compromising public statements and blunt diplomacy on the nuclear proliferation issue may have had just the opposite of their intended effect. The Brazilian nuclear power program, which was going nowhere fast and might have faltered from its own internal difficulties and high cost, now seems certain to continue. To stop it now would be to appear to bow to U.S. pressure, a posture that would be both politically difficult for the Geisel regime and contrary to the country's growing national pride. Brazilian officials also seem to hope that similar considerations will apply in West Germany and have been talking publicly about that country's reputation for keeping its promises.

Veteran observers recall the earlier and equally blunt efforts of the Johnson Administration, which in 1967 sent U.S. Atomic Energy Commission Chairman Glenn Seaborg to convince Brazil that it should sign the nonproliferation treaty, with much the same result. The political opposition and the academic community rallied behind the government's refusal to sign the treaty.

Yet the West German–Brazilian agreement, under which eight large nuclear reactors and a uranium enrichment facility that could in theory be used to make the material for nuclear weapons are to be built by 1990, will severely tax Brazil's resources. One of the major problems in Brazil, as in other developing countries, is a severe shortage of skilled manpower; and the nuclear program will need thousands of technicians and engineers capable of dealing with a sophisticated technology. These people will have to be trained nearly from scratch—the program calls for training 9000 in 6 years, half with advanced degrees, with West German help—which will make an unprecedented demand on the country's narrow and already strained base of technical expertise. Foreign exchange is also

Will Fertilizers Harm Ozone as Much as SST's?

The Berkeley physical chemist who first proposed that nitrogen oxide exhausts from supersonic transport planes (SST's) might hurt the earth's protective ozone layer now says that nitrogen fertilizer—upon which the world depends for an adequate supply of food—could be just as harmful over a period of 160 years and more.

In an article which has been accepted for publication by the *Journal of Geophysical Research* and which has also been submitted as a chapter in a report of the National Academy of Sciences, Harold S. Johnston, of the University of California at Berkeley, estimates that the ozone layer, which protects life on earth from the hazards of ultraviolet radiation including skin cancer, would be reduced by 12 percent after 160 years as a result of human use of fertilizer. In 1971, Johnston estimated that ozone could be depleted by 3 to 23 percent by a fleet of SST's: the hypothesis was supported by later research and played an important role in the eventual U.S. decision not to build a fleet of SST's.

This new ozone threat has arisen as a result of the ever-increasing use of nitrogen fertilizer worldwide. Nitrogen fertilizer is widely used to increase the yields of crops used for food and livestock fodder. However, when in the soil, the nitrogen in fertilizer undergoes a process called denitrification, in which nitrogen is reduced to gases, mainly nitrous oxide (N_2O). In the atmosphere, N_2O behaves similarly to the controversial, ozone-threatening aerosols from spray cans, the chlorofluorocarbons (CFC's). In the lower atmosphere they are inert, but in the upper atmosphere they become a catalyst for the destruction of ozone.

In a conclusion to his paper which appears in the academy of sciences' version, Johnston goes on to compare nitrogen fertilizer with the two other more widely studied threats to atmospheric ozone: SST's and CFC's. He writes that, if the use of fertilizer continues its exponential increase, it would destroy the ozone layer by 15 percent over a period of a century or more—whereas over a comparable period, a fleet of 500 SST's would destroy it by only 13 percent. And, if fertilizer use were somehow held to 1974 levels, it would still destroy ozone by 6 percent over a 50-year period—or be almost as harmful as CFC's, which at 1974 levels would destroy 7 percent.

Johnston's paper draws attention to the least studied, but most challenging, of the ozone threats scientists have discussed so far—a problem which makes the issues surrounding ozone destruction by SST's and aerosols look simple. Johnston's paper stresses the many uncertainties to be resolved about nitrogen fertilizers, and their role in the environment. But, as he explained to *Science*, his aim was to define all the variables so that soil scientists, agronomists, and other specialists in the various related disciplines are going to have to study. For example, it is not known what fraction of fertilizer undergoes denitrification, how long N_2O remains in the atmosphere, or whether the oceans contribute most of the N_2O found in the atmosphere.

Such a survey of the problem has been hampered by vigorous disputes among those few scientists who have looked at it. Paul Crutzen of the National Center for Atmospheric Research estimates reductions of only a few percent; Michael McElroy of Harvard has estimated reductions of "more than 10 percent." Johnston reviewed these and other supposedly conflicting research findings and concluded that indeed the problem is an important one and that the depletion levels so far estimated by others are "all in the same ball park."

The fertilizer-ozone problem is also going to be politically complicated. It goes without saying that fertilizers are far more integral to civilization than either spray cans or SST's. In 1950, the world consumed only 2 megatons of nitrogen fertilizer; by 1960, world use jumped to 9.7 megatons; thereafter, usage jumped—what with the Green Revolution spreading fertilizer over developing countries and developed, major grain producers such as the Soviet Union increasing their fertilizer use. In 1974, the world was consuming some 40 megatons of nitrogen fertilizer, and by the year 2000, that figure is expected to be anywhere from 120 to 300 megatons. Many scientists, including Johnston, assume that fertilizers will become the single major source—man-made or natural—of atmospheric N_2O within decades.

"Obviously if the choice is between eating and some long-term cancer risk, people are going to choose to eat," he says, noting that recycling of fertilizer and more organic farming might be partial answers. Another partial solution might be to cut back even more on other things that threaten ozone, things Johnston calls "more trivial, like spray cans and SST's."—DEBORAH SHAPLEY