The Metabolism of Cities

• ABEL WOLMAN

In the U.S. today attention is focused on shortages of water and the pollution of water and air. There is plenty of water, but supplying it requires foresight. Pollution calls for public economic decisions.

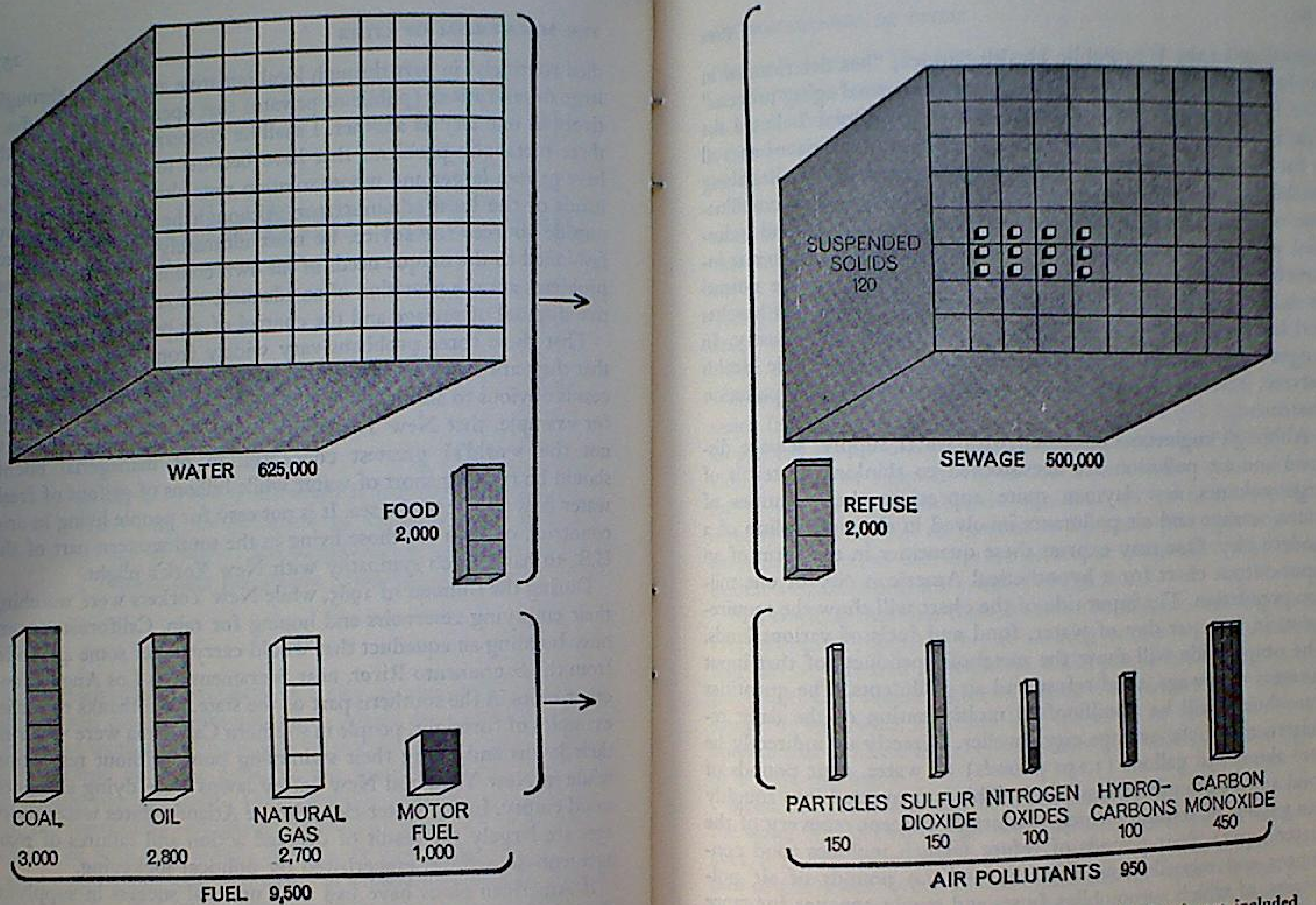
THE METABOLIC REQUIREMENTS of a city can be defined as all the materials and commodities needed to sustain the city's inhabitants at home, at work and at play. Over a period of time these requirements include even the construction materials needed to build and rebuild the city itself. The metabolic cycle is not completed until the wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard. As man has come to appreciate that the earth is a closed ecological system, casual methods that once appeared satisfactory for the disposal of wastes no longer seem acceptable. He has the daily evidence of his eyes and nose to tell him that his planet cannot assimilate without limit the untreated wastes of his civilization.

No one study could describe the complete metabolism of the modern city. Moreover, many of the metabolic inputs such as food, fuel, clothing, durable goods, construction materials and electric energy present no special problem. Their supply is handled routinely, in part through local initiative and in part through large organizations (public or private) that operate about as effectively 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.

During the summer of 1965, 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,"



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 shadings 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.

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. In August 1965 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 the metabolism of a modern city. One may express 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 will show the requirements in tons per day of water, food and fuels of various kinds. The output side will show the metabolic products of that input in terms of sewage, solid refuse and air pollutants. The quantities thus shown will be 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.

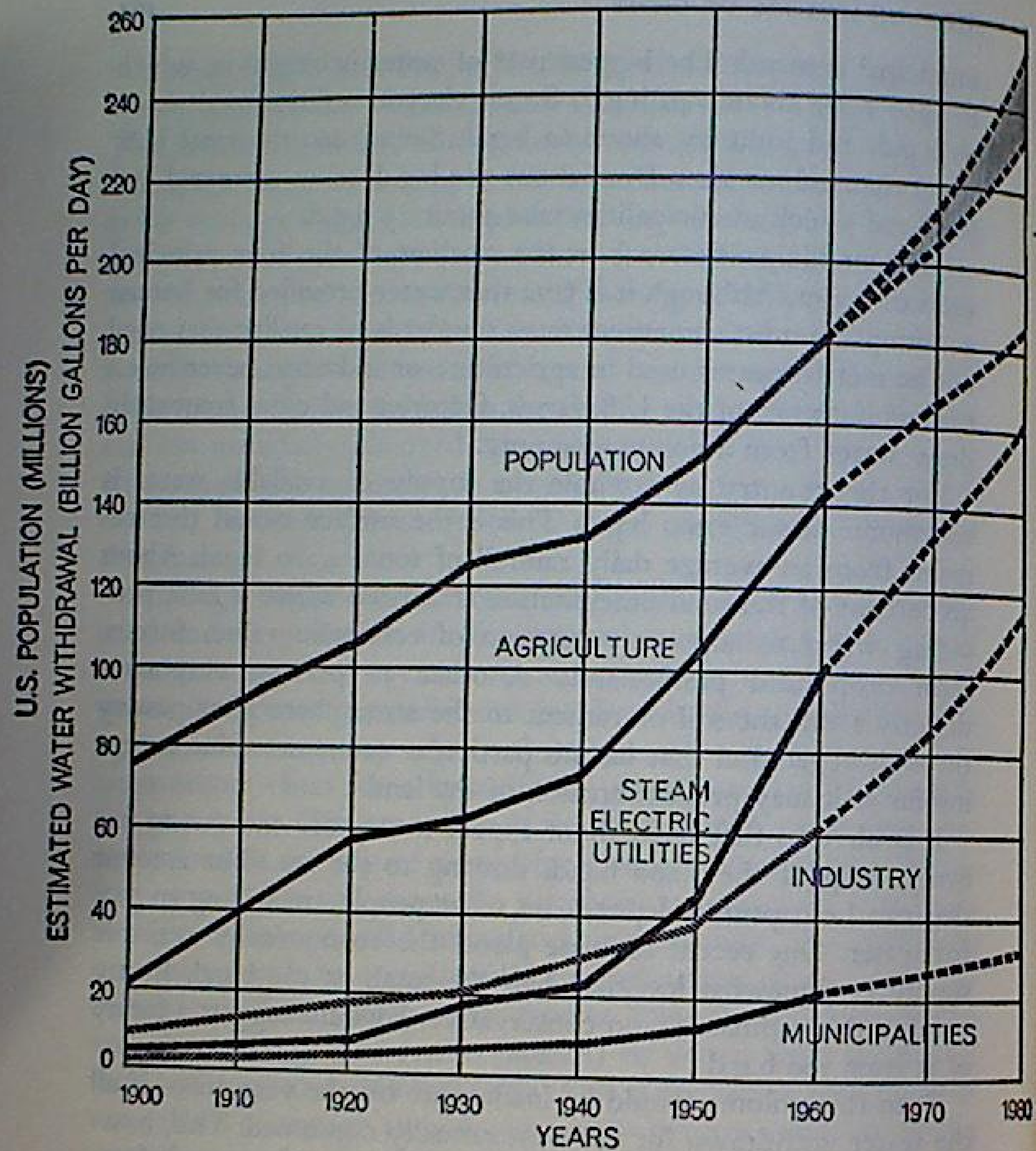
Thus municipalities rank as the smallest of the four principal users of water. Although it is true that water provided for human consumption must sometimes meet standards of quality that need not be met by water used in agriculture or industry, nevertheless throughout most of the U.S. farms, factories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

For the country as a whole the supply of available water is enormous: about 1,200 b.g.d. This is the surface runoff that remains from an average daily rainfall of some 4,200 b.g.d. About 40 percent of the total precipitation is utilized where it falls, providing water to support vegetation of economic value: forests, farm crops and pasturelands. Another 30 percent evaporates directly from the soil or returns to the atmosphere after passing through vegetation that has no particular economic value except insofar as it may prevent erosion of the land.

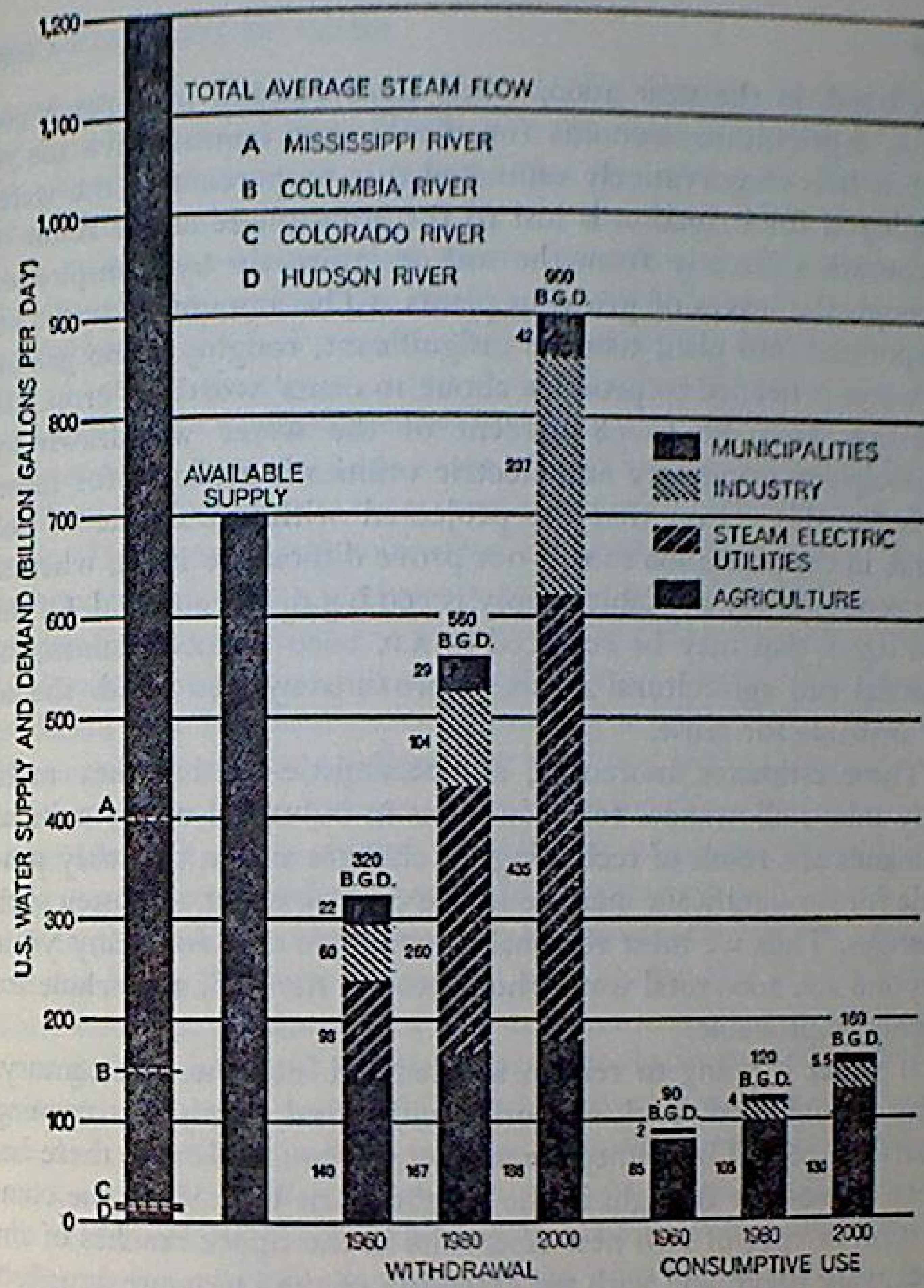
It is obvious that one cannot expect to capture and put to use every drop of the 1,200 b.g.d. flowing to the sea. The amount that can be captured depends on what people are willing to pay for water. One recent estimate places the economically available supply at somewhat less than half the total, or 560 b.g.d. In my opinion this estimate is too conservative; I would suggest a figure of at least 700 b.g.d.

Even this volume would be inadequate by the year 2000—if all the water withdrawn for use were actually consumed. This, however, is not the case now and will not be then; only a small fraction of the water withdrawn is consumed. In 1960 "consumptive use," as it is called, amounted to about 90 b.g.d. of the 320 b.g.d. withdrawn. Most of the remaining 230 b.g.d. was returned after use to the source from which it was taken, or to some other body of water (in some instances the ocean). A small fraction of the used water was piped into the ground to help maintain local water tables.

Estimates by a Senate Select Committee a few years ago projected a consumptive use of about 120 b.g.d. in 1980 and of nearly



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 the 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 per cent 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 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 preceding illustration. "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.

160 b.g.d. in the year 2000, when total demand may reach 900 b.g.d. Agriculture accounts for the biggest consumptive use of water. It is conservatively estimated that 60 percent of the water employed for irrigation is lost to the atmosphere as the result of evaporation directly from the soil or indirectly by transpiration through the leaves of growing plants. (The amount of water incorporated into plant tissue is insignificant; roughly 1,000 gallons of water is needed to produce about 10 cents' worth of crop.) In contrast, from 80 to 98 percent of the water withdrawn by municipalities, industry and electric utilities is available for reuse. It is for this reason that the projected withdrawal 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 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. In July 1965 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 15 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 done in West Texas, New Mexico, Arizona and California.

The fact that more than 150 million Americans can be provided with safe drinking water by municipal waterworks, regardless of their source of supply, attests the effectiveness of modern water-treatment methods. Basically the treatment consists of filtration and chlorination. The use of chlorine to kill bacteria in municipal water supplies was introduced in 1908. It is fortunate that such a cheap and readily available substance is so effective. A typical requirement is about one part of chlorine to a million parts of water (one p.p.m.). The amount of chlorine needed to kill bacteria and also to "kill" the taste of dissolved organic substances—many of which are introduced naturally when rainwater comes in contact with decaying vegetation—is adjusted by monitoring the amount of free chlorine present in the water five to 10 minutes after treatment. This residual chlorine is usually held to about .2 p.p.m. In cases where unusually large amounts of organic compounds are present in the water, causing the public to complain of a bad taste, experience has shown that the palatability of the water can often be improved simply by adding more chlorine. Contrary to a widely held impression, free chlorine itself has little taste; the "bad" taste usually attributed to chlorine is due chiefly to organic compounds that have been too lightly chlorinated. When they are more heavily chlorinated, the bad taste usually disappears.

Throughout history impure water has been a leading cause of fatal disease in man; such waterborne diseases as typhoid fever and dysentery were still common in the U.S. less than a century ago. In 1900 the U.S. death rate from typhoid fever was 35.8 per 100,000 people. If such a rate persisted today, the deaths from typhoid would far exceed those from automobile accidents. By

1936 the rate had been reduced to 2.5 per 100,000, and today the disease is almost unknown in the U.S.

In underdeveloped nations, where many cities are still without adequate water supplies, waterborne diseases are among the leading causes of death and debility. In Central and South America more than a third of 75 million people living in towns or cities with a population of more than 2,000 are without water service. Similarly, in India about a third of the urban population of 80 million are without an adequate water supply. As the chapter on Calcutta in this book [page 59] 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. 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. 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.

Although there was a significant improvement in sewage treatment in the U.S. between 1942 and 1962, a big job remains to be done. Only in the past five years of this period did the rate of

sewer installation begin to overtake population growth. The present U.S. investment in sewers and sewage-treatment works is about $12 billion (again the replacement value would be much higher). The Public Health Service estimates that replacing obsolete facilities, improving the standard of treatment and providing for population growth will require an annual investment of more than $800 million a year in treatment works for the rest of the decade. This does not include the cost of extending the sewage-collection systems into new urban and suburban 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 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 soot-fall. 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 showed improved lung function when allowed to breathe carefully filtered air for 48 hours.

In response to mounting public concern, and the urging of President Johnson, Congress in 1963 passed the Clean Air Act, which states in its preamble that "Federal financial assistance and leadership is essential for the development of cooperative Federal, state, regional and local programs designed to prevent and control air polution." The regulatory abatement procedures authorized in the act are similar to those found in the most recent Water Pollution Control Act. When an interstate pollution problem is identified, the Public Health Service is empowered, as a first step, to call a conference of state and local agencies. The second step is to call a public hearing, and the third step, if needed, is to bring a court action against the offenders.

The Clean Air Act takes special cognizance of air pollution caused by motor vehicles; it requires the Secretary of Health, Education, and Welfare to report periodically to Congress on progress made on control devices. He is also invited to recommend any new legislation he feels is warranted. Eventually the Secretary may help to decide if all new U.S. motor vehicles should be equipped with exhaust-control systems, such as "afterburners," to reduce the large amounts of unburned hydrocarbons and carbon monoxide that are now released.

California studies in the 1950's showed that exhaust gases accounted for 65 percent of all the unburned hydrocarbons then produced by motor vehicles. Another 15 percent represented evaporation from the fuel tank and carburetor, and 20 percent escaped from the vent of the crankcase. As a first step in reducing these emissions California began in 1961 to require the use of crankcase blowby devices, which became standard on all U.S. cars beginning with the 1963 models.

A new California law will require exhaust-control systems on all 1966 automobiles and light trucks sold in the state. The law is intended to reduce by 70 or 80 percent the amount of hydrocarbons now present in exhaust gases and to reduce the carbon monoxide by 60 percent. All the carbon monoxide is generated by combustion and is now released in the exhaust. From 1940 to 1965 there has been a steady rise in carbon monoxide vented into the atmosphere of Los Angeles County.

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 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 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."

The Renewal of Cities

· NATHAN GLAZER

Many U.S. cities, with the aid of the Federal Government, are engaged in ambitious efforts to renew themselves. It is not certain, however, that the overall gains of these programs have outweighed the losses.

When we speak of the renewal of cities, we mean all the processes whereby cities are maintained or rebuilt: the replacement of old houses by new houses, of older streets by newer streets, the transformation of commercial areas, the relocation of industrial facilities, the rebuilding of public utilities; we refer to rehabilitation as well as demolition and rebuilding; we mean too the laws and administrative and financial mechanisms by which this rebuilding and rehabilitation are accomplished. The only way to discuss such an enormous subject is to consider all the elements of change in a city: its changing economic role, its changing population, decisions to buy or sell, stay or move, rehabilitate or demolish, and the larger market and political forces that affect all this.

Fortunately we can narrow our subject considerably. There exist, in this nation and others, specific public policies designed to plan and control at least some part of these vast processes. In