Hot money. Researchers are gathering currency across Europe and testing its cocaine content.

CREDIT: BRETT PAULL/DUBLIN CITY UNIVERSITY

PUBLIC HEALTH

Hard Data on Hard Drugs, Grabbed From the Environment

Fieldwork in new and fast-growing areas of epidemiology requires wads of cash and a familiarity with sewer lines

BARCELONA—It's almost midnight when Fritz Sörgel and Verena Jakob walk into a chic cocktail bar. Still on the early side, the place is barely beginning to fill with the typical clientele of young, hip Spaniards. Installing themselves on low couches, the pair scan the drinks menu. "What I really want is a piña colada," says Sörgel with feeling. Returning from the bar, he looks defeated. "Only daiquiris."

You probably wouldn't guess that Sörgel and Jakob, environmental chemists who have been working since dawn, are still on the job. Indeed, despite the tragic absence of piña coladas, Sörgel gets what he's really after: Spanish bills in exchange for a crisp German €100 note. Jakob carefully squirrels away the change in a plastic tube. With the final sampling of the day done, they breathe a sigh of relief.

"It's so stressful always having to worry about the money," says Sörgel, director of the Institute for Biomedical and Pharmaceutical Research in Nuremberg, Germany. He's referring to the brick of new German bills worth €30,000 ($40,000) that Jakob, his Ph.D. student, has been carrying in a secret pocket under her shirt since they arrived in Spain a few days ago. (If it goes missing, the institute is out of luck, says Sörgel.) In a few days, they will have exchanged all of the German euros for Spanish ones. Back at the lab in Germany, they'll extract the chemical residues that have adsorbed to each bill—a process that destroys the money, but more on that later. Among the thousands of compounds that can be detected, Sörgel is looking for one: methylbenzoylecgonine, better known as cocaine.

It's been known since the mid-1980s that cocaine residue contaminates paper currencies, but Sörgel and others are taking advantage of a natural experiment that began in 2000 with the simultaneous introduction of the euro currency across Europe. Each country's circulating stock of bills is becoming contaminated with cocaine at a different rate.

Measuring cocaine on the money is part of a new effort to study the phenomenon of illicit drug use by turning to the environment. Epidemiologists have struggled to get a quantitative view of drug use for decades. But the traditional data—tons of drugs seized, the number of people seeking treatment for addiction, drug-related mortality, and responses to drug-use questionnaires—are biased and patchy, says Roberto Fanelli, a toxicologist at the Mario Negri Institute for Pharmacological Research in Milan, Italy. By interrogating the environment rather than the people, he says, "you can obtain data in real time" that are not only objective but also "rather affordable."

Follow the money

Money has a peculiar life of its own. When not folded into a wallet or crumpled in a pocket, the typical €20 bill can pass between hundreds of hands for about a year before getting recycled at a bank. In this time, it moves through every part of society, from the wealthy to the unemployed. But where most scientists see a symbolic unit driving social phenomena, Sörgel sees a cotton-paper filter ideal for sponging up chemicals. And because of the way that electrons are strung on cocaine's carbon frame, he says, it "binds perfectly to the fibers."

One explanation for the widespread contamination of paper currency is that cocaine is often snorted up the nose through rolled-up bills, and that sorting machines in banks cause cross-contamination. "We really don't know for sure yet," says Sörgel, but the evidence so far supports this story. In a typical sample of bills from European banks these days, he finds that the majority of euros carry detectable amounts of cocaine. Among the contaminated bills, about 1 in 20 is typically loaded with around 10 micrograms of cocaine, while the rest usually have a hundredth of that. (These amounts are minuscule compared with the typical 100-milligram line that goes up a nose.)

For 7 years, Sörgel has been playing the part of the annoying tourist, buying bottles of water with €100 bills in every European country, building a continent-wide map of cocaine use. There have been some close shaves on this trip, such as when Jakob was suspected of shoplifting because of a suspicious lump under her shirt—which was the money. (Sörgel managed to talk his way out of that one.)

Banks have at times been suspicious when Sörgel asks to exchange wads of bills for his "study of cocaine," but they also have been extremely helpful. The entire project would have been a nonstarter if a German bank had not agreed to redeem the entire €30,000 after laboratory testing. The cocaine is detected using a device called a mass spectrometer, but the first step is a methanol bath to extract the chemical residues. That makes the bills look crisp and clean at the end, but it also loosens the metallic foil used to check against counterfeit money. Sörgel exchanges the bills for crisp new money, and the bank recycles the treated bills.

Although Sörgel's study of money is the biggest and longest-running, it is not the only one. Parallel projects are under way elsewhere

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in Europe, and the collective data are adding up to a worrying picture. In Ireland, for example, "people have been in denial that there's a cocaine problem," says Jonathan Bones, an environmental chemist at Dublin City University (DCU). But he and fellow DCU chemist Brett Paull have been finding some of the highest levels of cocaine contamination on euros from Dublin's banks. In one case, 100% of a sample of 45 bills was coated in cocaine. They have recently analyzed a sample of 75 bills and again found them all to be contaminated.

The main advantage of using money is that it's quick and dirty: Instead of running around an entire country to get data, "the money does it for us," says Sörgel. Paull is confident that his data are at least a "warning light" that Ireland has a serious drug problem, but he says that many unknowns make it difficult to translate the data into quantitative statements about drug use. He and Bones are trying to nail some of them down. For example, to put a rate on the natural degradation of cocaine on money, Paull and Bones are spiking euro bills with varying amounts of pure cocaine and incubating them under controlled conditions.

One encouraging fact is that the rank of average amounts of cocaine found on euros from different countries roughly matches the ranking of national drug problems by the E.U.'s traditional survey-based statistics. Spain is in the lead, followed closely by Italy, with Ireland now catching up.

But tracking contaminated money is only one part of the epidemiology story. After cocaine enters the nostril of a drug user and messes with the brain's chemistry for about an hour, it is modified by enzymes in the liver and washed out of the blood by the kidneys. You can guess where it ends up next.

The sewers don't lie

One morning last month, Sörgel and Jakob went high up on a narrow, winding road in the Sierra Nevada mountains, dodging villagers and wood-hauling donkeys to reach the pristine, presumably cocaine-free snowmelt streams that feed the Spanish city Granada to the south. At a small bridge over a glassy brook, they dangled a plastic-lined net into the water, bringing up two samples that Jakob sealed in bottles and labeled. From there they sampled their way back down to Granada, following the Genil River as it wends through suburban sprawl, arcs through the city center, and there meets the two municipal wastewater treatment plants. For their final samples, Sörgel dipped right into the output of one of these plants, a trickle in a scummy gulley.

Sörgel aims to administer a drug test to the entire city. The metabolic byproduct of cocaine, benzoylecgonine, is chemically unique in the environment and breaks down slowly. Using the mountain stream water as his baseline, he can estimate the amount of cocaine that passes through the entire population. Repeating the procedure at intervals should reveal drug consumption in a fixed geographic area in full detail, from seasonal dips to weekend spikes.

Check the source. Researchers in Spain aim to drug-test an entire city.

CREDIT: J. BOHANNON/*SCIENCE*

Fanelli pioneered this technique in a 2005 study of water from the Po River near Milan. His group was studying the persistence of legal pharmaceuticals in the aquatic environment, he says, "but then we realized that we could detect other drugs as well." It is "completely proven" that cocaine can be detected in the environment, he says, and now the more difficult task is "how to use these data for drug epidemiology." Translating a minute and fluctuating signal in the environment to its ultimate source requires many assumptions, he says, "such as the percentage of the cocaine that is metabolized in the body and the amount that is degraded before it reaches the sampling site."

European researchers say they are putting the technique on firm experimental ground. Sörgel notes that about a ton of cocaine is seized annually in Germany, a country thought to have a "moderate" drug problem compared to others in Europe. Based on his sampling from rivers and wastewater at 29 locations across Germany, he estimates that Germans now consume on the order of 20 tons of cocaine per year. Sörgel's data suggest an upward trend, and indeed, the country's traditional indicators of drug abuse have all increased in recent years. "The methods are working," he says.

Fanelli has now hunted for cocaine residues in the wastewaters of London and of Lugano, Switzerland, a popular party destination for Italian tourists. He estimates that London's daily cocaine consumption is on the order of 1 kilogram for every 1 million people. He says this "reasonably translates" to cocaine use among 4% of Londoners 15 to 30 years old. Official estimates put that figure at 2%. "So we know we're close to the real figure," he says. Fanelli's team found similar per capita cocaine loads in Lugano's wastewater, but there they also extended the sampling over several months, revealing the variation by day of the week. Monday was consistently the low point of cocaine consumption, says Fanelli, whereas weekends were typically 30% to 40% higher than the weekday average, and sometimes double that.

U.S.-based researchers are hot on the trail as well, but some are running into barriers. Jörg Rieckermann, an environmental chemist at San Diego State University in California, has won a research grant from the Swiss National Science Foundation to survey cocaine contamination in wastewater. He selected San Diego for his analysis, but the city has forbidden him from taking samples.

Controversy has been brewing since September 2006, when city politicians learned that a representative of the White House's Office of National Drug Control Policy (ONDCP) wanted samples of San Diego's wastewater. ONDCP press secretary Jennifer de Vallance said that the study started about a year ago and is costing the office about $20,000. Samples have been collected from about 100 participating wastewater facilities across the United States, she says, generating about 500 samples, which are being analyzed at the Office of the Armed Forces Medical Examiner in Rockville,

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Maryland. Others have heard about ONDCP's project. "People from the White House contacted me soon after my 2005 study of the Po River," says Fanelli. "They plan to sample wastewater from 100 sites and publish a report."

If public concerns can be overcome and these methods can be scaled up to monitor "several thousand" wastewater treatment plants across a country, says Fanelli, "sewer epidemiology" will become a field in its own right. But several technical hurdles must first be cleared. For one, researchers use slightly different methods. Whereas Sörgel uses upstream river water for control samples, Fanelli uses sterile, deionized water. "Those differences can have significant effects on the results," says Sörgel, so "standardizing the methods is critical."

Beyond the lab, sewer epidemiologists will need the help of social scientists to draw meaningful conclusions from their data. Computer models already track shifts in crime patterns, income, and pollution in large urban centers—as well as the daily flow of water through pipes and sewers. Plugging in environmental drug data could allow researchers to "score" communities in terms of "drug-abuse levels," says Barbara Tempalski, a social geographer at the Center for Drug Use and HIV Research in New York City. And hunting for correlations between drug load and other social, public health, and economic factors may reveal useful risk predictors that so far have been obscured by the noise in the available data. "Finding the hot spots of drug consumption can let us focus resources in the right places," says Fanelli.

"I have no doubt that these data are meaningful," says Norbert Frost, chief drug epidemiologist at the European Monitoring Centre for Drugs and Drug Addiction in Lisbon, Portugal, "but we must bring this to the next level, where the techniques are standardized and producing peer-reviewed reports."

The first formal opportunity to compare notes will come later this month. Frost is gathering a small group of international drug-abuse researchers from various fields in Lisbon on 16 April to discuss environmental drug monitoring, the first meeting of its kind. It will be "an open discussion," says Frost, covering everything from analytical techniques to integration with the social sciences.

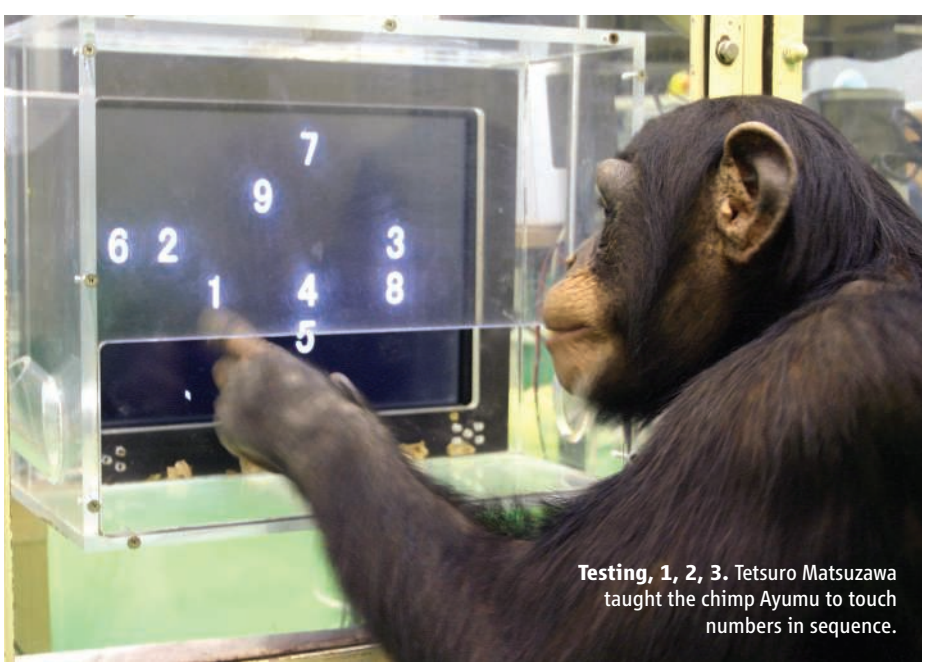
–JOHN BOHANNON

ANIMAL BEHAVIOR

The World Through a Chimp's Eyes

A novel meeting assembled the world's leading thinkers about chimp culture, tools, cooperation, reasoning, and other heady topics

CHICAGO, ILLINOIS—It's not every day that a scientific meeting opens with a roomful of eminent researchers pant-hooting like chimpanzees, but then "The Mind of the Chimpanzee" conference held here at the Lincoln Park Zoo last week marked a rare occasion in itself. For only the third time in 20 years, the zoo hosted a meeting that brought together researchers who study chimpanzees in the wild and in the laboratory. And surprisingly, it was the first one to focus solely on the cognitive abilities of our nearest animal relatives. "It's amazing," said pioneering field researcher Jane Goodall, one of approximately 300 participants at the meeting. "We're talking about things now that I couldn't talk about in the '60s. We couldn't even talk about the chimpanzee mind because chimpanzees didn't have one."



Testing, 1, 2, 3. Tetsuro Matsuzawa taught the chimp Ayumu to touch numbers in sequence.

CREDIT: TETSURO MATSUZAWA/KYOTO UNIVERSITY

The meeting, held from 23 to 25 March, covered a broad range of topics from cooperation and communication to tool use and culture, experimental design, and conservation of this endangered species. "It's a whole different quality of science from the exciting cowboy era of maybe 2 decades ago," said Richard Wrangham, an anthropologist at Harvard University who for 20 years has studied wild chimps in Uganda's Kibale Forest. "It's a sign of a maturing field. You have technical brilliance and tremendous innovation in a wide range of areas."

The cumulative effect of the talks—many of which included videos that few people had seen—powerfully demonstrated that new insights are continuing to redraw the dividing line between "us" and "them." And one clear theme emerged from the blending of laboratory and field studies: More effort than ever is being made to perceive the world the way that chimpanzees do, as opposed to simply asking how closely their behavior mirrors our own.

Beyond compare

After the zoo's Elizabeth Lonsdorf, a conference co-organizer, kicked off the meeting by having the participants give each other a "proper chimp greeting," she introduced Kyoto University's Tetsuro Matsuzawa, one of the few researchers who studies both wild and captive chimpanzees. Matsuzawa's talk kept the audience participation level high, eliciting loud "oohs," "ahhs," and guffaws. Matsuzawa described the numerical skills of a chimpanzee named Ai and her son Ayumu, who live at the university's Primate Research Institute in Kyoto. Building on work he first reported in *Nature* 7 years ago, he showed videos of Ayumu using a touch-screen monitor to select the randomly displayed numbers 0 through 9,

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