generator wall can be avoided. Other potential problems include plasma instabilities in the ionized gas arising from interactions between the flow and the magnetic field; corrosion of the generator walls or of the air heater by coal ash may also present difficulties.

Several generator designs have been proposed, but not yet tested, to overcome these problems. In the Avco design, coal ash will be deliberately allowed to condense on the generator walls, building up a protective layer that R. T. Rosa of Avco believes will keep seed material from shorting the electrodes. Research groups at the University of Tennessee Space Institute in Tullahoma, Tennessee, at Stanford University in California, and at the Westinghouse research laboratories in Pittsburgh, Pennsylvania, have proposed still other designs. For example, the Westinghouse team, headed by Stuart Way, prefer a design with hotter wall temperatures that will prevent ash buildup; Way believes that cleaner fuels than coal—such as char, which is produced as a byproduct in coal gasification plants—may ultimately be preferable for MHD. But there appears to be general agreement that the problems can be solved, and that long-term testing and further experience with a pilot plant will be necessary to arrive at the best design.

Perhaps the most promising aspect of MHD power generation is the potential environmental advantages of these plants over traditional coal burning plants. Experimental work directed by Daniel Bienstock at the U.S. Bureau of Mines laboratory in Pittsburgh, Pennsylvania, has confirmed that the seed particles react with sulfur to form potassium sulfate or similar compounds which are relatively easy to precipitate (*1*). Because the alkali particles are recovered from the exhaust gases by cloth traps or electrostatic precipitators—indeed, must be recovered and recycled for economic reasons—essentially all the sulfur can be removed from even high-sulfur coals.

Nitrogen oxide emissions, which at one time were expected to be a problem because of the high temperatures in MHD plants, can also be reduced, Bienstock finds, if the coal is burned in a fuel-rich mixture and excess air is added further downstream. Work at Avco and in Japan has confirmed the Bureau of Mines results. Detailed calculations at Avco of the kinetics of the nitrogen oxide production and consumption indicate that the temperature and composition of the combustion gases can be controlled to reduce $NO_x$ concentrations to acceptable levels.

If the predicted efficiencies can be achieved, and several independent analyses of the potential of MHD indicate that they can be (*2*), thermal pollution resulting from discharge of waste heat into cooling water would be reduced substantially, and would be less than that arising from any existing power plant. If gas turbines were used as the second half of an MHD power plant, the steam cycle and the need for cooling water could be eliminated.

Reliable estimates of the cost of MHD plants are not yet available, although there appears to be general agreement that construction costs should be approximately the same as those for traditional coal-fired plants and that, because of the more efficient use of fuel, operating costs per kilowatt would be significantly lower. The cost of the magnets is the largest single item, and the air preheaters are also expected to be expensive. Hence reductions in the cost of superconducting magnets or the cost of oxygen, which by enriching the fuel mixture would reduce the preliminary heating and hence the cost of the equipment, could further improve the prospects for this source of power. Developing the technology will be neither cheap nor without some financial risk, so that in the absence of substantial federal funding—which has not been forthcoming; current R&D spending is at the rate of about $3 million per year—only limited progress can be made. Both demonstration and commercial power plants will probably have to be large, because the power output of an MHD generator increases in proportion to its volume, while most of the losses increase in proportion to its surface area; 100 Mw is estimated to be the smallest size feasible for a plant that does not use oxygen enrichment.

The use of coal or fuels derived from coal to generate electricity carries with it the high cost to the environment and to human health that is associated with the mining of coal. But this energy source will not be replaced overnight; indeed the production of coal is expected to increase in coming years, so that efforts to improve the use of this fuel would seem well worthwhile. MHD generating plants would, at the very least, diminish the impact of mining by producing equivalent amounts of power with less fuel. What appears to be needed, as one proponent put it, is to "give MHD a chance."

—ALLEN L. HAMMOND

**References**


1. D. Bienstock, R. J. Demski, J. J. Demeter, "Environmental Aspects of MHD," in *Proceedings of the 1971 Inter-Society Energy Conversion Engineering Conference* (Society of Automotive Engineers, New York, 1971).
2. "Open Cycle Coal Burning MHD Power Generation: An Assessment and a Plan for Action," Report of the MHD Power Generation Study Group, Massachusetts Institute of Technology (U.S. Government Printing Office, Washington, D.C., 1971).


*Speaking of Science*

## Frog Shortage Possible This Winter

The acute shortage of gravid (egg-bearing) female *Rana pipiens* that occurred last winter will probably be repeated this year, according to Frank Nace, director of the University of Michigan Amphibian Facility at Ann Arbor.

Large numbers of frogs died during hibernation last winter, primarily from septicemia. The total number of dead is unknown, but three major dealers in the western United States, for example, lost more than 90 percent of their stock. Normally, some 15 to 20 million frogs are used each year for research and educational purposes.

Although the cause of last winter's epidemic is not definitely known, Nace suggests that an unusually large spawning in the spring of 1971 and a drought that summer depleted the frogs' food supply. Most of the frogs thus went into hibernation in a state of semistarvation and were particularly susceptible to bacterial infection.

Preliminary indications from the fall migration collections now in progress suggest that a high mortality rate can be expected again this year. Although the shortage will probably be less severe, he adds, "investigators who need gravid animals should order their winter supplies immediately." At least one major dealer contests this view, however, arguing both that enough frogs will be available and that dealers are better able to maintain them during hibernation.—T.H.M.




MONS 085210

# Polychlorinated Biphenyls: Still Prevalent, but Less of a Problem

The presence and danger of polychlorinated biphenyls (PCB's) in the environment is not yet a dead issue, but it is one that appears to be dying quite rapidly. Despite mounting evidence of both the omnipresence and toxicity of this widely used chemical, governmental and industrial curbs on its use have largely halted its influx to the environment, and the potential for ecological damage appears to have been averted.

PCB's have been detected in fish, wildfowl, foods, and highly polluted waterways (*Science*, 14 January, p. 155). New evidence presented at the 164th national meeting of the American Chemical Society, however, suggests that PCB's have pervaded the environment to a much greater extent than was previously suspected.

Gerald W. Bowes of the Canadian Wildlife Service, Ottawa, Ontario, for example, has found PCB's in tissues of polar bears and seals captured throughout northern Canada, including locations well within the Arctic Circle. In these nonmigratory bears, he notes, the concentration of PCB's was greater than the combined concentrations of the organochlorine pesticides DDT and DDE. In the United States, the U.S. Geological Survey has found PCB's in water and sediment samples from 17 of 39 states examined. Hans J. Crump-Wiesner of the USGS says that concentrations of PCB's in water samples ranged from 0.1 to 4.0 parts per billion (ppb), and that such residues were detected even in newly developed real estate lakes and at two USGS field stations far removed from industrial sources. Bottom sediment samples contained PCB concentrations as great as 3.2 ppm.

The Food and Drug Administration has detected PCB's in nearly 20 percent of some 3500 samples of fish, milk, eggs, and cheese examined during the past 18 months, according to Albert C. Kolbye, Jr., deputy director of FDA's Bureau of Foods. More than 54 percent of fish samples contained detectable amounts of PCB's, as did 29 percent of egg samples. Only 6 percent of cheese samples and 7 percent of milk samples contained detectable amounts, however. The average PCB concentration in a normal U.S. diet, Kolbye adds, is only about 10 percent of FDA's interim safety level of 5 ppm.

More important, Anne R. Yobs of the Environmental Protection Agency's Office of Pesticides Programs, Chamblee, Georgia, reported that PCB residues were found in 54.3 percent of 2189 human adipose (fatty) tissue samples collected in 18 states and the District of Columbia. More than two-thirds of the positive samples contained at least 1 part per million (ppm). PCB levels greater than 1 ppm, she says, were found in approximately twice as many males as females, and in three times as many whites as nonwhites but statistical evaluation of the results has not been performed because the study is still in its preliminary stages.

### Toxic Effects in Other Species

There is no evidence to suggest that these amounts of PCB's have any toxic effects in humans, but the toxic effects of amounts found in other species have been amply demonstrated. Mink, for example, are highly susceptible to PCB's. Robert K. Ringer of Michigan State University, East Lansing, has shown that PCB levels of 5 ppm in the food of minks completely halts their reproduction. This concentration is comparable to that in many Great Lakes fish—particularly coho salmon—that are used as food by the large mink industry in the area. Mink ranchers have thus been forced to more expensive ocean fish, poultry, and meat by-products, Ringer says, and the infant Great Lakes coho industry has been devastated.

Chickens are also affected by PCB contamination. Helene C. Cecil of the U.S. Department of Agriculture's Agricultural Research Service, Beltsville, Maryland, has found that the hatchability of chicken eggs declines drastically when hens are fed a diet containing PCB's at 20 ppm. After one group of hens had been fed such a diet for 5 weeks, for instance, only 8 percent of their fertile eggs hatched. More than a third of the embryos in the unhatched eggs, she adds, exhibited teratogenic abnormalities such as crossed beaks, rotated ankles, or edema. This poor hatchability was observed only with PCB's containing 32 to 54 percent chlorine, however; little or no effect was observed with those containing either 21 or 68 percent chlorine. Hatchability was restored when PCB's were removed from the hens' diet.

Many estuarine organisms are killed by low concentrations of PCB's, according to DelWayne R. Nimmo of the EPA laboratory in Gulf Breeze, Florida. Populations of the ciliate *Tetrahymena pyriformis*, one of the first links in the fish food chain, are significantly reduced within 96 hours by exposure to 1 ppb of PCB in water. Nimmo also finds that at least three species of fish and one species of shrimp die in water containing 5 ppb, and that the growth of one species of oyster is reduced. Foster L. Mayer, Jr., of the U.S. Department of Interior Fish-Pesticide Laboratory in Columbia, Missouri, has found similar results for invertebrates that are part of the food chain for freshwater fish.

Despite the ubiquity and toxicity of PCB's, the problem of their presence in the environment is "fairly well in hand," contends EPA deputy research director John Buckley. All of the answers about PCB's are not yet known, he concedes, but current regulatory actions seem adequate to deal with the problem, and the amount of PCB's in the environment should soon start declining.

Earlier this year, for example, EPA issued waste disposal restrictions designed to keep PCB levels below 0.01 ppb in rivers and streams. Shortly thereafter, the FDA prohibited the use of PCB's in materials used for food containers and for any application in food processing plants.

Most important, perhaps, the Monsanto Company of St. Louis, Missouri—the only U.S. producer of PCB's—has voluntarily discontinued sales of PCB's for uses that might allow the chemicals to enter the environment. Virtually the only remaining use of PCB's in this country will be as insulators in electrical transformers and capacitors, an application for which no acceptable substitutes are available. And even in these applications, Buckley says, the principal components will be the less highly chlorinated PCB's, which are certainly the least persistent and now appear to be the least toxic.

—THOMAS H. MAUGH II

MONS 085211