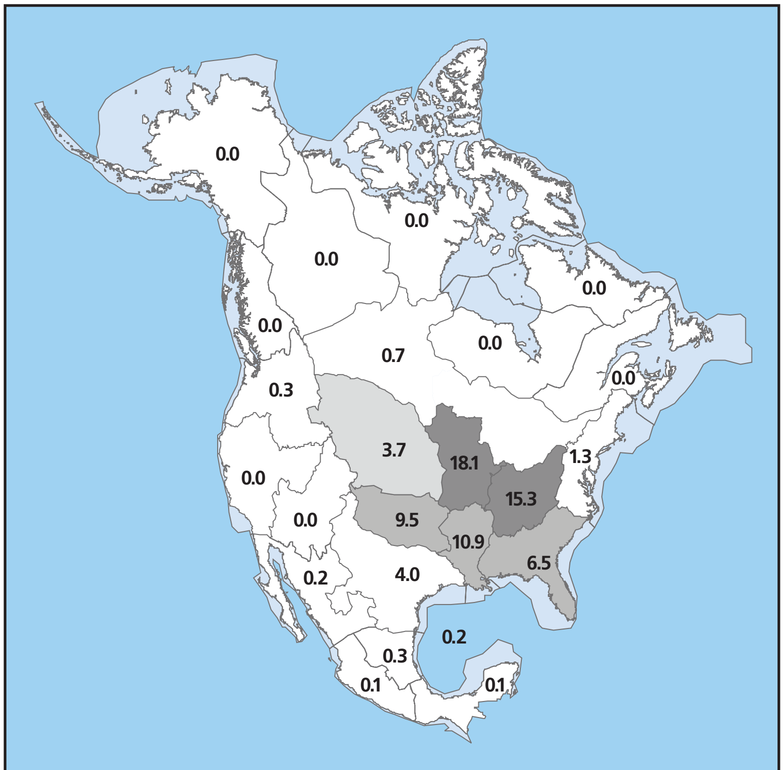
With funding under the Canadian government's Toxic Substances Research Initiative, a research program managed by Health Canada and Environment Canada, the Canadian scientists began developing interregional mapping that described the movement of pollutants. Because the Canadians had already formed a collaborative link with the Berkeley lab, which was interested in working on the new model, the international effort to apply the method to all of North America was born.

The prospect of creating a continental model was enticing because, as McKone says, scientists still have much to learn about long-distance movement of persistent pollutants such as dioxin, mercury, and DDT. To date, the bulk of the work on BETR North America has been to develop data on the mass balance of chemical substances—that is, where and in what amounts they will tend to end up following release. But the next phase, according to McKone, will be greater examination of human exposure calculations.

"What we're investing our time in now is food distribution," he says. "We tend to think of exposure and risk assessment as being done on a fairly local scale. But with a model like this, we now can do the kind of things that were done with [nuclear] fallout studies in the fifties, where they would track fallout across the country and realize that, even though a nuclear test was done in Nevada, it impacted the milk in New York State."

McKone says this investigation will mean taking food distribution patterns and laying them over the model's pollution movement patterns. "It may be that you're exporting your pollutant but bringing it back in with your food supply," he says. For example, he explains, San Francisco enjoys clean air because pollution is usually blown inland to agricultural areas—which sell produce that might contain the same pollutants back to San Franciscans. On a broader, continental scale, McKone says that BETR North America may be able to identify where a pollutant that's showing up in Washington State apples—which could be eaten in, say, New England—is coming from.

"What we'll be able to do once this is up and running," MacLeod says, "is, for example, take data from the Toxics Release Inventory [a U.S. Environmental Protection Agency–operated public database of information on toxic chemical releases and other waste management activity reported by industry] and estimate the resulting human exposure. Then we can look at individuals who live in different parts of the continent and where the food that they eat comes from and extrapolate further to a dose, or rate of intake, of the chemical that can be expected. The tack we're taking is to describe the intake rate in terms of the fraction of the total release that leaves the end of the pipe that's inventoried in the Toxics Release Inventory that will eventually make its way into some member of the population."



Traveling toxaphene. This insecticide, used primarily in the southeastern United States, is transported across North America and deposited from the atmosphere to the Great Lakes. The darker the region on the map, the higher its contribution of toxaphene to the Great Lakes. The number in each region is the percentage of total atmospheric loading that is due to toxaphene usage in that region.

Other Possible Applications

McKone and MacLeod predict that BETR North America may be an effective tool in assisting states, regions, or even nations in fostering greater understanding of pollution consequences and perhaps more effective regulatory activity. "[The model] really does allow you to look at the reach of pollutants," McKone says. "I think that will have ramifications for things like transboundary pollution, which has always been an issue even state to state. [The transboundary pollution issue] came up with acid precipitation, but it hasn't come up with persistent pollutants."

MacLeod points to the toxaphene study as a good example of how the BETR North America model can enlighten policy makers. "One of the incentives for looking at toxaphene was that people were perplexed by what was apparently a 'stickiness' to these concentrations—you institute severe restrictions on a chemical that you are concerned about, and you don't see continued improvement in environmental quality," he says. "But what the model says is that the improvements are happening; it's just that once you eliminate the local sources, the concentrations in the whole environment start to become influenced by these larger-scale processes that are going on." MacLeod thinks that in terms of encouraging governments and individuals to support programs to regulate chemicals, the model will be very valuable. "It will show you in a tangible way what kinds of benefits you're going to get from taking this action right now," he says. "And it encourages the idea that you have to cooperate internationally."

Tim Watkins, an assistant laboratory director at the U.S. Environmental Protection Agency's National Exposure Research Laboratory in Research Triangle Park, North Carolina, has studied and discussed BETR North America at length and concludes that it has potential use in many different applications in one of the areas he works in: developing a strategy for tracking trends of persistent toxics in the environment. Models are nothing new at environmental agencies. But according to Watkins, the model's multimedia framework is something new that offers certain advantages over other model types. "Any attempt to draw connections between air and water and between water and soil are of potentially great benefit, I think, because linking those different compartments is a tough nut to crack," he says.

Does BETR North America hold promise as a global tool? Perhaps. MacLeod says that the Berkeley–Trent team has already begun work on a global application for the model. But the task is a big one because political realities as well as differences in data collection and monitoring in different parts of the world pose serious problems. "For North America, it's not that difficult because Canada and the United States have existing databases for the environmental parameters that we need—things like rate of rainfall and river flow rates and weather data," he says. "But when you extend the model to Africa and China and the former Soviet Union, the data quality and quantity aren't as good, and gathering this data becomes a much bigger task."

But as McKone points out, at a time when some people believe that the biggest threat to the quality of California's air may soon be China's emissions of persistent pollutants, global air pollution is an increasingly serious issue. BETR North America, he says, can be an effective tool in helping policy makers understand the problem.

"It does provide an opportunity to do some scenario development," he says, "like, what happens with rapid industrialization in Mexico along the border if there are lots of new emissions of hundreds of organic chemicals? How will that affect the United States? I think it has a certain benefit as a tool for policy makers to look at those sorts of problems."

Richard Dahl

Suggested Reading

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Matt MacLeod, Matt Ray/EHP