Chemistry Background Book

Water

hours, as distinguished from the 'clockwork' or striking part; also the 'works' or parts composing the movement of a watch.

Water (wǭ·təɹ), *sb.* [Com. Teut.: OE. *wæter* :—OTeut. *watar- :—Indo-Eur. *wod- (as in Russ. *vodá*, cf. VODKA): *wĕd- (OTeut. *wĕt- WET *a.*): *ud-* (as in Skr. *udán*, Gr. ὕδωρ, genit. ὕδατος :—**udn̥tos*, L. *unda* wave).] **I. 1.** The liquid of which seas, lakes, and rivers are composed, and which falls as rain and issues from springs. When pure, it is transparent, colourless (except as seen in large quantity, when it has a blue tint), tasteless, and inodorous. **b.** With various qualifying words, as *ice-w.*, RAIN-w., etc. **c.** Considered as antagonistic to fire. late ME. **d.** As supplied for domestic needs, esp. as distributed through pipes to the houses of a district 1535. **2.** As a drink, as satisfying thirst, or as necessary aliment for animals and plants OE. **3.** As used for dilution of liquors OE. **b.** *fig.* (*Stock Exch.*) Fictitious capital created by the 'watering' of the stock of a trading company 1883. **4.** As used for washing, steeping, boiling, etc. OE. **b.** Each of the quantities of water used successively in a gradual process of washing ME. **5.** Water of a mineral spring or a collection of mineral springs used medicinally for bathing or for drinking, or both. Freq. *pl.* with *the*. 1542. **6.** Water regarded as collected in seas, lakes, etc., or as flowing in rivers or streams. (The pl. is often used instead of the sing., esp. with ref. to flowing water or water moving in waves.) OE. **b.** *Hunting*, etc. Streams or ditches which a horse is required to leap 1860. **7.** Quantity or depth of water as sufficient or insufficient for navigation 1546. With prefixed adj., a particular state of the tide; see HIGH W., LOW W. late ME. **8.** Water received into a boat or ship through a leak, or by the breaking of the waves over the sides. late ME. **9.** As an enveloping or covering medium; in various phrases. late ME. **10.** A body of water on the surface of the earth. (In sense 'a stream, river', now chiefly *Sc.* and *north.*) OE. **11.** *pl.* Floods: esp. in phr. *the waters are out.* 1523.

1. W., w., every where, Nor any drop to drink COLERIDGE. All else..runs off them like w. off a duck's back 1871. Phr. *To write on* or *in w.*, to fail to leave abiding record of (something). (To spend money) *like w.*, profusely, recklessly. **d.** *To cut off, turn on the w.* **2.** *Bread and w.*, the type of extreme hard fare, as of a prisoner or penitent. *W. bewitched* (colloq.), excessively diluted liquor; now chiefly, very weak tea. **3.** *Brandy-and-w.*, *whisky-and-w.*, etc.; hence joc. in nonce-combs.; The weak Addison-and-w. of the 'Mirror' 1882. **5.** It is..very long, Mr. Pickwick, since you drank the waters DICKENS. A wine-glass of Orezza w. after breakfast every morning 1879. **6.** Thy waye was in the see, and thy pathes in the great waters COVERDALE *Ps.* lxxvii. 19. *fig.* Therfore she loves to fish in troubled Waters 1628. Phrases. *Deep waters* (after *Ps.* lxix. 2, 14), grave distresses and anxieties; also difficult or dangerous affairs. *To make a hole in the w.* (slang), to commit suicide by drowning. *By w.*, by ship or boat on the sea or a lake or river or canal. *On* or *upon the w.*, on the sea, in naval employments or enterprises. *Across, over, on this side the w.*, *to cross the w.*, across, etc. the sea; (in London *the w.* in such phrases is often = the Thames). *The king over the w.*: see OVER *prep.* IV. 4. *To take* (*the*) *w.*, (*a*) to enter the sea, or lake, or river, and begin to swim; (*b*) to embark, take ship; (*c*) *U.S.* 'to abandon one's position'; (*d*) of a ship, to be launched. **7.** *To draw* (so much) *w.*: see DRAW *v.* I. 11. **8.** *To make w.*, *take* (*in*) *w.*, to leak, or to admit or 'ship' w. over the side, etc. **9.** *Under w.*, below the surface of w.; (of land) flooded, submerged; hence *fig.* unsuccessful in life; also (*Sc.*) in debt. *Above w.*, above the surface of the w.; also *fig.*, esp. in *to keep one's head above w.*, to avoid ruin by a continued struggle. **10.** By the waters of Babilon we sat downe and wepte COVERDALE *Ps.* cxxxvii. 1. The winters..are seldom severe enough to freeze any considerable w. BURKE. Within a little [we] found ourselves crossing the w. of Leith 1793. On one side lay the Ocean, and on one lay a great w., and the moon was full TENNYSON.

II. The substance of which the liquid 'water' is one form among several; the chemical compound of two volumes of hydrogen and one of oxygen (formula H_2O); in ancient speculation regarded as one of the four (or later, five) elements of which all bodies are composed. OE.

III. A liquid resembling (and usu. containing) water. **1.** An aqueous decoction, infusion, or tincture, used medicinally or as a cosmetic or perfume ME. **b.** With defining word, applied to liquid preparations of various kinds (see LAVENDER-W., LIME-W., SODA-W., etc.). late ME. **2.** Used to denote various watery liquids found in the human or animal body, either normally or in disease 1533. **b.** The fluid contained in the amniotic cavity (*liquor amnii*); now usu. *pl.* 1688. **c.** Tears. late ME. **d.** Saliva; now only, flow of saliva provoked by appetite 1598. **3.** *esp.* Urine. late ME. **4.** Applied to vegetable juices 1585.

2. *W. on the brain, in the head*, hydrocephalus. **c.** A dexterous rap on the nose..which brought the w. into his eyes DICKENS. **3.** *To make w.*, to urinate. *To pass w.*, to void urine (usu. with ref. to obstruction or the absence of it).

IV. The transparency and lustre characteristic of a diamond or a pearl 1607.

The three highest grades of quality in diamonds were formerly known as the *first*, *second*, and *third w.*; the phrase *of the first w.* survives in pop. use as a designation of the finest quality N.E.D. *fig. Of the first* (occas. *purest*, *finest*) *w.*, orig., of the highest excellence or purity; now only with the sense 'out-and-out', 'thorough-paced'.

attrib. and *Comb.*, as *w.-biscuit*, *-brook*, *-broth*, *-bucket*, *-cask*, *-cock*, *-diet*, *-drainage*, *-gauge*, *-pole*, *-pool*, *-pump*, *-sprite*, *-supply*, *-tap*, *-trough*, *-turbine*, etc.; *w.-cooled* adj.; also (designating substances which harden under water) *w.-cement*, *-lime*, *-mortar*.

Comb.: **a. w. authority**, a municipal body administering a system of w.-supply; **-balance**, a machine for raising loads to a height by the weight of w.; **-ballast**, cisterns filled with w., placed in the hold of a vessel to serve as ballast; **-bearing** *a.* producing w., not arid; *Geol.* through which w. percolates; **W. Board**, an administrative body having control of the supply of w. to a town or district; **-boot**, a boot intended for those who have to stand or walk in w.; **-bound** *a.* of macadam roads: solidified by watering and rolling; **-breather**, any animal capable of breathing in w. (by means of gills); **-cell**, each of the cells in the walls of the stomach of the

Water

If it suddenly stopped raining, what would happen to us? At first, we might be pleased not to have to worry about the weather. After a time however, we should begin to see alarming changes around us. The surface of the earth would begin to dry; grass would turn brown; the leaves on trees would wither and fall; the year's crops would fail. An emergency would be declared, and water would have to be rationed. If the drought continued animals would begin to die. Cows, for example, which consume about twelve gallons of water a day, would need more water than rations would allow. They would have to be slaughtered. The parched earth, now no longer moist underneath, would turn to dust and disappear. Finally, vast migrations from the country would begin. In a matter of a year or two, a whole country could look like the Sahara Desert.

Extreme action might be taken. We might turn to the sea with the hope of purifying enough water from it to keep us alive. All the country's strength might have to revolve around the elementary fact that we need water to survive.

The drought of 1934 (*above*) dried up most of the reservoirs near London. Water in this Hertfordshire reservoir was usually 12 feet deep. *Radio Times Hulton Picture Library*

The beginnings of a dust bowl. The wind slices off the top soil leaving the sandy underlayers exposed. Since these can retain only small quantities of water, the chances of further wind damage are greatly enhanced.

This actually happened in the western United States. The state of Oklahoma had a small rainfall. When the first settlers arrived at the end of the nineteenth century, no one seemed to know how very little rain it was. The land was extremely fertile and the first crops were enormous. Just a few decades later, there was nothing left but a vast desert. The simple practices of turning up the soil, growing wheat, and harvesting seem to have begun a chain reaction. The rainfall was slightly below an already very low average. Farmers followed old routines, paying little attention to problems of soil exhaustion. The crops became smaller. Their roots could no longer hold as much water as the wild grasses that grew there before. When the fields were ploughed in the spring and the autumn, small quantities were carried off by the wind. The more that was carried away, the more the sandy underlayer was exposed. Finally there was simply too little moisture left in the earth to hold it down. A vast cloud of dust blew up from the fields and spread two thousand miles to fall as far away as New York City. In a very short time there was literally no land left for farmers to till. They had to leave—a story you can read about in John Steinbeck's *The Grapes of Wrath*.

It took almost thirty years to repair a tiny fraction of the damage. New underground water supplies were found, irrigation systems set up, new methods of restoring the soil used, and Oklahoma gradually regained some of its productivity. It will probably never be as productive as it was when it was first settled. If farmers had used water more efficiently, if they had supplemented natural rainfall with irrigation supplies, if they had sown crops in rotation and refertilized fields, there is little likelihood that the Oklahoma disaster would have occurred.

Oklahoma is by no means unique; vast parts of Africa and Asia suffer from conditions very similar to those in Oklahoma. Today, growing populations and the need for more water to drink and to grow food have made the search for new water resources and for new supply systems a vital necessity in many parts of the world.

We shall see here how water is supplied in complex water systems, how it is purified, how it is used. Although its presence in oceans and lakes and rivers may make these processes appear relatively simple, many years of hard work lie behind present-day water technology.

Part One

Chemical and Physical Properties of Water

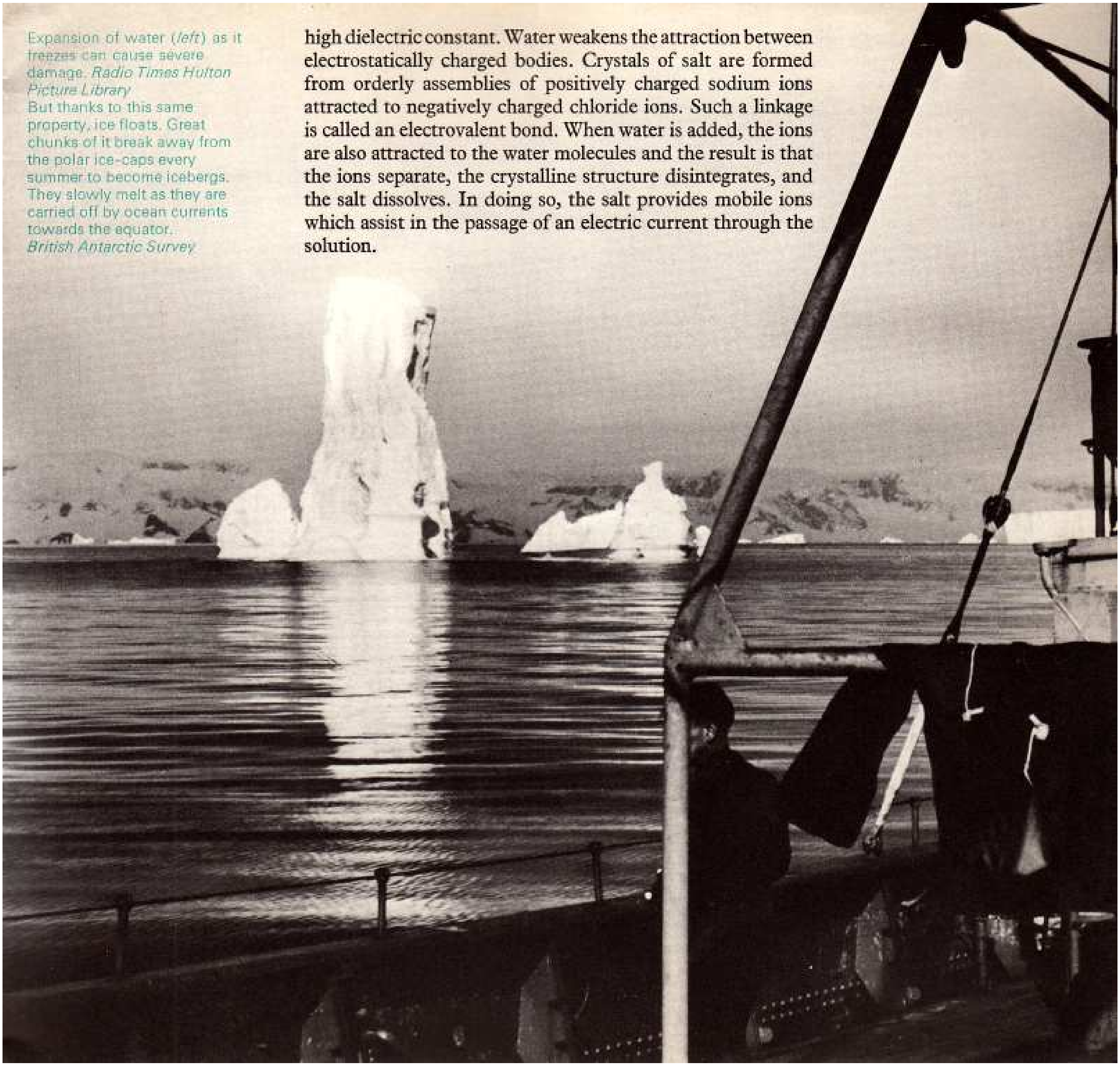
Chemically water is not a very complicated substance but its physical and chemical behaviour is not at all what one would expect from such a simple formula. Its melting and boiling points, the familiar zero and 100 degrees of the Centigrade scale, are abnormally high for a substance with such a small molecule. If water behaved like other compounds of low molecular weight it would be a gas at ordinary temperatures and the earth would be an arid desert.

Another property of water has had an incalculable effect on the world's climate. When water is cooled it predictably contracts in volume; but, as it cools from 4°C to zero, it expands. Apart from causing burst pipes and pot-holes in roads during frosty weather, this expansion means that ice will float in the surrounding cold water. This may seem trivial, but what would happen if, rather than floating, it sank in increasing amounts to the bottom of seas and lakes, far from the melting rays of spring sunshine?

Water dissolves at least tiny quantities of a vast number of substances. The very purest water can be made only by repeated distillation in tin vessels, because glass is very much more soluble than tin. Such pure water is obviously extremely difficult to keep or to use without allowing gases from the air to dissolve in it.

The ability of water to dissolve salts like common salt can be traced to its abnormally high 'dielectric constant'. For example, water decreases the attraction between two charged bodies within it. If a gramophone record is dusted with a dry cloth the dust sticks to it because rubbing has caused an electrostatic attraction; but if the duster is dampened, the dust comes away easily, because the water has considerably weakened the attraction between the dust and the plastic record. This is what is meant by saying that the water has a

high dielectric constant. Water weakens the attraction between electrostatically charged bodies. Crystals of salt are formed from orderly assemblies of positively charged sodium ions attracted to negatively charged chloride ions. Such a linkage is called an electrovalent bond. When water is added, the ions are also attracted to the water molecules and the result is that the ions separate, the crystalline structure disintegrates, and the salt dissolves. In doing so, the salt provides mobile ions which assist in the passage of an electric current through the solution.



Expansion of water (*left*) as it freezes can cause severe damage. *Radio Times Hulton Picture Library*
But thanks to this same property, ice floats. Great chunks of it break away from the polar ice-caps every summer to become icebergs. They slowly melt as they are carried off by ocean currents towards the equator. *British Antarctic Survey*

In other cases, the dissolution in water is accompanied by 'hydrolysis' – a reaction between the solute and water in which both compounds are split up and each reacts with the other. In such cases water changes the chemistry of the solute as well as dispersing it in solution. There are many examples of this phenomenon in chemistry from the hydrolysis of comparatively simple inorganic salts, such as ammonium sulphate, to complex organic reactions like the breakdown of starches to form simpler carbohydrates such as glucose. Although the process is much more complicated, such an organic reaction might be represented like this:

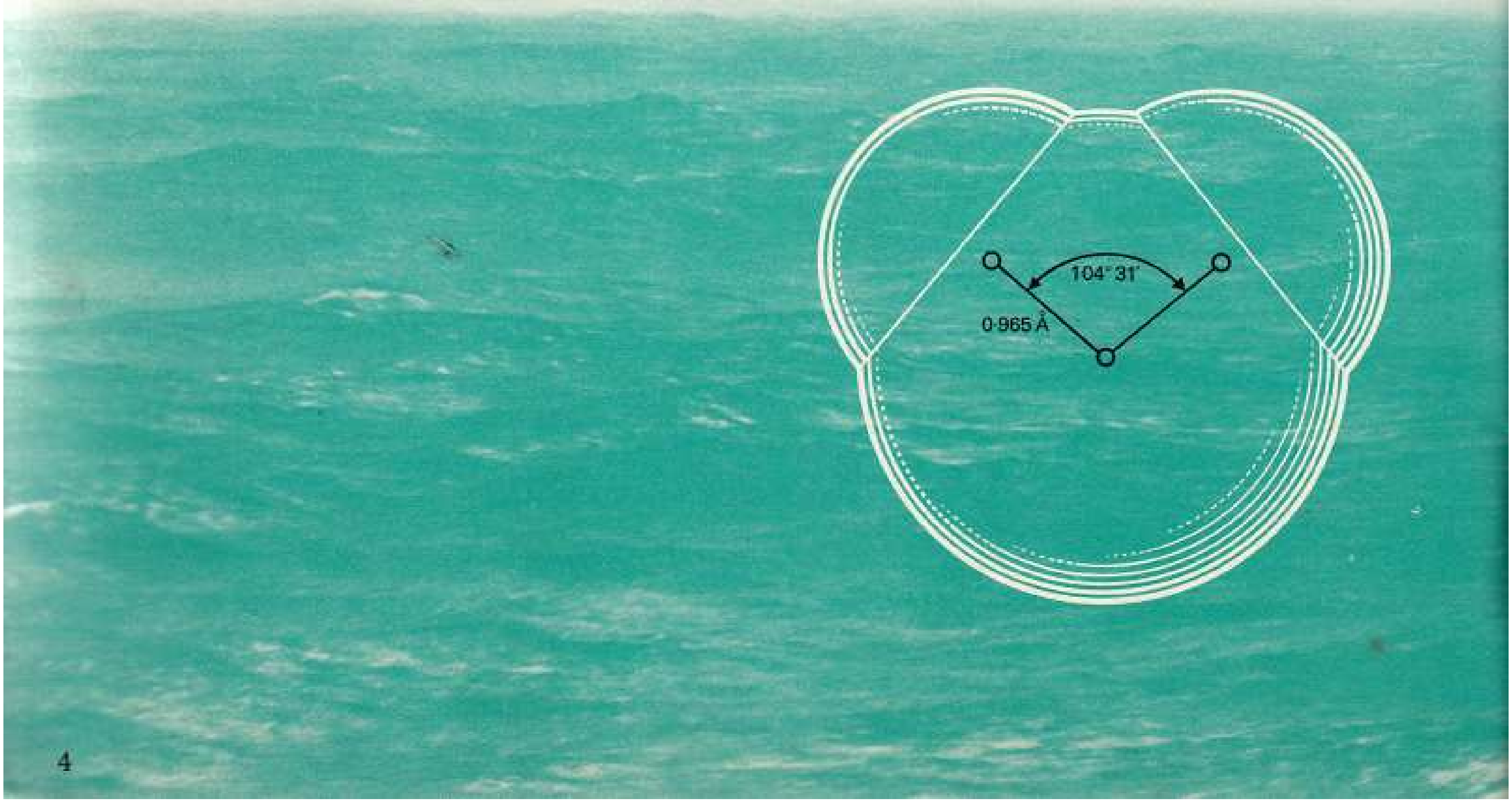
$$(C_6H_{10}O_5)_n + nH_2O = nC_6H_{12}O_6$$

The simple formula H—O—H will obviously be of little help in an attempt to explain the remarkable properties of water. Such a formula is only two-dimensional and static whereas the actual molecule must be three-dimensional and very mobile. Furthermore the links between the atoms are essentially electrical.

Oxygen is much more electronegative than hydrogen: it attracts electrons more readily. This leads to an electrically lopsided molecule since the electrons are pulled over to the oxygen side of the molecule. Such sharing of electrons constitutes covalent linkages. The water molecule may thus be represented as shown below. The hydrogen 'ends' of the

Photo, Radio Times Hulton Picture Library

Diagram of water molecule (*below*). *After Pauling, Linus 'The Architecture of Molecules', published by W. M. Freeman & Co. Ltd.*



molecule are positively charged, while the oxygen 'end' is negative. Such a molecule is said to be 'polar' and it is the large polarity of the water molecule which helps to explain its properties.

A substance which is highly polar is bound to have a large dielectric constant. When placed between two plates of which one is positively charged and the other negatively charged, water molecules will orientate themselves so that their positive ends point towards the negative plate. This arrangement leads to a weakening of the electric field between the plates.

Furthermore since the hydrogen ends of the water molecule are comparatively small in volume, their electrical effect is concentrated into a smaller volume and is correspondingly intense. They attract the negative ends of neighbouring molecules. This attraction is known as 'hydrogen bonding' and is of great importance in chemistry. In water itself it leads to a clumping together of molecules and to resistance in separation. When a liquid is transformed into a vapour by heating, the molecules separate because they have been supplied with extra energy. The clumps of molecules in liquid water require abnormally great heat to effect a separation; in other words, water has a high boiling point.

A similar explanation applies to the high freezing point. In the solid state this grouping of water molecules leads to an orderly three-dimensional arrangement comparable with the crystalline structure of salt. In fact, giant ice crystals are formed. We see their effect on a window on a frosty morning and we may discover even more beautiful patterns if we look at snowflakes with a microscope. Ice crystals have a relatively 'open structure'; they occupy more space than the bulk of the separate molecules. This explains the expansion of water as it freezes; the liquid takes up less room than the solid.

If we look a little more closely into the chemistry of water we find its chemical behaviour just as unexpected as its physical properties. This may also be explained by the polarity of water molecules. Water molecules cling to metallic ions in solution giving rise to the phenomenon known as 'water of crystallization'. Water acts as a bonding agent when it transforms the white powder known to chemists as anhydrous sodium carbonate into large crystals of hydrated sodium carbonate, the familiar washing soda crystals. This hydration is caused by the attraction that a small, positively charged metallic ion, like sodium, exerts on charged water molecules. It is significant that salts containing such small ions crystallize with several molecules of water of crystallization, whereas those with large metallic ions have only a few such molecules of water or none at all. The copper ion attracts four molecules of water making the blue ion $Cu^{2+}(4H_2O)$, which loses water on heating and becomes white.

Water readily causes acids to ionize. Acids contain hydrogen which is able, in certain circumstances, to detach itself (to ionize) and be replaced by a metallic ion. The new compound is a salt. The gas hydrogen chloride shows no acid properties either in its normal gaseous form or when dissolved in toluene; the hydrogen 'part' remains firmly attached to the chlorine. But when the gas is dissolved in water the solution shows all the reactions we expect from an acid – hydrochloric acid, in fact. In the molecule of hydrogen chloride, the chlorine atom is highly electronegative and pulls away electrons from the hydrogen. When water molecules are added this pulling away is increased and the hydrogen ion leaves the chlorine and becomes associated with the water molecule: it is, in fact, hydrated and represented by H_3O^+:

$$HCl(g) + H_2O(1) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Because of its role in the formation of hydrogen ions it is not surprising to find that water itself is ionized to a very small extent into hydrogen and hydroxyl (OH^-) ions. This ionization explains the hydrolysis of salts like ammonium sulphate. Because ammonium hydroxide is not greatly ionized (it is said to be a weak base), the ammonium ions (from ammonium sulphate) and the hydroxyl ions (from water) link up. This leaves an excess of hydrogen ions in solution – in other words, an acid solution.

$$NH_4^+(aq) + [H_3O^+ + OH^-] \rightarrow NH_4 \, . \, OH(aq) + H_3O^+(aq)$$

The part that water plays in the hydrolysis of carbohydrates and proteins and in other biological processes is more complex, but it does throw some light on the importance of the hydrogen bond in biochemical synthesis, as a sort of glue in some chemical compounds which are fundamental to all forms of animal life.

Part Two

The Supply of Water

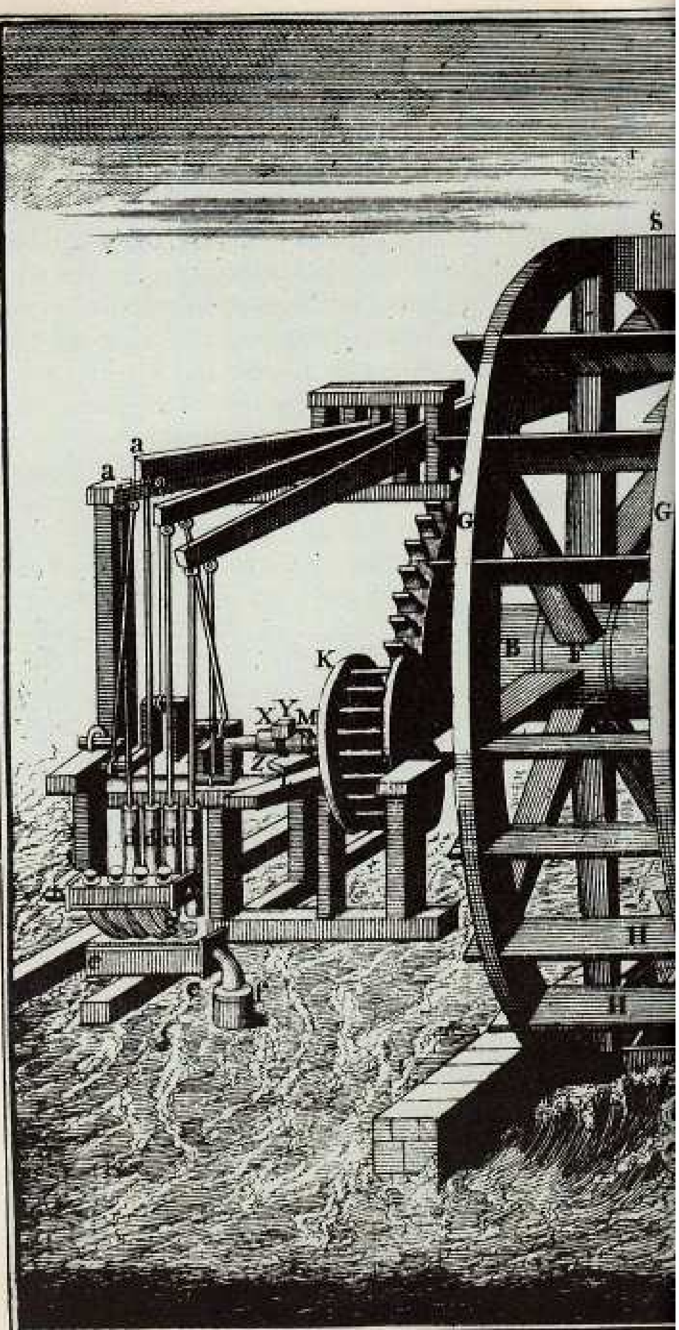
Water supply in the past – The history of London's water supply is an interesting example of how problems connected with water arose and were solved over the past 600 years. Medieval London was small enough to rely on the limited resources at hand (its population in 1400 was about 50,000). Wells had been dug in Roman times to reach the plentiful supply in the subsoil. These were enough to meet the city's needs until the end of the sixteenth century. By this time London had outgrown her city walls. New water sources were needed. In 1582 a Dutchman, Peter Morrys, obtained permission to build a water-wheel beneath the arch of old London Bridge. The swift current of the Thames turned the wheel which operated a pump for forcing water through wooden conduits to the City. It eventually supplied four million gallons of water a day. The Thames at this time was still comparatively unpolluted.

Sir Hugh Myddleton, Lord Mayor of London, began the first official venture in water supply in 1631. He constructed an open trench, which he called the New River, to bring reasonably pure water from chalk springs at Chadwell and Amwell in Hertfordshire.

Wooden pipelines were usual until the end of the eighteenth century. At this time some water companies began to lay cast iron pipes. A law of 1817 required that all future pipelines be of cast iron. Iron pipelines allowed for a wider distribution of water. They permitted water supply to areas of clay subsoil, which could not depend on local underground resources like gravel subsoil areas. Water companies, however, made no attempt to keep abreast of growing needs until much later.

In the nineteenth century water problems were aggravated by population growth and industrial expansion. Urban population in England grew from three million to about twenty-four

The WATER WORKS *at* LONDON-BRIDG



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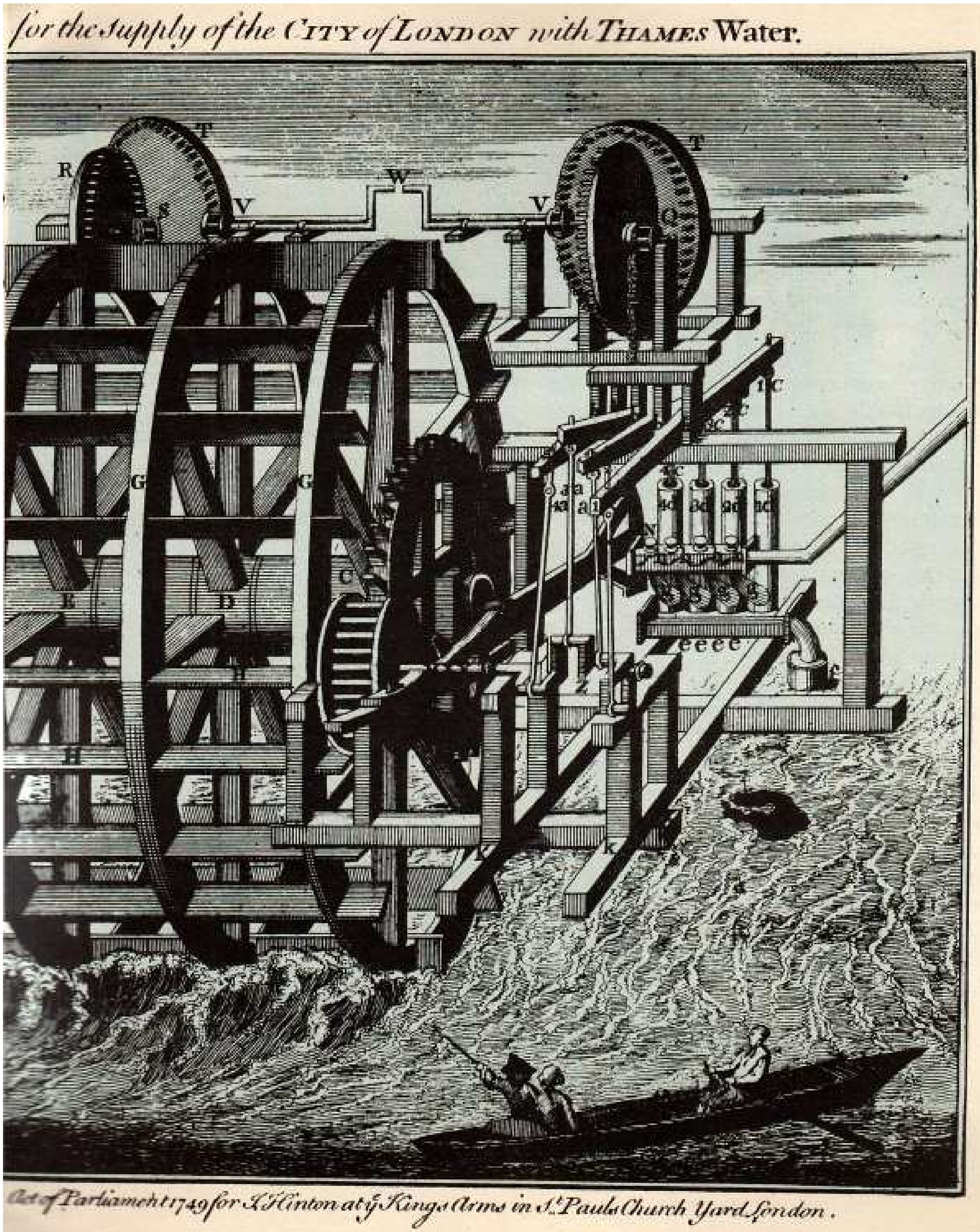


A water-wheel under London Bridge in the eighteenth century.

million between 1801 and 1891. During this time industrial expansion stimulated great technological advances, but there was little practical application of new technology to water supply systems.

Pollution became a serious problem in the early nineteenth century. Because sewage and factory wastes were not treated, vast epidemics of waterborne diseases, such as Asiatic cholera and typhoid, ravaged the city. The great cholera epidemic of 1831 cost more than 50,000 lives in London. The situation was made considerably worse by a vast sewage system introduced about this time. Its waters were dumped into the Thames upstream from the inlet pipes of a number of the London water companies.

In 1842 the Poor Law Commissioners issued a report on the dangers arising from inadequate water supply and sanitation systems. It was written by their Secretary, Edwin Chadwick (1800–92). The report and Edwin Chadwick's continuous hard work brought about the first public health laws in 1848. A brief description of some sanitary conditions only 125 years ago will show what sort of problems Chadwick faced:

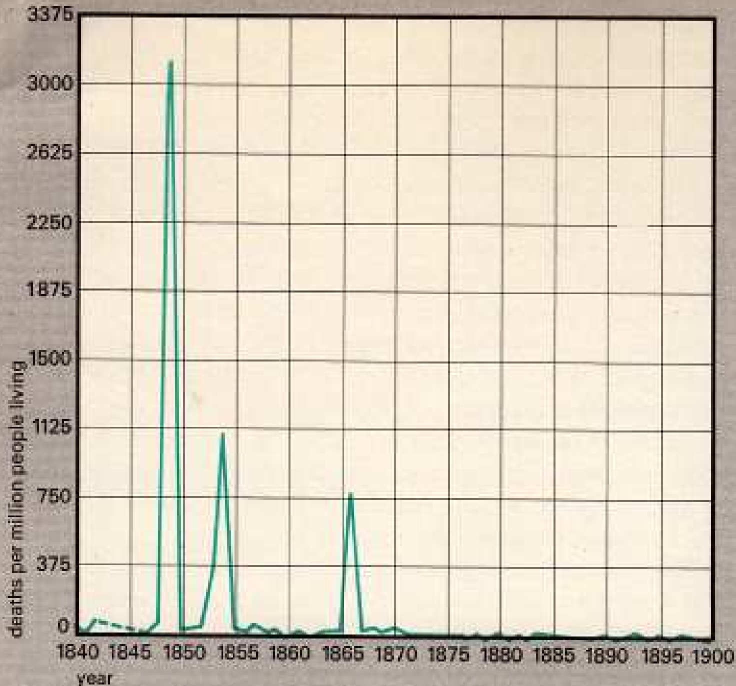
'The whole family of the labouring man in the manufacturing town rise early before daylight in winter-time, to go to their work, they toil hard and return to their homes at night. It is a serious inconvenience, as well as discomfort to them to have to fetch water at a distance out-of-doors, from the pump or the river on every occasion that it may be wanted, whether it may be in cold, in rain, or in snow. The minor comforts of cleanliness are of course foregone, to avoid the immediate and greater discomforts of having to fetch water.'

Chadwick's campaign led to much controversy. The tools for improvement were available, but it took several decades to convince suppliers to use them, and almost a century to convince them to use them properly. James Simpson, a consulting engineer to the Chelsea Water Company, devised a system of water purification. Water was filtered through a series of fine grade sand beds. Known abroad as the 'English system' it laid the foundations of modern processes of water purification. It was made compulsory for all water companies by a law of 1852. Unfortunately the law was widely disregarded and the epidemics went on. In 1854 a London doctor, John Snow, proved that an outbreak of cholera in Soho could be traced to polluted water from the Broad Street well. The handle of the pump was removed and the epidemic ended almost at once with about 600 deaths in all.

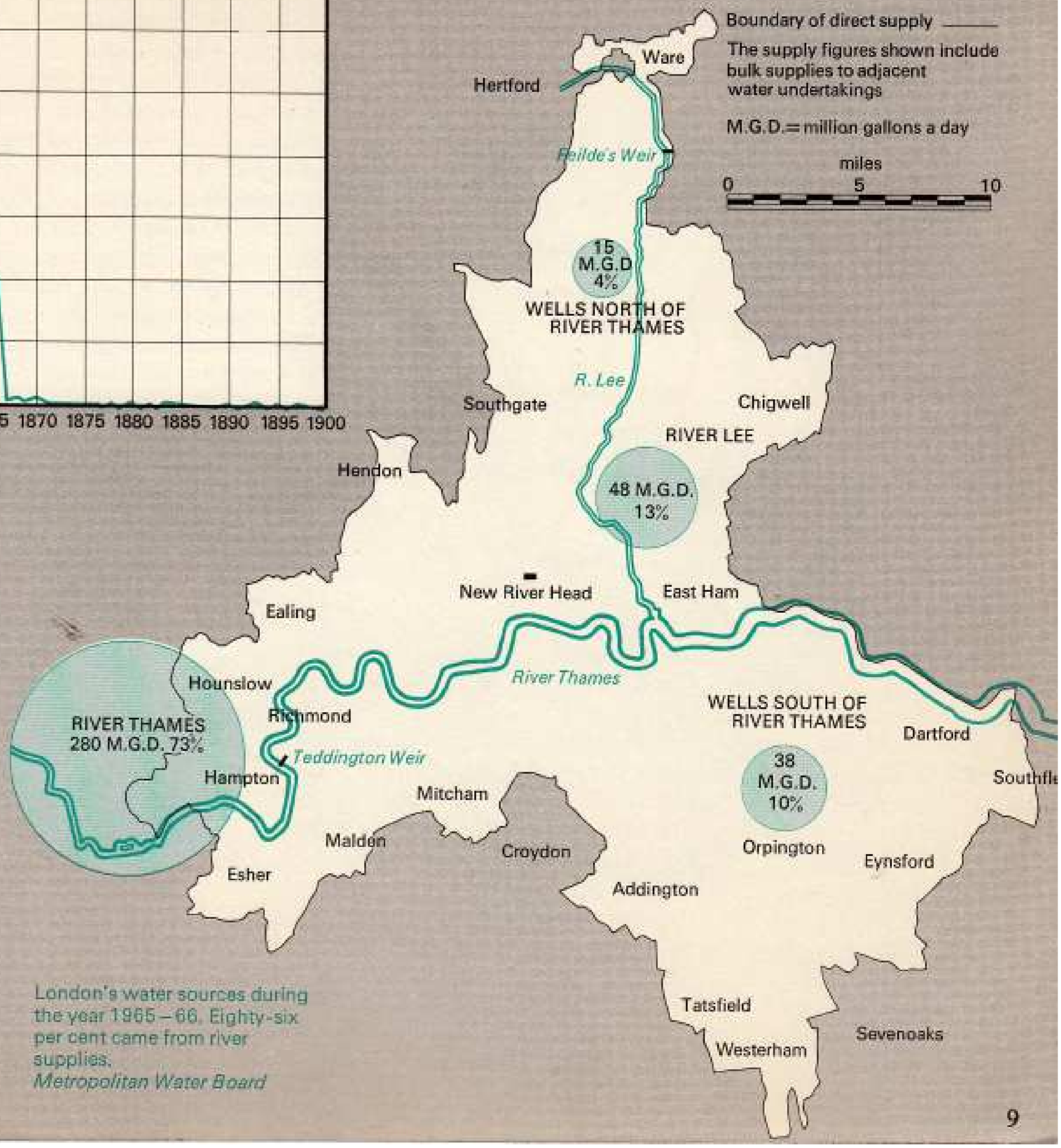
Regular chemical analysis of water supplies was required by law after 1858. Water companies were not allowed to draw water below a certain point in the Thames, so as to avoid confusion of drinking water with sewage. The flagrant disobedience of these laws led to the cholera epidemic of 1866.

The Public Health Act of 1875 laid the foundations for modern health codes. Although the era of great epidemics was over, small outbreaks continued to occur as a result of faulty water systems. To reduce these, chlorination was made standard practice in a growing number of water companies from 1904 onwards. The last serious outbreak of waterborne disease in England was a typhoid epidemic at Croydon in 1937. It was entirely a result of the water suppliers' negligence.

The growing need for larger water resources and for improved quality forced small water companies to combine. In London, a single Metropolitan Water Board has replaced many small companies. It serves an area of 540 square miles, supplying 6¼ million people with a daily average of 60 gallons each.

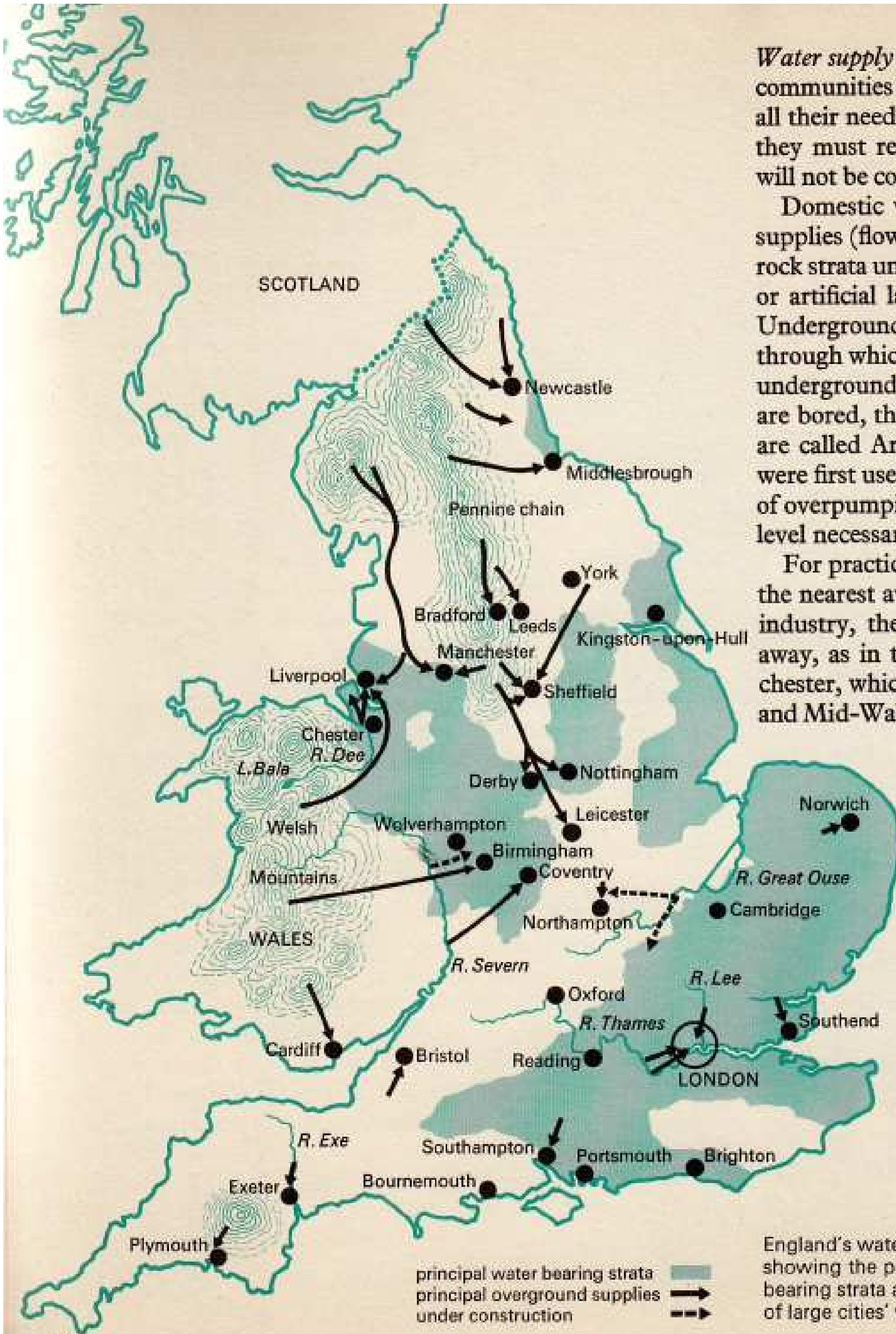


Graph showing deaths due to cholera in nineteenth century.
Institution of Civil Engineers



In the eighteenth and nineteenth centuries, spas like Cheltenham (*left*) became very popular resorts. During the summer, they were the centre of the social season, as well. This is the Cheltenham literary salon in about 1825.
Ronan Picture Library

London's water sources during the year 1965–66. Eighty-six per cent came from river supplies.
Metropolitan Water Board



England's water resources, showing the principal water-bearing strata and the sources of large cities' water supplies.

Water supply today – Today water authorities seek to provide communities with enough clean, pure, palatable water to meet all their needs. They must see that sources are large enough; they must remove impurities; they must ensure that water will not be contaminated by the time it reaches the consumer.

Domestic water is normally obtained either from surface supplies (flowing or static) or from natural deposits in porous rock strata underground. Surface supplies, rivers, and natural or artificial lakes served by rivers, can be reached directly. Underground sources are reached by wells or boreholes through which the water is brought to the surface. Sometimes underground water deposits are under pressure. When holes are bored, the water rises to the surface by itself. Such wells are called Artesian Wells after Artois in France where they were first used. They have disappeared from London because of overpumping, which gradually reduced pressure below the level necessary to push the water to the surface.

For practical reasons each community draws its water from the nearest available source. With the increasing demands of industry, the nearest source is sometimes a great distance away, as in the cases of Liverpool, Birmingham, and Manchester, which have been forced to turn to the lakes of North and Mid-Wales and to the Lake District itself for their supply.

Water supply tomorrow – Although there is no present shortage of water in Great Britain, demand increases continuously, rising by three to four per cent annually. It may soon be necessary to tap entirely new sources to meet increasing needs.

In many parts of the world, present needs are not being satisfied. In a recent survey of seventy-five developing nations, the World Health Organization indicated that about seventy per cent of the populations of South and Central America, Africa, and southern Asia have inadequate piped water services or are supplied with unsafe water. Each year 500 million people in these countries contract disabling diseases which can be traced to water systems. Forty-one per cent of their populations, or about 129·3 million people, have no access to piped water. A WHO fifteen-year programme is attempting to improve purification systems and to build dams by which to increase supplies.

In other countries, inadequate rainfall coupled with increasing populations has made rationing and large-scale distillation a necessity.

Redistribution of existing natural waters is one possible solution to shortage problems. In Israel, and now in the

Drilling for water in Algeria (*above*). Many desert areas lie above underground reservoirs. *Radio Times Hulton Picture Library*

Millions of people have no access to piped water; they have to carry it from the nearest source, which is sometimes miles away. *WHO/Pierre Pittet*

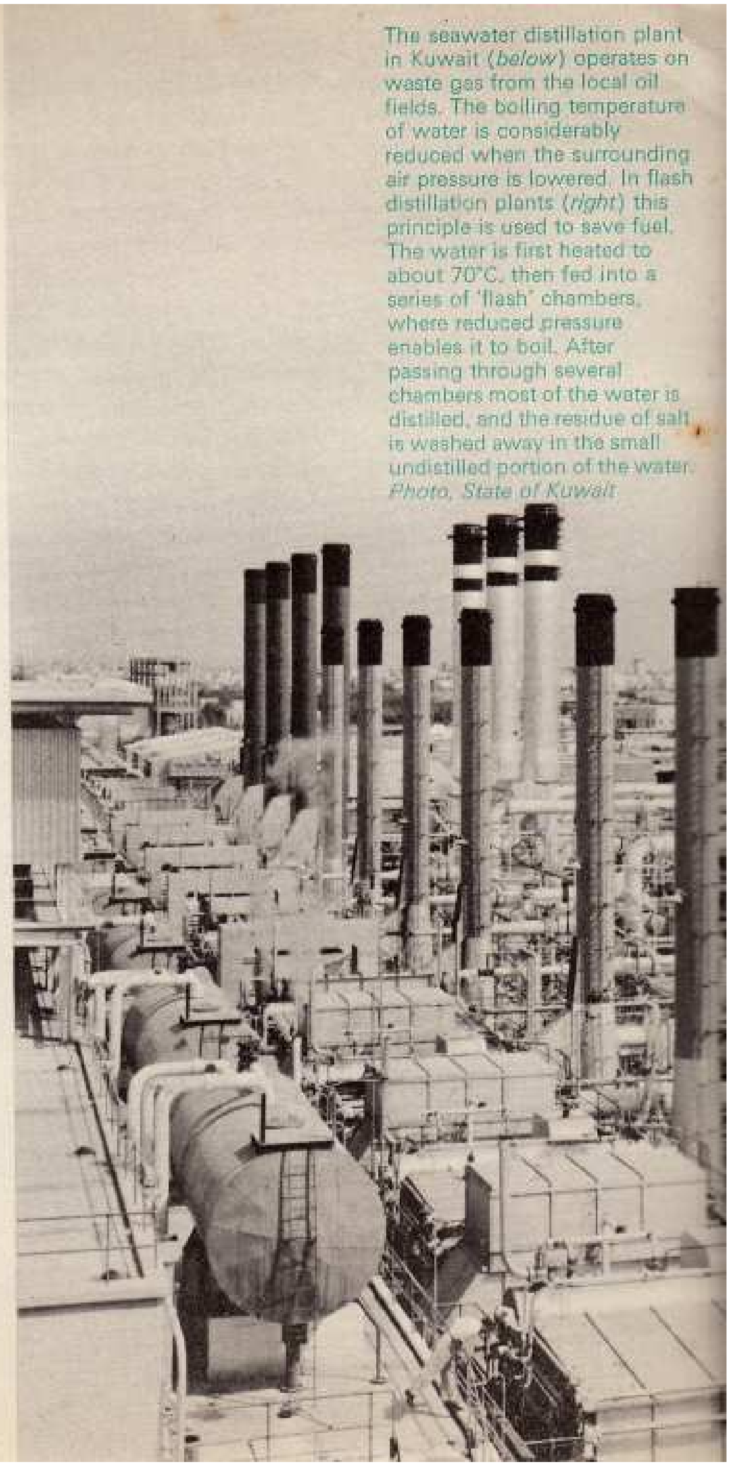
Sahara Desert, arid areas have been turned into agricultural land by water irrigation. In some cases the courses of rivers are shifted; in others water is stored in dams and piped to where it is needed. In the Sahara vast underground supplies have recently been discovered. Redistribution of these could make the world's largest desert into the largest wheat growing area.

An interesting idea for water conservation has been tried in Australia. A long-chain hydrocarbon derivative such as cetyl alcohol ($C_{17}H_{35}OH$) is poured into the lakes. This forms a layer on the surface, perhaps one molecule thick, and reduces evaporation. It could be useful in hot countries.

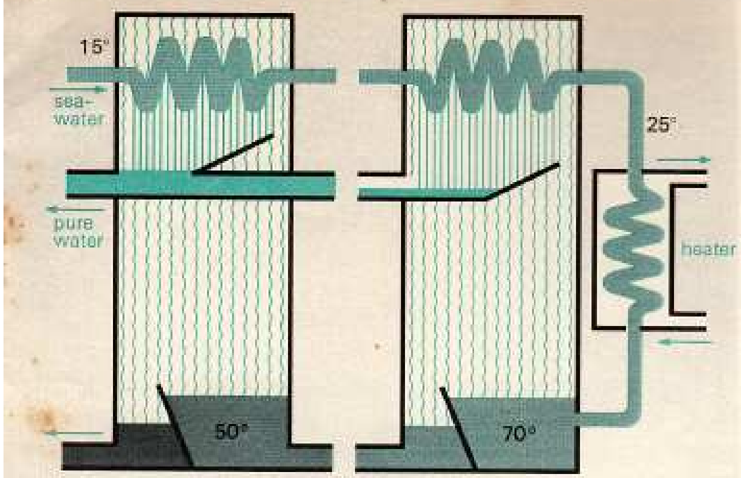
In most countries, however, redistribution and conservation are only of short-range value. Long-term water needs will have to be met by drawing upon sea water. If all surface and underground supplies could be measured accurately, they would probably be no more than one per cent of all the total water on earth. The remaining ninety-nine per cent is salt water.

Water shortage problems everywhere could be solved for several centuries to come if an inexpensive method of purifying sea water could be devised. The simplest way of removing minerals from sea water is by distillation. Unfortunately, the fuel for distillation plants is far too expensive for most countries. It takes about 6,400 tons of coal to heat and evaporate enough sea water to equal one inch of rainfall on one square mile of land. There are a few water distillation plants, however. One in Kuwait operates on waste gas from local oilfields. It produces 8 million gallons of fresh water daily. There is a water distillation plant in Aruba, Barbados, producing about $2\frac{1}{4}$ million gallons daily, and one is under construction in Antigua in the West Indies.

Another method of purifying sea water, and one of the most promising methods suggested, is electrodialysis. A compartment containing sea water is separated from compartments on either side by membranes which are permeable to the dissolved salts. One of the side-compartments contains a positive and the other a negative electrode. An electrical potential induces cations to pass through the membrane to the cathode compartment and anions to pass to the anode compartment, gradually reducing the sodium (Na^+) and chlorine (Cl^-) ions in the water. An ion-exchange plant could contain many such cells so that the process would be continuous. This method is particularly useful for water of low salinity as in the case of



The seawater distillation plant in Kuwait (*below*) operates on waste gas from the local oil fields. The boiling temperature of water is considerably reduced when the surrounding air pressure is lowered. In flash distillation plants (*right*) this principle is used to save fuel. The water is first heated to about 70°C, then fed into a series of 'flash' chambers, where reduced pressure enables it to boil. After passing through several chambers most of the water is distilled, and the residue of salt is washed away in the small undistilled portion of the water. *Photo, State of Kuwait*

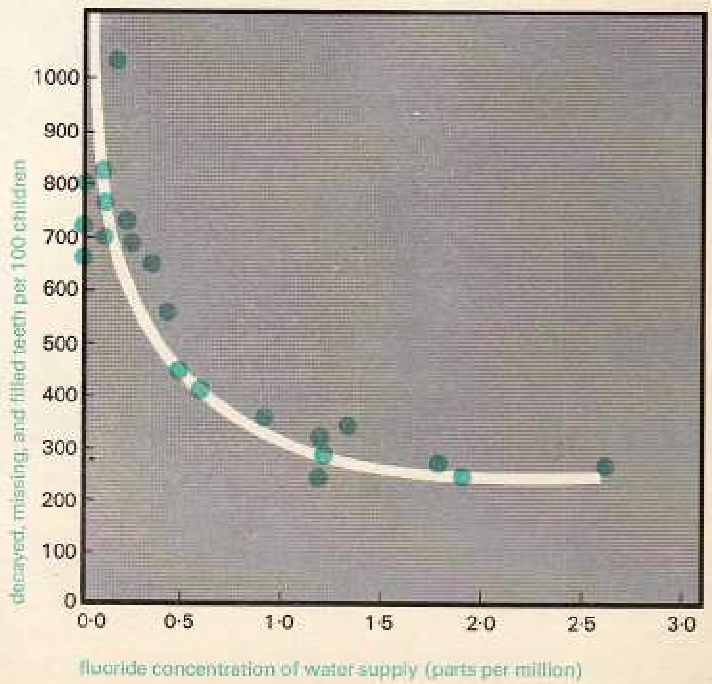


water purified by an ion-exchange plant in Johannesburg, South Africa. Water from this plant is used for uranium refining.

Ways are now being sought to harness the sun's energy for water distillation. Natural purification of water takes place in just this way: the sun's energy turns sea water into vapour.

In addition to meeting demands for increasing supplies, planners are now concerned with another more controversial consideration. It has been known for some time that people living in areas where local water contains large amounts of fluoride ions are liable to have stained teeth. Although the effect is sometimes unsightly, tooth decay is much rarer. Research has demonstrated that a controlled fluoride content of about one mg/litre of water is not harmful and radically reduces tooth decay. There has been a great deal of discussion about whether or not water fluoridation is a desirable interference with natural resources, but the trend seems to be in this direction.

Correlation between tooth decay and fluoride content of drinking water. *From Dean et al.* (1942), *quoted in the* Memorandum on the dental health of children (*1959 of the British Dental Association*).



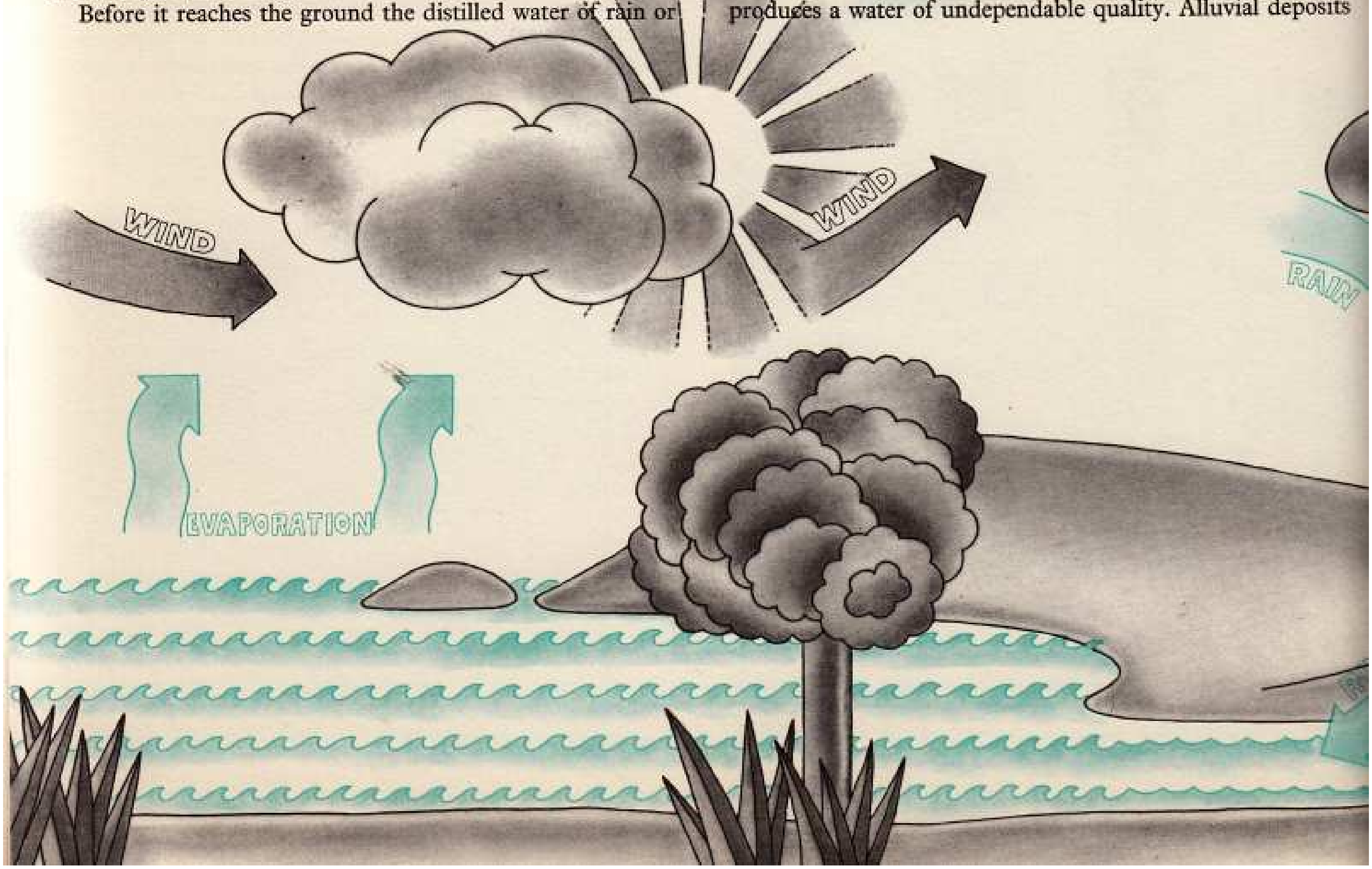
Part Three

The Water Cycle

Water from both surface and underground sources comes originally from rain or snow. Large expanses of natural water evaporate continuously. The water vapour produced is carried away by air currents. When the currents are forced to rise, by meeting either land masses or belts of cool air, the water vapour is cooled and condensed into droplets of water. The droplets gradually increase in size and eventually fall to the ground as rain or snow, according to the temperature of the air through which they pass.

Before it reaches the ground the distilled water of rain or snow dissolves carbon dioxide (as carbonic acid) and oxygen. In coastal regions, it may also dissolve salts from sea spray. In industrial zones it may dissolve dust or sulphur dioxide, which is then oxidized into sulphuric acid. Perfectly pure water does not occur in nature.

About 30 per cent of rain returns directly to the sea. What happens to the remainder after it touches earth depends on the kind of ground on which it falls. If it falls on non-absorbent rock, it will quickly run off to form streams and rivers. If the rock is porous, the water soaks through and collects beneath the surface of the earth. The quality and the reliability of underground water supplies depends largely on the geological strata in which they collect. Chalk yields a clean, pure water whose solid content is mainly calcium carbonate. Sandstone produces a water of undependable quality. Alluvial deposits



yield an impure water of varying compositions and quality. Limestone like chalk produces a 'hard' but usually good water. Over the ages the flow of water through limestone areas forms caves or tunnels, like the Cheddar caves. In them there is sometimes a constant dripping of calcium hydrogen carbonate solution at definite points. The successive evaporation and decomposition of calcium hydrogen carbonate solution from insoluble calcium carbonate produces stalactites and stalagmites. These are frequently coloured by contact with other metal salts.

As water flows towards the sea it dissolves other substances and becomes progressively more impure. Pollution results from decaying animal and vegetable matter. In some areas impurities and pollution are increased by industrial waste and sewage. Constant evaporation along the way helps to concentrate the dissolved matter still further.

The sea, which receives all these impurities, is a vast repository of chemicals. A cubic mile of sea water could yield 110 million tons of table salt, 27 million tons of magnesium chloride, 22·5 million tons of magnesium sulphate, 7·2 million tons of gypsum (calcium sulphate), 3 million tons of potassium chloride, and perhaps 37 lb of gold. All naturally occurring elements are present to some degree.

In years to come, just as the sea may become a major source of pure water, it may also be a valuable source of chemicals. Inland seas, like the Dead Sea, contain up to 7 – 10 times as much dissolved matter as ordinary sea water. The density of water is greatly increased and the yield per cubic mile even larger than that of ordinary sea water. Extraction of potash from the Dead Sea is one of Israel's largest industries.

Part Four
Purification

Regular samples of water are taken at every stage of purification. Here coliform tests are being performed. *Radio Times Hulton Picture Library*

Man was, as we have seen, concerned almost exclusively with water supply problems until comparatively recently. In the last century, epidemics and industrial growth made purification a crucial necessity. Today many water authorities seek to produce not only safe drinking water but also water that is attractive in appearance, taste, and smell, non-corrosive to metals, and convenient for domestic and industrial use. In addition to organic impurities, suspended insoluble matter and dissolved salts must be removed to achieve these results.

Organic impurities – The source of water pollution and waterborne disease is in man himself. Diseases such as typhoid, cholera, bacillary and amoebic dysentery, and infectious hepatitis originate and multiply in man's intestines. These diseases spread when untreated sewage is permitted to enter drinking supply lines.

In order to minimize the possibility of infection, public health laws require close inspection of areas where river water constitutes a source of supply. The World Health Organization of the United Nations has set a standard of one coliform bacterium/100 cm^3 of water as safe for treated water and 10 bacteria/100 cm^3 for untreated water. The presence of coliforms in excess of these figures can be highly dangerous. Such regulations have effectively eliminated waterborne diseases in most of Europe. But recurrent outbreaks of cholera in Spain and India and a recent hepatitis outbreak in Rome serve to remind us that the threat is still present. One way of reducing the chance of epidemic is by eliminating bacteria in sewage. Sewage from all large communities should be thoroughly processed before it returns to rivers. The failure of some communities to do this is an echo of nineteenth-century negligence, which caused so much waste of human life.

Exposure to sunlight in reservoirs kills a considerable quantity of bacteria, but when water enters a community's supply system it must be rigidly tested. The most important test is for coliform bacteria, which are hardier and more frequent in normal populations than other disease bacteria. Various quantities of water are mixed with a special culture medium (known as MacConkey's broth) and incubated at body temperature (37°C). The 'broth' is particularly favourable to the growth of coliforms but inhibits the growth of other bacteria. It contains a sugar called lactose. If coliforms are present they will act on the lactose to produce lactic acid. A given quantity of water and a given quantity of 'broth' will produce a proportional quantity of lactic acid and carbon dioxide after a certain time. By measuring these, it is possible to calculate how many coliforms are present.

The membrane filter test is another method for detecting the presence of coliforms. It may become widespread, particularly in new laboratories. Water is filtered through a special gridded membrane which is then placed on a culture medium and incubated. Bacterial colonies may then be counted directly under a low-power microscope.

When the bacterial content of a given supply system is known, diseases can be eliminated in various ways. One of these ways is by chlorination. The disinfectant properties of chlorine have been known for some time. It was first used in England at Maidstone in 1897, when bleaching powder proved effective for controlling a typhoid epidemic. Chlorine is usually added to a small quantity of water from 70 lb liquid chlorine cylinders. The resulting strong solution is then added to the main bulk of the water.

On a smaller scale and in emergency cases, sodium hydrochlorite may be used, and less frequently, bleaching powder. Organic compounds which liberate chlorine or iodine are used in water purifying tablets for treating small quantities of water.

The amount of chlorine added to water must be carefully controlled. Amounts of less than 0·1 mg of chlorine/litre of water are not enough to kill bacteria and amounts of more than 1·0 mg/litre give the water an unpleasant taste and smell. To avoid this problem and nevertheless eliminate bacterial content a process of superchlorination followed by dechlorination has frequently been adopted. The raw water is treated with a considerable excess of chlorine. The high concentration of chlorine gives strong and rapid bactericidal effects. Then the excess chlorine is eliminated by adding sulphur dioxide.

Question. Can you explain this in terms of a chemical reaction?

Another way of treating bacteria-bearing water is by ozonization. Ozone (O_3) is an allotropic form of oxygen. The molecule consists of a group of three atoms. It is produced by passing a silent electrical discharge through air or pure oxygen. The discharge causes some oxygen atoms to group in threes. When ozone is introduced into water, the oxygen atoms revert to a paired state. The remaining atom oxidizes and destroys any germ it may encounter. Ozonization produces particularly sparkling and attractive water. It is widely used in France and by a few authorities in England – especially for swimming pools. Although it is more expensive than chlorination, it has the advantage of removing colour, taste, and smell. It is useful in the removal of dissolved salts since it precipitates iron and magnesium as oxides.

Question. What other substances do you think must be produced by the precipitation of iron and magnesium as oxides?

Suspended insoluble matter – Twigs or coarse particles are found mainly in river water. If the water is left to stand in large reservoirs, most of the insoluble matter settles within twenty-four hours. This process is known as sedimentation.

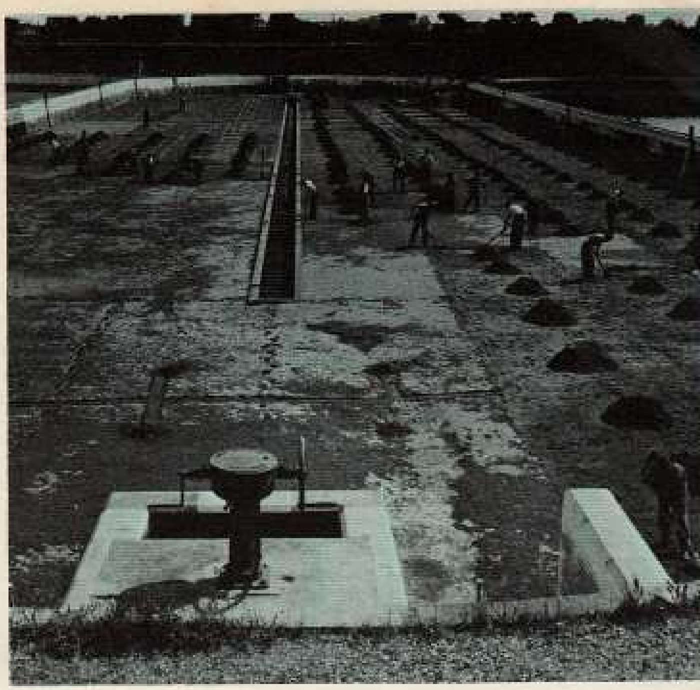
The matter which is not removed by sedimentation consists mainly of minute colloidal particles. These particles are charged relative to the water and are surrounded by a thin layer of water of opposite charge. They do not coagulate into larger particles unless the balance between the charge of the water and the charge of the particles is disrupted. Highly charged positive ions, like the aluminium ions in aluminium sulphate, disrupt the balance. The colloidal particles coagulate and the majority settle. The process can be hastened by mechanical stirring. The particles which do not settle can be removed by filtration.

There are several methods of filtration. In slow filtration water is passed through a filter bed consisting of a deep layer of fine sand spread out over a gravel base. When water filters through the sand, suspended matter is gradually removed along with a good part of the bacterial content. Although many slow filters are still used today, rapid filters are more common. Two different methods are employed: open gravity filtration and closed pressure filtration. In each case the principle is the same as in slow filtration. In pressure filtration, the water is forced through a sealed sand bed under high pressure. Gravity filtration takes advantages of a large difference between inflow and outflow levels to force the water through the sand quickly.

In 1945 the Metropolitan Water Board adopted a system of microstraining for preliminary filtration. It involves a rapid flow of water under pressure through a rotating drum. The drum is covered by a fine stainless steel screen which removes even the smallest solids from the water. As the drum rotates, the screen is cleaned on one side, and it in turn cleans the water on the other.

Dissolved salts – As we have seen, water varies considerably according to its source. Frequently it contains large amounts of dissolved calcium, iron, and magnesium salts. These salts are undesirable as they have a bitter taste, cause discoloration of washing (iron mould), and may even block pipes. In industrial use, particularly in paper making, even minute quantities are harmful.

Hard water is considered undesirable by most water supply



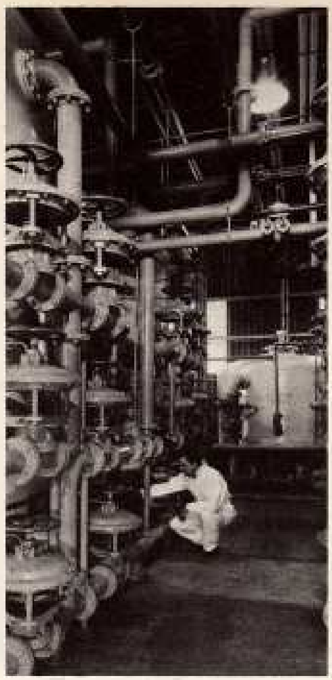
authorities. Deposits of calcium in the housewife's kettle (called temporary hardness because it is eliminated by boiling) and deposits of calcium sulphate (permanent hardness) in industrial boiler tubes are examples of undesirable effects. Calcium sulphate is a poor conductor of heat. Deposits of it make increased heat supply necessary for heating boilers. Since the deposits are always uneven, local overheating and metal 'failure' can occur. Hard water can thus be dangerous.

Degrees of hardness are usually determined by calcium and magnesium salt content (usually quoted in terms of the equivalent amount of calcium carbonate). One established test of hardness involves adding a standardized soap solution to a specified volume of water. Increasing amounts are added until shaking obtains a lather. The quantity of soap necessary is a measure of the degree of hardness. A more rapid, more accurate test involves ethylene diamine tetracetic acid (EDTA), or its sodium salt. These form complexes with ions of the alkaline earth metals. When the dye Eriochrome Black is added, the solution will turn blue if the ions have been removed by combination with EDTA. If there is still an excess of calcium and magnesium ions, the dye gives a red

An open slow sand filter (*left*). *Radio Times Hulton Picture Library*

Ion-exchange apparatus for removing hardness (*right*). *Paterson Candy International Ltd*

A closed vertical pressure filter (*below*).



colour. Total hardness is determined by titration with EDTA. To determine the presence of calcium only, the dye Murexide is used. It is sensitive to calcium ions but not to magnesium ions. Magnesium hardness can then be determined by subtracting the amount of calcium content from the total EDTA reading.

Where amounts of dissolved salts are small, they can be eliminated by the ion-exchange method. Ions causing hardness are 'exchanged' for ions such as sodium which do not have this effect. A Japanese firm claims that its ion-exchange unit can deionize 60,000 gallons of water a minute. Its potential use in large-scale deionization makes it one of the most important water softening methods.

Simple softening of the water is sometimes worth while, since processes like the lime-soda process remove all traces of these salts: sodium carbonate (soda) removes the calcium present in the water by precipitating it as calcium carbonate. This process is often used by the few water authorities who soften water before distribution.

Oxidation followed by sedimentation of insoluble oxides is also effective. Iron can be removed as a hydrated oxide by aeration, sedimentation, and filtration. Catalytic filters are often employed: potassium permanganate, ozone, and chlorine are reagents which assist oxidation.

Faced with the more pressing demands of preventing disease and removing insoluble particles, few water authorities can afford to remove hardness. Because acid waters are corrosive, however, they require special attention. Their action on lead is particularly dangerous. As the water passes through lead pipes lead salts are formed. When the water is drunk, lead salts collect in the bones. If drunk for a long time, the salts can cause lead poisoning. If waters contain bicarbonate, there is little danger of lead poisoning, because a protective coating of lead carbonate forms in the pipes. Other waters with acid pH values, especially waters containing nitrates, are particularly prone to dissolving lead. Water supplies drawn from moorland are, for this reason, carefully controlled. An alkaline substance, such as sodium aluminate, is used to coagulate suspended organic matter. This also reduces acidity. Milk of lime is added to neutralize the remaining acidity. Lead dissolution is best avoided by replacing lead pipes, still widely used today, with copper or plastic pipes.

Dissolved gases, such as carbon dioxide, can be removed by aeration. Occurring most often in water from underground sources, some gases are corrosive or, as in the case of hydrogen sulphide, unpleasant in odour. In one method of aeration, water cascades over a series of shelves. The water mixes with air as it falls. Carbon dioxide escapes and oxygen dissolves in the water. If iron is present, it is oxidized to insoluble iron (III) hydroxide, which can then be removed by sedimentation and filtration.

Radioactivity and detergents – Indiscriminate application of new technology has produced several new purification problems in recent years. The increasing use of atomic substances in industry and power supply has brought with it a commensurate output of radioactive waste material. Some of this can find its way into the water supply. The World Health Organization has set a standard of 10^{-7} microcuries/cm^3 as the limit of radioactive safety. This limit has been passed in some areas. Possible contamination of water is a new hazard facing water authorities.

Another problem which has harassed authorities for some time is that of detergents. These tend to produce vast quantities of foam which find their way into rivers and sewage works. They are not only a threat to domestic water supplies, but a serious hindrance to natural repurification since they limit oxygen absorption in sewage. The situation became so serious in one area of the United States that soapless detergents had to be banned.

Investigation of the problem has shown that detergents whose molecules contain long, straight chains of carbon atoms are readily broken down by bacteria in sewage works and in streams, while detergents which consist of branched chains of carbon atoms are resistant to bacterial attack and therefore result in persistent foam. The problem would most easily be solved if only detergents of the straight chain variety were manufactured, but these are technically difficult to make and they are also expensive, while the branched chain ones are easy to make and cheap. Manufacturing firms have devoted much thought and time to devising new types of detergents and new production processes, and although the situation has not been wholly overcome, some improvements have been made.

Detergent foam accumulates in rivers to the detriment of plants and fish.

Part Five

The Uses of Water

We use water habitually in so many ways that we rarely realize how important it is. Our use of it as a standard of comparison for physical properties is a good example: litres and calories are both units based on the physical properties of water. If we consider the extent of its use for transportation, we begin to see how important it is to civilization.

Water for power – Water has been used to drive mills for hundreds of years. With the widespread use of electricity in most parts of the world, it is now even more important as a source of power. Water is stored in a dam at as great an altitude as possible. A controlled flow is released to drive a turbine and generate electricity. The best example in Great Britain is the Canon Valley in Scotland.

Another way in which water can be used for power is by harnessing the tides. The French already have a tidal power station in the Rance estuary. When the sea level rises to high tide, the water drives turbines as it enters a dam; when the tide ebbs, the trapped water is released and drives turbines as it returns to the sea (p. 21). A large variation in tidal water levels is essential. A scheme for a station similar to the Rance estuary one has been suggested for the River Severn in England.

The Central Electricity Board is another major user of water. Because large dams and high waterfalls are not generally available, electricity is usually generated by passing steam under pressure through the turbines. The heat required to produce steam comes from burning coal or oil, or from nuclear power. Water is needed both for steam and for condensing the surplus steam so that it can be used again. Water for steam must be carefully purified. Water used for cooling needs much less treatment. Hinckley Point Nuclear Power Station in Somerset uses 35 million gallons of water per hour for cooling. In addition, its boilers are capable of producing $5\frac{1}{2}$ million lb of steam (equivalent to $\frac{1}{2}$ million gallons of water) an hour. The water used as steam is recirculated. The cooling water is returned to the sea.

Water for industry – In industry, water is used in countless ways. For example, table salt in England is obtained from

The tidal power station in the Rance estuary. Water drives the turbines in the semicircle of cylindrical drums as the tide rises and as it falls again. *French Government Tourist Office*

underground deposits, like those in Cheshire, by allowing water to dissolve the salt. The resulting brine is then pumped to the surface. Chemical industries also make use of water's solvent properties. In purifying gases, water is used to wash out insoluble impurities. The gas industry removes ammonia, sulphur dioxide, and some hydrogen sulphide from coal gas by allowing water to trickle down the towers through which the impure gas reaches the surface.

Water is used for cooling in stone cutting, for dyeing and bleaching in the textile trades, for cleaning in silk, wool, nylon, china manufacturing, and in leather tanning and manufacturing motor cars. In almost all forms of mining it is used for separating impurities from ores: gold, tin, coal. It is used as a solvent in paper manufacturing, and in tin and chrome plating.

One last example is the manufacturing of industrial hydrogen. In the Bosch process steam is blown over white hot coke. A mixture of carbon monoxide and hydrogen results:

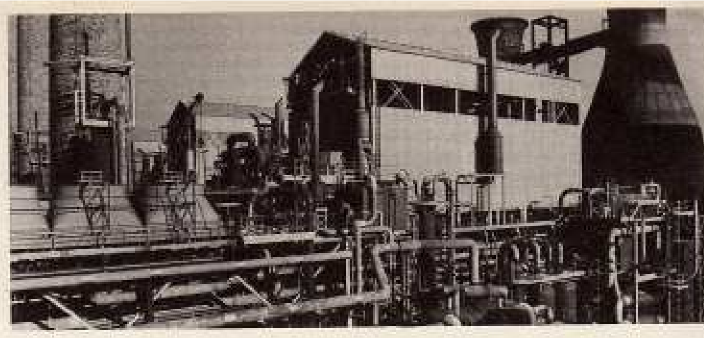
$$C(c) + H_2O(g) \rightarrow CO(g) + H_2(g)$$

To remove the carbon monoxide, the mixture is treated with more steam:

$$H_2(g) + CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + 2H_2(g)$$

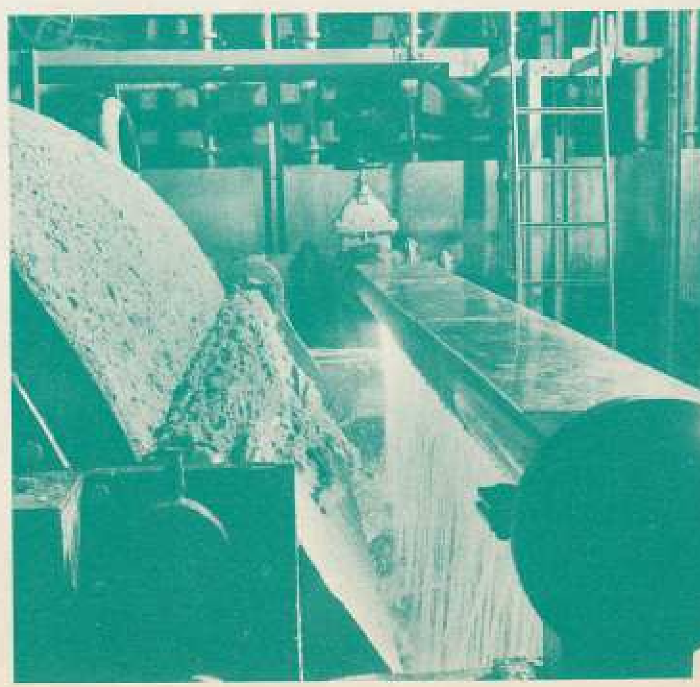
Catalysts of metallic oxides, such as iron, chromium, or cobalt oxides, are necessary for the reaction to take place. It can then be regulated by temperature. If a proper temperature is reached, most of the carbon monoxide will be removed. The resultant carbon dioxide is removed by passing the hydrogen through water, in which carbon dioxide dissolves. The remaining carbon monoxide is removed by passing the hydrogen through a compound like ammoniacal cuprous chloride. Ammoniacal cuprous chloride dissolves carbon monoxide forming $CuCl.CO.H_2O$. The remaining water is then either frozen out or removed by a dehydrating agent.

More recently, in the I.C.I. continuous catalytic reforming process, hydrogen is made by mixing gaseous, sulphur-free naphtha with steam at about 700°C. By maintaining the steam-carbon ratio at about 3:1, and using a nickel-based catalyst which favours hydrogen formation over carbon formation, the reforming process produces hydrogen and carbon monoxide. The carbon monoxide is removed, as in the Bosch process, by treating with more steam. A similar process is used in making town gas.



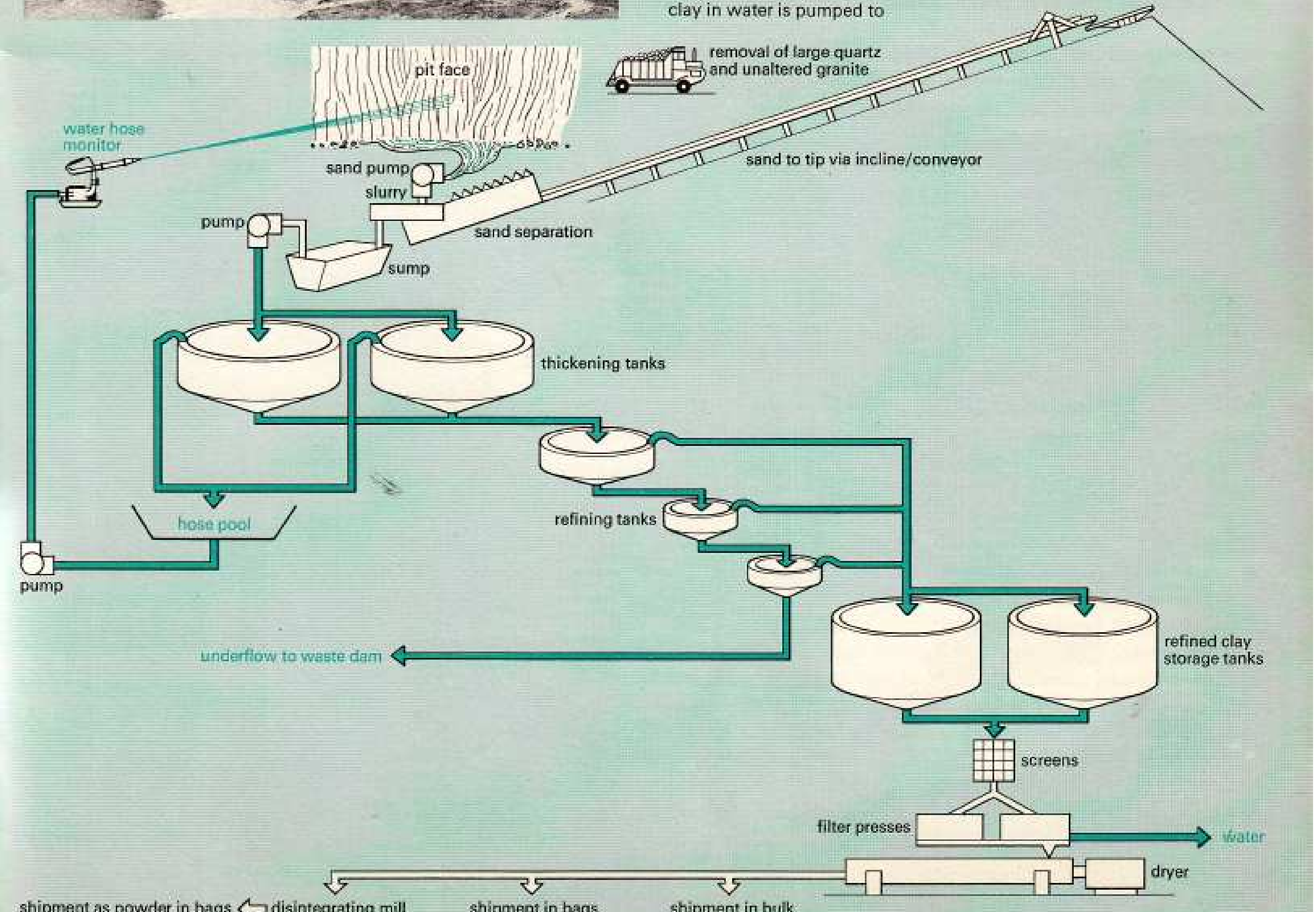
A steam reformer in the continuous catalytic reforming process (*left*). *ICI*

It takes 100 litres of water to produce 1 kilogram of paper; 600 litres of water for 1 kilogram of woollen cloth, and 3,500 litres of water for 1 ton of dry cement. *Wiggins Teape Group*



Washing china clay (kaolin) from the pit face with a high-pressure hose.
English China Clays Group

This flow diagram of china clay production (*below*) shows the importance of water in clay mining. Water is used to wash clay from the pit face. The sand is then separated out from the clay and the suspension of clay in water is pumped to thickening and refining tanks. In the refining tanks, grades of clay are separated and water is used to transport clay to storage tanks. Before packaging and shipping, the clay is filtered to remove the water.
English Clays Lovering Pochin & Co. Ltd



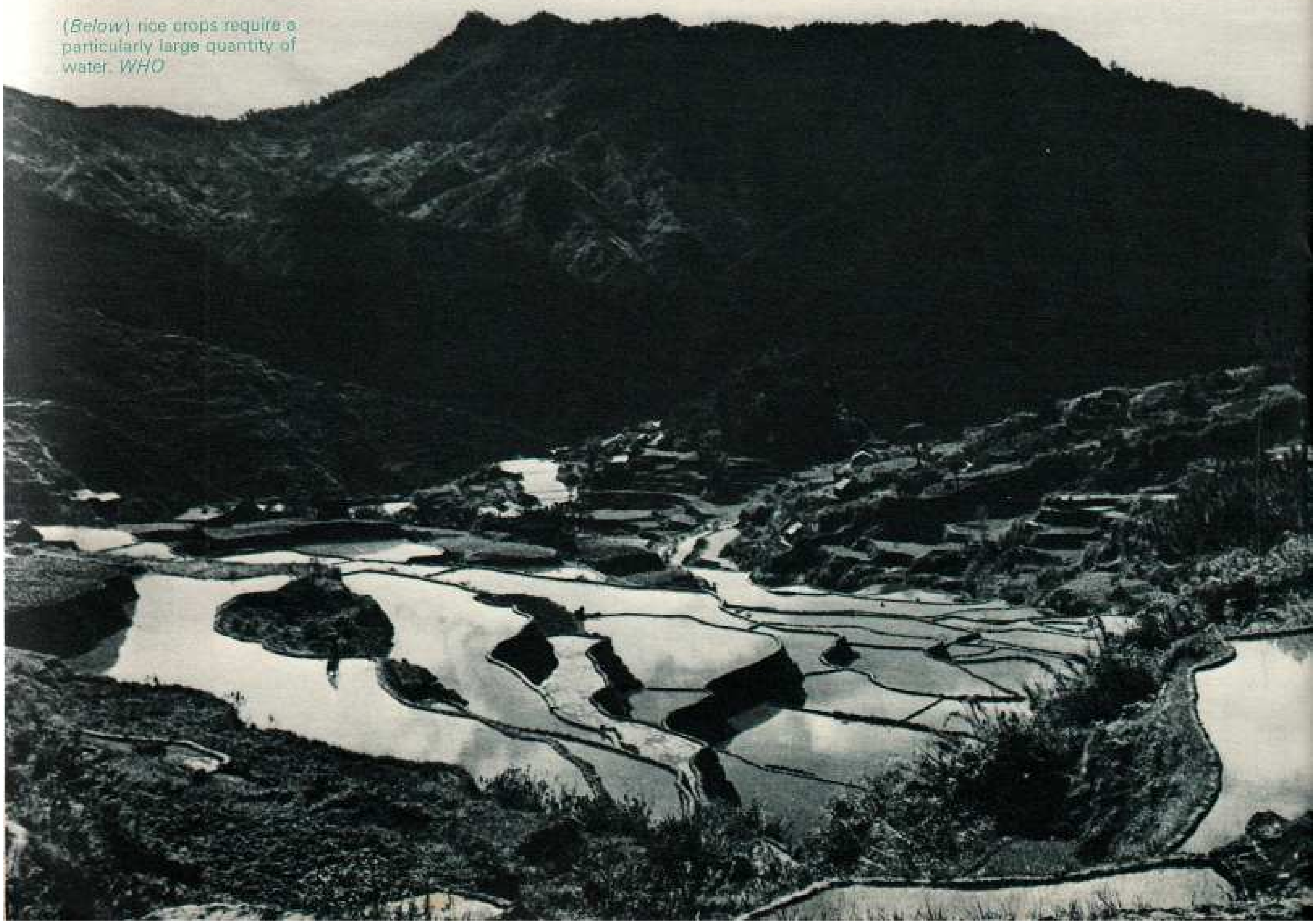
Water for agriculture – Agriculture demands a supply of water that far exceeds industrial needs. Water used in farming cannot be recirculated as can often be done in industry: 2½ million gallons are needed to grow a single ton of cotton, while steel production requires between 40,000 and 70,000 gallons per ton; sugar farming, which uses moisture more efficiently, still consumes 240,000 gallons of water per ton of crop.

Although the British farmer is well supplied with water, water is by no means so readily available elsewhere. The vast amount of water needed to grow food and the uneven world distribution of rainfall make improved irrigation imperative for the majority of the world's nations.

Dams are being constructed in almost every country of the world both for hydroelectric power and for irrigation projects. Mexico, Japan, Peru, Iran, Thailand, Sudan, Columbia, Austria, Jordan, and Spain are only a few countries which are now building dams to increase agricultural production.

In India and West Pakistan, the construction of the Mangla and the Tarbela Dams in the Indus Basin will supply water for drinking, transport, and power to several hundred thousand

(*Below*) rice crops require a particularly large quantity of water. *WHO*



A power station on the Rio Grande in Brazil, which provides both electricity and irrigation to a wide area. Water runs down the righthand channel and falls to drive turbines for electricity.
International Bank for Reconstruction and Development

people. The projected Qatrana and Sultani Dams in Jordan will provide the surrounding area with a continuous supply of water. Annual rainfall in this area is 106·3 mm/annum and falls only a few days a year. The dams which store waters coming from many miles away, will allow an area which is now practically destitute to become a large agricultural centre.

Similarly in Uganda an irrigation project has been suggested to create over a half million acres of farm land. Drawing water from Lake Victoria and a group of lakes to the north, the project could make Uganda largely self-sustaining as a food producer.

Dam construction has, in some cases, had unpleasant side effects. Controlled flow of rivers up-stream allows ocean waters to enter the mouths of rivers. Land gained by irrigation sometimes has to be written off by land lost from increased salinity at the mouth. This has been the case in the Mekong River Valley project in Thailand, Cambodia, and Laos. Similarly, the Kariba Dam in Zambia and Rhodesia changed water conditions in such a way as to stimulate growth of the fern *Salvinia auriculata*. Decaying vegetable matter covered by the dam's waters produced a rich 'broth' ideal for the fern's growth. The fern proliferated to such an extent that some 175 square miles of the artificial lake's surface were covered by it. As the lake filled the 'broth' was diluted, however, and growth stabilized. Chemicals have been used to clear certain areas, but it is now believed that the fern will slowly die off. The Volta Dam project in Ghana has met with similar difficulties from weeds and fish. Such problems could often be avoided if an adequate ecological survey preceded construction.

A new agricultural industry for which large amounts of water are needed is fish-farming. In Israel where good arable land is scarce and protein foods are difficult to obtain, fish-farming has proved particularly important. Its practice in countries such as Czechoslovakia, China, Malaysia, India, and the Belgian Congo is helping to relieve food shortages.

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camel, in which w. is stored; **-company**, a commercial association for the purpose of supplying w. to a town or district; **-diviner**, one who finds subterranean springs or supplies of w. by means of a divining-rod; **-doctor**, (*a*) = W.-CASTER; (*b*) a hydropathist; **-finder** = *w.-diviner*; **-gilding**, the process of gilding metal surfaces by applying liquid amalgam, the mercury being afterwards removed by evaporation; so **-gilt** *a.*; **-head**, the head or source of a stream; **-jacket**, a casing containing w., placed about something to prevent its becoming unduly heated or chilled; hence **-jacketed** *ppl. a.*; **-jump**, a place where a horse is required to leap a stream or ditch; **-knot**, a knot used in joining together lengths of fishing-line; **-lead** (lid), (*a*) a mill-lead; (*b*) an open channel through an ice-field; **†-leader**, one who carts w. for sale; **-leaf** *Arch.*, an ornament used on capitals, supposed to represent the leaf of some w.-plant; **-mouth**, (*Sc.*), the mouth of a river; **-organ**, the hydraulicon or hydraulic organ; **-parting** = WATERSHED 1; **-pistol**, a weapon constructed to discharge a sudden jet of w. or other liquid; **-plane**, an aeroplane that can rise from or alight on water; a hydroplane; **-plate**, a plate with a receptacle underneath for hot w. to keep the food warm; **-power**, the power of moving or falling w. employed to drive machinery; **-quake**, a seismic disturbance in the sea; **-rate**, a rate or tax levied by a municipality or a w.-company for the supply of w.; **-spaniel**, a variety of spaniel, much used for retrieving w.-fowl; **-splash**, a shallow stream or ford crossing a road; **-stone**, a nodule of chalcedony having an internal cavity containing w.; **-tower**, (*a*) a tower serving as a reservoir to deliver w. at a required head; (*b*) a long iron tube, carried vertically on a wheeled frame, for discharging w. to extinguish fires in the upper stories of buildings; **-waggon**, *U.S.* = W.-CART; also *slang* in phr. *on the w.-waggon* = teetotal; **-worn** *a.* (chiefly *Geol.*), worn or corroded by the action of w.

b. Prefixed to names of animals to denote species inhabiting the w.: **w.-bear**, a sloth-animalcule; **-beetle**, a beetle of the group *Hydradephaga*; **-boatman**, a w.-bug of either of the families *Notonectidæ* or *Corixidæ*; **-buffalo**, the common domestic Indian buffalo, *Bos bubalus* or *Bubalus buffelus*; **-bug**, (*a*) any heteropterous insect of aquatic habit; (*b*) *U.S.* the cockroach, *Blatta orientalis*; **-flea**, any of the small crustaceans that hop like fleas; **-fly**, a fly that frequents w. and the w.-side; **-lawyer** *joc.*, a shark; **-mole** *Austral.*, the ornithorhyncus or duck-bill; **-mouse**, the w.-vole; **-rail**, a bird, *Rallus aquaticus*, having a general resemblance to the landrail; **-scorpion**, an aquatic bug of the family *Nepidæ*; **-serpent**, **-snake**, any snake that inhabits or frequents the w.; **-vole**, the common w.-rat, *Arvicola amphibius*; **-worm**, any aquatic annelid.

c. Denoting vegetable growths that live in w., as *w.-plant*, *-reed*, etc.; also **w.-blob** *dial.*, a name for the marsh-marigold and similar plants; **-elder**, the guelder-rose; **-flag**, the yellow flag, *Iris Pseudacorus*; **-oak**, a hard coarse-grained oak, *Quercus aquatica*, of the southern U.S.; also applied to certain Australian trees of the genera *Casuarina* and *Callistemon*; **-parsley**, name for *Sium latifolium* or other aquatic umbellifers; **-parsnip**, name for aquatic umbelliferous plants of the genus *Sium*, esp. *S. latifolium*; **-plantain**, the plant *Alisma Plantago*, with leaves somewhat like those of the plantain, growing in ditches, etc.; **-violet**, the feather-foil, *Hottonia palustris*.

d. *Med.* Designating specific ailments, eruptions, etc., as *w.-blister*; also **w.-blebs**, pemphigus; **-pox**, chicken-pox.

Water (wǭ·təɹ), *v.* [OE. *wæterian*, f. *wæter* WATER *sb.*] **I.** *trans.* **1.** To give a drink of water to (an animal, esp. a horse on a journey); also, to take (cattle) to the water to drink. **2.** To furnish with a supply of water OE. **3.** To supply water as aliment to (a plant, crop, etc.), esp. by pouring or sprinkling with a watering-can, hose, or the like; to pour or sprinkle water on (soil) OE. **b.** To supply (land, crops) with water by flooding or by means of irrigation-channels; to irrigate 1555. **4.** Of a river, etc.; To supply water to (land, etc.). Now chiefly passive. OE. **5.** *To w.* (something) *with one's tears*; to make wet or moist with copious and continued weeping. *Obs.* or *arch.* Also †said of the tears. ME. **†6.** To soak in or with water, to steep in a liquor –1675. **b.** To sprinkle or drench (a road, pavement, etc.) with water, in order to lay the dust 1662. **c.** To sprinkle or drench (a material) with water in order to moisten it or with a solution to impregnate it 1474. **d.** *To w. one's clay*, to take liquid refreshment 1769. **7.** To add water to as a diluent or solvent, thereby increasing the bulk and reducing the strength. late ME. **a.** To **w. down** To reduce the strength of (liquor) by dilution; *fig.* to weaken the force or strength of (language) by addition or alteration; to reduce in efficacy or potency 1850. **b.** *Comm.* To increase the nominal amount (the stock or capital of a trading company) by the creation of fictitious stock 1870. **8.** To produce a moiré or wavy lustrous finish on (silk or other textile fabrics) by sprinkling them with water and passing them through a calender 1450.

1. *Cymb.* II. iii. 23. 2. Lord Hood has gone to w. the Fleet NELSON. In a campaign like this..It should be easy to w. troops at fixed intervals 1898. 3. *fig.* The Apostles..planted this Faith..and watred it with their blood 1672. 4. That pleasant district..which is watered by the river Don SCOTT. 7. Tea twice watered with a good deal of sugar in it 1902.

II. *intr.* **1.** Of the eyes: To fill and run with moisture; to flow with tears ME. **2.** Of the mouth, also (now *Sc.*) of the teeth: To secrete abundant saliva in the anticipation of appetizing food or delicacies 1530. **3.** Of a ship, ship's company, etc.: To take on board a fresh store of water 1557. **4.** To drink water; to obtain water to drink 1607.

1. *Mids. N.* III. i. 200. The smoke..got into the Captain's eyes, and made them blink and w. DICKENS. 2. He sees no green cheese but his mouth waters after it 1639. 4. Cattle were watering in a lake 1839. Hence **Wa·tered** *ppl. a. spec.* of silk, etc., having a wavy lustrous damask-like pattern or finish; of steel, damascened. **Wa·terer**, one who waters (plants, etc.); one who is sent ashore to obtain fresh water for a ship's company; one who supplies animals with drinking-water.

Wa·ter-bag. 1638. A bag of skin or leather used for holding or carrying water, esp. one used in Eastern countries for transporting and distributing water.

Wa·ter-bai·lage. 1669. A duty or tax levied on all goods brought into or carried out of the Port of London.

Wa·ter-bai·liff. late ME. **†1.** An officer in various port towns, charged with the enforcement of shipping regulations, the collection of

ö (Ger. Köln). ö (Fr. peu). ü (Ger. Müller). ü (Fr. dune). ɒ (curl). ē (ē·) (there). ē (ē¹) (rein). ɛ (Fr. faire). ɜ (fir, fern, earth).