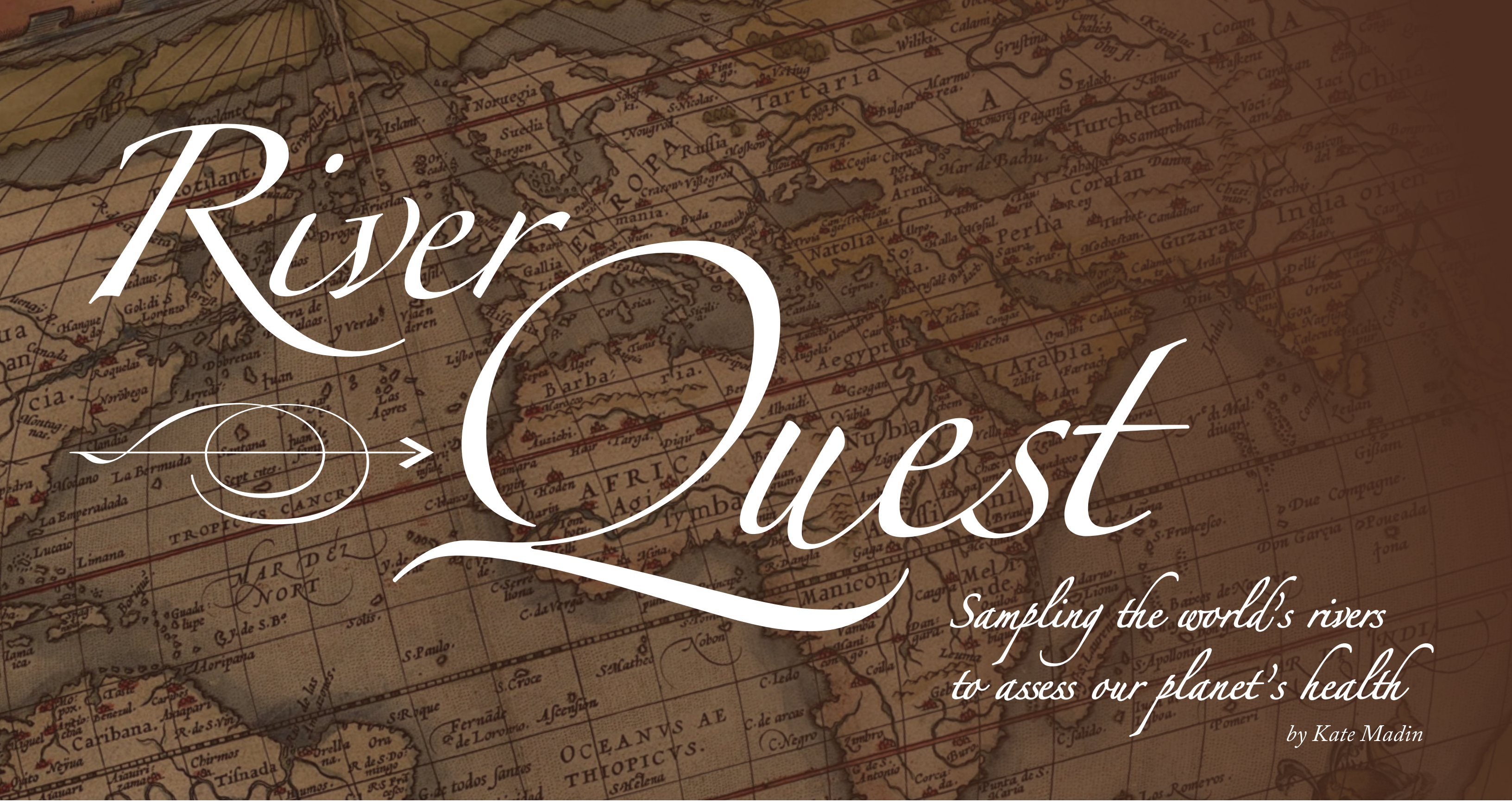

River Quest

Sampling the world's rivers to assess our planet's health

by Kate Madin

Max Holmes and Bernhard Peucker-Ehrenbrink spend a lot of time upriver—one day bundled in a parka on the icy banks of the Fraser River in Canada, another day paddling in small dugout canoes called pirogues through jungles along the steamy Congo River.

"Usually I think I have the most incredible job on Earth," said Holmes, "and other times I think it's the most miserable. In the Arctic, the thickness of the bugs around you is unbelievable. We've got clothing covering everything we can cover, even our heads, so we're hot, and we're sweaty. We spray all our clothes with DEET. It holds 'em back a little. If we weren't here, I guess they'd have to go look for a moose."

The two have teamed up to lead the Global Rivers Observatory project—fanning out with students, collaborators, and citizens to sample the world's major rivers and analyze their chemical makeup.

"We're interested in how disturbances influence the chemistry of the rivers," said Holmes, an Earth systems scientist at Woods Hole Research Center (WHRC). "And we're interested in what the chemistry of the rivers can tell us about what's happening in the watershed areas through which they flow."

A lot has been happening along rivers in recent decades, and at a rapid pace. Human activities—deforestation, dams, mining, manufacturing, sewage, livestock wastes and fertilizers from farming—disturb river flows and add chemicals to rivers and the coastal oceans they flow into. Meanwhile, climate change and rising temperatures are melting glaciers, altering the planetary water cycle that delivers rainfall, thawing frozen permafrost, raising water temperatures, and threatening to cause other significant impacts on rivers and the ecosystems around them.

"We need to do this research now," said Peucker-Ehrenbrink, a geochemist at Woods Hole Oceanographic Institution (WHOI). "Now is the period of change. We are conducting an experiment on our planet: Population growth, erosion, pollution, and temperatures have all been going up and will continue to go up for a couple of decades. It's a unique opportunity to understand how the surface of our planet responds to those changes"—and to find ways to mitigate the threats or adapt to the changes.

'River doctors'

Incised across continents, river systems are a key component of the planet's circulatory system, acting much like veins in our bodies. Like the blood in veins, river water also transports a variety of chemical compounds, from nutrients to waste products. As veins deliver blood back to the heart, rivers carry water through watershed lands back to the sea. Through various seasons—winter and summer, rainy and dry—river flows rise and fall, like a planetary pulse.

"Just like when a person goes to get a physical, and the doctor takes a blood sample and analyzes the blood to learn something about the health of the person, we do a similar thing on rivers," said Holmes. "We collect water and measure the chemical composition of that water, and that can tell us something about the health of the river and its tributaries."

"Hydrologists find out how river flow changes with the seasons, which is equivalent to doctors taking your pulse to find out the blood pressure," said Peucker-Ehrenbrink. "Then we follow up with the equivalent of doing internal medicine and blood work. Both are necessary to know the health of the patients."

In this case, the patients are the watersheds through which the rivers flow, and their conditions are changing rapidly. The researchers fly across the globe with students and colleagues, WHOI geochemist Bernhard Peucker-Ehrenbrink (left) and graduate student Britta Voss sample water from the Fraser River in British Columbia. Their work is part of an ambitious effort, co-led by WHOI and Woods Hole Research Center, to analyze the chemical makeup of Earth's major rivers, which are experiencing rapid changes caused by climate shifts and human activities such as dams, mines, and logging.

packing plastic jugs, bottles, beakers, tubes, poles, filters, and a bicycle pump. Then they pile into buses, vans, canoes, or boats, sometimes with armed guides, to help them reach the rivers they want to sample.

The seeds of the project germinated when Holmes worked with Marine Biological Laboratory scientist Bruce Peterson studying the changing ecology and biogeochemistry of several Arctic rivers. The project expanded when Holmes and Peucker-Ehrenbrink combined their approaches into "a happy marriage," they said—with Holmes sampling a few rivers repeatedly and Peucker-Ehrenbrink taking single samples from as many rivers as possible.

So far, Global Rivers Observatory researchers have worked on rivers that span a range of climates, soils, and population conditions: the Kolyma, Lena, Yenisey, and Ob Rivers in Russia, the Fraser and Mackenzie Rivers in Canada, and the Yukon River in Canada and Alaska—all ice-covered in winter; the Ganges, Brahmaputra, and Yangtze Rivers in Asia, whose flows are influenced by monsoonal rains; the Amazon in a tropical rainforest; the largely pristine tropical Congo River; and, most recently, the heavily populated and developed Mississippi. The list includes eight of the ten largest rivers on Earth.

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—Max Holmes

Downstream journeys

All river systems start in high country, where rain or snow falls on mountain rock. That's where the similarity ends.

Different elements dissolve into river water from the different rock types that each river flows over. Different climates produce different vegetation, whose decomposition introduces different chemical compounds. Agriculture, industry, and sewage add to the chemical soup.

Rivers carry a signal of all these inputs from the land to the coastal ocean, said Peucker-Ehrenbrink, and each compound, element, or ion has a story to tell about the rivers.

Major ions such as calcium, sodium, and silicon reveal the rock types in the rivers' watersheds. Carbon, nitrogen, and phosphorus compounds, from decomposed plants or from fertilizers or wastes, disclose the vegetation and land use along the rivers. Trace elements such as mercury, arsenic, and chromium provide information about natural soil types or industrial contamination. Water samples collected in the field are distributed to collaborators at WHOI, WHRC, and other institutions, where scientists specialize in analyzing different chemical compounds.

Identifying and measuring all these compounds is a complex,

Photos © Chris Linder

choreographed process. At WHOI, Britta Voss and Jerzy Blusztajn analyze strontium isotopes, and Alec Wang measures inorganic carbon, for example. WHRC scientists Rob Spencer, Paul Mann, and Kate Bulygina investigate dissolved organic matter.

The plan is to measure even more elements—"the whole periodic table," said Peucker-Ehrenbrink. WHOI engineer Chip Breier is building automated sampling instruments for the project. WHOI chemist Marco Coolen has begun analyzing DNA on particles filtered from river water to identify microbial populations and how they change over time and seasons. Tim Eglinton and colleagues at the Federal Institute of Technology (ETH) in Zürich, Switzerland, are examining radiocarbon ages of organic carbon compounds.

Carbon is a primary target for the scientists. It is a fundamental component in rocks, living things, fossil fuels, and the greenhouse gas carbon dioxide. Tracking how carbon compounds cycle between air, rock, water, and organisms reveals the interdependent workings of the planet's land, ocean, atmosphere, and life.

"You can imagine a tree high up in the Himalayas losing a leaf," said Peucker-Ehrenbrink. "That leaf extracted carbon from carbon dioxide in the air via photosynthesis. The leaf decomposes, becomes part of the soil, and some of its carbon gets flushed into the river and is dissolved in compounds in the water. Or the carbon attaches itself to a grain of sand, and the carbon is transported downriver. Other parts may not decompose entirely, and turn into what we call particulate organic carbon." These particles sink, flow downstream, or are eaten by animals and microbes, respired, and converted back to inorganic carbon dioxide that may end up in shells, sediments, or the atmosphere.

Different waters, different concerns

The diverse rivers are also windows into ongoing environmental processes that the scientists seek to understand.

Around Arctic rivers, for instance, slowly decomposing carbon-rich vegetation is locked in permafrost. But rapid Arctic warming may thaw the permafrost, hasten decomposition, and release large amounts of methane, a potent greenhouse gas that could trigger even greater warming. That, in turn, could cause more thawing that releases more carbon compounds into the rivers and into the Arctic Ocean, spurring even further changes to the ecosystem.

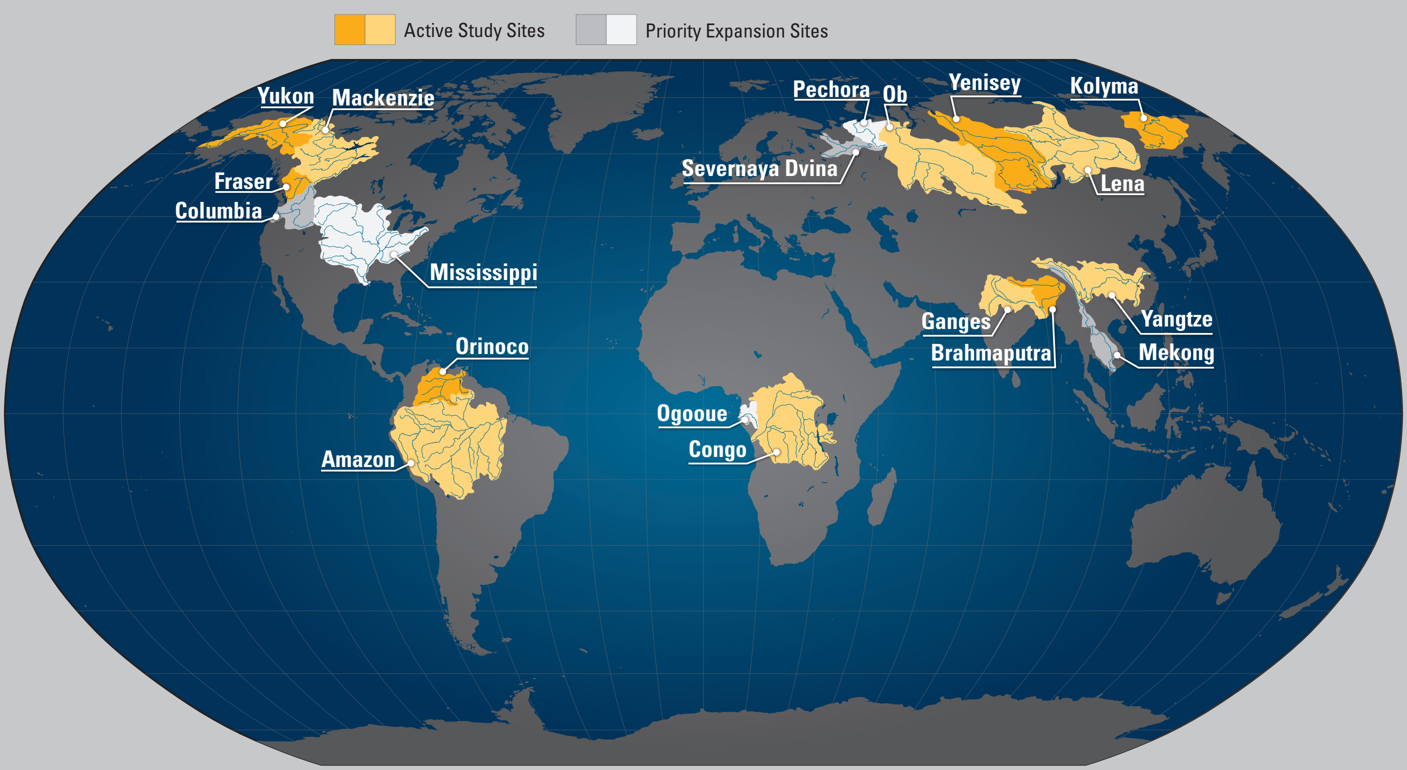
In the Ganges-Brahmaputra river system, sediments contain naturally occurring toxic arsenic. Will climate changes release more arsenic into rivers and groundwaters? How will anticipated changes in the monsoons affect the rivers? Farther east, how will the mammoth Three Gorges Dam affect the Yangtze River and coastal ecosystems downstream?

On the Mississippi, dams have reduced sediment flows to coastlines that are now eroding. The Mississippi also brings excess fertilizers from agricultural runoff to the Gulf of Mexico; every spring, this infusion of nutrients causes blooms of marine plants that deplete oxygen and create "dead zones" where no fish can live.

Along the Amazon and Congo River basins, unregulated mining and farming, and deforestation from logging, are increasing. Inevitably, these will cause changes to the rivers.

Global Rivers Observatory Sites

Global Rivers Observatory scientists have targeted major river basins from the tropics to the Arctic. Each river has its own characteristics, and each river faces potential changes. Arctic watersheds, for example, will experience thawing permafrost. The Amazon and Congo face deforestation from logging. A large new dam and changing monsoons will affect the Yangtze.



Watch the Multimedia Videos:
www.globalrivers.org/category/multimedia

A tale of one river

The Fraser River in British Columbia illustrates the interconnected complexities of climate effects.

"The Fraser has one of the world's biggest salmon runs and habitats," said Peucker-Ehrenbrink. "Salmon are kind of picky fish. They don't like water warmer than about 20°C [68°F]."

But tributaries to the Fraser are warming, and some already reach nearly 20°C in summers. Worse, mountain pine beetles are killing trees around the Fraser basin. Warming is to blame: Winters are less harsh now, and beetles survive unchecked to eat through the forest.

"British Columbia is losing probably 80 percent of its pine trees," said Peucker-Ehrenbrink. "When the trees aren't there anymore, the sun hits the ground, and the ground heats up. If the rain falls on that warmer ground, the water that runs into the tributaries and eventually into the Fraser will be warmer than before. Any further increase in temperatures could fundamentally change this basin and may threaten it as a salmon habitat. How will this place look 20, 30, maybe 40 years from now?"

Partners for the job

To accumulate this big picture of the planet's circulation system requires many partners.

"The partnerships vary," said Peucker-Ehrenbrink, "from large science institutions like East China Normal University to smaller institutions like the University of the Fraser Valley, where undergraduates sample the Fraser every other week. On the Congo, where they have little equipment and no reliable power, we pay people to sample for us. And on the Lena River, we work with schools. School kids drill holes in the ice to sample once a month in winter. We wouldn't be able to do that."

The scientists have promoted art projects with students who contribute paintings and drawings that illustrate their river's influence on their lives. Artwork from students near the Lena River has become an exhibition that has traveled to the United Nations, Washington, D.C., Russia, Poland, and Alaska.

An important part of the project is training people to sample rivers they live near (above). The scientists also provide "citizen scientists" with kits containing equipment and instructions to sample rivers (right).

Courtesy of Bernhard Peucker-Ehrenbrink, WHOI

The scientists are also enlisting "citizen scientists." Holmes and Peucker-Ehrenbrink created single-use sampling kits that they send to people living near or visiting rivers, with containers, bags, bottles, and directions on how to collect water. (See www.whoi.edu/rivergroup/volunteer.)

"They go do it once and send the sample," said Peucker-Ehrenbrink. "If they want to get more involved, we train them to do more sampling. We entice them to become local partners."

Another project goal is to create a repository to preserve samples of water and particles from tributaries of all the rivers sampled—an archive of the rivers' health before they changed.

"Water flows past and is gone," said Peucker-Ehrenbrink. "Maybe ten years from now, you want a sample of 2010 Fraser River water. Where do you go? How do you get it? We're archiving it as well as we can, as things are changing, to analyze in the future with methods we don't have or know about today. I would give a lot for a 1930 or 1960 water sample from the Mississippi! But it's gone.

"In 2100, we'll see that there was an urgent need to look at the transition time," he said. "If we miss that, if we miss doing the measurements and gaining understanding, we've done ourselves and following generations a real disservice—because that opportunity will not come back."

This research is supported by the National Science Foundation, the Harbourton Foundation, and the WHOI Coastal Ocean Institute.

SAMPLING

By day, scientists around the world collect water samples from rivers.

At night in their hotel, researchers filter water samples using a bicycle pump.

Britta Voss, WHOI

FILTERING

The filters separate out particles from the water.

Specimens are sent to collaborating labs.

WHAT ARE SCIENTISTS MEASURING?

Major ions from rocks dissolve into river water, telling the story of the lands through which the rivers flow.

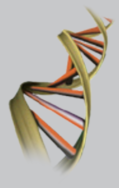
Nutrients composed of nitrogen and phosphorus compounds enter rivers from decayed plants, animal waste, sewage, and agricultural fertilizers. They reveal vegetation and pollution in the watersheds.

Trace elements such as heavy metals disclose information about the rivers' places of origin, the vegetation and soils they flow through, and the pollutants the waters pick up.

Carbon cycles through the Earth as a central component in rocks, living things, fossil fuels, and the greenhouse gas carbon dioxide. The carbon cycle links Earth's atmosphere, history, life, and climate.

Water isotopes, containing the naturally occurring "heavy" forms of hydrogen and oxygen, reveal where rain falling on watersheds came from. Heavier isotopes rain out nearer the sea; lighter isotopes stay longer in clouds, traveling farther inland.

Scientists are also analyzing **DNA** to identify microbes inhabiting rivers and see how their populations change with seasons or over time.



hydrogen H																	helium He
lithium Li	beryllium Be											boron B	carbon C	nitrogen N	oxygen O	fluorine F	neon Ne
sodium Na	magnesium Mg											aluminium Al	silicon Si	phosphorus P	sulfur S	chlorine Cl	argon Ar
potassium K	calcium Ca	scandium Sc	titanium Ti	vanadium V	chromium Cr	manganese Mn	iron Fe	cobalt Co	nickel Ni	copper Cu	zinc Zn	gallium Ga	germanium Ge	arsenic As	selenium Se	bromine Br	krypton Kr
rubidium Rb	strontium Sr	yttrium Y	zirconium Zr	niobium Nb	molybdenum Mo	technetium Tc	ruthenium Ru	rhodium Rh	palladium Pd	silver Ag	cadmium Cd	indium In	tin Sn	antimony Sb	tellurium Te	iodine I	xenon Xe
caesium Cs	barium Ba		hafnium Hf	tantalum Ta	tungsten W	rhenium Re	osmium Os	iridium Ir	platinum Pt	gold Au	mercury Hg	thallium Tl	lead Pb	bismuth Bi	polonium Po	astatine At	radon Rn
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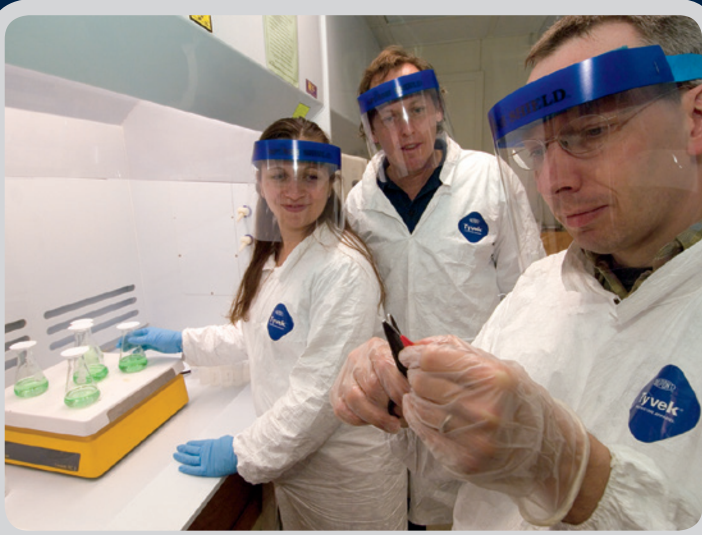
DNA Illustration by E. Paul Oberlander, WHOI

ANALYZING

Scientists in the labs measure a wide array of chemicals in the particles and dissolved in the water.



Tom Kleindinst, WHOI

ARCHIVING

River water samples will be preserved for future scientists to study.

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