The Metabolism of Cities

he U.S. today attention is focused on shortages of water and the ution of water and air. There is plenty of water, but supplying quires foresight. Pollution calls for public economic decisions

by Abel Wolman

metabolic requirements of a y can be defined as all the aterials and commodities need- ustain the city's inhabitants at t work and at play. Over a peri- me these requirements include e construction materials needed and rebuild the city itself. The ic cycle is not completed until stes and residues of daily life een removed and disposed of minimum of nuisance and haz- man has come to appreciate that th is a closed ecological system, methods that once appeared tory for the disposal of wastes er seem acceptable. He has the vidence of his eyes and nose to n that his planet cannot assimi- ithout limit the untreated wastes civilization.

one article could describe the te metabolism of the modern Moreover, many of the metabolic such as food, fuel, clothing, dura- oods, construction materials and c energy present no special prob- Their supply is handled routinely, t through local initiative and in hrough large organizations (pub- private) that operate about as ively in one city as another. I shall be concerned therefore with three metabolic problems that have become more acute as cities have grown larger and whose solution rests almost entirely in the hands of the local administrator. Although he can call on many outside sources for advice, he must ultimately provide solutions fashioned to the unique needs of his own community. These three problems are the provision of an adequate water supply, the effective disposal of sewage and the control of air pollution.

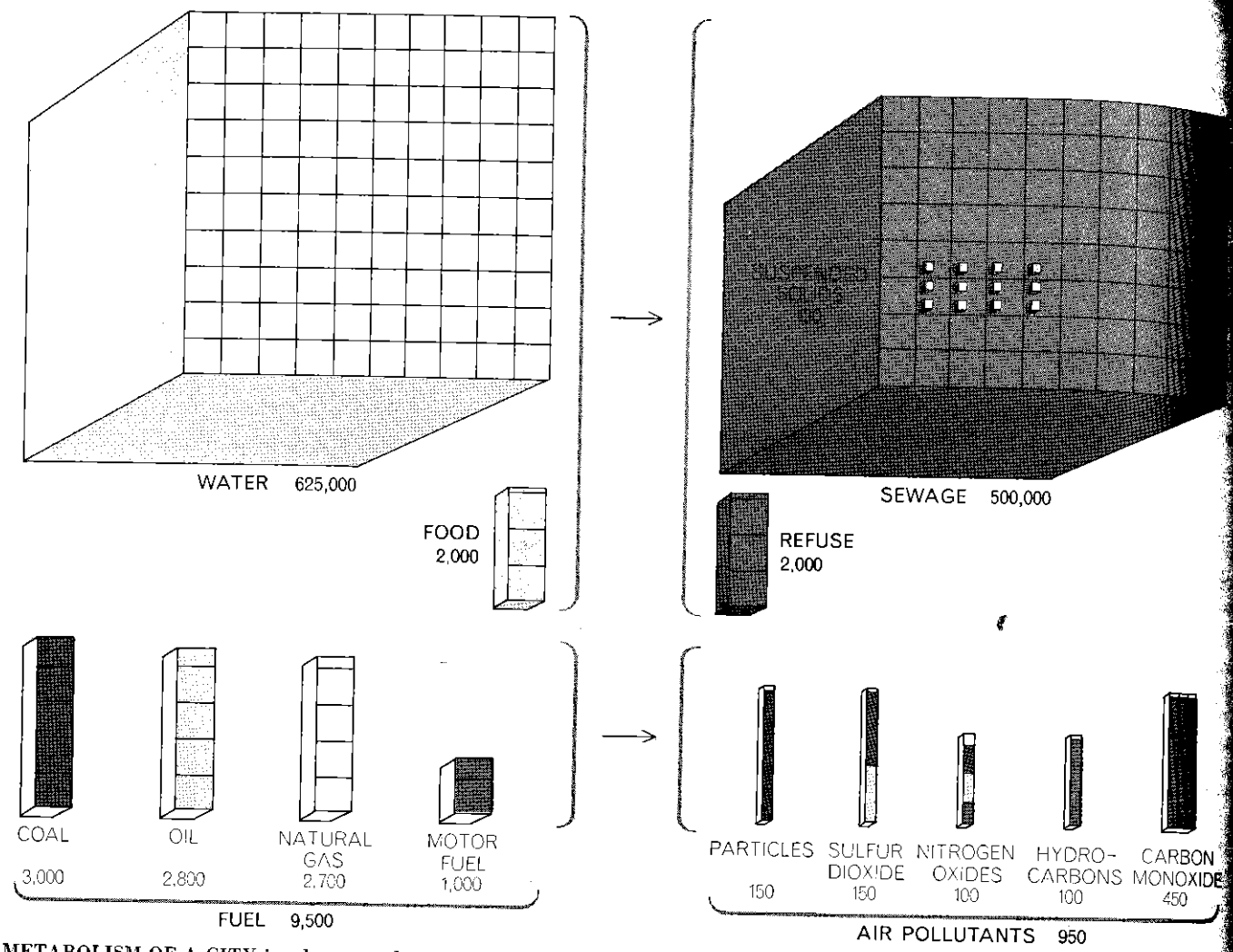
That these three problems vary widely from city to city and that they are being managed with widely varying degrees of success is obvious to anyone who reads a daily newspaper. It is ironic, for example, that New York City, which houses the nation's (if not the world's) greatest concentration of managerial talent, should be running short of water while billions of gallons of fresh water flow past it to the sea. It is not easy for people living in arid countries, or even for those living in the southwestern part of the U.S., to have much sympathy with New York's plight.

This summer, while New Yorkers were watching their emptying reservoirs and hoping for rain, Californians were busy building an aqueduct that would carry water some 440 miles from the Sacramento River, near Sacramento, to Los Angeles and other cities in the southern part of the state. And thanks to earlier examples of foresight, people in southern California were watering their lawns and filling their swimming pools without restriction, while in New York and New Jersey lawns were dying and pools stood empty. In the water-rich Middle Atlantic states water shortages are largely the result of delayed action and failures of management—sometimes exacerbated by political jockeying.

If American cities have had such unequal success in supplying their citizens with water, it is hardly surprising that some should have an even less satisfactory record in controlling water and air pollution, areas in which the incentives for providing remedies are much weaker than those that motivate the supplying of water. To make matters worse, pollutants of water and air often do not respect state boundaries. For example, the wastes of five states—Michigan, Indiana, Ohio, Pennsylvania and New York—have contributed to the accelerated pollution of Lake Erie. "The lake," according to the U.S. Public Health Service, "has deteriorated in quality at a rate many times greater than its normal aging process." The fourth-largest and shallowest of the five Great Lakes, Lake Erie is the main water supply for 10 million U.S. citizens as well as for the huge industrial complex that extends for 300 miles along the lake's southern shore from Detroit to Buffalo. The combination of treated and partially treated municipal sewage and industrial wastes that enters Lake Erie directly, and also reaches it indirectly through a network of rivers, has disrupted the normal cycle of aquatic life, has led to the closing of a number of beaches and has materially changed the commercial fishing industry. Last month the five states, in consultation with the Public Health Service, reached agreement on a major program of pollution abatement.

Although engineers concerned with water supply, sewage disposal and air pollution are accustomed to thinking in terms of large volumes, few laymen quite appreciate the quantities of water, sewage and air pollutants involved in

-SHROUDED about 100 days a year, ngeles (*opposite page*) has made a res- effort to reduce the volume of air-pol- emissions. California will require ex- control systems on all new cars and trucks sold in the state, beginning with 966 models. These systems should do to remove the unburned hydrocar- and carbon monoxide now released automobile exhausts (*see illustration ge 186*). The topographic and meteoro- l factors that underlie smog develop- in Los Angeles are unique in the U.S.



METABOLISM OF A CITY involves countless input-output transactions. This chart concentrates on three inputs common to all cities, namely water, food and fuel, and three outputs, sewage, solid refuse and air pollutants. Each item is shown in tons per day for a hypothetical U.S. city with a population of one million. Water, which enters the city silently and unseen, overshadows all other inputs in volume. More than .6 ton (150 gallons) must be supplied to each inhabitant every day. After about 20 percent of the water has been diverted to lawns and other unrecoverable uses, it returns, contaminated, to the city's sewers. The city's most pervasive nuisance, air pollution, is accounted for chiefly by the combustion of fuels. (If refuse is burned in incinerators, it can also contribute heavily, but that contribution is not included here.) The various air pollutants are keyed by shading and color to the fuel responsible. Most of the particle emission (soot and fly ash) is produced by coal burned in electric power plants, and in well-designed plants more than 90 percent of the particles can be removed from the stack gases. For this hypothetical city one may assume that 135 of the 150 tons of particles produced by all fuel consumers are removed before they reach the atmosphere. All other emissions, however, pollute the atmosphere in the volumes shown. Sulfur dioxide is based on use of domestic fuels of average sulfur content.

the metabolism of a modern city. The illustration above expresses these quantities in the form of an input-output chart for a hypothetical American city of one million population. The input side of the chart shows the requirements in tons per day of water, food and fuels of various kinds. The output side shows the metabolic products of that input in terms of sewage, solid refuse and air pollutants. The quantities shown are a millionfold multiplication of the daily requirements of the average city dweller. Directly or indirectly he uses about 150 gallons (1,250 pounds) of water, four pounds of food and 19 pounds of fossil fuels. This is converted into roughly 120 gallons of sewage (which assumes 80 percent recovery of the water input), four pounds of refuse (which includes food containers and miscellaneous rubbish) and 1.9 pounds of air pollutants, of which automobiles, buses and trucks account for more than half.

As of 1963 about 150 million out of 189 million Americans, or 80 percent, lived in some 22,000 communities served by 19,200 waterworks. These 150 million people used about 23 billion gallons per day (b.g.d.), a volume that can be placed in perspective in several ways. In 1960 the amount of water required for all purposes in the U.S. was about 320 b.g.d., or roughly 15 times the municipal demand. The biggest user of water is irrigation, which in 1960 took about 140 b.g.d. Steam electric utilities used about 98 b.g.d. and industry about 60 b.g.d. Since 1960 the total U.S. water demand has risen from about 320 b.g.d. to an estimated 370 b.g.d., of which municipalities take about 25 b.g.d. [*see illustration on opposite page*].

Thus municipalities rank as the smallest of the four principal users of water. Although it is true that water provided for human consumption must sometimes meet standards of quality that need not be met by water used in agriculture or industry, nevertheless throughout most of the U.S. farms, factories and cities frequently draw water from a common supply.

For the country as a whole the supply

lable water is enormous: about b.g.d. This is the surface runoff emains from an average daily of some 4,200 b.g.d. About 40 of the total precipitation is uti- here it falls, providing water to vegetation of economic value: farm crops and pasturelands. r 30 percent evaporates directly he soil or returns to the atmo- after passing through vegeta- at has no particular economic except insofar as it may prevent of the land.

obvious that one cannot expect ture and put to use every drop 1,200 b.g.d. flowing to the sea. mount that can be captured de- on what people are willing to pay ter. One recent estimate places onomically available supply at hat less than half the total, or g.d. In my opinion this estimate conservative; I would suggest a of at least 700 b.g.d.

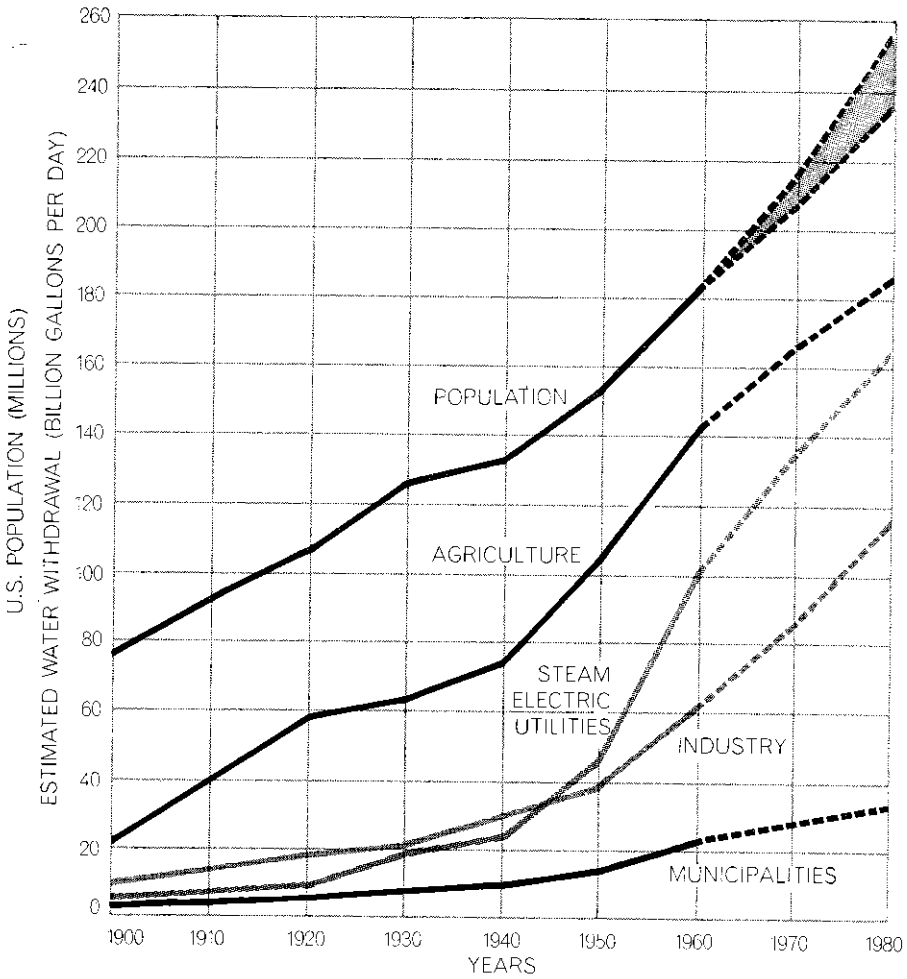
n this volume would be inade- by the year 2000—if all the water awn for use were actually con- . This, however, is not the case nd will not be then; only a small n of the water withdrawn is con- . In 1960 "consumptive use," as lled, amounted to about 90 b.g.d. 320 b.g.d. withdrawn. Most of maining 230 b.g.d. was returned use to the source from which it aken, or to some other body of (in some instances the ocean). A fraction of the used water was into the ground to help maintain water tables.

imates by a Senate Select Com- a few years ago projected a con- tive use of about 120 b.g.d. in and of nearly 160 b.g.d. in the 2000, when total demand may 900 b.g.d. It will be apparent in lustration on the next page, where projections are plotted, that agri- e accounts for the biggest con- tive use of water. It is conserva- estimated that 60 percent of the employed for irrigation is lost to tmosphere as the result of evapo- directly from the soil or indirectly anspiration through the leaves of ng plants. (The amount of water porated into plant tissue is insig- nt; roughly 1,000 gallons of water eded to produce about 10 cents' of crop.) In contrast, from 80 percent of the water withdrawn unicipalities, industry and electric es is available for reuse. It is for eason that the projected withdraw- al rate of 900 b.g.d. in the year 2000 should not prove difficult to meet, whether the economically available supply is 560 b.g.d. or 700 b.g.d. Of the 900 b.g.d. that may be required in A.D. 2000 to meet human, industrial and agricultural needs, approximately 740 b.g.d. should be available for reuse.

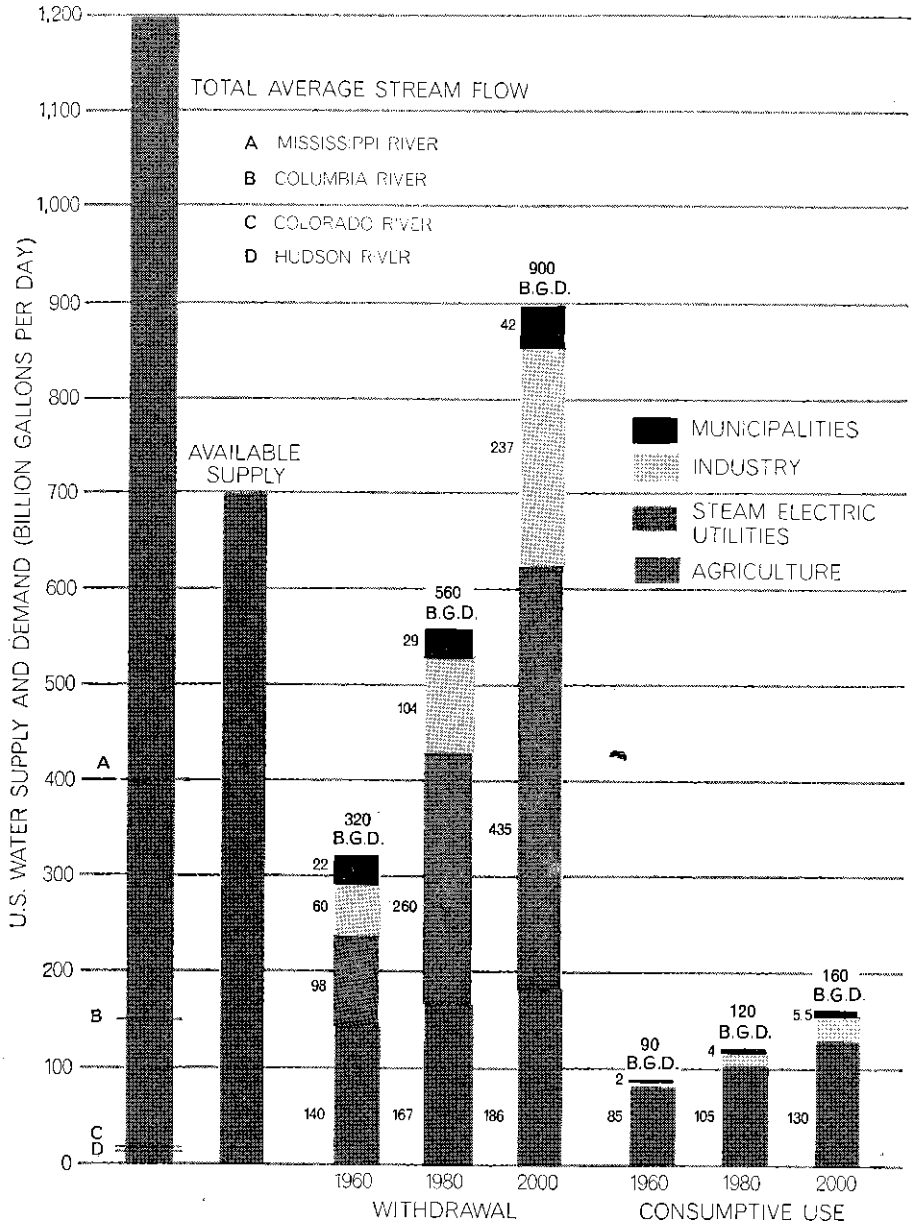
These estimates, moreover, are pessimistic in that they make only minor allowances for reductions in industrial or agricultural demands as a result of technological changes and in that they provide for no significant increase in the cost of water to hasten such changes. Thus we must reasonably conclude that for many years beyond A.D. 2000 total water shortages for the U.S. as a whole are highly improbable.

If water is going to remain so plentiful into the 21st century, why should New York and other cities find themselves running short in 1965? The immediate answer, of course, is that there has been a five-year drought in the northeastern U.S. With the completion in 1955 of two new reservoirs in the upper reaches of the Delaware River, and with the extension of the Delaware aqueduct to a total distance of more than 120 miles, New York City believed it could satisfy its water needs until the year 2000. This confident forecast reckoned without the unprecedented drought.

There is no point in criticizing New York's decision to depend so heavily on the Delaware watershed for its future needs. The question is what New York should do now. As long ago as 1950, in an earlier water shortage, New York was advised to build a pumping station on the Hudson River 65 miles north of the city to provide an emergency supply of 100 million gallons per day, or more



U.S. WATER REQUIREMENTS will be 53 percent greater in 1980 than in 1960, according to the most recent estimates of the Department of Commerce. Virtually all water used by agriculture is for irrigation; nearly 60 percent of all irrigated land in the U.S. is in five Western states (California, Texas, Colorado, Idaho and Arizona) where water tends to be scarcest. Steam power plants need water in huge amounts simply to condense steam. In 1960 municipalities used about 22 billion gallons per day (b.g.d.), which represented only about 7 percent of the total water withdrawal of about 320 b.g.d. The important distinction between water "withdrawal" and "consumptive use" is shown in the illustration on next page.



U.S. WATER SUPPLY consists of the approximately 1,200 b.g.d. that flows to the sea through the nation's waterways. This is the streamflow that results from an average precipitation volume of some 4,200 b.g.d. About 70 percent of all precipitation returns to the atmosphere without ever reaching the sea. The average flow of four important rivers is marked on the streamflow column. The author estimates that about 700 b.g.d. of the total streamflow can be made available for use at a cost acceptable to consumers. The estimates of water withdrawal and consumptive use for 1980 and 2000 are (with slight rounding) those published a few years ago by a Senate Select Committee. The 1980 estimate is 13 percent higher than that of the Department of Commerce shown in the illustration on the preceding page. "Consumptive use" represents the amount of water withdrawn that subsequently becomes unavailable for reuse. Except for irrigation, consumptive use of water is and will remain negligible. Thus a 700-b.g.d. supply should easily meet a 900-b.g.d. demand.

as needed. (New York City's normal water demand is about 1.2 b.g.d. The average flow of the Hudson is around 11 b.g.d.) The State of New York gave the city permission to build the pumping station but stipulated that the station be dismantled when the emergency was over. By the time the station was built (at a point somewhat farther south than the one recommended) the drought had ended; the station was torn down without ever having been used. This July the city asked the state for permission to rebuild the station, a job that will take several months, but as of mid-August permission had not been granted.

Meanwhile there has been much talk of building atomic-energy desalination plants as the long-term solution to New York's water needs. The economic justification for such proposals has never been explained. New York now obtains its water, delivered by gravity flow to the city, for only about 13 cents per 1,000 gallons (and many consumers are charged only 12 cents). The lowest predicted cost for desalination, assuming a plant with a capacity of 250 million or more gallons per day, is a highly optimistic 30 to 50 cents per 1,000 gallons. Since a desalination plant would be at sea level, its entire output would have to be pumped; storage and conveyance together would add about 20 cents per 1,000 gallons to the basic production cost. Recent studies in our department at Johns Hopkins University have shown that if desalinated water could be produced and delivered for as little as 50 cents per 1,000 gallons, it would still be cheaper to obtain fresh water from a supply 600 miles away. (The calculations assume a water demand of 100 million gallons per day.) In other words, it would be much cheaper for New York City to pipe water 270 miles from the St. Lawrence River, assuming that Canada gave its consent, than to build a desalination plant at the edge of town. New York City does not have to go even as far as the St. Lawrence. It has large untapped reserves in the Hudson River and in the upper watershed of the Susquehanna, no more than 150 miles away, that could meet the city's needs well beyond the year 2000.

Few cities in the U.S. have the range of alternatives open to New York. The great majority of inland cities draw their water supplies from the nearest lake or river. Of the more than 150 million Americans now served by public water supplies, nearly 100 million, or 60 percent, are reusing water from sources that have already been used at least once for domestic sewage and industrial waste disposal. This "used" water has of course been purified, either naturally or artificially, before it reaches the consumer. Only about 25 percent of the 25 b.g.d. now used by municipalities is obtained from aquifers, or underground sources. Such aquifers supply about 65 b.g.d. of the nation's estimated 1965 requirement of 370 b.g.d. Most of the 65 b.g.d. is merely a subterranean portion of the 1,200 b.g.d. of the precipitation flowing steadily to the sea. It is estimated, however, that from five to 10 b.g.d. is water "mined" from aquifers that have been filled over the centuries. Most of this mining is

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The use of chlorine to kill
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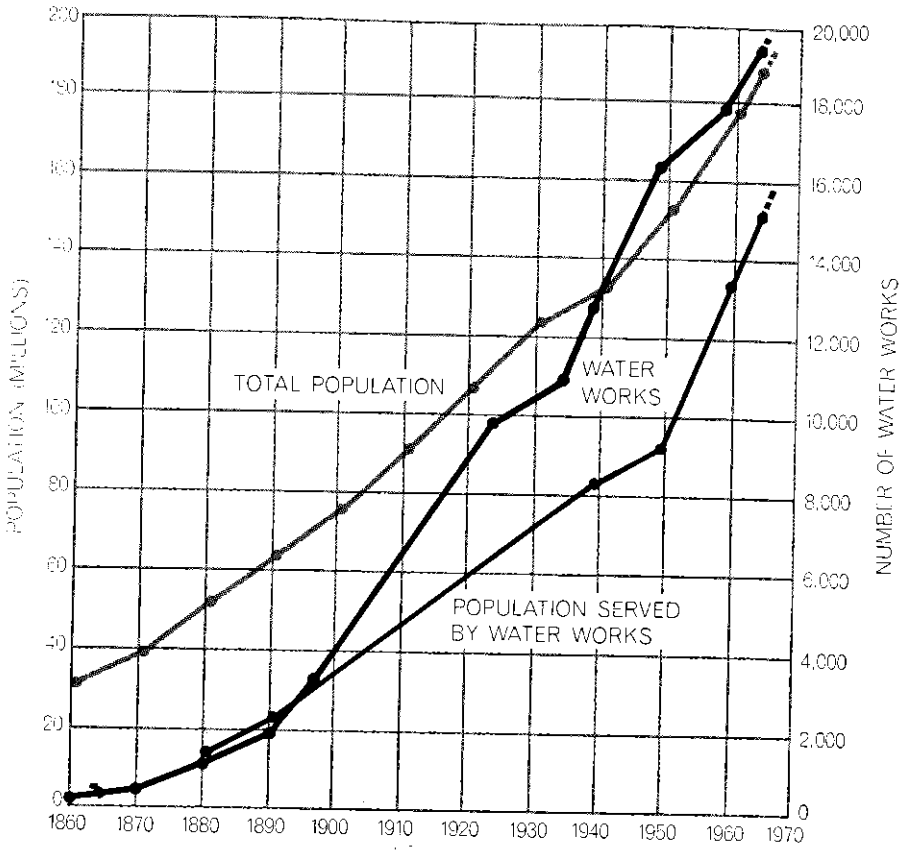
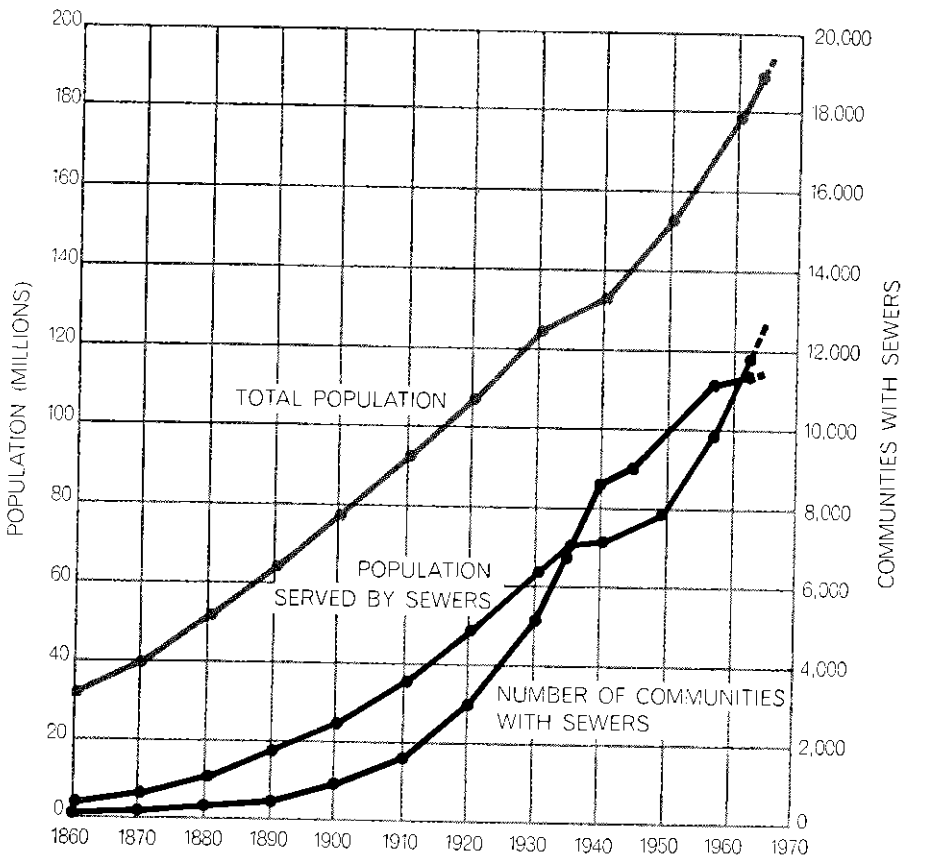
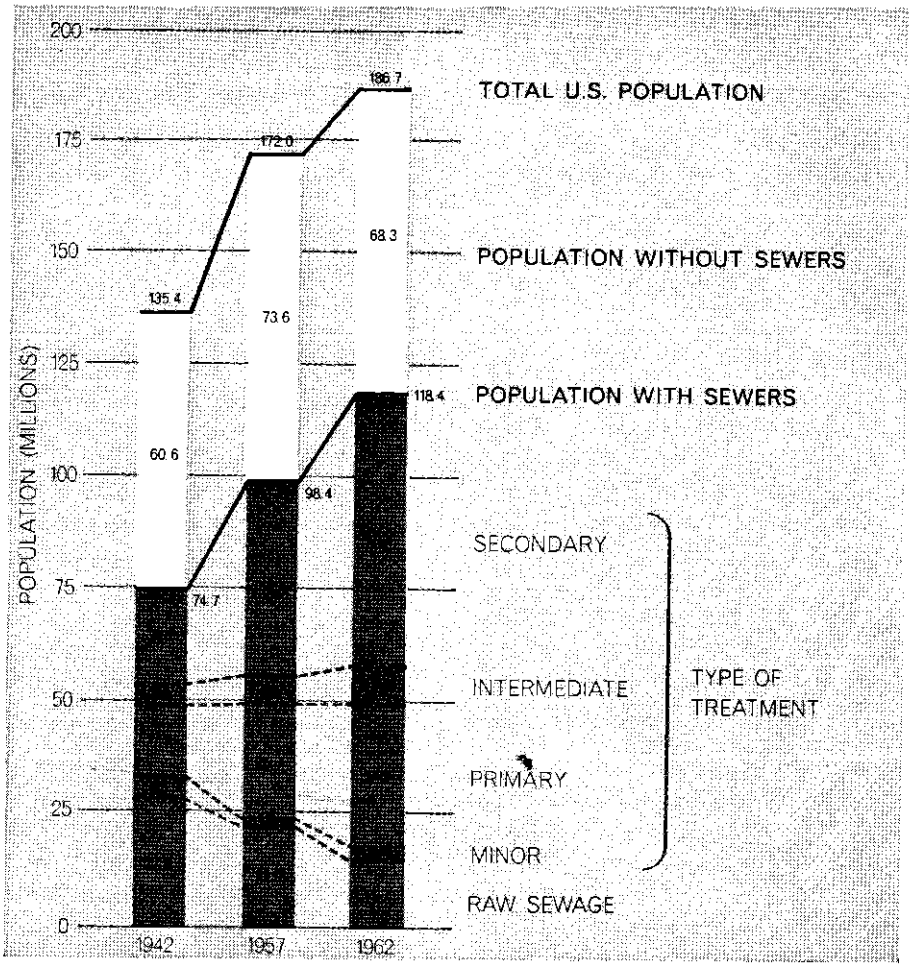


GROWTH OF MUNICIPAL WATER SUPPLIES accelerated after 1880, when less than a fourth of the U.S. population was served by waterworks. By 1939 the number served by waterworks exceeded 60 percent and by 1963 the figure had reached nearly 80 percent.



GROWTH OF SEWERAGE FACILITIES has lagged behind the growth of community water supplies, chiefly because people are reluctant to pay taxes for what long seemed a nonessential service. Nevertheless, 63 percent of the population was served by sewers in 1962.



RACE BETWEEN SEWERS AND POPULATION GROWTH is depicted in this chart. Between 1942 and 1957 population outstripped the increase in sewerage service. Between 1957 and 1962 sewerage service grew slightly faster than population. People without sewers do not necessarily contribute to the water pollution problem if they use effective septic tanks and cesspools. The principal pollution is caused by communities—and by industries—that discharge wastes into waterways with little treatment or no treatment at all. Data for this chart and the two preceding ones were supplied by the U.S. Public Health Service.

supply. As the article on Calcutta in this issue [*page 90*] points out, that city is regarded as the endemic center of cholera for all of southeast Asia.

No general prescription can be offered for bringing clean water to the vast urban populations that still lack it. I have found in my own experience, however, that the inhabitants of communities both large and small can do much more to help themselves than is customarily recognized. If the small towns and villages of India and elsewhere wait for their central governments to install public water supplies, most of them will wait indefinitely. It is surprising how much can be accomplished with local labor and local materials, and the benefits in health are incalculable.

In the larger cities, where self-help is not feasible, municipal water systems can be built and made to pay their way if an appropriate charge is made for water and if the systems can be financed with long-term loans, as they have been financed traditionally in the U.S. Such loans, however, have only recently been made available to underdeveloped countries. A few years ago, when loans for waterworks had to be paid off in six to 12 years, the total value of external bank loans made to South American countries for water supply and sewerage projects was less than $100,000 in a six-year period. Under the leadership of the Pan-American Health Organization and the U.S. Agency for International Development bankers were encouraged to extend the repayment period to 28 or 30 years. Today the total value of bank loans made to South American countries for waterworks and sewerage systems has surpassed $660 million.

Outside the U.S., as within it, adequate water resources are generally available. The problem is to treat water as a commodity whose cost to the user must bear a fair relation to the cost of its production and delivery. The total U.S. investment in municipal waterworks is about $17.5 billion (replacement cost would approach $50 billion), or about half the nation's investment in telephone service. More significant than investment is the cost of service to the consumer. The average American family pays about $3 a month for water, which it cannot live without, compared with about $7.30 for telephone service. One might also note that the average household expenditure for alcoholic beverages is more than $15 a month. It should be clear that Americans can afford to pay for all the water they need.

The question of fair payment and allocation of costs is even more central to the problem of controlling water pollution than to the problem of providing water. Whereas 150 million Americans were served by waterworks in 1963, only about 120 million were served by sewers [*see bottom illustration on preceding page*]. Thus the wastes of nearly 70 million Americans, who live chiefly in the smaller towns and suburbs, were still being piped into backyard cesspools and septic tanks. When these devices are properly designed and the receiving soils are not overloaded, they create no particular sanitation hazard. Unfortunately in too many suburban areas neither of these criteria is met.

The principal pollution hazard arises where sewage collected by a sewerage system is discharged into a lake or river without adequate treatment or without any treatment at all [*see illustration on this page*]. As of 1962 the wastes of nearly 15 million Americans were discharged untreated and the wastes of 2.4 million received only minor treatment. The wastes of 32.7 million were given primary treatment: passage through a settling basin, which removes a considerable portion of the suspended solid matter. Intermediate treatment, which consists of a more nearly complete removal of solids, was applied to the wastes of 7.4 million people. Secondary treatment, the most adequate form of sewage treatment, was applied to the wastes of 61.2 million people. The term "secondary treatment" covers a variety of techniques, often used in combination: extended aeration, activated sludge (an accelerated form of bacterial degradation), filtration through beds of various materials, stabilization ponds.

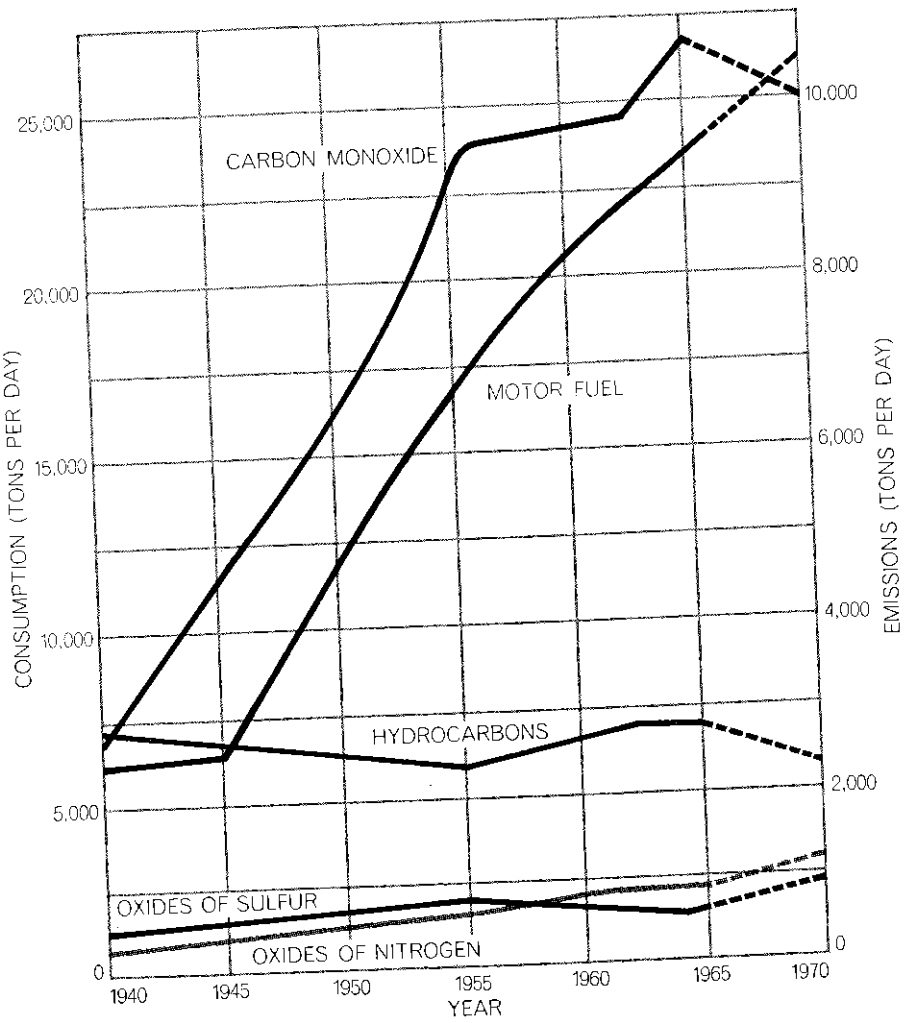
can be seen from the chart on the site page that although there was a icant improvement in sewage treat- in the U.S. between 1942 and a big job remains to be done. in the past five years of this period he rate of sewer installation begin vertake population growth. The nt U.S. investment in sewers and ge-treatment works is about $12 n (again the replacement value d be much higher). The Public h Service estimates that replacing ete facilities, improving the stan- of treatment and providing for lation growth will require an an- investment of more than $800 mil- a year in treatment works for the of the decade. This does not include cost of extending the sewage-col- n systems into new urban and ban developments. This may add another $800 million to the annual requirements, making an approximate total of more than $1.6 billion a year.

Unfortunately some municipalities have not found a satisfactory or painless method for charging their residents for this vital service. Many simply float bonds to meet capital costs and add the cost to the individual's bill for property taxes. In Baltimore (where the tax bill is completely itemized) it was decided some years ago that sewerage costs should not be included in the citizen's *ad valorem* taxes but should be made part of his water bill. In the Baltimore system the charge for sewerage service is half the water service charge. A good many other cities charge for sewerage service on a similar basis.

Cities, of course, account for only a part, and probably not the major part, of the pollution that affects the nation's waterways. Industrial pollution is a ubiquitous problem. Industrial pollutants are far more varied than those in ordinary sewage, and their removal often calls for specialized measures. Even in states where adequate pollution-control laws are on the books, there are technological, economic and practical obstacles to seeing that the laws are observed. The Federal Water Pollution Control acts of 1954 and 1962, which enlarged the role of the Public Health Service in determining the pollution of interstate waterways, have sometimes been helpful in strengthening the hand of local law-enforcement agencies.

My final topic—air pollution—is much harder to discuss in quantitative terms than water pollution, which it otherwise resembles in many ways. It is never going to be possible to provide

LLUTION OF LAKE ERIE takes place along 300 miles of **hly industrialized shoreline. Cleveland, shown here, is the largest city directly on the lake. The five states responsible for the lake's pollution have recently agreed to undertake remedial measures.**



LOS ANGELES AIR POLLUTION is tied closely to the steep rise in automobile use in Los Angeles County. This chart compares gasoline consumption with the computed output from all sources of carbon monoxide, hydrocarbons, oxides of nitrogen and oxides of sulfur. Motor vehicles produce only small amounts of the last two substances and their output has been controlled chiefly by curbs on the emission of pollutants by industry. Carbon monoxide and hydrocarbon emissions should decline when cars start carrying exhaust-control systems.

a collection system for air pollution emissions, almost all of which result from combustion processes. Every house, every apartment, every automobile, truck, bus, factory and power plant is vented directly into the open air and presumably will have to remain so.

There are perhaps only three general approaches to controlling the amount of pollutants entering the atmosphere. One is to switch from a fuel that produces undesirable combustion products to one that produces fewer such products. Thus fuel oil produces less soot and fly ash than bituminous coal, and natural gas produces less than either. The second expedient is to employ a new technology. For example, atomic power plants produce none of the particulate and gaseous emissions that result from the burning of fossil fuels. One must then decide, however, whether the radioactive by-products that are released into the environment—either in the short run or the long—by an atomic power station are more or less hazardous than the fossil-fuel by-products they replaced. The third recourse is to remove the undesired components from the vented gases. Fly ash, for example, can be largely removed by suitable devices where coal or oil is used in large volume, as in a power plant, but cannot readily be removed from the flue gases of thousands of residences. The problem of dealing with many small offending units also arises in trying to reduce the unburned hydrocarbons and carbon monoxide emitted by millions of automobiles.

At this point it is worth asking: Why should air pollution be considered objectionable? Many people enjoy the smell of the pollutants released by a steak sizzling on a charcoal grill or by dry leaves burning in the fall. The cigarette smoker obviously enjoys the smoke he draws into his lungs. In other words, a pollutant per se need not necessarily be regarded as a nuisance. If by accident or design the exhaust gases emitted by a diesel bus had a fragrant aroma (or worse yet, led to physiological addiction), not many people would complain about traffic fumes.

The criteria of what constitutes an objectionable air pollutant must therefore be subjectively defined, unless, of course, one can demonstrate that a particular pollutant is a hazard to health. In the absence of a demonstrated health hazard the city dweller would probably list his complaints somewhat as follows: he objects to soot and dirt, he does not want his eyes to burn and water, he dislikes traffic fumes and he wishes he could see the clear blue sky more often.

Many conferences have been held and many papers written on the possible association of air pollution with disease. As might be expected, firm evidence of harmfulness is difficult to obtain. The extensive epidemiological data collected in the U.S. on smoking and human health suggest that in general place of residence has a minor influence on the incidence of lung cancer compared with the smoking habit itself. British statistics, however, can be interpreted to show that at times there is something harmful in the British air. In any event, it will be difficult to demonstrate conclusively—no matter how much one may believe it to be so—that air pollution is associated with long-term deterioration of the human organism. Eric J. Cassell of the Cornell University Medical College recently summarized the situation as follows: "I do not think that it is wrong to say that we do not even know what disease or diseases are caused by everyday pollution of our urban air.... We have a cause, but no disease to go with it."

Two diseases frequently mentioned as possibly associated with air pollution are chronic bronchitis and pulmonary emphysema. In Britain some investigators have found strong associations between chronic bronchitis and the level of air pollution, as measured by such indexes as fuel use, sulfur dioxide in the air and sootfall. In California the death rate from emphysema increased fourfold in the seven-year period from 1950 to 1957. This increase may indicate nothing more than the fact that older people go to California to retire, but there is objective evidence that emphysematous patients in Los Angeles

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lean Air Act, which states in its
ble that "Federal financial assist-
and leadership is essential for the
opment of cooperative Federal,
regional and local programs
ed to prevent and control air pol-
." The regulatory abatement pro-
es authorized in the act are simi-
those found in the most recent
r Pollution Control Act. When an
state pollution problem is identi-
the Public Health Service is em-
red, as a first step, to call a con-
ce of state and local agencies. The
d step is to call a public hearing,
he third step, if needed, is to bring
rt action against the offenders.

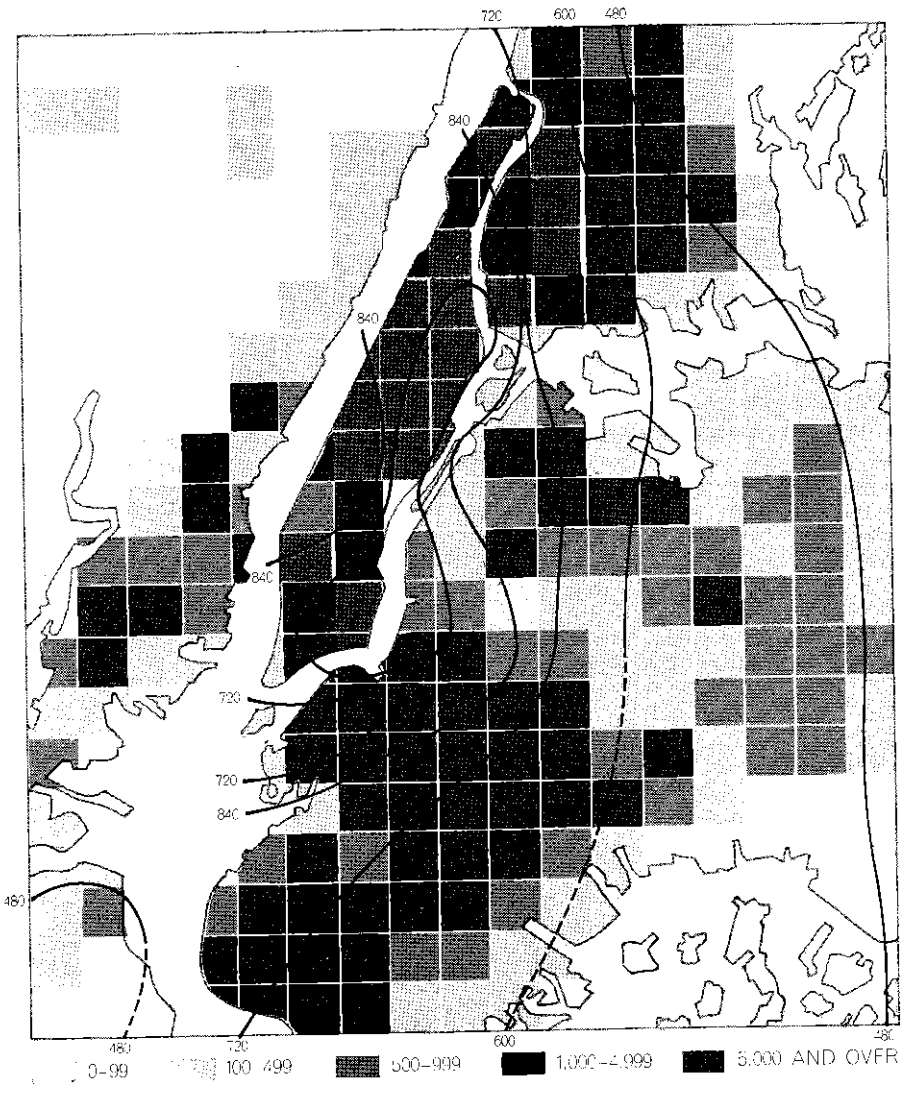
e Clean Air Act takes special cog-
nce of air pollution caused by mo-
vehicles; it requires the Secretary
Health, Education, and Welfare to
rt periodically to Congress on prog-
made on control devices. He is
invited to recommend any new
lation he feels is warranted. Even-
y the secretary may help to decide
ll new U.S. motor vehicles should
equipped with exhaust-control sys-
s, such as "afterburners," to re-
e the large amounts of unburned
rocarbons and carbon monoxide that
now released.

California studies in the 1950's
wed that exhaust gases accounted
65 percent of all the unburned hy-
carbons then produced by motor
icles. Another 15 percent repre-
ted evaporation from the fuel tank
d carburetor, and 20 percent escaped
m the vent of the crankcase. As a
st step in reducing these emissions
alifornia began in 1961 to require the
e of crankcase blowby devices, which
came standard on all U.S. cars be-
nning with the 1963 models.

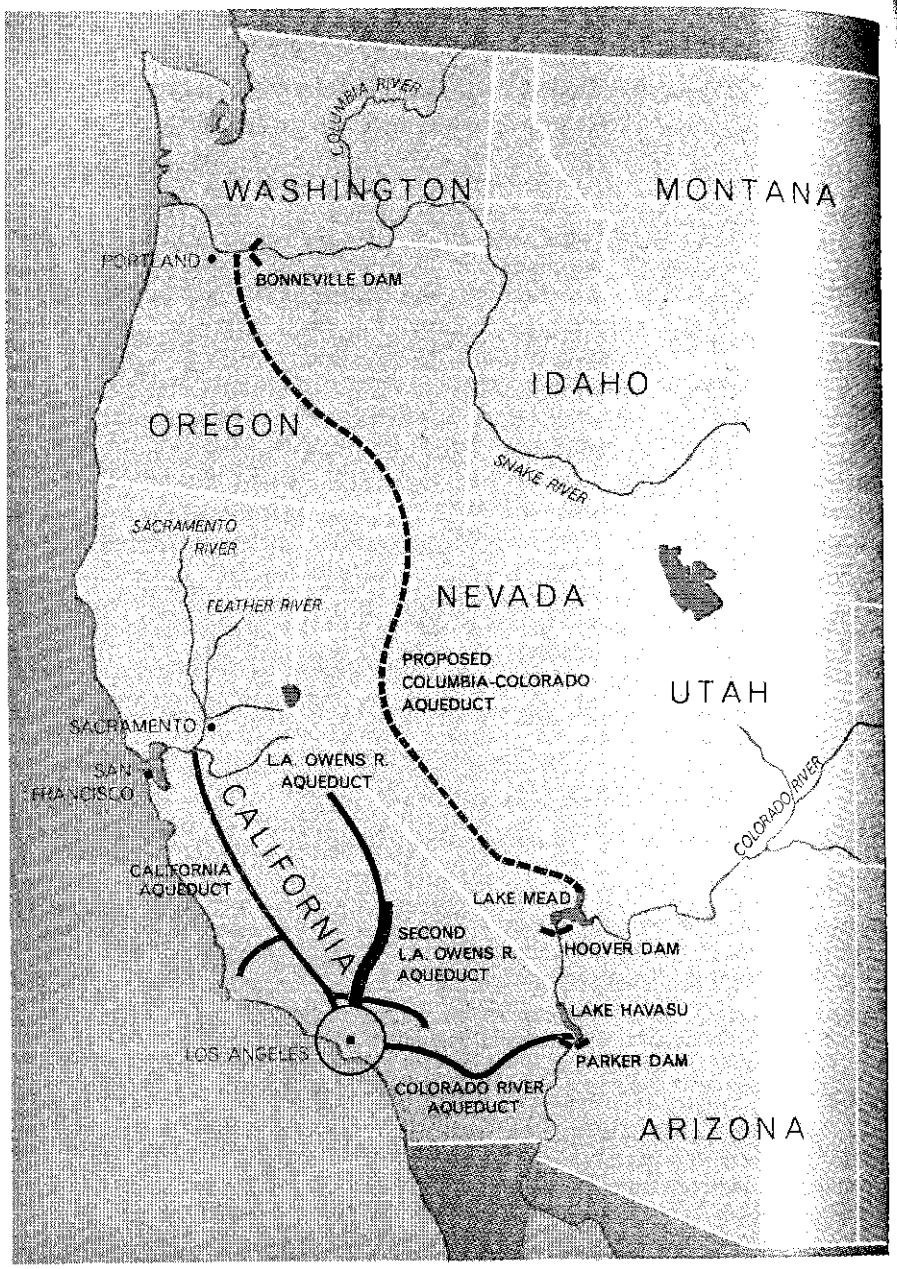
A new California law will require
haust-control systems on all 1966
tomobiles and light trucks sold in
e state. The law is intended to re-
uce by 70 or 80 percent the amount
of hydrocarbons now present in exhaust
gases and to reduce the carbon mon-
oxide by 60 percent. All the carbon
monoxide is generated by combustion
and is now released in the exhaust. The
steady rise in carbon monoxide vented
into the atmosphere of Los Angeles
County is plotted in the illustration on
the opposite page.

No one questions that an affluent society can afford to spend its money without a strict accounting of benefits received. Any reasonable expenditure that promises to improve the quality of life in the modern city should be welcomed. It is not obvious, however, that any American city except Los Angeles will be significantly benefited by the installation of exhaust-control systems in motor vehicles. The cost of these systems will not be trivial. At an estimated $40 to $50 per car, such systems would add more than $300 million to the sales price of new cars in an eight-million-car year—and this does not include the annual cost of their inspection and maintenance. If one objective of reducing the air pollution caused by automobiles is to increase the life expectancy of the city dweller, or simply to make his life more pleasant, it can be argued that $300 million a year could be spent more usefully in other directions.

In most large cities, for example, the electric utilities consume up to half of all fuel burned. Most utilities have made reasonable efforts to reduce the emission of soot and fly ash; virtually all new power plants, and many old ones, are now equipped with devices capable of removing a large fraction of such emissions. Utilities, however, are



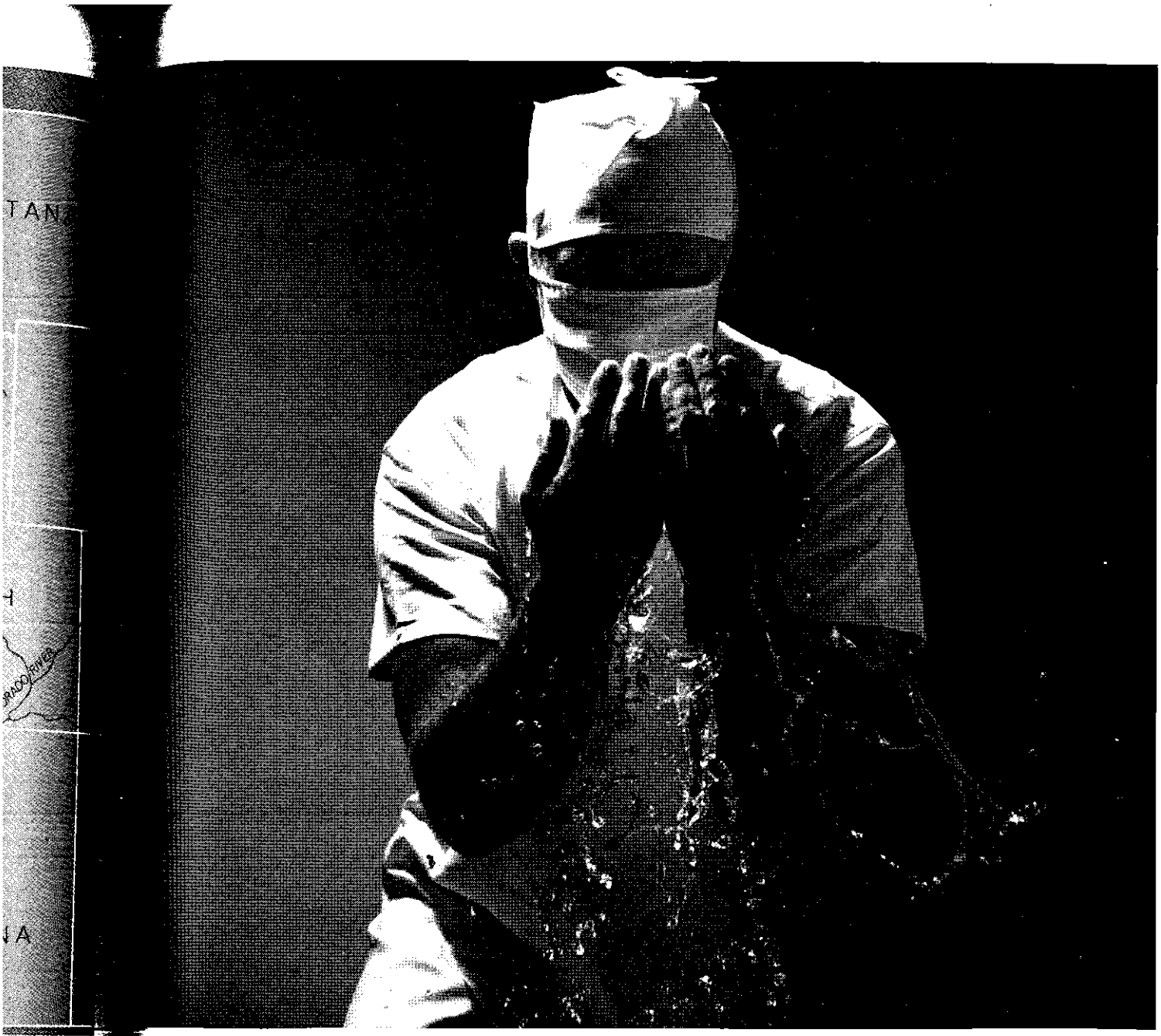
NEW YORK AIR POLLUTION contains large components of sulfur dioxide and particulate matter (soot and fly ash). The grid shows for the central part of New York City the computed output of sulfur dioxide per square mile in tons per year based on fuel used for space heating and producing hot water. About 55 percent more sulfur dioxide is released into the atmosphere by such "point sources" as power stations and industrial plants. The total figure for the entire city is estimated at more than 600,000 tons a year. The grid is taken from a larger map prepared under the direction of Ben Davidson of the Geophysical Sciences Department of New York University. The contour lines show the average dustfall levels in tons per year as measured by New York City's Department of Air Pollution Control.



DISTANT TRANSPORTATION OF WATER has been practiced in the West for many years. Los Angeles now has three major sources of supply to meet its daily demand of 470 million gallons. About 15 percent comes through the 300-mile Colorado aqueduct, completed in 1941, about 21 percent is pumped from local wells and the remainder, 64 percent, comes from Owens Valley, 340 miles to the north. An enlargement of the Owens Valley supply system (*color*) is nearly completed. Meanwhile the state is building a new 444-mile aqueduct (*color*) that will deliver water from the Sacramento River to southern California. Proposals are now being made to move water from the Columbia River, which accounts for more than 12 percent of total U.S. streamflow, to the arid Southwest. The water might be taken from below Bonneville Dam and diverted some 800 miles to Lake Mead on the Colorado River, following the general route shown (*broken colored line*).

still under pressure, both from the public and from supervising agencies, to use the cheapest fuels available. This means that in New York and other eastern-seaboard cities the utilities burn large volumes of residual fuel oil imported from abroad, which happens to contain between 2.5 and 3 percent of sulfur, compared with only about 1.7 percent for domestic fuel oil. When the oil is burned, sulfur dioxide is released. Recent studies show that the level of sulfur dioxide in New York City air is almost twice that found in other large cities.

Sulfur dioxide is difficult to remove from stack gases, but it is estimated that for about $1 a barrel most of the sulfur could be removed from the oil before it is burned. For the volume of oil



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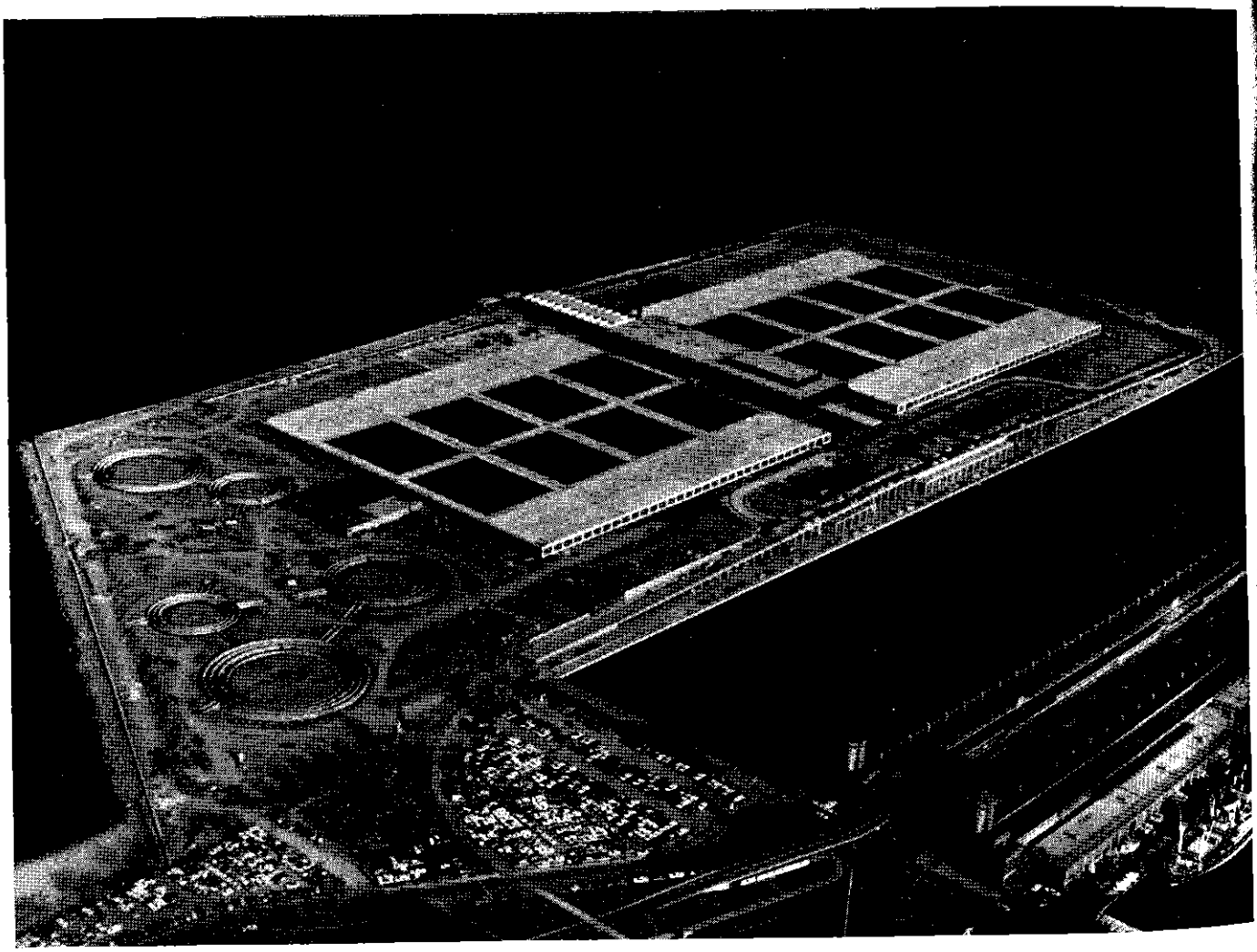
burned by the Consolidated Edison Company in New York City the added cost would come to about $15 million annually. If the cost were divided among Consolidated Edison's three million customers, the average electric bill would be increased about $5 per year. One would like to know how this expenditure would compare in improving the quality of New York City's air with New York's pro rata share of the more than $300-million-a-year investment that would be required by the installation of exhaust-control systems in motor vehicles. That share would be on the order of $8 million a year. Perhaps New Yorkers should insist on both investments. But these are only two of many options, all of them expensive. It is the responsibility of the city administrator and the public health officer to make choices and assign priorities, even while admitting that air pollution is never beneficial.

One must also recall that when large-scale changes are contemplated, the whole spectrum of society is involved. Rarely do all forces march forward in step, particularly where public policy and scientific verity are not crystal clear. Competitive forces delay correctives until public opinion rises in wrath and pushes for action on an *ad hoc* and intuitive basis.

Let me sum up by observing that in the case of water supply the accomplishments of the U.S. have been extraordinarily good, not only in the prevention of waterborne and water-associated diseases but also in providing water generously for comfortable living in most places at most times. The prospect for the future is likewise good. The realities are that we are not running out of water and that we are capable of managing our water resources intelligently.

In the area of water and air pollution our successes are only partial. Rapid urbanization and industrialization have intensified the problems of controlling both. At the same time one must concede that there is much stronger scientific justification for mounting vigorous programs to abate water pollution than to abate air pollution. Nevertheless, public pressure on behalf of the latter is increasing, and as has happened so often in the past, we may find action running ahead of knowledge. This is not necessarily to be deplored.

My own view coincides with that recently expressed by P. B. Medawar of University College London at a symposium on the interaction of man and his environment. "We are not yet qualified," he said, "to prescribe for the medical welfare of our grandchildren.... I should say that present skills are sufficient for present ills."



WORLD'S LARGEST FILTRATION PLANT was completed last year by the city of Chicago. Located on Lake Michigan, its normal rating is 960 million gallons per day, but it can safely provide 1.7 b.g.d. Another filtration plant helps to meet Chicago's average daily demand of .9 b.g.d. and to supply 61 nearby suburban communities. Chicago's per capita water use of 256 gallons per day, almost half of it metered, is about 100 gallons higher than that of New York, where residential use is not metered. Because of growing industrial pollution of Lake Michigan, Chicago's drinking water had an unpleasant odor on 89 days in 1961, up from 72 days in 1963.