ENVIRONMENT

Under the Rug

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Cover: Filmstrips showing a malfunctioning deep disposal well. See page 8.

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This 135-foot water spout erupted in late 1968 near Marshall, Michigan and blew steadily for 24 days. The eruption occurred one-half hour after an oil-drilling rig hit an unexpected high-pressure zone underground and was quickly shut-in (temporarily sealed) at the surface.

Oil and Gas Journal, Tulsa

By David M. Evans and Albert Bradford

Under the Rug

THE IRONY OF RECENT pollution laws is that they stop at our feet. The Water Quality Act of 1965 and the Water Pollution Control Act of 1966, two of the most important, are devoted almost exclusively to protection of surface water — lakes, rivers, and streams — and other legislation is aimed primarily at controlling air pollution and preventing the disfiguring of the countryside.

Few states regulate in any specific way what substances go underground. Rapidly increasing numbers of industries and government agencies are taking advantage of this gap in control laws and are now dumping their toxic wastes below the ground through deep injection wells. Such wells are usually cheap to build and operate compared with the cost of cleaning up wastes or storing them. But although the deep-well method saves money for industry, it offers only temporary safety from the many permanently toxic wastes being injected.

The changeover to deep wells is occurring more and more rapidly. Before 1960 there were no more than 30 known deep injection wells for industrial wastes; in 1965 there were about 60 wells, today there are 150 or more. One water pollution control official explained this activity by saying, "the closer we come to tough antipollution enforcement . . . the more wells will be built." He predicted that the number would double by 1971.

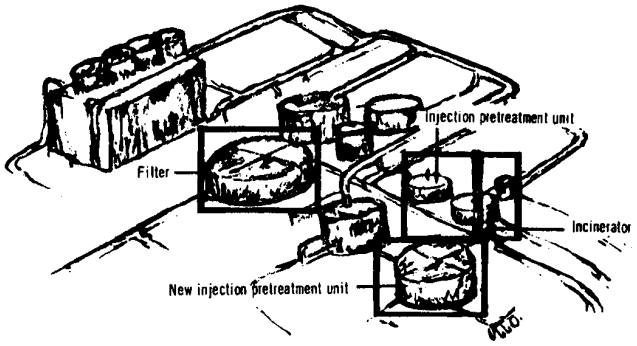
The industrial wastes which are already going down deep wells are extremely diverse, ranging from steroids and photographic chemicals to uranium tailings. Many wastes are highly toxic, such as organic phosphates, chlorinated hydrocarbons, steel pickling liquors, cyanides, and radioactive wastes. Several types of chemicals are often injected together into a single well, in numerous combinations. Many wells dispose of wastes which must first be filtered and otherwise treated to prevent clogging of the well or the permeable rock formation around it; these treatment systems are a major part of the cost of such wells. A properly equipped well 3,000 feet deep may cost over $200,000, the surface equipment making up at least 60 percent of the total.

Although even those experts who favor deep-well disposal say that it should be used only for concentrated wastes and then only when they are for all practical purposes untreatable by other means, many materials obviously not in either category are being injected. Pickle liquor, for example, an acid solution used in steel manufacturing, is a favorite material for deep-well disposal, but many adequate processes exist for surface treatment. U.S. Steel recently installed a deep well for pickle liquor in Gary, Indiana. The well is so cheap to operate that wastes from U.S. Steel's Chicago Works are being barged 50 miles on Lake Michigan, unloaded at Gary, and pumped down the well.

Radioactive wastes are still rare in deep wells,

DAVID M. EVANS, Director of the Potential Gas Agency of the Colorado School of Mines Mineral Resources Institute, is an exploration geologist. He was the first to call public attention to the relationship between earthquake frequency in the Denver, Colorado area and deep well injection of wastes at the Army's Rocky Mountain Arsenal.

Waste Treatment Area



but there is at least one company using this method. The Anaconda Company in Grants, New Mexico, processes uranium sandstone ore. Since 1960 the company has been pumping approximately 400 gallons of waste per minute into an 1,830-foot well. This is low-level radioactive waste but would still have to be diluted hundreds or thousands of times before uranium, thorium, and radium concentrations were below Atomic Energy Commission limits for discharge to surface water. The volume of water this would require in an arid area makes well disposal far more attractive. Z. E. Arlin of the Anaconda Company states that "the cost of handling such large volumes of waste by surface methods was exorbitant compared to the cost of a disposal well." The well was designed to last at least ten years, although corrosion of well equipment has occurred and may shorten the life of the well. There is observation equipment within the well itself to pinpoint sources of malfunctions. Monitoring of freshwater zones consists of an observation well in the freshwater reservoirs adjacent to the disposal system and also a program of periodic sampling of wells, springs, and ponds representing all known freshwater underground reservoirs over an area of more than 20 square miles.

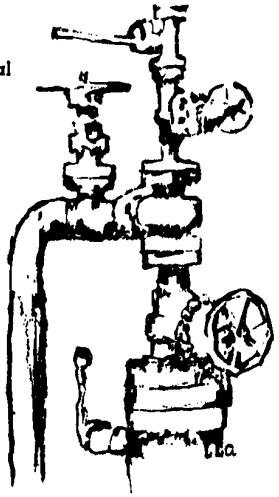
Another well for dumping radioactive fluid is a distinct possibility in the state of Washington. At the Atomic Energy Commission's Hanford complex, liquid wastes containing radioactive fission products are now stored on the project in huge underground tanks. At present a 7,500 foot exploratory hole is being drilled on the 600-square mile complex in hopes that geological conditions considered suitable for deep-well disposal of low-level radioactive wastes will be found. Drilling began April 27 and was expected to take six months.

The Atomic Energy Commission (AEC) has been conducting studies for several years, using experimental deep wells in two areas, Idaho and Tennessee. At the National Reactor Testing Center in Idaho, intensive investigations have been made on what happens to various radioactive substances injected into a well about 600 feet deep. Over 30 observation wells have been drilled to determine the distribution and migration of these materials in the underground water reservoir at the base of the well. The main radioactive waste is tritium, which has been detected in trace quantities as far away as five miles from the injection well; none of the other secondary wastes have been observed beyond 1,400 feet from where they were injected.

At the Oak Ridge National Laboratory in Tennessee, the AEC has been studying the disposal of intermediate level radioactive wastes in layers of shale or other suitable rock which have first been fractured by injecting fluid under pressure (hydraulic fracturing). According to an AEC spokesman, "the feasibility and reliability of the technique have been evidenced by the satisfactory injection of about 460,000 gallons of waste during the past two years into uniform, nearly horizontal fractures in shale at Oak Ridge, Tennessee, well below the zone of circulating groundwater."

One uncommon safety feature of this disposal system is that the wastes are first mixed with cement, local fly ash, and other materials to form a grout which is then injected into the artificially produced cracks in the shale formation, where it hardens. According to present evidence, the inherent

Head of Typical Disposal Well



impermeability of the shale combined with the exchange capacity properties of the mix and the immobility of the waste produces an apparently safe disposal method in the geological environment at Oak Ridge. However, The Commission on the Geological Aspects of Radioactive Waste Disposal of the National Academy of Sciences, which has served for some time in an advisory role in this disposal experiment, cautioned the Atomic Energy Commission not to use the apparently successful results at Oak Ridge for other locations in the country, since each geological formation must be separately investigated and evaluated. At present, the AEC and the United States Geological Survey are studying ways to show the applicability of the hydraulic fracturing method of waste disposal in other geological settings, and have stated that the main purpose is to advance industrial acceptance of this technique.

The Deep-Well Concept

In theory, a deep well sounds safe. A typical well is drilled below freshwater zones until a layer of sandstone, limestone, dolomite, or other reasonably porous, permeable rock is found. (Permeability refers to the ability of the rock to transmit fluids; porosity is a measure of the amount of space between the grains of rock which could be filled by fluids.) Such absorbant layers must be confined above and below and, if possible, on the sides by sufficiently thick impermeable rock layers, commonly such material as unfractured shale or clay. The impenetrable layers must be without cracks and extend for some distance so that wastes cannot creep through them or around them. Steel casing is extended downward into the disposal formation, and cement is forced in between the casing and the outside of the shaft as a sealant. Inner casings, also sealed with the cement or stuffed with fibrous materials, continue to the bottom of the well, passing through the confining layers of impermeable rock. Waste is then injected into the disposal zone, usually under pressure, since it must often displace other liquids or gases already trapped there.

Engineers say that a disposal zone 50 feet thick, a square mile in area, and with an effective porosity of twenty percent could contain about 2.1 billion gallons of waste. Approximately 410 million gallons could be contained within a quarter of a mile of such a well, and 590,000 gallons within 50 feet. In some existing wells, up to 550,000 gallons may be injected in one day. Life of a well would depend mainly on the capacity of the reservoir and the smooth functioning of the well itself; these factors vary enough so that the period of usefulness of most wells is unpredictable.

Problems of Deep Wells

The basic problem of this concept is that the ideal geological and engineering conditions required are almost nonexistent. Wastes injected under pressure into even "safe" geological formations often won't stay put, and the well mechanism itself is subject to many sorts of failure. Within weeks, or years or generations, wastes can migrate from their reservoir into other underground regions, to subsurface water, or even to the surface. Those toxic wastes which do remain in the general area where they were placed poison it and make it permanently useless.

For example, even "impermeable" layers of rock often have undetected flaws and fissures, and when pressure is applied new cracks may appear and old ones enlarge. Fluid can find its way out through such openings and may emerge miles from the well. Wastes can also come to the surface through abandoned, uncapped (and often unmarked) gas, oil, and water wells nearby, simply going down a new hole and returning through an old one. In some cases the diffusion of waste fluids by osmosis may raise pressure in the injection formation high enough to fracture it. The highly permeable rocks which receive the wastes in the first place may transfer them in time to areas not as well insulated as the original reservoir.

In a nutshell, when the natural equilibrium pressure of a subsurface area is upset by the increased injection pressure, the results are often unpredictable. Frank R. Conselman, past President of the American Association of Petroleum Geologists, says, "Water injected underground, whether for flooding (to increase oil recovery in oil fields) or disposal, is

a prime source of trouble. It is difficult to control, and may be diverted by any paths of least resistance, known or unknown, natural or artificial. These escape routes multiply with nearness to the surface of the ground." Escape routes also multiply as pressures are raised.

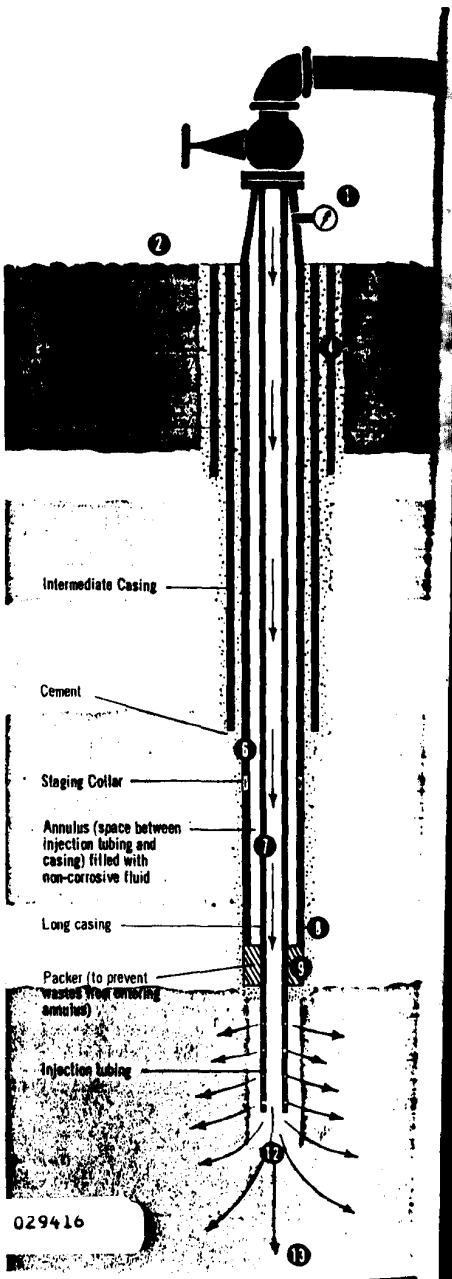
Who would have imagined that brine wastes injected into the earth in Canada would spout forth in Michigan? Deep brine injection wells in Texas have erupted like geysers. The brine waste from a well near Abilene burst through the overlying limestone formation, broke a sewer line, and created literally quite a stink. Formerly dry creek beds have spouted salt springs in several areas, and sweet wells have become unfit to drink as the salt water reached them. Deep injection wells for brine disposal have been used in large numbers for several decades to get rid of the brine found in oil and gas deposits; when toxic industrial wastes have had an equal history, it may be poisons like cyanide compounds or organic phosphates that make such unexpected appearances.

Even without disruption of the reservoir from high pressures, underground water and injected wastes may mingle. Testifying before the Daddario Subcommittee Hearings on Environmental Quality in 1968, Dr. William T. Pecora, Director of the U.S. Geological Survey, pointed out:

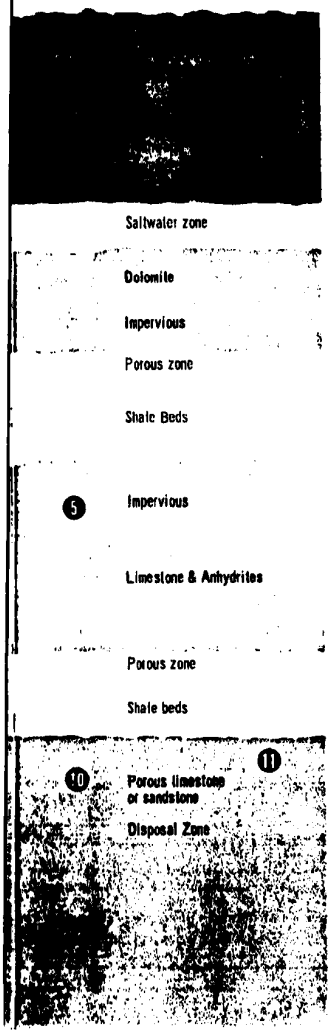
> There is a constant interaction of the water locked up in the porous and permeable rocks of the earth, a constant interaction of this water supply with the streams. . . . no one is properly prepared to recharge water or liquid wastes into complex underground systems with certainty of the results that such an operation may yield. Hopefully, the time is approaching when large quantities of polluted material cannot be dumped into the ground without considerable thought being given to the consequences.

Even when geological problems are few, problems of well-technology are likely to help wastes out of their dumping place. In the most common cases, the casing breaks or corrodes, and underground pressure forces wastes and other nearby fluids to the surface.

One reason why steel casing corrodes in the ground is illustrated by the following instance. Recently in Texas, the casing of an industrial disposal well had corroded within a few years. The old well was plugged and a new well drilled at great expense. This time, to prevent corrosion, stainless steel casing was welded to the regular casing through the troublesome salt water zone. The combination of two metals and a weld in a salt water solution made such a good battery that the casing corroded out in three months.

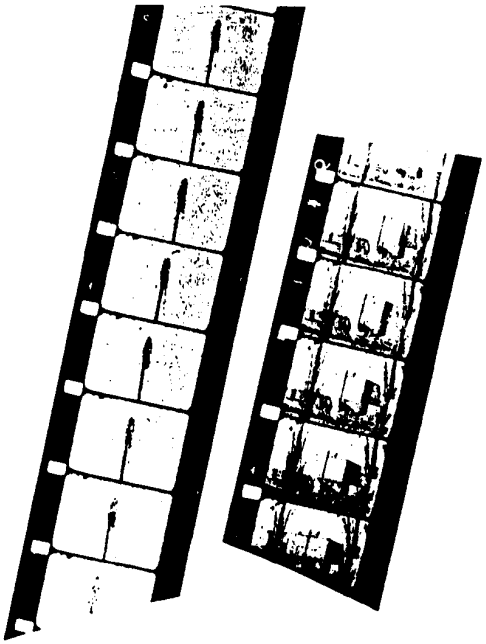


The Disposal Well and Its Problems



1. Improper pressure monitoring, resulting in failure of injection equipment or fracturing of disposal formation.
2. Mining, excavations, or additional wells might lower subsurface pressures. This could trigger escape of the waste fluids from disposal zone (into other formations, water reservoirs, or the surface).
3. Wastes under pressure can escape through abandoned and improperly plugged oil, gas, or water wells nearby.
4. Corrosion of well with age, allowing fluids under pressure to escape.
5. Natural or induced fractures in rock formations, through which wastes may escape.
6. Corroded or broken casing, through which wastes can escape.
7. Corrosion break in injection tubing, allowing wastes to enter space between tubing and casing (annulus).
8. Poor cement job . . . wastes under pressure can break out between outer casing and the surrounding geological formation if outer casing not adequately cemented to formation.
9. Leaking or faulty packer, allowing wastes to enter annulus.
10. Several wastes injected together can react and form new compounds. Wastes can also react with the injection formation, or with other wastes injected into nearby wells which share the same disposal area. Such reactions could in some cases create toxic fluids or poisonous gases.
11. Fluid could invade injection zone by means of osmosis with resulting rise in pressure and fracturing of zone.
12. Clogging of injection tubing or disposal formation. This can cause pressures to rise abruptly with consequent possibility of rupturing of tubing or fracturing of formation and consequent escape of wastes.
13. Wastes under pressure reducing friction between rocks under stress, triggering earthquakes.

(Well sketch adapted from "Subsurface Disposal of Industrial Wastes" Interstate Oil Compact Commission, 1968.)



Malfunctioning deep well — wastes gushing from a Hammermill Paper Company deep disposal well at Erie, Pennsylvania, shortly after it failed on Easter Sunday, 1968. The film clip on the right shows an overall view of the well, and on the left is the tip of the injection tubing, which was forced more than 30 feet into the air past surface equipment by the pressure of upwelling wastes. Approximately 150,000 gallons of spent sulfite liquor spewed from this tubing every day into Lake Erie for a three-week period before the well was successfully capped. At last report, Hammermill is drilling two new wells in the same area.

A second way in which casing can be damaged is from the inside by the highly corrosive liquids — hydrochloric acid, sulfuric acid, chromic acid, and carbolic acid, to name a few — that are injected. The pipes carrying these acids are plastic-lined to avoid direct contact with the wastes. But will the plastic lining last forever? Last year at one of the two deep injection wells of the Hammermill Paper Company at Erie, Pennsylvania, the injection tubing, made of steel coated with a plastic, corroded at one of the joints, permitting wastes to get into the void space between the injection tubing and the well casing. This allowed the wastes in the formation to flow upward and escape at the underground pressure, and in the process the surface fittings were dislodged and the tubing was forced 30 feet into the air. Approximately 150,000 gallons per day of evil-smelling spent sulfite liquor containing various fibers and materials from pulp manufacture spewed into Lake Erie for a three-week period, spreading a concentrated brown scum over the waters nearby. The well was finally capped, and Hammermill at last report was drilling two new deep wells in the same area.

Well failure and consequent runaway underground pressures were also the undoing of the offshore well near Santa Barbara, which recently leaked 20,000 gallons of oil a day and is still sending oil into the sea despite all efforts to plug the leak. What caused this problem? Normal pressure from a deep oil and gas zone escaped up the hole being drilled and out into a shallow cracked sandstone formation. Although the pressure was normal for the deep zone, it was much above normal for the shallow one. Result: rupture along a geologic fault to the surface. Once pressure opened the crack, oil in the shallow zone escaped.

Pollution is only the most common result of injected wastes which migrate. There is at least one spectacular instance of a deep well directly setting off earthquakes. At the Rocky Mountain Arsenal in Denver, wastes from the manufacture of poison gas had been dumped into above-ground holding ponds since 1943. These wastes eventually polluted six and one-half square miles of subsurface water, and the army had the choice of cleaning up future wastes before release into the environment or injecting them into a deep well. A deep well was drilled without making prior feasibility studies, and wastes were released into cracked granite basement rocks 12,040 feet below the surface. Between 1962 and 1965 more than 150 million gallons of nerve-gas waste and insecticide waste were injected.

A month after injection began, Denver had its first earthquake in 80 years, and in November 1965, David Evans (one of the authors) pointed out that the 710 Denver earthquakes recorded by that time correlated with the volumes of fluid pumped into the Arsenal well. Periods of high pumping rates resulted in many quakes, low rates resulted in fewer. When injection pressures were doubled, the number of earthquakes doubled. The points of origin of all the earthquakes were near the well.

A likely explanation of what happened is that the fluid pressure of the injected wastes forced open cracks in the rocks far enough to reduce friction and relieve strain. Result: the rocks slipped past each other and the "sliding vibrations" were recorded above as earthquakes.

Monitoring Wells

There are many proposals for monitoring wells put forward by those who feel that some wells would be safe if properly supervised. Some spokesmen advocate observation wells drilled into geological forma-

tions some distance from the disposal well so that if the supposedly impenetrable barrier around the well contains some permeable or fractured formations, migrating wastes would be identified before they reach underground water or the surface. However, complete monitoring would seldom be assured even if numerous observation wells were built circling the disposal well, as wastes could sometimes escape through rock between observation areas. On the other hand, if the rock around the disposal well were only slightly permeable, the waste might seep very slowly outward, possibly not reaching the observation area until the disposal well was no longer receiving waste. Care would have to be taken to keep the observation wells functioning for many years. Other experts favor drilling monitoring wells directly into underground freshwater zones to check on any contamination that might occur. Presumably if it occurs, everyone leaves town; experts do not say what to do next. Once loose, the wastes cannot be retrieved.

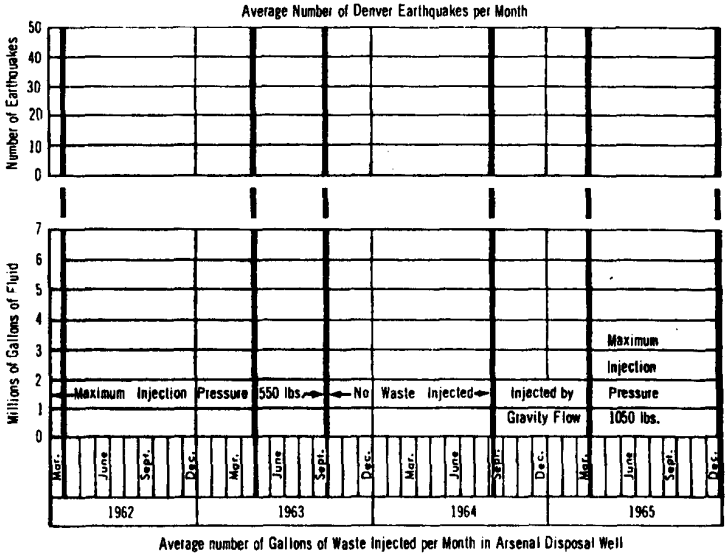
Sometimes it is hard to know what to look out for when monitoring a well, since a close check on the types of wastes that go into particular geological formations is at present difficult: many companies don't want the full nature of their wastes revealed, as this might disclose information to their competition about their manufacturing processes. At present, most state agencies cooperate with these proprietary interests, but many are hesitant about continuing this practice.

Pressure monitoring has been advocated. Wells would have automatic cutoffs, so that pumping could be stopped promptly after any sudden rise or decrease in pressure. Some government experts suggest that any underground storage system take into account long periods of planned or accidental shutdown, and that in such cases auxiliary wells be built to take the wastes while the main well is not in operation.

Most of the precautions and supervisory measures which might be useful are also expensive. And how long would proper monitoring continue if a company went out of business? What if the land became a community park, a schoolyard, or even just a parking lot? What if some mineral in the vicinity of the well became greatly valued in the future? Would a company risk poisonous blowouts by drilling in search of minerals in such an area?

Much of the monitoring that is currently being done is to check the safety of freshwater reservoirs underground. Disposal engineers are careful to point out that poisonous wastes will only be injected into disposal zones containing salt water and that fresh-

Relationships between Waste Injection and Frequency of Earthquakes



(Adapted from The Mountain Geologist.)

water resources will be carefully avoided. However, geologist William C. Finch of Houston, Texas, who is an authority on desalting, explains the folly of this course of action. "To begin with," he says, "there are four kinds of water — freshwater that has less than 1,000 parts per million of dissolved salts; brackish water that contains less salt than seawater and more than freshwater; salt or seawater; and brine, which contains more salt than seawater (or over 35,000 parts per million dissolved salts.)" The so-called salt water in most potential disposal wells is in reality brackish water. There is hundreds of times more brackish water underground than freshwater. Brackish water can be desalted at about one-fourth of the cost of desalting seawater and is likely to be our next big source of freshwater as human and industrial demands rise. It is an irreplacable natural resource, and Finch contends it would be the wildest kind of folly to contaminate it with industrial waste.

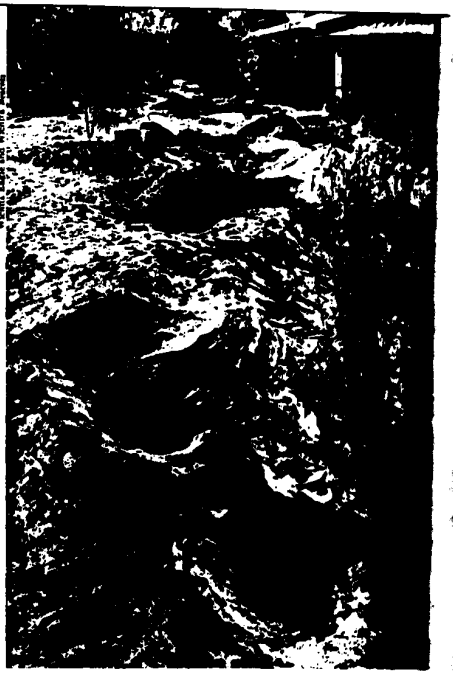
"We can desalt brackish water with 2,500 parts per million salts for 25 cents a thousand gallons, against 98 cents a thousand gallons for seawater," Finch says. "Brackish water is located where it will soon be needed — beneath the deserts of Arizona and Nevada and the plains of west Texas and eastern Colorado, for example."

Are Safe Wells Technically Possible?

There are those who explain the failures which have already occurred with injection wells as results of poor engineering or choice of site, and feel that future wells will be free of such problems as proper precautions and advanced technology are used. Neilson Rudd, President of Geo-Engineering Lab., Inc., an engineering geologist who is concerned about deep well hazards, has suggested that deep wells can be a safe way of dumping wastes if the geological areas are carefully selected, the pressures used for pumping are within a safe range for the particular formation being used and are carefully controlled, dumping is properly limited, and wells are built utilizing the sophisticated technology presently used in geohydrology, oil and gas production, and underground gas storage. For example, underground fluids that could be easily treated for surface disposal could be pumped out and more difficult-to-treat wastes injected in their place, bringing the underground pressures back to normal. Immiscible liquids (those liquids which are incapable of mixing with other liquids) could be injected into a new reservoir to create artificial permeability barriers, and other techniques now known could be utilized to keep wastes in place.

In theory, many of the problems of deep-well disposal could be overcome by such methods under the right conditions and by extremely careful supervision over the years. But in most cases the cost of such carefully-made wells would make them less attractive to operators than cheaper methods of treating the wastes on the surface. And the expense of long-term strict regulation and supervision which the states and the national government would have to assume would mean costs passed on to the taxpayer. Also, there remains the problem of retrieving the poisonous wastes if something goes wrong. Once poisons get loose underground, it is impossible to clean up the mess.

We do not have such sophisticated choices at present, however. The experts who promote the widespread large-volume dumping that is becoming so popular cannot assume that well engineering or geological conditions are going to become much safer. The geological factors which make the difference between safe conditions and hazardous ones are often impossible to predict. And as for the well engineering, one has only to look at the thousands



Unstable underground pressures caused tons of saltwater to erupt on and around the lawn of the James Lowe family in Wichita, Kansas last July, creating sinkholes, killing vegetation, and damaging the Lowe's house. No investigations were made of causes of the problem, and it is not known whether the upheaval was caused by pressures building up in nearby abandoned oil and gas wells or by subsurface gas pressures of natural origin.

of abandoned oil and water wells in the country today to be aware that the long-term care that even an otherwise well-behaved well would need would be hard to muster, technologically or politically. Even if such care were forthcoming and even if wells were tightly plugged after they were used, some danger of leakage would remain. The danger would increase with time and would be even greater if the wells' locations were forgotten and mines or new wells were dug in the same area.

The Next Fifty Years?

What spokesmen for the deep well concept do not seem to remember is that even a small percentage of well failures will be extremely dangerous when the numbers of wells reach into the tens or hundreds of thousands. The percentage of truly dangerous wastes being injected will remain high since these are precisely the ones which are uneconomical to treat; just a few slips could endanger the water supplies of millions of people.

The Interstate Oil Compact Commission, an organization of state-level oil and gas regulatory agencies in 33 states, has compiled a report, "Subsurface Disposal of Industrial Wastes," on the disposal wells known in 1968. Disposal operations had not started on ten of these wells, but of 114 deep wells listed, fourteen percent were shut down for one reason or another. Six wells had casing failures, three after less than four years of operation. Five wells were "shut down" or "abandoned" because the wastes plugged the injection zone or were incompatible with it. In addition, three wells were never put into operation because injection formations were discovered to be relatively impermeable and would not receive significant amounts of fluid waste. One well was shut down after it was discovered that it had triggered hundreds of earthquakes in Denver, Colorado. (This was the Rocky Mountain Arsenal well previously mentioned.)

If 100,000 wells are constructed in the next fifty years, and just ten percent of these fail, and if only one percent of the total involve dangerous release of toxic wastes to water or to the surface, then we have 1,000 or so wells which are directly dangerous to population centers nearby. In addition, the eventual malfunction and resulting harmful effects of "safe" wells as the years pass is a disturbing prospect.

We may be getting closer to such massive waste injection than official figures would indicate. While the number of known legal deep injection wells is still rather small, there are many additional wells being used for dumping at the present. If we include all the early water wells converted to disposal, wells drilled for disposal purposes prior to any recognition of their effect and before regulatory efforts were imposed, and the continuing number of clandestine disposal operations drilled in full knowledge of their effect and illegality, the total number is probably already in the thousands.

For example, the *Courier Express* of Buffalo, New York reported last year that "the Erie County and State Health Department and numerous other state agencies contacted by the *Courier Express* have no record of any existing deep injection wells in New York. They maintain the three recently issued drilling permits are the only ones." However, the article continues, a former State Health Department official indicated there were "22 underground waste disposal sites in the Buffalo area . . . operating either legally or illegally." These include steel and chemical plants and a large chrome plating firm.

State Regulations

Many known wells have been drilled with little state regulation. The 1968 survey by the Interstate Oil Compact Commission indicates that the growth in number and type of deep disposal wells has been so rapid that most states still have no specific regulations to deal with subsurface disposal, although this situation may have changed recently to some extent as many states are revising their pollution laws. There are no federal regulations, although it is significant that the Task Force on Environmental Health omitted any mention of deep injection wells as an acceptable method of waste disposal in their recommendations to the Secretary of Health, Education, and Welfare. Only Texas has legislation dealing exclusively with industrial deep wells; Ohio, Pennsylvania, and Kansas have added regulations involving this type of disposal to existing laws. Georgia holds that subsurface disposal of industrial wastes is generally not an accepted method and that any such storage should be approached with great caution. Those states which do attempt some control over deep wells usually have several already-existing agencies advise upon and, in some cases, regulate deep-well construction.

The fact that detailed regulations exist does not necessarily mean that a state disapproves of deep-well disposal; rather, some proof of the well's safety is required. Permits are being approved and new wells being drilled in several areas such as Ohio, where there are reasonably comprehensive regulations. Even strict regulations or suggested safe standards often have a final clause that says something like "a company is not permitted to build a deep well unless other waste disposal methods are not economically feasible," which sidesteps the really important geological and engineering problems in favor of the cheapest means of dumping.

Michael Sheldrick, then Chicago Regional Editor of *Chemical Engineering*, pointed out in a recent

article that many industries welcome comprehensive approval procedures which involve several state agencies. In this way, when pollution or other problems occur with an approved well, the state would take the blame for the bad situation, since it permitted the well to be built under regulations permitting only "safe" wells. An additional benefit which might appeal to some industries is that the passage of a permit by so many separate agencies assures a greater degree of protection from future state legislation.

With or without regulations, many industries are careful to construct deep wells only in geological areas where long-term confinement of wastes seems most likely. Their waste pre-treatment and injection systems are designed for the unique geological and chemical conditions they are likely to encounter. The safety even of such carefully planned wells is still not assured, as it it not easy to predict what sudden jumps of pressure, inflows of chemicals, increased temperatures, and other factors might do over a period of time to formations that are never completely known. And the well itself may develop problems as the years go by.

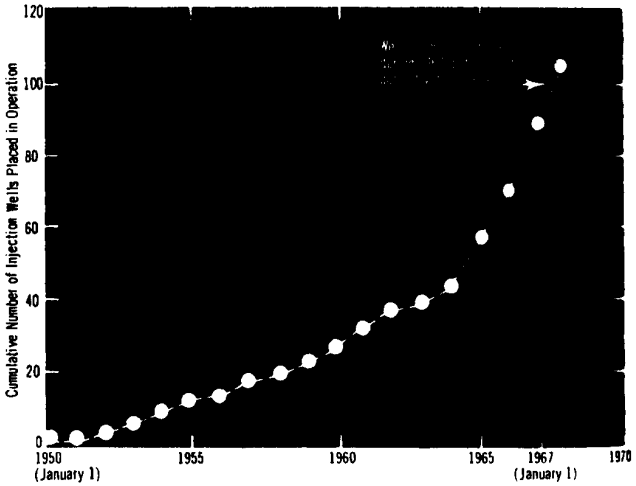
Michael Sheldrick reports that one company, aware that considerable faulting was suspected in the area in which they proposed to drill a deep well, consulted the United States Geological Survey on suggestions for an adequate survey of the geological conditions at the proposed well site. Implementing the geologists recommendations would have made the cost of the well much higher than other methods of disposal, and the company decided not to drill a deep well.

However, many wells are drilled without adequate concern for careful surveying and construction. The Interstate Oil Compact Commission reports that ". . . often a party will indicate that a formation will take a fluid with the implication that . . . other [complex geological] factors have been satisfied."

Space-Age City

The dimensions which such indifference can reach is indicated by a recent battle between the Colorado Water Pollution Control Commission and The Atomic Storage Corporation of Denver. The company, headed by Dr. William A. Colburn, a petroleum engineer and former physics professor, sought authority to dispose of wastes 3,000 to 5,000 feet below the surface in a geological formation it claimed was rare low-pressure sandstone ideally suited for holding industrial wastes. According to the *Denver Post*, Dr. Colburn commented that "all waste that is placed in these low-pressure zones will remain isolated perpetually from man's environment because the higher pressure of the water which surrounds the waste will prevent any leakage out of the storage zone. The existence of faults, fractures, or other leakage paths will result only in the further dilution of the [highly toxic] wastes by water from the outside." The Atomic Storage Corporation "de-

Injection Wells, 1950-1967



(From "Deep Wells for Industrial Waste Disposal in the U.S.A." by Don Warner.)

scribed the potential of a city of at least 30,000 persons, supported by a complex of advanced space-age industries springing up on the prairie," as all these industries would be attracted by the vast capacities of the reported underground waste storage "vault" for cheap disposal of their toxic wastes. This project "had the ardent support of former Colorado Governor Dan Thorton."

After four months of hearings, during which Evans and other geologists challenged the existence of the low pressure area and warned of eventual water pollution problems, the Pollution Control Commission denied permission to the Corporation for deep-well disposal at the intended site. The Commission's findings stated, in part, "that the waters of the state . . . would be polluted by the injection of toxic wastes" into the sandstone formation; that Colburn, despite extensive testimony and exhibits, "didn't furnish specific wastes to be injected, the specific method of monitoring the disposal operation, nor the quantity of toxic wastes to be injected."

The Commission also commented that while the evidence established that some of the wastes to be injected could remain toxic indefinitely, no related plan was submitted for the public health and safety, either presently or in the future. The Commission noted that "the respondent submitted no satisfactory alternative or standby disposal facility which would be available or assurances that the wastes could be retrieved should the deep-well disposal system fail or cease to operate." Nor was there any evidence given "in regard to the specific procedures and practices to be followed in the disposal of the wastes."

Legal Problems

The Interstate Oil Compact Commission comments that it is often difficult to prove that water or mineral pollution came from a particular well, and that usually only the industries themselves have the financial and scientific resources to conduct proper investigations of pollution sources.

The State of California experienced a similar problem when it tried to bring suit against the Union Oil Company over the leaking Santa Barbara oil well. The *Los Angeles Times* reported that oil experts, whether associated with academic or industrial circles, have been extremely reluctant to speak for the record about the blowout, although many of them are familiar with the details.

Both industrial engineers and state officials are seeking the cause of a series of catastrophes in southern Michigan. Circumstantial evidence implicates oil industry drilling activities, but there is no conclusive proof.

In late 1968, a drilling rig near the town of Marshall in southern Michigan hit a high-pressure zone at 4,550 feet. When gas blew out of the well, the well was shut-in (temporarily sealed) at the surface. Within half an hour an abandoned water well half a mile to the west turned into a 130-foot water spout. Nearby farm wells began to spout and blow highly explosive natural gas. Next, two drilling rigs in a nearby oil field hit high pressures at shallow depths. Rigs were toppled and gas blew to the surface around steel casings.

Thanksgiving Day a tremendous explosion, followed by violent gas and water spouts and caving sink holes, shook the outskirts of the town. Christmas Eve a water well at a roadside park three miles north of Marshall suddenly erupted.

The toll thus far: two drilling rigs collapsed into craters, a park closed, several families temporarily evacuated from their homes, and eruptions of gas, oil, and water over a twelve-mile area. Such destruction resulted from an accidental disturbance of underground pressures by oil drilling. However, most deep disposal wells also alter underground pressures as a normal part of their operation and thereby run the risk of pressures getting out of hand.

At least one major oil company decided that it was cheaper to treat poisonous wastes for surface disposal than to inject the wastes underground and run the risks of costly suits in the future. Two years ago, David Evans visited company officials who were then using twelve disposal wells for underground dumping to avoid polluting the rivers and

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Deep Injection Wells, 1968

State	Total No. Wells	Out of Operation
Alabama	1	1
California	4	
Colorado	1	1
Florida	4	1
Illinois	3	1
Indiana	9	
Iowa	1	1
Kansas	7	2
Kentucky	1	1
Louisiana	25	
Michigan	21	7
New Mexico	1	
Ohio	2	2
Oklahoma	2	
Pennsylvania	5	1
Tennessee	1	
Texas	34	
West Virginia	2	2
Total	**124**	**20**

From "Subsurface Disposal of Industrial Wastes," Interstate Oil Compact Commission, 1968.

Antibiotics, hormones and many other medicines used to treat human sickness have found their way into agriculture. The drugs are used to treat animal diseases, to promote growth, to preserve food and to protect plants. Far more antibiotics are used on farms than in hospitals, and the growing reliance on those and other medicines in agriculture raises a host of problems. The most serious of these may be the appearance of resistance in microbes to antibiotic treatment. It has recently been discovered that innocuous bacteria which have developed such a resistance may transfer their ability to resist antibiotic treatment to disease-causing bacteria.

The following is the first in a series of three articles on the farm use of drugs.

Penicillin by the Pound

By Margaret E. Duffy

FARMERS CAN BUY antibiotics by the pound from their local feed store, although they need a doctor's prescription to buy one penicillin tablet for their personal use. People need a prescription for the antibiotics they buy for their own use because, like all other drugs, antibiotics can be dangerous if they are not used properly. They can cause allergic and toxic reactions and the proliferation of microorganisms which are resistant to antibiotics. The Food and Drug Administration (FDA), whose job it is to protect the consumer from poor or misbranded drugs, requires a doctor's prescription for the purchase of an antibiotic drug if that drug is to be used in the treatment of human disease. Yet, in the United States, over half the annual antibiotics production—more than a thousand tons—is purchased and used in animal feeds without a prescription. In 1965, the total value of antibiotics used in feed was $42 million.

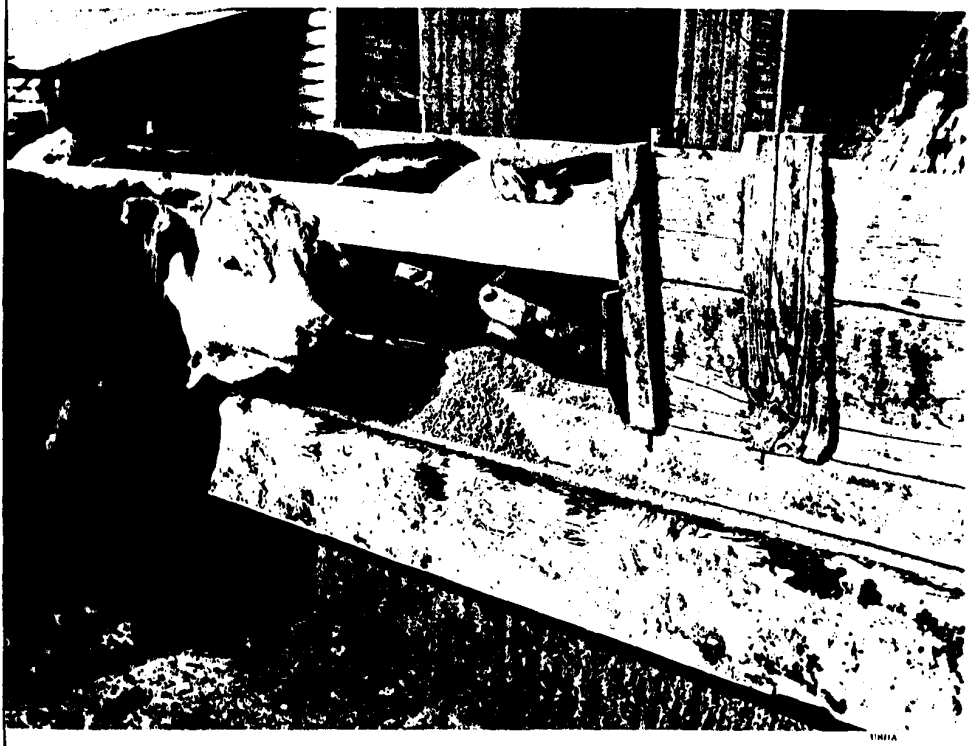
Most of the antibiotics used in agriculture are

added to the feed of cattle, pigs, chickens and lambs in order to promote growth. Although there is some question about how, or even whether, antibiotics promote growth, they have been added to animal feeds since the 1940's, and the practice is now almost universal. Penicillin, bacitracin, chlortecracycline, oxytetracycline, streptomycin and tylosin are used in amounts ranging up to 50 parts per million parts of feed.

Do antibiotics promote growth in farm animals? At a symposium held in 1967 by the National Academy of Sciences in Washington, D.C., several scientists questioned whether antibiotics do what is claimed for them. In his introductory address to the conference, James Goddard, then head of the Food and Drug Administration, remarked that the use of drugs in feed is "based more on hope and less on hard data."

Much of the experimental data on the growth-promoting effects of antibiotics comes from studies of poultry. Some scientists have noted that adding small amounts of antibiotics to feed increases growth rate and results in more efficient use of nutrients in young chickens and turkeys. Results in a number of experiments, however, have raised doubts about the efficacy of antibiotics in feeds. Antibiotics have had a greater effect on chickens and pigs raised in a previously occupied and therefore unsanitary environment, than on those raised in sanitized or new quarters. Prolonged feeding with antibiotics has more than once been reported to result in a *decreased* growth response in chicks. Penicillin, bacitracin, erythromycin, and tylosin fed to chicks over a three-year period produced an in-

If a few cattle in a large herd get sick and there is danger that the disease will spread to the whole group, it is common practice for the farmer to feed all the animals in the group prophylactic levels of antibiotics.
These preventive feedings are sometimes carried out when no disease is even suspected in the herd.



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crease in growth rate when they were initially fed, or if they were not fed continually. One experiment with chicks showed no change in growth after prolonged use of antibiotics. The data on growth promotion in other animals—calves, beef cattle, and sheep —is even less clear. In cattle, the greatest increase in growth and feed efficiency was noted in cattle fed low-gaining diets. At best, the effects of antibiotics on animal growth have been variable. Dr. H. Williams Smith of the Animal Health Trust in Essex, England has said: "The degree of growth stimulation obtained by feeding antibiotics is not large; it requires careful measurement to appreciate that it is in fact occurring and in some cases does not occur at all."

The large amount of data on the growth promoting effects of antibiotics used at low levels in animal feed is so confusing that it seems impossible to draw firm conclusions from it. Dr. David Smith of Harvard Medical School has said that early experiments on antibiotic-induced growth promotion were not adequately controlled and were carried out before modern breeding and sanitation procedures became a part of animal production.

Proponents of antibiotic use also disagree among themselves as to how the drugs work their beneficial effects. Several theories have been proposed, but the one most generally accepted is the "disease control" theory. According to this view, antibiotics simply reduce the incidence of low-level infection in young animals, thus making it easier for the animal to grow. Animals undergoing stress because of less-than-ideal sanitation or nutrition have responded better to antibiotics than animals kept under ideal conditions. These findings lend credence to the "disease control" effect. Horace W. Norton of University of Illinois' Department of Animal Science has said that although "the beneficial effects have been clearly demonstrated repeatedly, and a net economic return is certainly commonplace" after using antibiotics in animal feeds, the term "growth promotion" should not be used if the "disease control" effect is *the* mode of action. S. G. Bradley of the Medical College of Virginia's Department of Microbiology has said there is no such thing as growth promotion because antibiotics do not promote growth in germ-free animals.

The lack of firm knowledge about growth promotion has contributed to the confusion about the proper levels of antibiotics to use in feeds. In the early 1950's low levels of two to five or five to fifteen parts antibiotic per million parts of feed were used to promote growth and increase feed efficiency in animals. Levels as low as one part per million were reported to increase growth in those early days. By 1959 scientists were arguing about the amount of antibiotic which constitutes the low or nutritional level needed to promote growth. The data on the growth promoting effects of antibiotics was apparently so contradictory that in 1959 one reviewer suggested making an "arbitrary compromise," proposing that levels of 0.1 to 25 parts per million be considered low levels. In spite of the controversy over what constituted the effective growth promoting levels of antibiotics used in animal feeds, the Food and Drug Administration permitted levels of up to 50 parts per million in feed for growth promotion in the 1950's. Thus levels used for this purpose have been increasing since the early 1950's, although there is no scientific data to show that the 50 parts per million is a more effective growth promoting level than two to fifteen parts per million.

There are several possible reasons for the increase. The price of antibiotics has gone down, so the farmer can buy them in greater quantity at a lower price. There is also the possibility that microorganisms are becoming increasingly resistant to antibiotics, thus making higher amounts necessary to produce the growth response that smaller amounts once produced. A third reason may be that agriculturalists now believe that maximum weight gain is reached at levels of 40 ppm, while maximum feed efficiency is realized at levels of 80 ppm. Dr. Virgil W. Hays, of Iowa State University has put all these reasons together: ". . . the level selected in practice is usually a compromise based on the cost-benefit ratio."

Farmers also use antibiotics to prevent and treat disease in their animals. If a few animals in a herd or flock get sick and there is danger that the disease will spread throughout the whole group it is common practice for the farmer to feed the whole group antibiotics in "prophylactic" levels ranging from 100 to 400 parts per million. Higher "therapeutic" levels of up to 2,000 parts per million are used to treat existing disease. There is evidence to show that these prophylactic and therapeutic levels are fed when there is no disease present or even suspected in animals. Also, there is apparently some confusion about what levels constitute prevention and what levels constitute treatment. The use of antibiotics to prevent disease is of questionable value.

Using less than a therapeutic dose of antibiotics for the specific purpose of curing disease is not an accepted practice in human medicine. According to Dr. Hans Ericsson, of the Bacteriological Department of Karolinska Sjukhuset in Stockholm:

> From the bacteriologic aspect sub-therapeutic doses of antibiotics are always to be condemned, since they favor the emergence of resistant bacterial strains. Therapy should always be instituted in full dosage and should as a rule be interrupted when the clinical objective has been achieved.

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THE UNDERGROUND EXPLOSION of a nuclear device at Amchitka Island was carried out as scheduled this month, over strenuous opposition and threats of legal action. Resolutions asking for a postponement of the military test had been introduced in both the House and Senate, and state legislators from Alaska and Hawaii protested that the explosion might trigger earthquakes and tidal waves (see Environment, July-August 1969). The Atomic Energy Commission (AEC) conceded, in an appearance before the Alaskan Legislative Council, that there was some risk that the test would trigger a major earthquake, but argued that the chance was slight.

The 1.2-megaton test was only the first--and smallest--in a series of explosions planned by the AEC for the Aleutian Island, 1,400 miles from Anchorage. Future tests, presumably for antiballistic missile development, will range upwards to several megatons; one drill-hole already completed could accommodate a 5.5-megaton explosion.

Environment has learned that the October test was opposed by geologists performing seismological research for the AEC on Amchitka. A group of scientists at the Colorado School of Mines, headed by Dr. Morris W. Major, has set up two monitoring stations on Amchitka and one on nearby Adak. At each station strainmeters will record changes in the tensions building up in the region of major faults. The group hopes to be able to identify periods during which earthquakes are most likely to be triggered by nuclear explosions, and to identify changes produced by tests themselves. A geologist has informed us that the group will require at least a year to produce preliminary results, since earlier research in Colorado had shown seasonal variations in strain in the earth's crust which obscured long-term trends. Some members of the group opposed conducting the test until at least these preliminary data had been established.

QUESTIONS HAVE BEEN RAISED about an insecticide used in plastic strips and dog collars. DDVP (2,2-dichlorovinyl dimethyl phosphate), marketed in this country by Shell Oil Company under the trade name Vapona, is used to impregnate the strips and collars, from which it then slowly vaporizes, acting against fleas or other insects in the room where the strip is hung, or on the dog wearing the collar. Vapona strips have become widely popular, and mechanical dispensers have also been used to disseminate DDVP in the air of warehouses, aircraft, and restaurants.

Studies made on human volunteers were used by industry as evidence of the safety of the insecticide when registration was applied for. The manufacturers interpreted these studies as showing no difference between exposed and unexposed individuals. Now reexamination of the same data by Dr. Goran Lofroth of the University of Stockholm indicates that there was a significant difference in the blood cholinesterase of the subjects, with those exposed showing some depression of cholinesterase (an enzyme important in the proper functioning of the nervous system).

DDVP is rather quickly broken down by the liver when taken orally. However, when exposure is by inhalation or through the skin, this process takes much longer. Dr. Lofroth reported his reevaluation of early DDVP studies to the Panel on Mutagenicity of the Secretary's Commission on Pesticides, United States Department of Health, Education and Welfare on September 3. He also told the Panel: "The

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preliminary studies reported here show that DDVP is an alkylating agent and that the compound may cause disturbance in the hereditary structure of dividing cells." (Most alkylating agents are known to cause either mutations or cancer or both.)

A copy of the full report may be obtained from Dr. Lofroth at the University of Stockholm, Box 6409, Odengatan 63, S-113 82 Stockholm, Sweden. (For a previous discussion of the danger of mutagenic chemicals see "Chemical Risk to Future Generations," by James F. Crow, Environment, June-July, 1968.)

HIGH MERCURY LEVELS may stop pheasant and partridge hunting in Canada's Alberta Province. In a press conference in Edmonton, Dr. J. Donavon Ross, Alberta Lands and Forests Minister, announced that mercury found in the flesh of the game birds was from two to five times the tolerance level set by the World Health Organization (0.1 parts per million). The mercury is thought to have come from wheat seeds treated with mercury fungicides which are taken by the birds from freshly-sown fields. The death of many birds from this cause had been observed in Sweden, which subsequently banned the mercury fungicides. Ross called for cancellation of this year's hunting season for partridge and pheasant, but the situation is likely to be repeated next year unless the U.S. and Canada follow Sweden's lead in banning the mercury seed-treatments.

"ANTICIPATING THE BEST...marked by an eager hopefulness...confidently optimistic..." Those are the dictionary's definitions of "Sanguine." It will take a large amount of confident optimism as well as from one-and-a-half to five billion dollars to complete the Navy's Project Sanguine without undesirable side effects. Sanguine is a communications station designed to send messages around the world, mainly to Polaris submarines. It will require 240 transmitter sites in 26 counties in northern Wisconsin and about six thousand miles of antennae running in lengths of about 25 miles along the ground.

Sanguine will operate at extremely low frequencies and will result in very powerful electromagnetic waves in the area. According to some of the research conducted by private agencies for the Navy, this electromagnetic radiation could cause mutations and even kill living organisms near the antennae. Some evidence indicates that life cycles, fertility, and possibly other biological activities of plants and animals may be affected. Lowell L. Klessig of the University of Wisconsin's College of Agriculture and Life Sciences is one of the scientists expressing fear of the effects on wildlife.

One such possibility, in addition to immediate effects on wildlife nearby, is that Sanguine might cause changes in the flight patterns of birds migrating through the area. This is most serious in the case of waterfowl which flock to Horicon Marsh, about 150 miles to the south. Horicon is one of the major stopover points along the central flyway which extends down the Mississippi River. Senator Gaylord Nelson (D., Wis.) is concerned about the safety of the project as well as its environmental aspects. One of the major safety questions is raised by the "induced magnetic fields" that may result from this super radio. Such fields may electrify wire fences, railroad tracks, and even chain saws. A thousand-foot stretch of pasture fence a hundred feet from one of the antennae would carry 52 volts. To avoid this, fences and railroad tracks could be cut in lengths to be determined by a computer and separated by small insulators. Normal radio and telephone communications nearby would also be affected, and the Pentagon has spent 50 million dollars in the search for a solution to this problem.

"REMEMBER THE TORREY CANYON" is the phrase running through the minds of some Canadians after a warning of possible disaster involving the super tankers planned to haul oil through the Northwest Passage from Alaska, according to the Vancouver Sun. Gordon Gibson of the Canadian Northwest Territories Council gave the warning and charged that the dangers of Arctic oil pollution were partly due to the "apple box design" of the ships. He expressed

doubt that the $20 million tanker Manhattan would make many voyages without serious incident. And what effect would the oil from a 100,000 ton tanker have on Arctic ecology?

AN ALTERNATIVE TO SUPER TANKERS in the Arctic is an oil pipeline, but it, too, has serious "hang-ups." Besides the danger of pipeline breakage and the initial damage to the tundra through construction of the line, there is the problem of melting the permafrost in the area. The pipeline would be heated to keep oil flowing easily despite sub-zero temperatures. Melting could range from 24 feet in depth in one year to 40 or 50 feet in twenty years. The effects of the melting might be huge mudslides moving downslope along the path of the pipe, and the eventual uncovering of the pipe.

FOUR SMALL NATURAL EARTHQUAKES occurred in the hour immediately following the underground nuclear blast of Project Rulison on September 11, according to Ruth Simon at the Seismological Observatory of the Colorado School of Mines. The Rulison blast itself registered as a middle-sized earthquake of magnitude 5.5, and the four natural earthquakes which followed measured between magnitudes 1 and 2. Preliminary investigations indicate that all four of these earthquakes were in the immediate area of the Rulison blast. Previous underground testing in Nevada had triggered swarms of similar small natural earthquakes, and the great majority of these were within ten kilometers or less of the original shot. Although the four earthquakes were small, they strongly indicate the presence of fractures in the geological formations in the area of Project Rulison. This is because natural earthquakes are vibrations resulting from movement of blocks of rock along a fracture or fault. Promoters of Project Rulison have claimed that no underground fractures are present in the test area, and that therefore underground liquids contaminated by the blast would be sealed away and could not escape. If fractures are indeed present, underground fluids can move along them, which raises the possibility that radioactivity can migrate along the fractures and get into subsurface and surface water supplies.

MANY MORE NUCLEAR explosions may be set off in Texas, Utah, Wyoming, Oklahoma, Kansas, Montana, New Mexico and the Dakotas. A report published by the U.S. Bureau of Mines calls these areas "amenable to stimulation (for extracting petroleum and natural gas) using nuclear explosives." David Evans of the Colorado School of Mines (see "Under the Rug," p. 2) predicts that this could mean as many as ten thousand underground nuclear explosions.

DEFOLIATION of the United States-Canada border is continuing, with helicopters spraying Tordon (picloram--see "Picloram in Vietnam," Environment, October, 1968). The program is being conducted by the International Joint Commission of the U.S. and Canada, which informs Environment that the entire 3,000-mile border--except for cities and waterways--is included. The swath of trees and brush being sprayed is from 50 to more than 100 feet wide. Tordon is a persistent herbicide, not licensed for use on crops. Repeated spraying of the border to keep it barren will result in a dead strip of eroded, impoverished soil. Drift of the herbicide will damage plants on either side of the strip. Long-range ecological effects of this break of unprecedented length in the natural continuity of plant and animal life are difficult to predict. No statement from either government on the reason for the defoliation has been made as far as we have been able to discover.

THE OYSTER HAS BEEN KING in Chesapeake Bay, but a new development may threaten more than his throne. The University of Maryland's Natural Resources Institute has developed a synthetic oyster bed in the hope that this will supplement the natural beds. Water pollution has caused the loss of about $2 million worth of shellfish in Maryland, and the artificial beds, as well as pollution clean-up efforts, have been marshalled to save the commercially and traditionally important oyster. Now the tables

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have been turned and the synthetic oyster beds are being used as an excuse for letting down the barriers to pollution.

Elgin Dunnington of the Institute which developed the synthetic beds points out the dangers in this course. Although the synthetic beds may supplement the natural ones, he says, it is not clear that they can replace them. Furthermore, he calls the natural oyster beds a "keystone in the ecological arch" of Chesapeake Bay. If production of oysters in synthetic beds is used as an excuse to strip the natural beds and allow pollution levels to rise, the consequences to other shellfish, to commercial fish, and to the whole interrelated environment of the bay could be extremely serious.

A MILLION TONS of dangerous material pass some points on the Mississippi and Missouri rivers in a single month, according to a recent Coast Guard survey. The Department of Transportation has also reported huge amounts of dangerous materials constantly on the move over highways and railroads, and the number of railroad accidents is rising at an alarming rate. Industrial chemicals, explosives, poison gas and petroleum products make up much of the cargo of American railroads, according to the records of the American Association of Railroads and the Department of Transportation. As an example, William C. Jennings of the Department's Office of Hazardous Materials, cites the fact that phosgene is regularly shipped by commercial manufacturers. Phosgene is a lung irritant, manufactured for use in World War II. It can cause serious lung damage, and at high doses it can kill.

On September 12, an accident in Mississippi involved the explosion of a railroad car of vinyl chloride used in the manufacture of plastics. Ten thousand people were evacuated because vinyl chloride produces phosgene when burned. Uniroyal, Inc., of Geismar, La., the company shipping the material, stated that "it is impossible to liberate phosgene, other then inconsequential trace amounts, when vinyl chloride is freely burned in the air." A representative of the company also stated that vinyl chloride is not lethal. Hazardous Chemicals Data, 1969, a publication of the National Fire Protection Association in describing the "life hazards" of vinyl chloride says, "(it) acts as a general anesthetic and may be fatal in high concentrations...fires involving this material result in production of highly toxic combustion products such as hydrogen chloride, phosgene and carbon monoxide." Dangerous Properties of Industrial Chemicals, by Irwin Sax, the standard reference work in this field similarly describes the dangerous properties of this chemical. Who is kidding whom?

A SCIENTIFIC TEAM from the British Society for Social Responsibility in Science has gone to Ulster for an on-the-spot investigation of the physiological effects of CS, the riot-control gas used in Londonderry. On the team are Dr. Norman MacDonald, chest physician; Dr. M.F. Khan, Professor of Medicine, University of Paris, a specialist on riot control agents; Dr. J. Mongar, Department of Pharmacology, University College, London; and Mrs. Hilary Rose, London School of Economics, specialist in social medicine.

JET AIRPORT plans for the Everglades have been abandoned, although the already constructed jet practice field remains. John Volpe, Secretary of Transportation, and Walter Hickel, Secretary of the Interior, expressed concern for the environment of the area in announcing the decision to halt the project. The airport has been vigorously opposed by conservationists.

--John William Folstad and Albert Bradford

(continued from page 16)

The reasoning behind this point of view goes something like this: A sub-therapeutic dose of an antibiotic would not kill all the target disease-causing microorganisms. The more resistant individuals would not be destroyed and could therefore multiply in the presence of the antibiotic. If the antibiotic were bacteriostatic, that is if it only hindered bacterial multiplication, then the sensitive microorganisms would not be able to multiply as fast as the resistant individuals and would gradually be supplanted by them. A few generations of such selection would work in favor of an increase in the population of resistant strains of disease-causing individuals. The net result would then be to make treatment of a disease far more difficult than it would have been without the "preventive" treatment.

There was a sharp disagreement on the use of antibiotics in animal feeds at the 1967 Symposium. Dr. C. K. Whitehair from Michigan State University, and Dr. B. S. Pomeroy from the University of Minnesota, said: "There has been no noticeable decrease in the incidence of disease of livestock and poultry that can be associated with the increased use of antibiotics in rations."

Dr. Thomas Jukes, Professor of Medical Physics at the University of California, took issue with this point of view:

> There are no statistics on the incidence of most of these diseases. Antibiotics in the feed are known to be effective against many diseases of livestock. Most significant of all . . . the number of livestock have increased enormously in the past 15 years, and animals today are kept under intensive and crowded conditions that greatly magnify problems of infection and necessitate the use of antibiotics.

Whether or not routine feeding of antibiotics has beneficial effects, there is no question about the existence of harmful side-effects. Some of these are: allergic and toxic effects of drugs, alterations in microbial flora which can cause disease, and the development of resistant strains of microorganisms. At the 1967 Symposium, Dr. William Buck of the Iowa State University of Science and Technology presented documented cases of untoward effects resulting from the use of antibiotics and other drugs in animal feeds and water supplies. Among the ill effects which Buck discussed is disease arising from alterations of microbial populations. To understand this effect, it is helpful to know something about relationships which exist among microorganisms. In the small world of the animal intestine where nutrients not completely digested in the stomach are further broken down and absorbed into the bloodstream, bacteria, fungi, and, protozoa live together in a delicate balance. Their world reflects an order parallel to the order we observe in the world around us. Any alteration of this environment affects the organisms which live in it. The relationships among the various organisms which live in the intestine are not completely understood. It is a complex place where the same species of bacteria act differently in different parts of the intestine, act differently according to the number present, and respond differently to chemicals introduced from the outside, depending upon their condition. Some bacteria aid in the process of digestion. Other bacteria which can cause disease inhabit the intestine but do not cause overt symptoms of disease unless something happens to upset the ecological balance. In addition to bacteria, there are fungi which live in the intestine and are kept in check if bacteria are allowed to grow freely.

The introduction of antibiotics into animal feed may upset the balance which exists among the flora in the gut of animals and cause disease. If a disease results from such an upset in the microbial flora, it is called endogenous disease, in contrast to exogenous disease which results from introduced disease-causing microorganisms. In the United States and other countries with highly developed technologies where much exogenous disease has been brought under control by sanitation and drugs, endogenous disease is becoming widespread.

Digestive problems in ruminant animals with multiple stomachs may arise from alterations in the microbial flora. Dr. Buck pointed out that sufficient doses of antibiotics (25 milligrams of chlortetracycline or aureomycin per kilogram of body weight) administered to dairy cows can reduce the bacterial count in their stomachs, hinder milk production, and cause loss of appetite and weight. Twenty-five milligrams per kilogram of body weight is about ten times the amount recommended for use in feed for purposes of growth promotion. Buck said, however, that it would be very easy for the farmer to add ten times the recommended amount to feed. Feedlot cattle can also have digestive problems as a result of continued feeding with antibiotics.

Other less serious problems can result from alterations in the flora of ruminants through the use

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of antibiotics. A farmer reported to his doctor friend that thousands of gallons of milk which he had taken from his cows would not make cheese. He had treated mastitis in the cows with injected penicillin which destroyed the *lactobacilli*, the bacteria responsible for making cheese from milk. This incident resulted from the injection of therapeutic amounts of antibiotics, rather than oral dosage, but it demonstrates well that the use of antibiotics can bring about unexpected results.

Another problem associated with the use of drugs in animal feeds is sensitivity reactions. There have been documented cases of these reactions in human medicine and in veterinary medicine. A survey of 46 Canadian veterinarians in 1963 revealed that 22 of them had noted problems with sensitivity to antibiotic drugs in the animals they had treated. There were reactions in 1,200 animals, twenty of which died.

Antibiotics may indirectly cause hemorrhages in chickens by slowing down the synthesis of vitamin K, which enhances blood clotting. Scientists have reported that levels of 10, 100, and 200 parts per million (ppm) of some antibiotics caused an increase in hemorrhaging in chickens, especially in those chickens which consumed larger amounts of food. The incidence of hemorrhaging appears to depend on the amount of antibiotic consumed and the grade of the antibiotic, the cruder grades producing more hemorrhages.

Buck also reported reactions to combinations of drugs used in animal feeds and water supplies. One farmer lost 50 of 2,000 young turkeys which showed symptoms of anemia before they died. He had been feeding them large amounts of oxytetracycline and 4-nitro-phenylarsonic acid in the feed and large amounts of sulfa drugs in water. Buck mentioned four incidents of reactions involving the use of antibiotics in combination with sulfa and other drugs.

Buck's report on untoward reactions resulting from the use of drugs in animal feed did not seem to cause much stir in the discussion afterwards. In his discussion of Buck's paper, Dr. Harold Peck of Merck Institute for Therapeutic Research said, "Dr. Buck indicated the possibility that drugs may alter the intestinal flora, with consequent increased or decreased growth of specific bacteria or fungi. Generally speaking, safety tests in the appropriate species of animals may alert the investigator to the fact that the drug is altering the intestinal flora." In relation to using combinations of drugs in feeds, Dr. Peck said that combinations can be, and are, tested for safety and efficacy. "The real problem arises when the manufacturer of a specific drug or drug combination, or the veterinarian or the farmer treating the animals, is not aware of the other drugs or natural food and water constituents the animal is or is not receiving."

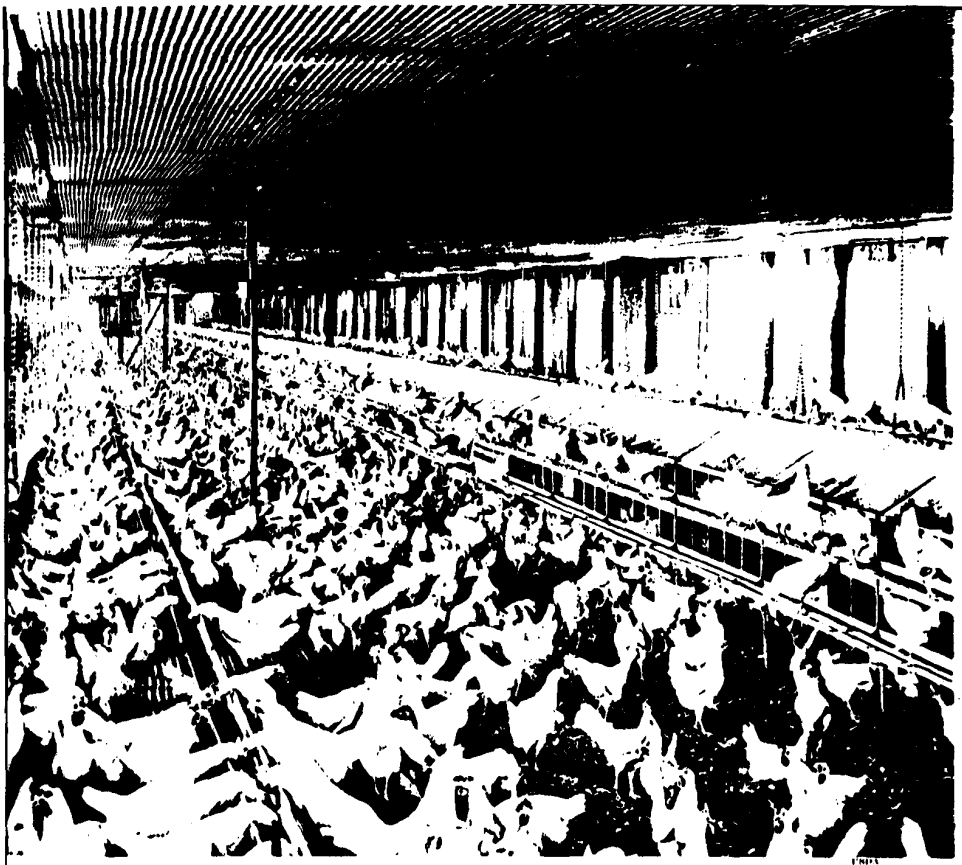
Scientists do not know what effects drugs used in animal feeds have on human health. They have shown concern about possible residues reaching the consumer in food products. Federal regulations prohibit residues of most antibiotics in meat and dairy products, but such residues nevertheless appear occasionally. About three percent of all milk on the market is contaminated with penicillin, according to one estimate. Despite repeated requests for information from the United States Department of Agriculture, *Environment* has not been able to obtain estimates of the amount of meat on sale which may contain antibiotic residues, nor would the Department provide figures on the proportion of inspected meat which is condemned as exceeding FDA tolerances.

When a farmer injects penicillin directly into the cow's udder for the treatment of mastitis infection, the cow's milk contains high residues of penicillin for some time. After such treatment a waiting period is required before the milk is put on the market. If this period is not observed, people drinking the milk may have allergic reactions. There have been reports of reactions ranging from skin irritation to total collapse.

There is a good deal of experimental evidence to show that animals may accumulate antibiotics in blood and muscle tissue when given antibiotics in their feed. Hence antibiotics may find their way into meat products if animals are slaughtered before antibiotic residues have disappeared.

When animals were fed chlortetracycline at levels of 50 ppm over an extended period of time, there were residues in the serum. At higher feeding levels, residues were still higher. The investigators recovered antibiotics from tissues at a level of 1 part per 1,000 parts of tissue after feeding at levels of 1,000 parts per million.

In assessing the effects of antibiotic residues on the consumer, it is important to remember that different antibiotics act differently in respect to tissue concentration and rate of disappearance from tissue. At the 1967 Symposium, Dr. Sven Ullberg, of the Royal Veterinary College of Sweden, reported on tissue concentrations of antibiotics after injection into mice. By freezing the mice soon after injection, and by making thin cross-sections and subjecting these to analysis, Ullberg was able to make some interesting comparisons of the fate of penicillin, dihydrostreptomycin, and the tetracycline antibiotics in tissue. Penicillin is rapidly excreted. The concentrations of this antibiotic are always lower in tissue, with the exception of the excretory organs, than in the blood. Concentrations of penicillin in the kidney are five times higher than in the blood. Dihydrostreptomycin showed the lowest tissue concentration of the three antibiotics tested, although it did not disappear as rapidly from tissue as did peni-



Antibiotics are routinely fed to poultry to stimulate growth. They have had a greater effect on the growth of poultry raised in a previously occupied and therefore unsanitary environment, than on those raised in sanitized or new quarters.

cillin. The tetracycline antibiotics are especially likely to concentrate in bones and teeth. They can remain in bones for months at a time. Other organs of accumulation for the tetracyclines are the kidney, liver, and intestine. Tetracyclines tend to concentrate at higher levels in tissue than in blood in comparison to penicillin and dihydrostreptomycin. Ullberg pointed out that antibiotic residues disappear faster from small animals than large animals.

Higher levels of antibiotics in animal feeds would be required to cause noticeable residues which might affect the consumer. Farmers are supposed to observe withdrawal periods after feeding high levels of antibiotics, to allow antibiotics to disappear from organs in which they tend to concentrate. As noted above, the United States Department of Agriculture, despite repeated requests, has failed to provide any information on the extent to which these regulations are followed.

Other Agricultural Uses of Antibiotics

Before September 7, 1967, the tetracycline antibiotics were used on raw fish and poultry to prevent the growth of microorganisms which cause spoilage. On that date, the FDA revoked tolerances for the tetracyclines for those purposes because they felt that the benefits derived from the preservative powers of these drugs were outweighed by the danger that

microorganisms resistant to antibiotics would develop and find their way into human food. It is now illegal to use antibiotics as preservatives on raw agricultural commodities in the United States.

Previous to this regulation, one method for preserving fish and poultry was by dipping in antibiotic solution or in antibiotic-treated ice. This could be done in the factory in large tanks, or with fish in the hold of a ship soon after catch. Some fish factories had problems because resistant organisms collected on the walls of the dip tanks creating a sanitation problem. The factory workers had to clean the tanks frequently to maintain the effectiveness of the antibiotics.

Another factor which may have contributed to the FDA's decision to ban the use of antibiotics in food preservation is this: Such treatment leaves some residue on food products. In poultry, residues were from one to four ppm. In fish they ranged from one to five ppm. These residues were apparently of minor concern to officials as compared to concern over the development of resistant microorganisms.

The present ban on the use of antibiotics as food preservatives does not mean that an antibiotic will never be approved for that purpose. The FDA stated: "At the present time such approval would be likely only to solve a particularly serious problem."

Farmers also use antibiotics to protect their crops from bacterial and fungal diseases. The United States Department of Agriculture has approved three antibiotics for use on crops: streptomycin; polyamidohygrostreptin (a derivative of *Streptomyces hygroscopicus*) and cycloheximide, an antibiotic which is too toxic for use in animal and human medicine. About ten tons of streptomycin are used annually on various crops in concentrations ranging from 25 to 2,000 parts streptomycin per million parts of solution: on celery transplants, potato seed pieces, hops before vine training, tobacco, a variety of ornamentals, and on apples and pears to control fireblight. Although cycloheximide is not used on food crops, about ten tons of it are used annually on ornamentals, lawns, golf course fairways, hawthorne, cedar and white pine trees to control fungal disease in concentrations ranging from 2 to 150 parts cycloheximide per million parts of solution.

Another antibiotic-like substance, Blasticidin S, produced by *Streptomyces griseochromogenes*, has proved effective in controlling rice blast disease in Japan where over 10,000 tons of it are used annually on rice fields.

In addition to their positive effects against plant disease, antibiotics have also had effects on plant growth. Depending upon the kind and amount of antibiotic used, both growth stimulation and depression have been noted. Antibiotics are not now commercially used to alter the growth rate of plants.

The Controversy

Despite their drawbacks, antibiotics in feeds have strong supporters. Some experts feel that antibiotics have effectively promoted growth, improved feed efficiency, and decreased the level of infectious disease in animals. They see the possible dangers of allergic or toxic reactions and the development of resistance as minor problems when weighed against the benefits derived from using antibiotics.

At the 1967 Symposium, Thomas Jukes said, ". . . the maintenance of the supply of food at the present level is not possible without using the full resources of scientific technology, including the use of antibiotics in animal production."

Dr. M. R. Clarkson of the American Veterinary Association said, "Speaker after speaker has shown the value of these additives, attesting to the genius of American science in their development, and of the American industry in their integration into the production and marketing system."

Others feel that antibiotics have not always promoted growth and have not reduced the level of infectious disease. They are concerned that the practice of feeding antibiotics routinely to animals will lead to the development of resistant disease germs which might transfer their resistance to human pathogens, thus putting the control of infectious disease back before the time when antibiotics were discovered. The latter point will be discussed at greater length in another article in this series. ☐

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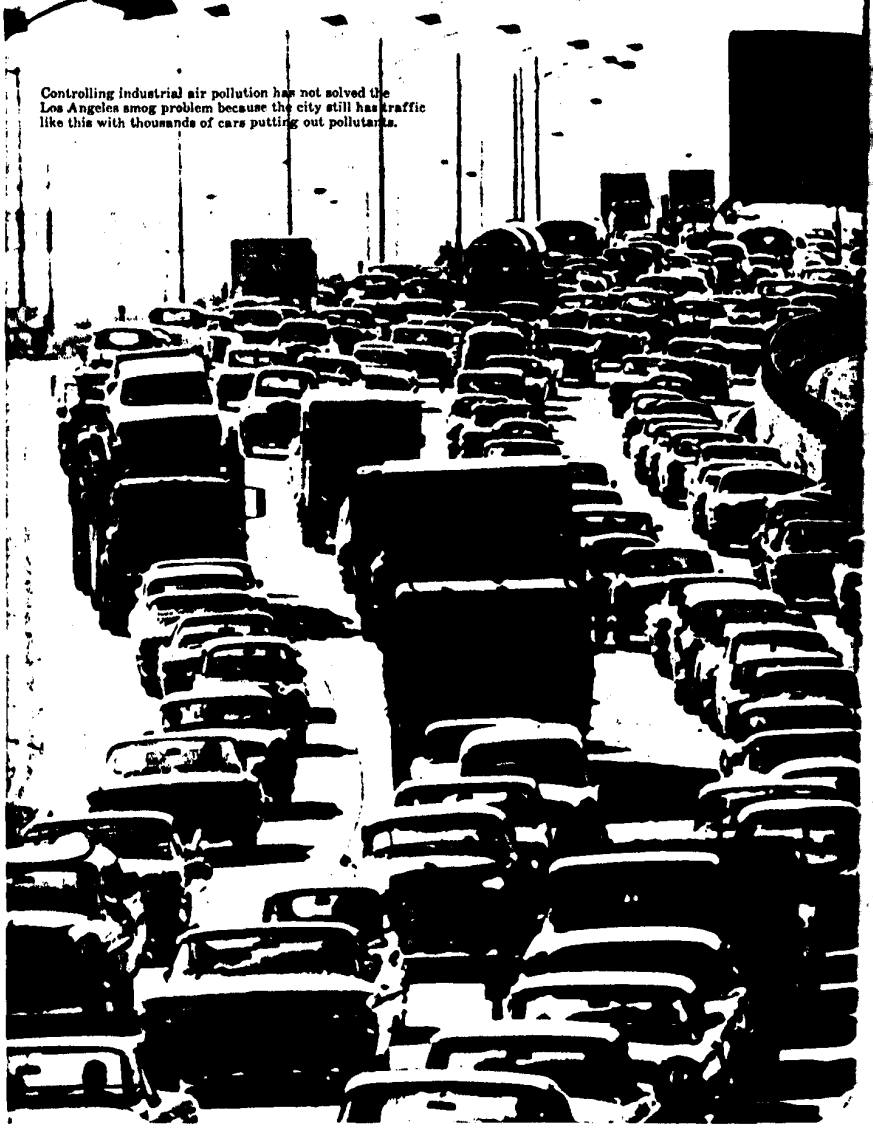
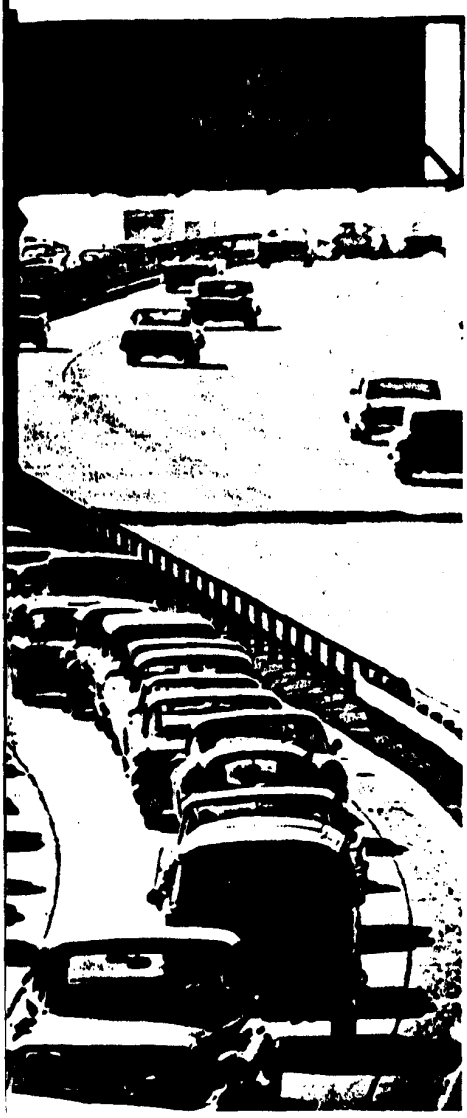
The author and ENVIRONMENT are indebted to Dr. Nelson B. King, Assistant Dean, School of Veterinary Medicine, Auburn University, who first brought the agricultural use of antibiotics to our attention, and was helpful in the preparation of this article. Responsibility for the content of the article and any errors therein remains with the author and the Scientific Division of the Committee for Environmental Information.



Controlling industrial air pollution has not solved the Los Angeles smog problem because the city still has traffic like this with thousands of cars putting out pollutants.



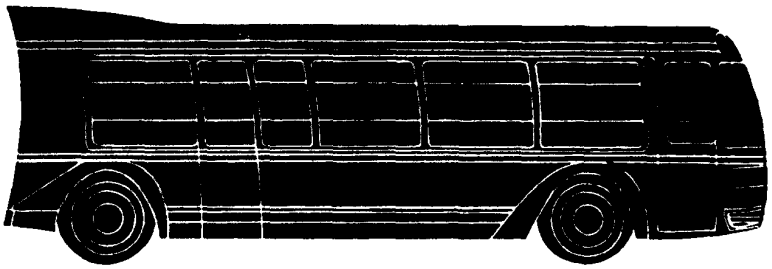
Tempest Over a Teapot

By Terri Aaronson

THE AUTOMOBILE is the single largest source of air pollution. It is accountable for 60 percent of this nation's total air pollution ills and for more than 85 percent of the air pollution in some cities.

Because of these discouraging figures, Congress has become keenly aware of the need to redesign the automobile if air pollution is to be curtailed. The Senate Commerce Committee and the Subcommittee on Air and Water Pollution of the Committee on Public Works held steam vehicle hearings in May, 1968 to determine the feasibility of one type of low-emission vehicle. The report which grew out of these hearings, "The Search for a Low-Emission Vehicle," was published early this spring by the Commerce Committee.

The source of automobiles' pollutants is, of course, the internal combustion engine (ICE). The ICE does an incomplete job of burning its fuel and emits the unburned portions into the atmosphere. The unburned fuel contains carbon monoxide, hydrocarbons, and lead. By-products of the combustion pro-



Santa Clara County, California residents recently considered initiating a low-emission bus transportation system which would use this steam-driven coach.

cess and the subsequent photochemical process in the atmosphere are nitrogen oxides, ozone, and other oxidants. Each of these substances is known to have deleterious effects on humans, and some are harmful to plants as well. Obviously, if we are to attempt to cleanse the air we breathe the ICE must either be refined, controlled, or replaced.

The Commerce Committee identified the following considerations which led them to look for power sources *other* than the ICE. Under present auto emission controls it is projected that air pollution will double in the next 30 years due to an increased number of vehicles and greater use of each vehicle. And under present standards nitrogen oxides would actually be greater than if there were no controls at all. California is the only state which has adopted emission standards for nitrogen oxides. However, the report notes that there is no guarantee that Detroit will produce vehicles capable of attaining California's standards. Finally, and most important of the considerations, is that the technology to control emissions in the ICE is sorely lacking. This is especially true of nitrogen oxides, which are produced from atmospheric nitrogen and oxygen at high temperature and pressure. And it must be noted that even if control devices are developed, there is no assurance of their continued effectiveness. A further point is that if cost is kept reasonable, these devices will be such that they can be tampered with by automobile owners disappointed with the decreased efficiency of the car engine when the controls are properly engaged. The report concludes that present controls are preferable to none at all, "but the present approach will not solve the air pollution epidemic. A new approach is needed."

The Commerce Committee, under the direction of Chairman Warren Magnuson, has been interested for some time in alternative power systems to the ICE. In 1967 the Committee held hearings on electric vehicles but determined that research and development on them had not reached the point at which electric vehicles could be competitive with the ICE in general-purpose automobiles. In May, 1968, however, the U.S. Department of Commerce published a staff report, "The Automobile and Air Pollution: A Program for Progress (Part II)," which commented favorably on steam-powered vehicles. The Senate Commerce Committee then began hearings on the merits of such power systems. The findings of the Committee overwhelmingly support the use of steam-powered vehicles as a feasible and reasonable substitute for ICE vehicles and as "a dramatically superior alternative in terms of emissions."

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The Rankine Engine

The steam engine considered by the Commerce Committee is a Rankine or vapor-cycle propulsion system. Although there are other types of engines in various stages of development, the Committee hearings dealt primarily with the Rankine engine, which, at the time and in view of such considerations as cost, size, and efficiency, seemed to be the best alternative to the ICE. The Rankine engine is an *external* combustion engine like its predecessor, the old Stanley Steamer; but the comparison just about ends there. The Rankine engine basically consists of a closed tube containing a working fluid which is heated *externally* by a burner using low-grade gasoline or kerosene as a fuel. The working fluid, transformed to a vapor, drives either pistons or a turbine. The vapor is then passed through a condenser and recycled. This process allows the fuel to be burned more completely than in the ICE, in which the fuel is exploded rather than burned evenly. Thus, emissions are greatly decreased:

	8-Year Old Williams Steam Car	Uncontrolled Internal Combustion Engine
Hydrocarbons	20 ppm	9000 ppm
Carbon monoxide	0.05%	3.5%
Nitrogen oxides	40 ppm	1500 ppm
Lead	None	Depending on type of gasoline used

One of the most important features of the Rankine engine emission figures is that emission control is an integral part of the engine. As long as the engine runs it will operate at roughly the original emission level. This is particularly noteworthy in comparison to the ICE which must have pollution controls added which are subject to deterioration apart from the engine.

Clearly, the Rankine engine is a power source superior to the ICE in terms of pollution control. But does it meet other requirements as a general-use automotive power source? Although the affirmative answer has been questioned by some of the Detroit vehicle manufacturing companies, the Commerce Committee sees no disadvantages to the Rankine engine.

The Rankine, or external combustion engine (ECE), delivers full power immediately ("high torque at low speeds") and therefore does not need a transmission to accelerate from a dead stop or at low speeds. A simple transmission may be needed, however, to gear down the power train to avoid wheel spins and too-rapid acceleration. The ECE-powered automobile can use either the reverse torque of the engine for braking or conventional braking methods.

That the Rankine engine can be used in normal automobile bodies has been proven by the installation by Lear Motors Corporation of a steam power system into a Dodge Polara for the California Highway Patrol. The Senate report suggests that the burner, generator, and condenser fit into the existing space under the front hood, and that the engine itself be placed further back in the current transmission casing or near the differential. The May 1968 hearings included some discrepancies as to size and weight of the ECE. General Motors, in particular, was quite concerned that the ECE would weigh three times as much as current ICE's. Most other witnesses disagreed with this conclusion. The Commerce Committee concluded that size and weight of the ECE were no real problem, particularly since the complicated transmission is unnecessary.

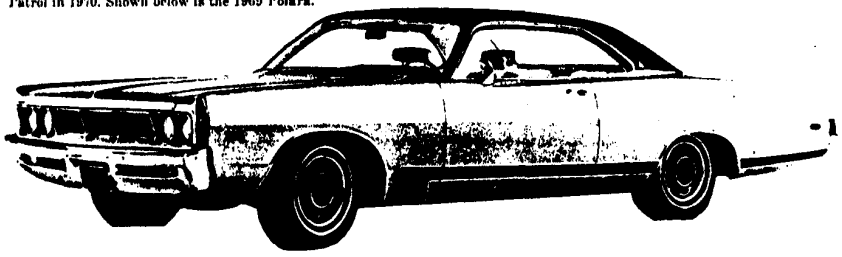
A further benefit of the Rankine system is that it permits a small Rankine engine to operate even when the main engine is shut off. The small engine can run accessories such as heating and air conditioning without the possibility of overheating when the car is not in motion.

Wide use of the Rankine engine would also reduce noise pollution. The report claims that a great deal of noise pollution stems from trucks and buses gearing up and down. With the Rankine system this noise would be reduced to "a tolerable whirring sound."

Probably the most vital consumer consideration concerning steam vehicles is whether they will be cost-competitive with ICE automobiles. From current evidence they will be, although it is impossible to determine the exact cost of an ECE vehicle in advance. Nevertheless, the report quotes a Batelle Memorial Institute research report which states that "the best available evidence indicates that the specific cost [of the ECE-powered vehicle] will be less than that of a comparable diesel engine and about equal to that of an equivalent V-8 engine with automatic transmission. The additional cost of a transmission will be eliminated with steam power."

The auto manufacturers have challenged these assertions. Since the publication of the Commerce Committee report, General Motors has revealed for

Steam-powered engines may be used in contemporary automobile bodies. Such a power system has been installed into some Dodge Polaras for use by the California Highway Patrol in 1970. Shown below is the 1969 Polara.



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the first time some of its own research into steam engines. In a press briefing reported in the July issue of *Industrial Research*, GM showed two operational steam cars with which it had been experimenting. The more advanced of these was a 1969 Pontiac Grand Prix fitted with a four-cylinder piston steam engine. GM engineers were quoted as saying that the 160-horsepower motor weighed 204 kilograms more than the engine it replaced and produced less than half the power. Drawings published in the magazine showed an engine far different and more complex than that considered by the Commerce Committee, and included an automatic transmission and air-conditioning.

One attractive feature of the Rankine system considered by the Commerce Committee is that it runs on low-grade white kerosene or, if need be during a transition period, on any service station gasoline. The steam engine does not need additives such as lead, further reducing its pollution potential.

Other consumer concerns, however, should be regarded. These concerns take the form primarily of doubt about reliability and ease of maintenance of steam-powered vehicles. One fear of consumers—left from the Stanley Steamer days—is that a long period of time may be required for warming up the engine. Actually, it takes only twenty seconds for the Rankine engine to achieve full power when it has been started cold. If the engine is started after a short period of disuse—up to three hours—start-up is instantaneous. Another fear attributable to the Stanley is that of "freeze-up" during cold weather. This problem is being overcome by steam-engine manufacturers through the use of new working fluids such as freon, the use of new anti-freeze agents, special design of the water tank, or by use of a small pilot light within the burner.

William Lear, principal entrepreneur and exponent of steam cars, was quoted in the *Wall Street Journal* July 25 as saying that his new anti-freeze ("Learium") will stand the intense heat of a steam engine, yet prevent freezing down to 60 degrees below zero.

As for safety features, the Rankine engine appears to be at least as safe as the ICE. There is virtually no chance of explosion, even upon impact. Very little vapor is in the engine at any time. If the monotube in which the vapor is contained is ruptured, there is a release of vapor but no explosion—a minor risk compared to the possibility of explosion of twenty gallons or so of high octane fuel.

The question of durability and ease of maintenance of the steam-powered vehicle remains unsettled according to the evidence contained in the report. Ford Motor Company claims that the ECE is more complicated than an ICE and hence more difficult to maintain. Other evidence presented to the Commerce Committee stresses the fact that an ICE with the emission controls necessary to achieve desirable pollution standards will be a very complicated piece of hardware. The Committee concluded that the Rankine engine will be at least equal to and probably better than the ICE in terms of maintenance.

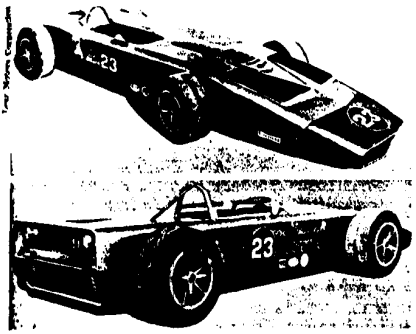
Obstacles and Recommendations

The Commerce Committee report concludes that "the Rankine cycle propulsion system is a satisfactory alternative to the present internal combustion engine in terms of performance and a far superior engine in terms of emissions." This strong avowal is reinforced by the Committee's noting that "opponents of change" may disagree with the report's conclusion, but that old criticisms which arose at the Committee hearings, particularly from the Big Three (General Motors, Chrysler, and Ford) motor companies, are simply no longer valid. And new criticisms will probably be outdated within a short time. A very pertinent point made in the report is that comparatively little money has gone into research and development of steam-powered vehicles. This leaves the potential for the ECE wide open, whereas the great amount of time and money which have gone into the ICE have failed to achieve an acceptable low-emission vehicle.

While advocating a change to steam-propelled vehicles, the Commerce Committee noted three obstacles to their wide acceptance. First is the inertia of the automobile industry. Representatives of Ford remarked at the hearings that the automobile industry is not adverse to change but rather that it sees no consumer demand at the current time for low-emission vehicles. Wryly, the report notes that American Motors, which does not have a large stake in the present market, does see such a demand and is pursuing an active research program on steam-powered vehicles.

The report states that the federal government is not doing very much to foster demand for ECE-driven vehicles. In fiscal year 1967 the Department of Health, Education & Welfare spent $3.2 million for research on emission controls for the ICE, and only $115,000 on research for low-emission alternatives to the ICE. With the automobile industry and the federal government doing little to direct attention to the ECE, the public is largely unaware of its possibilities. The report suggests that perhaps some consumer demand for the ECE can be fostered by publicizing it — through such glamorous means as a steam-powered racing car.

The second obstacle for steam engines to overcome is in the petroleum industry. If the Rankine propulsion system is widely accepted, it will require a drastic overhauling of the petroleum industry. Refineries for high-octane fuels will have to be revamped to produce low-grade kerosene. The report



In its attempt to develop a low emission automobile engine, Lear Motors has developed this championship class steam racing car which has been on display in the New York Coliseum.

acknowledges that steam-powered vehicles will seriously disrupt the petroleum industry.

At this point, the report says, it seems unlikely that the Detroit manufacturers will develop an alternative to the ICE — they simply have too much invested in it. An independent manufacturer might be expected to lead the way with steam automobiles, but this raises the third difficulty: the costs of entering the automobile market are almost prohibitive. To produce enough vehicles to achieve economies of scale would require an enormous initial investment. Other problems would include the difficulties of establishing dealerships and servicing facilities.

The Commerce Committee report suggests that one way of overcoming the cost of entry is for a Rankine propulsion-system producer to contract with an established automobile producer to put the steam system into some of the producer's vehicles. Then, dealerships and servicing would be transferred to steam vehicles in the simplest manner.

Or, the report continues, the Rankine-propulsion vehicle manufacturer might sell exclusively to specialized markets during the initial marketing period. This would consist mainly of selling fleets of taxies, buses, or trucks. Servicing of fleets is usually performed at a central place and thus once a center was constructed servicing would be of little difficulty. Dealerships, also, would not create problems as they would be unnecessary. Costs would be high for nonpropulsion parts since there would not be large-scale production; but this method might be a practical way to enter the market.

Even this method, however, is not very likely to succeed. If such a method were attempted and succeeded in creating a viable market, it is practically certain that the Detroit automobile manufacturers would then enter the market and overwhelm the initial, independent promoter. There is, therefore, little incentive for an independent manufacturer to assume the initial risks.

In spite of these dire predictions of difficulties the Commerce Committee offers a series of recommendations for encouraging steam vehicle development. These recommendations are:

> Congress should pass legislation requiring government procurement of low-emission vehicles.
>
> State and local governments should adopt low-emission vehicle procurement policies.
>
> The Department of Transportation should finance demonstration projects which would test various transportation applications of low-emission propulsion systems.
>
> The Department of Health, Education, and Welfare should devote a greater portion of its research funds to inherently low-polluting propulsion systems.
>
> State licensing and taxing authorities should consider creating economic incentives for private ownership of low-emission vehicles.

These recommendations are aimed at creating a demand for low-emission vehicles. The demand which could be created by the federal government alone is sizable and might induce the automobile industry to hasten its development of low-emission vehicles. The Post Office Department has expressed an interest in steam-powered vehicles and indicates that "research and engineering appropriation is available for the purchase of experimental units." Financial investments by the Department of Transportation and the Department of Health, Education, and Welfare would also give impetus to development and publicity of steam-powered vehicles.

The picture drawn by the Commerce Committee report is one in which technical issues, despite the space they are given, are much overshadowed by political and economic factors. Low-pollution alternatives to the internal combustion engine are available or can be developed. The Committee performs a service in pointing this out and an even greater service in asking how, and whether, we are going to avail ourselves of these choices. ❑

NOTES

p. 23. *"It is accountable for 60 percent . . . 85 percent. . . ."* **The Search for a Low-Emission Vehicle, a staff report prepared for the Committee on Commerce, United States Senate, U.S. Government Printing Office, p. 2, 1969.**

"The report . . ." **Ibid.**

Reviews

Attack on Atomic Power

THE PERILS OF THE PEACEFUL ATOM
Richard Curtis and Elizabeth Hogan
Doubleday and Co., 1969
$6.95, 244 pages.

This book might be considered an antidote to the constant litany on the benefits of nuclear power coming from the nuclear industry and the Atomic Energy Commission (AEC). The book's language is not meant to be soothing; it tends to be shrill and somewhat repetitious. It is calculated to prod and twist and irritate those nuclear industry nerve-ends which the Novick book ("The Careless Atom," Houghton Mifflin Company, 1969) has already exposed.

Unfortunately, some technical inaccuracies have been included, for example, in explaining the source of radioactive hazards from nuclear power plants. This is understandable in view of the enormous complexity of the so-called nuclear art, but it seriously damages the authors' credibility.

The burden of the book is that the peaceful atom for electric power production is not as safe, clean, reliable or economical as its public relations advocates would have us believe. The authors state at the outset that "in the case of atomically generated electric power, human ingenuity has created technological hazards far beyond mortal competence to control." They support their contention with page after page of examples which, in spite of the protestations and contradictions which are issuing from the industry, still raise serious questions. The point is made that, notwithstanding care in design and review, the probabilities for errors, mistakes, poor workmanship and the like can override the effectiveness of "fail-safe" mechanisms and "redundancy" in safety measures.

Curtis and Hogan point to the potential disasters which could result from human failure or sabotage. They question whether communities near nuclear plants have plans of any kind for the evacuation of the population in the event of a serious accident. They wonder about the adequacy of medical services versed in the handling of radiological exposure. They raise the important query of whether operating nuclear power plant personnel, although examined physically, are screened for mental fitness. How would they function during emergencies and moments of stress? In this regard, one thinks of the careful screening and long training of astronauts; can we learn some lessons from this national experience?

Excellent discussion is included in the book regarding the farce of insurance coverage for nuclear accidents. (The August 4, 1969 issue of McGraw Hill's *Electrical World*, in its "Management Newsletter" parallels many of the Curtis-Hogan questions.) As the authors point out, an early AEC report estimated a "maximum" accident might cause deaths in the several thousands, injury to tens of thousands, and damage of $7 billion. The nuclear power industry insurance pool so far provides coverage up to $82 million; the U.S. Government through the Price-Anderson Indemnity Act makes available up to $478 million. One may wonder, as do Curtis and Hogan, who picks up the tab on the other $6,440,000,000 if an accident reaches these proportions.

The book deals at length with the nature of the public relations effort by the industry to make a nuclear power plant acceptable to a community in which such a plant is proposed. It stresses the attempts by the industry to lull public fears at all stages, and to avoid confrontation with some of the less palatable facts.

Dispersed through the book are references to the monolithic character of the atomic energy establishment: the AEC and its supposed watchdog, the Joint Committee on Atomic Energy of the U.S. Congress. It questions whether both regulatory and development functions should be vested in the AEC. The authors express the view that the AEC mandatory public hearings are "window-dressing" and that "actual decisions are made behind closed doors beyond public scrutiny." These are serious charges and deserve a serious reply from the AEC.

The concluding views of the authors concerning national power needs are both extreme ("continued effort to develop a safe atomic power program is not worth the risk to humanity") and technically faulty. They are naively optimistic about developments very much in the research and development stage, if that far. It would have been better, in this reviewer's opinion, if the authors had pointed out the urgent need to accelerate research and development in such areas as magneto-hydrodynamics (MHD) and fuel cells with the type of financial and industrial vigor which unfortunately has been concentrated on nuclear energy.

The value of this book is that it raises questions which should be raised. Some may be answerable by the nuclear power industry; in other cases there may be no answers, or they may be imperfect ones. The general public, to whom the book is addressed, should use it with caution because of its technical weaknesses.

IVAN BLOCH
Industrial Consultant
Portland, Oregon

Faith

GARDEN IN THE WEST
George S. Wells
Dodd, Mead & Company, 1969
$5.00, 270 pages.

California is by far the biggest garden in the West. Both its yields per acre and its total production of many major agricultural products are the highest in the world. This is possible, says George Wells, because scientific research has provided "a miracle a day" to increase and improve what the land yields and at the same time to outwit Nature's constant threats to production: plant diseases, pests, bad weather, lack of water, and low soil fertility. This book is a folksy, enthusiastic, and non-technical account of some of these

dramatic production "miracles" from the early wheat boom to the development of commercial types of pears and tomatoes. The introduction and the last chapter frame these success stories with hopes that the rest of the world will follow the principles of sophisticated scientific food production that have so dramatically proven themselves in California.

Already many countries are seriously trying to transform traditional farming into California-style cash-crop, vast-acreage mechanized agriculture. Statesmen and farmers everywhere have looked with amazement at the spectacular yields of Western gardens. Since many of them, like Wells, have looked no further, they have evolved a faith in miracles similar to his and proceeded home to transform their lands. This faith, which is reiterated in every chapter of Wells's book, is based on two assumptions: Nature is to be fought, controlled and exploited by man, and science will make this possible by coming through in time with the answers to most significant problems of food production.

There is a great deal of evidence, some of it actually in GARDEN IN THE WEST, that miracles must be paid for dearly and that in fact it is Nature, not man, who finally calls the shots. The author discusses how heavy use of pesticides has often encouraged great increases in the number of insects pests harmful to certain crops, after a preliminary grace period of wonderful effectiveness in pest control. The pesticides kill off all natural enemies of the harmful insect, which itself develops resistance to the pesticide and then expands in numbers. Control of the pests has come only with greatly reduced and more selective spraying and a reintroduction of natural enemies of the pest. Yet Wells apparently interprets such natural control measures as an example of man outwitting the insect pests. He does not seem to consider it significant that the conditions making the pests a problem were created by man, and the conditions removing the pests required man to understand and submit to natural control.

Modern irrigation systems are acclaimed by Wells as another triumph of man over the environment. Such systems, often including huge dams, have usually been built to obtain specific goals of food, power production, and sometimes flood control. But in some cases the results have been unexpected. In Pakistan, extensive impoundment of waters and irrigation caused a rise in the subsurface water level. This water was sufficiently laden with dissolved minerals and salts to ruin millions of acres of good land. In California serious proposals are being made to drain away the high water table caused by abundant irrigation water so that dissolved minerals will not continue to seep up into the topsoil and take it out of production. (See "Desalting California" by Frank Stead, *Environment*, June, 1969.)

Who will care how many battles with Nature man wins if Nature wins the war? Who will be around to count the money? As long as we concentrate on the miracles and the short-term economic gains and ignore the pervasive and often enormous hidden costs to the natural world we may continue to "control" Nature until it is to late. For it is the natural world, not our own wit, that supports us and on which we depend for the miracle of our continued existence.

A.B.

In a Radioactive Hole

SYMPOSIUM ON PUBLIC HEALTH ASPECTS OF PEACEFUL USES OF NUCLEAR EXPLOSIVES

Sponsored by the Southwestern Radiological Health Laboratory, U.S. Department of Health, Education, and Welfare. Las Vegas, Nevada, April 7-11, 1969.

Government agencies were out in full battle dress to impress all with the meticulous and extensive safeguards for public welfare that were built into the Plowshare Program for the peaceful uses of nuclear explosives. The conclusion was to be inescapable: Plowshare was no threat to health or to safety within the confines of the appropriate controls that had been devised.

Thirty-nine papers were presented to illustrate how problems were tackled in the fields of airblast, groundshock, radioactive contamination, ecology, geology, hydrology and engineering. Craig Hosmer, the ranking minority member of the Joint Congressional Committee on Atomic Energy, was present to assure the assemblage that Plowshare was thoroughly researched and nearing the stage of productive implementation. He termed the uninformed dissenters a "paranoiac clique." Finally, tours were available to the Nevada Test Site and to the Southwestern Radiological Health Laboratory where extensive safety facilities and hardware were displayed for those who needed to see and to touch — not merely to listen — in order to be convinced.

Four hundred scientists, engineers and business representatives ranging from members of Howard Hughes's organization to foreign observers, attended, but there were very few medical or public health people to scrutinize the radiological health data presented.

Twenty-three Plowshare events have taken place since 1961. The radiation released by these detonations was the crucial data needed for independent evaluation of the government safeguard program; it was not presented.

Serious doubts and misgivings grow in an atmosphere where blind faith, nurtured by an unbreachable wall of "security," is offered as a substitute for factual proof. This observer left with the uneasy feeling that more trouble is brewed by withholding information than by presenting information.

Reviews

although government spokesmen obviously felt that the opposite was true.

If Plowshare is to dig canals and harbors, create underground reservoirs, and mine locked-up stores of gas, oil and copper, then it is not enough to know that it is technically feasible. We must know, and in convincing detail, that it is "bioenvironmentally feasible," to use a Lawrence Radiation Laboratory phrase. A wealth of government-sponsored research was presented along this important avenue, but without the aforementioned hard radiation data.

Many elaborate studies shared a common research approach. The worst possible case of radiation exposure was always properly assumed for the mathematical models and hypothetical equations. All the many pathways of internal and external exposure were fed into the computations, when that was possible. Unfortunately, it was not not always possible, as the investigators readily pointed out.

Most studies were confined to systems that were "closed" to one or more important variables. This means, for example, that the studies concerned with the terrestrial effects of radiation neglected the contributions made by airborne or waterborne contamination, and *vice versa*. Certain radionuclides were measured and followed through the environment with admirable tenacity, while the shared exposure from other radioactivities was ignored. No study could handle all the pathways and variations in exposure. No study took into account the changes in isotope distribution induced in an ecosystem by the very radiation being studied. All this was honestly admitted by the researchers as a measure of the work still to be done before bioenvironmental feasibility is an accepted fact.

Several papers will serve to illustrate the serious inherent problems in safeguarding the Plowshare Program.

The off-site safety program around the Nevada Test Site was explained to show the kind of precautions that would serve as protection in larger, industrially significant projects. Monitoring equipment of advanced design assayed radiation contamination before and after all shots. Measurements were made in air, water, milk, vegetation, animals, employees and adult residents of the areas at risk on appropriate schedules. When J. R. McBride, Deputy Director of Southwestern Radiological Health Laboratory, was asked if children, those unique concentrators of iodine 131, were regularly monitored the answer was "no." The difficult mechanics of monitoring school children (and the effect on the community?) were not worth the effort.

Project Gasbuggy came in for much comment. This 26-kiloton Plowshare event was detonated on December 10, 1967, 4200 feet below the San Juan basin of New Mexico to explore the mining of gas by nuclear explosives. The authorities concerned stressed that the gas was produced for exhaustive study and not for marketing. The gas contained a plethora of radionuclides, the most troublesome being iodine 131, xenon 133, krypton 85 and tritium. Analyses revealed that while the commercially valuable methane portion of the gas initially formed over 85 percent of the total, it dropped in seven months to 37 to 44 percent, while the inert carbon dioxide rose from less than 1 percent to 36 percent. Studies are underway on how to remove the impurities, including the radioactivity.

Gasbuggy highlights the difficulties in the commercial marketing of products mined by nuclear methods. As the researchers realize, for each product to be safely distributed, we must know its varied radionuclear contaminants and their concentrations, the quantity of product to be used in a given operation, and the radiation doses to different populations to be exposed (both the full-body doses and the doses to particular organs that concentrate a particular radionuclide). Only then are we ready to sit down and calculate the probable dangers of such exposure. Until such technical requirements are satisfied, Gasbuggy must languish in its radioactive hole.

Only now are some detailed studies from Sedan, an early Plowshare shot (June 7, 1962) being completed and reported. Lawrence Radiation Laboratory scientists traced the path of tritium from Sedan in ecosystems from water to plants to the pregnant female kangaroo rat to the placental (afterbirth) transfer to its embryo to the liver of the newborn rat all the way down to a basic tritium-induced alteration in the DNA (the very stuff of life) in the liver. The multitude of other radionuclides await such elaborate sleuthing, as well as genetic studies of transference of such basic alterations.

Public relations problems in winning acceptance of the Plowshare Program were not overlooked. T. M. Gerusky of the Pennsylvania Department of Health pointed out that Project Ketch, the 1966 proposal to build a gas reservoir in his state, had to be cancelled because of public alarm. Pennsylvanians had been educated to accept thirteen nuclear power plants, but not one radioactive explosion. Gerusky stressed the necessity for independent review of such projects as Ketch in order to win public confidence.

This naturally opened up the Pandora's box of the propriety of having the promoter of a new technology (government or private promoters) serve in the dual role of regulators of that same technology. Or should development and regulation be scrupulously separate phases?

The philosophy to be applied to development, regulations and safeguards was almost universally accepted to be the "theory of optimization," or "benefit-risk theory." This holds that it should be possible to weigh all the benefits in one pan and all the risks in another in order to decide if new technology should be further implemented. In practice, according to several speakers, the precise definition of benefits and risks often proved impossible in suitable and equivalent units, not to mention the difficulty in finding an appropriate scale for the weighing-in. As a result, many wished to turn to an alternate pragmatic concept of "acceptable risk." In Plowshare jargon, acceptable risk means that when the radiation exposure is "negligible" the risk is acceptable. The mind, however, boggles at the definition of acceptable radiation.

On this imprecise philosophical note, the symposium adjourned. Several participants rushed off to Vienna where meetings were starting with the Russians to trade "secrets" about the peaceful uses of nuclear explosives, and to devise means for sharing with other nations the benefits (and the risks?).

Meanwhile, the words of G. D. C. Thompson, the Utah State Director of Health, who had already suffered his baptism by fire in the iodine 131 fallout episode of 1962 and last year's Dugway sheepkill, sounded like a torsion: ". . . The decision as to whether or not to continue promoting the possible benefits of a program to society revolves around questions of how adequate are our predictions and measurements of contamination and what are some long-term effects of pursuing a certain course of action."

ROBERT KARSH, M.D.

Under the Rug

(continued from page 13)

the ocean in the area. But during a more recent visit the same officials said they have plugged all but four of their disposal wells and are getting rid of the remaining four as fast as they can. They explained that in the long run it will be cheaper and less troublesome to clean up pollution at the plants. Disposal wells, they stated, are unpredictable and expensive. The risk of costly lawsuits resulting from pollution breaking out at unknown times and places is too great. "We finally decided that we were turning snakes loose in the grass that might come back and bite us," remarked one official.

The company now has a new $4 million plant that cleans every drop of water from the company's oil refining and petrochemical complex on the Houston Ship Channel. After being cleaned, the water is discharged into an artificial lake full of healthy fish. The plant superintendent said that the fish are inspected every day and "if one of them gets sick, there's hell to pay in the plant until we find out what's bugging him. Then we clean up the water."

Most of the many deep-well problems discussed here can be avoided. Wastes can be purified and recycled back into the environment or stored for future use when material in the wastes might be valuable. In the case of brine taken from gas and oil wells, the brine can be pumped back into formations from which fluid had been extracted, thereby bringing the formation back to equilibrium pressure. Injecting radioactive and poisonous industrial wastes into virgin formations, upsetting the subsurface balance of pressures, promises nothing but trouble. ❑

NOTES

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"Water injected underground, whether for . . ."
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p. 8. *"At one of the two deep . . ."*
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Input

Mercury and Grain

I wish to congratulate you on your recent issue of *Environment* covering many aspects of the mercury problem. There are however a few things in your article that are not quite correct. The question of mercury poisoning in nature is not one of poisoning via grain etc. as is suggested on page 14 of your May issue. It is slightly more complicated.

Methyl mercury is a compound that is transported to man via many food chains. Let me give an example: From the pulp factories, methyl mercury is discharged into the lakes, where it is taken up by plankton, which in its turn is eaten by fish at different levels of the food web. In this way it is concentrated in the bodies of some fish which are eaten by man.

There is as yet no indication that grain takes up mercury from the seeds or the soil. In our country chickens got most of the methyl mercury when farmers gave the chickens and the hens seed dressed with mercury fungicides, primarily methyl mercury, and from fish containing mercury. There are thus two problems, one is the seed dressing and its routes towards man via the chickens and the eggs. The second route is via the waters, where it is taken up in fish and in its turn very often taken up in the predatory birds, where the symptoms are aggravated by chlorinated hydrocarbons, like DDT, dieldrin and the newly discovered, but old substance, pcb, polychlorinated biphenyls.

I think an attack on your articles from those wishing to retain these compounds on the market will be directed against the assumption that mercury is taken up in dangerous amounts in grain. This seems not to be the case as far as our preliminary investigations here in Sweden show.

HANS PALMSTIERNA
Secretary, Swedish Government Committee on Environmental Problems

Down to the Sea — 1969

Come glide with me in my outhouseboat
Past the Messyippi's shores—
Past babbling sewers with muck afloat,
Adding their noxious stores;

Bring along your best bathing-suits
(Worn only on deck or land):
Pollution and Fastbuck are in cahoots;
They go, dirty hand in hand.

You vulture-lovers, it's carrion
They relish,—plus filth and slime.
Our Styxx is the river to tarry on
For an offally restful time.

P. J. WHITE
St. Louis, Missouri

Apples without Pesticides

In answer to William Remington, who wrote (*Environment*, June, 1969) that if he doesn't spray, he doesn't get apples.
We have a small home orchard which we have planted and maintained organically. No chemical fertiliser and no poisonous sprays have been used in its 23-year existence. I don't claim perfect fruit but good-tasting and keeping apples, mostly Golden Delicious.

HERBERT R. ISENBURGER
St. John X-Ray Laboratory
Califon, New Jersey

Faith in Question

I am very glad to see that there are responsible people who undertake to defend us from the unfortunate side effects of ill considered technology. I am particularly interested in your article "Poisoning the Wells" from which it appears that the very fertilizers which feed the enormous and increasing population eventually poison the soil from which they are nourished. I wonder if this means that in time the population will have to decline for lack of clean soil to feed it?

I wonder if I could put forward a suggestion? What you are trying to do in effect is to set up some kind of control of technological operations in order to safeguard the population from unexpectedly bad consequences which seem to be increasing in number. This gives you a certain negative aspect. That in itself is not very appealing, but there is a more serious consideration. Technology has had such astounding successes in three centuries that in all that time it has never ben seriously criticized. On the contrary, it has increasingly been accepted on faith as the best means of solving man's problems, particularly as religious faith has declined.

I believe that the increasing evil effects of technology which you describe so forcefully trouble the people and for the first time open their minds for a discussion *au fond* of the meaning and value of technology. But I do not think that the mere description and catalogue of its evils are sufficient.

I do not think you ought to hold yourselves responsible to find a cure for each evil you describe. But I do think that an occasional article of philosophical criticism or more broadly cultural commentary would do a lot to foster the view that there are more aspects to the problems of man than merely technological ones; that in these aspects there may be elements which can be used to complete, complement, limit and strengthen technological solutions; and that therefore you are not merely a magazine of lamentation and fear. If you can do that I believe that your readers will take your criticism more seriously because they will think it more meaningful. In any case you have my best wishes.

My compliments and best wishes to Mr. Novick whose excellent book, "The Careless Atom," I have recently read.

JOHN WISNER
Washington, D.C.

People in a Hurry

Congratulations on your new format!

I particularly like the drawings and illustrations. I would suggest possibly having short newspaper-story type summaries of some longer articles so people in a hurry could get an idea of the problem without going into details.

STEPHEN SHAPROTH
Department of Physics
The University of North Carolina at Chapel Hill

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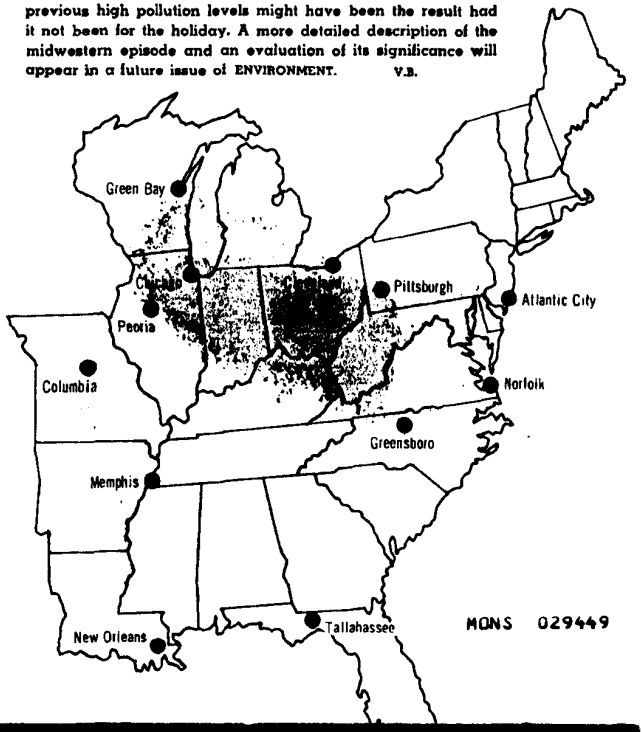
For several days in late August, millions of Americans in the midwestern and southern states participated involuntarily in a smog-in. Just previous to this episode, one of the Los Angeles Air Pollution Control District's stations had recorded the highest ozone reading in nearly two years, qualifying August for designation as National Air Pollution Month.

On Saturday, August 23, adverse meteorological conditions were first noted in an area extending from Green Bay, Wisconsin in the northwest to Greensboro, North Carolina in the southeast. "Sluggish dispersion of air pollutants" could be expected throughout this area, according to a report by G. C. Holzworth of the Division of Meteorology, National Air Pollution Control Administration, distributed by the Smithsonian Institution's Center for Short-Lived Phenomena. The midwestern problem didn't come home to most people until the following Monday, since the volume of pollution spewed into the air over cities is much less on weekends. By Monday, the sluggish air pattern had moved somewhat south, and a dirty haze was discernible over St. Louis, Chicago and some smaller cities. Sulphur dioxide, nitrous oxides, particulates, hydrocarbons and other pollutants discharged every day from stacks and automobile exhausts, but usually moved more or less rapidly by the winds, hung in the air. Smog alerts were announced in both St. Louis and Chicago, but neither has an emergency plan ready to cut down on the production of pollution when levels rise. Pollution continued high until winds brought relief on Thursday, August 28. However, stagnant air was characteristic of the same general area over the Labor Day weekend. A quick return to previous high pollution levels might have been the result had it not been for the holiday. A more detailed description of the midwestern episode and an evaluation of its significance will appear in a future issue of ENVIRONMENT. V.B.



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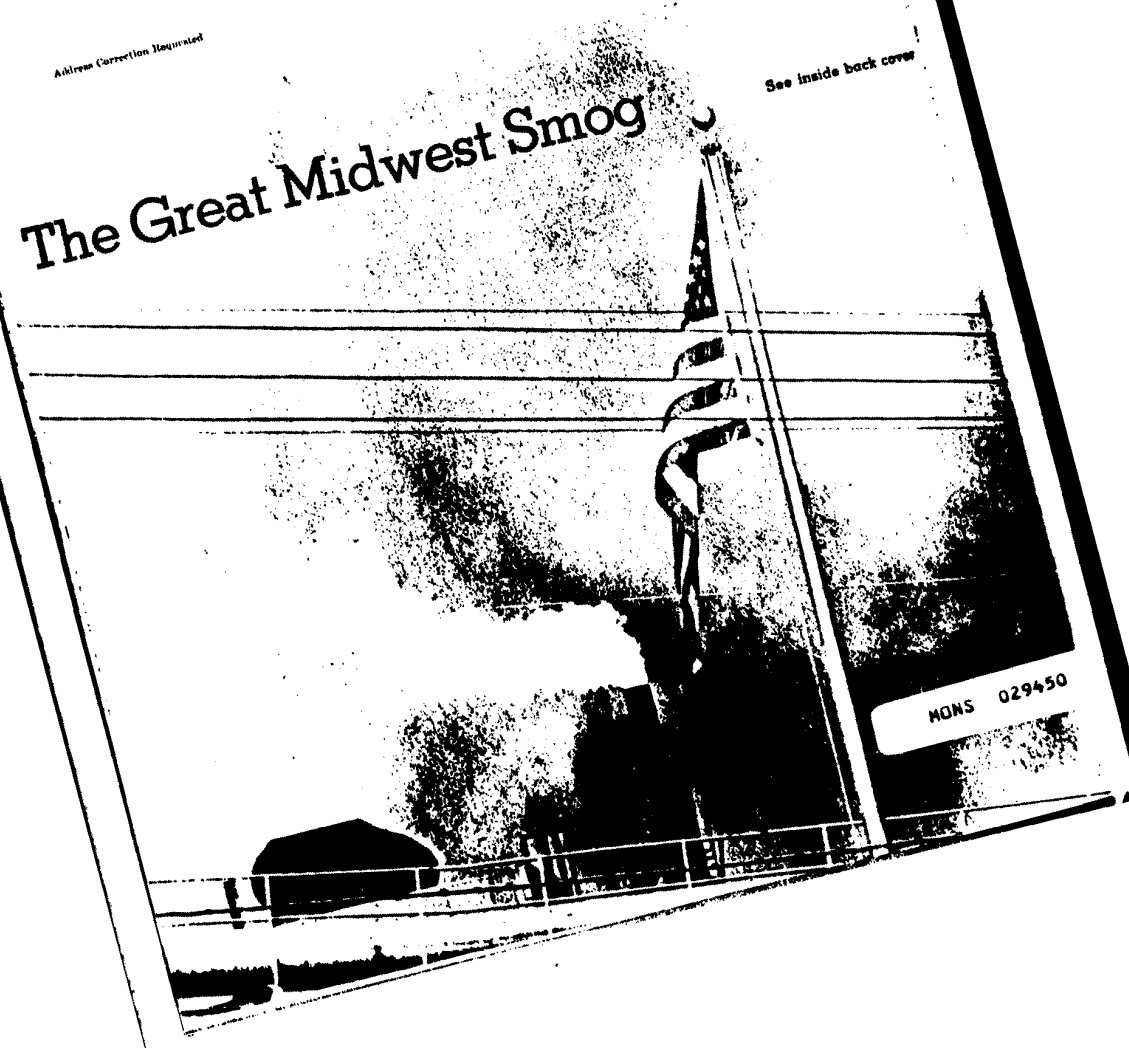
See inside back cover

The Great Midwest Smog



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