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PROGRESS IN SANITATION[1]

By Professor EDWARD BARTOW

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WHEN the title of this address was sent to the secretary, the plan was to describe the progress in sanitation for the past thirty years, that is from about 1906, when *Chemical Abstracts* was started and when "Standard Methods of Water Analysis" was first published by the American Public Health Association. Then it was decided to discuss the progress of water chemistry for about seventy years, that is, from the time when Wanklyn published the first edition of his "Water Analysis."

Again the plan was changed, because of a visit to the German Industrial Museum at Munich, the discovery of a book on "Water," written in 1757 and because of a statement attributed to a president of the American Mathematical Society. He said that mathematics is *the science,* while all other sciences are merely divisions of mathematics. For example, physics is the noisy part, zoology the messy part and chemistry the smelly part.

I do not propose, as might be expected from this introduction, to try to prove that chemistry is *the science,* and that all other sciences are mere branches. Quite the contrary, I wish to show that chemistry helps the other sciences, that chemistry is dependent on other sciences in the building of what we might call the house of chemistry and that it is the service science.

The house of chemistry, or perhaps we should call it the mansion, castle or palace of chemistry, can not exist alone. Can we not imagine that it is built on the rocks of geology and mineralogy? Indeed, the alchemists looked for the philosopher's stone and attempted to turn the baser metals into gold. This mansion is built in the garden of agriculture. Its foundation is in the healing art of medicine, for the alchemists and the early chemists sought for the elixir of life, and at all times medicine has been an incentive to chemical re-

[1] Address of the president of the American Chemical Society, Pittsburgh, September 9, 1936.

search. Mathematics is a flight of steps leading to higher places where calculations may be proven correct by chemical experimentation. Physics is the windows, where physical instruments shed light on the intricacies of the composition of matter and the changes which chemistry may cause it to undergo. Astronomy is the upper story, from which chemistry looks out on the universe and studies the composition of the stars. History is the walls, which bind the various parts together and include chemistry and the sciences in one homogeneous system.

Chemistry in its turn serves the other sciences and other divisions of learning. It has sometimes been said that chemistry serves all the colleges in a university, except law, fine arts and theology. Yet, even these, while there may be no direct connection, are served indirectly. In law, the lawyer, in certain criminal trials involving cases of poisoning, must call on the chemist to teach him the chemistry of such cases. It is easier to develop a patent lawyer to deal with chemical patents from a chemist than from a graduate in law.

In fine arts, the artist must rely on the chemist to obtain fast colors for his paintings, the sculptor must look to the chemist to be assured of the lasting quality of the stone or metal, which he uses in his art.

Every science must call on the chemist for help. Geology and mineralogy ask for the composition of the rocks, of oils and of natural waters. Medicine calls for preservatives, anesthetics, antiseptics and healing drugs. The early Egyptians had a knowledge of preservatives when they wrapped the dead in cloth and chemicals. What a help to the physician has been the discoveries of nitrous oxide, ether, chloroform and other anesthetics.

The physicist discovers a new phenomenon, and comes to the chemist for an explanation. The arrangements of the atoms in the molecules and the composition of the molecules explain the physical phenomena, and the physical phenomena explain the variation in chemical composition.

The history of nations is deeply affected by chemical discovery. Gunpowder, synthetic ammonia and poison gas are notable examples.

The mansion of chemistry has many rooms. The relation of the members of the chemical family are so close that the rooms are often shared and there is frequent exchange of visits. It is difficult to assign definite rooms to the various members. Let us again imagine that the lower floors are assigned to the older and fundamental branches of chemistry. Inorganic is the older and should be near the entrance, and then will come analytical organic and physical, with the applied branches on the upper floors. Biochemistry, sanitary chemistry, industrial chemistry and chemical engineering are located there and are all dependent on the group on the lower floors.

It is impossible to dwell in detail on all the members of the family. I am planning to go into more detail concerning the member known as water, sewage and sanitation, and especially that space that deals with water. The most important information regarding water since history began is the knowledge of its content. Precautions have always been taken to make certain that it was satisfactory for its intended use. This fact is admirably brought out by the exhibit in the Industrial Museum at Munich.

Beginning with natural springs such as were used in ancient times, various types of water supply are illustrated in the museum. These include a simple well of the Egyptians, the cisterns of the Greeks, the great aqueducts of the Romans down to a model of one of the extensive water purification plants of the present day.

Our water purification plants often have models of their buildings and equipment at the plant to show visitors how the water is treated. There should be such exhibits in every plant and also in some public place, such as the city hall or a museum.

Recently, with two friends, I visited the water purification plant in their home city. While they had lived in the city for many years, they knew in general that the water was purified, but they had never visited the plant, and did not know how to reach it. They were astonished at the equipment required, the careful control of the chemical and bacterial condition of the water and the automatic devices that were used to give a pure and wholesome water. I hope that many of my hearers, if they have not already visited the water purification plant in their home city, will take an opportunity to do so. I can guarantee that they will be welcomed by the superintendent or the chemist, and they will be pleased with such a visit.

Most of us do not realize how greatly conditions have changed. It was formerly necessary to carry the water from the well or the fountain in the street. Now we receive a bill for 30 cents per 1,000 gallons, which pays for the delivery of seven and one half tons of water to our faucets.

Modern water analysis and water purification are of comparatively recent origin. Wanklyn, in England, wrote the first edition of his book on "Water Analysis" in 1868. His work was entirely chemical. He endeavored to use the amount of ammonia formed by distilling a water with an alkali and potassium permanganate as the index of pollution. The method was arbitrary. Many of the tests Wanklyn describes are in use to-day.

The first edition of Mason's "Water Analysis" was published in 1899. It was the pioneer and for many years the standard in this country.

Bacteriological methods were introduced at a later date. As an index of pollution they are better than the chemical tests. The test for *Bacillus coli* is the best index. It does not indicate infection, but does show the presence of fecal matter and the past, present or future presence of possible infection.

The claim of Wanklyn is not justified, when he states in the preface to his first edition of "Water Analysis, A Practical Treatise on the Examination of Potable Water," "We believe that this is the first book which has been published on Water Analysis."

John Rutty, M.D., published in 1757, over one hundred years before, a book with a title page very comprehensive in its claims.

A
METHODICAL SYNOPSIS
OF
MINERAL WATERS

Comprehending
The most celebrated Medicinal
Waters

Both COLD and HOT
Of Great-Britain, Ireland, France, Germany
Italy, and several other parts of the World

Wherein

Their several impregnating Minerals being previously described, and their Characteristics investigated, each water is reduced to its proper Genus, and beside the particular Analysis, the Virtues, Uses, and Abuses of the Water are described,

IN A METHOD ENTIRELY NEW
INTERSPERSED WITH TABLES

Tending to throw a Light on this intricate Subject;

AND

Abstracts of the principal Authors who have treated of Mineral Waters; and the Accounts dispersed in the Acts of the most learned Societies in Europe, are collected and properly digested.

By JOHN RUTTY M.D.

LONDON:

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in St. Paul's Church-Yard.

MDCCLVII

The book is dedicated to Dr. Peter Shaw, Dr. Stephen Hales and Dr. Thomas Short, as competent judges of his work. Rutty refers to the work of Shaw and Short, and I have found[2] that Dr. Short wrote a book on "Water Analysis" in 1733. This antedates Rutty's book.

Rutty's book was written before the separation of water into the elements hydrogen and oxygen, as shown by his statement: "Although we know of no water absolutely pure or free from all admixture of saline or terrestrial matter, yet many springs contain so exceedingly small a quantity of these, that it is in a manner inconsiderable, and make the nearest approach to pure element." Or again, "It abundantly appears by these tables that none of these waters are pure element, but all contain some pittance, more or less, of earth, marine salt, calcareous nitre and sulphur."

The phlogiston theory was still dominant. He describes the preparation and use of lime water by saying that "the particles of fire united to the stone, being analogous to that of an acid, there is an exchange between the lime with its acid, (fire), on the one hand, and of the earth and its acid on the other hand, and the formation of a cloud, sediment or crust."

It is often stated that cities are located where there is a satisfactory and abundant water supply. This is not a new idea, for Rutty in 1757 wrote, "It is of great importance in building a town to choose a proper situation with regard to the quality of springs."

He also states: "The sacred records, (2 Kings ii, 19) mention a city, the situation of which was pleasant, but the springs naught, and the land barren; which waters were not amended, except at the expense of a miracle tho' it is observable, that this was not wrought without means, viz., by salt put in a new cruse, and cast into the spring of the waters by the prophet, whereby they were healed."

Rutty compares this procedure with the use of ashes for softening water in his day, nearly two hundred years ago.

Rutty carried out experiments on the hard waters about the city of Dublin, and as a matter of history states: "The brackishness of the springs of Dublin is a matter of very ancient observation: for Hanmer, in his Chronicles of Ireland informs us that when St. Patrick (who landed in Ireland A. D. 432) came to Dublin, the inhabitants complained that they were annoyed with brackish waters, which they were of necessity driven to drink, but that he walking about the (then) village turned up the clods and digged the earth and found a well, which has since been called St. Patrick's well; and indeed a fine spring of this denomination was well known and esteemed for many years, tho' lately lost."

The fact that they were *driven to drink water* reminds me of the plight of a man in one of the cities of Illinois, who wrote in great haste to the State Water Survey for a bottle for the collection of samples of water, because the city had voted *dry,* and

[2] R. Watson, "Chemical Essays," London, 1789.

until they had the water analyzed they would have nothing to drink.

Also of the Bishop of Springfield, Ill., who, before they had the filter plant, visiting the laboratory of the Water Survey with some of his fellow clergymen, called them to see a sample of Springfield water with the remark, "See what we have to bathe in in Springfield."

In his discussion of snow water, Rutty says: "A vulgar prejudice has prevailed thro' a series of ages, being supported by no less an authority than the Father of Physic, against the use of snow-water, as hard, rough and unwholesome: and the bronchocele (goiter) of the inhabitants of the Alps has been generally charged to the use of snow waters: but a more accurate search into the nature of waters, and the discovery of their distinguishing impregnating parts reserved for these later ages, together with observations from experience with the use of snow waters have shown the groundlessness of these traditions, and now almost established the credit of snow water as the purest of all others. . . . Bronchocele does not occur in Greenland where snow water is used, and does occur in certain mountainous parts of Africa where brook water is used." The recent discovery that goiter is due to the lack of iodine confirms Rutty's conclusion that the snow water in itself was not the cause of goiter, but that lack of iodine was.

Rutty made and reported analyses of 309 springs in England, Ireland (his own country), where he practised medicine for thirty years, during which time he took every opportunity of examining all mineral waters he could procure, and compare them with the published data on waters from all over Europe.

The tests correspond to some made to the present day. He determined the quantity of contents in a gallon, and its quality, the action with soap, solution of silver, solution of lead, solution of alum, lime water, acids and flesh. One of the most interesting, a forerunner of the alkalinity and of the pH test by indicators, was a comparison of the hard and soft waters as follows: "The syrup of violets gives a deeper green, and more quickly to the hard waters, as do also galls and sumach, and logwood a deeper red, even approaching to crimson and purple in several of the hard water more than in the soft, rhubarb also gives a deeper amber, and ash-bark a deeper blue to the hard waters, *viz.* from the greater quantity of calcareous nitre and earth. And all these appearances are perfectly agreeable to the respective accounts of the greater quantities of the saline and terrestrial contents in the hard and soft waters." Other examples of the work described by Rutty might be given, but these should suffice to show the information concerning the quality of water known nearly two hundred years ago.

Now consider some of the improvements in sanitation made in recent years. Prior to 1910 the typhoid fever death rate was 20 to 25 per 100,000. Since 1915 it has been 1.3 to 2.2 or less. In 1893 the rate in Chicago was 170 per 100,000. For years, it has been less than 1.0. By the destruction of the mosquito and its larvae in water, malaria has been eliminated. Cholera is a disease of the past.

There has been improvement in water for domestic use, the improvement in water for industrial uses, including water for boilers, and in the protection of water supplies by sewage disposal.

(1) Water for domestic use was first treated on a large scale in the so-called slow sand filters. In the latter part of the last century, rapid filters were invented. There was a controversy concerning their merits. The controversy was practically settled, when it was found that slow sand filters could not be used with very turbid water, and with the introduction of sterilization of the water by bleaching powder or liquid chlorine. The rapid filters are now more generally used.

Methods of water purification have been improved. The great settling basins formerly used, which had to be cleaned by the removal of all water and digging or flushing out of the sediment, have been superseded by basins containing mechanical rakes for the continuous removal of the sediment. The layer of slime on top of the slow sand filters has been replaced by a layer of hydroxide of aluminum or iron, which in many cases is sterilized and is frequently removed. Sterilization of water by bleaching powder was first used at Boonton, New Jersey, and at the Union Stock Yards in Chicago. Liquid chlorine, which is gasified before it enters the water, has given even greater satisfaction so that practically no bleaching powder is used at the present time. The cost of chlorine, also, has dropped from fifteen cents in 50-pound containers to two cents in one-ton containers. Additions of ammonia or one of its salts gives chloramine, more effective than chlorine.

Chemical and bacteriological control of water, exercised by the National Institute of Health, in interstate commerce, by the State Boards of Health in each state and by laboratories at each water purification plant, insure pure water.

(2) Industry demands good water, usually a soft water for industrial processes, especially for the production of power. No large textile centers have grown up in the hard-water territory of the upper Mississippi valley.

Power plants, especially as boiler pressures have increased, have demanded better and better water. About thirty years ago, the chief chemist of the Santa Fe Railroad told me that he hoped to soften all waters on the system that had a hardness of more than 10 grains per gallon (170 parts per million). Now efforts are made to have all waters with hardness as near zero as possible. In some cases distilled water is used.

As an example of the effort to procure the proper water in one power plant, Mississippi River water is first treated with lime and alum to remove suspended matter and partially soften; the excess of lime is neutralized with sulfuric acid; the water is passed through a base exchange softener to reduce the hardness to zero, and it is finally distilled to remove all mineral matter.

It is only since 1912, when Ganz announced his discovery, that the base exchange process of water softening has been known. The base exchange mineral takes calcium from the water, to which it gives up sodium. The mineral is regenerated by treatment with a solution of common salt, which gives up its sodium and takes the calcium out of the mineral. The regeneration of the mineral can be continued indefinitely.

The base exchange softeners came into use slowly, in the home at first, but to-day they are in use in laundries, textile mills and power plants. The discovery of the base exchange process was really revolutionary in its effect on the process of water softening.

The electro-osmose process, developed by Siemens and Halske, in Germany, furnishes a water, in most respects, equal to distilled water. In some respects it is superior. By a series of three-compartment electrolytic cells, the positive and negative ions are removed. Silica and non-electrolytes are not removed.

The process has been used to a considerable extent in Germany and France, but very little in this country. The first installation was not successful, because an attempt was made to treat a water high in chlorides. So much chlorine was set free that it destroyed the canvas diaphragms of the cells. It is hoped that future trials will be made in the United States. We have tested one of the machines in our laboratory and have found it efficient, producing a better product at less expense than distillation.

We recently saw one of the machines in use at the Agricultural Experiment Station of the Kali Syndicate, near Berlin, Germany. The machine gave a water free from electrolyte, including ammonia, needed for tests being made on the efficiency of fertilizers.

The latest method of water treatment, of which I have any knowledge, was demonstrated at the recent World Chemical Engineering Congress in London, England. The Chemical Research Laboratory of the Department of Scientific and Industrial Research at Teddington exhibited condensation products with absorption properties, prepared from formaldehyde, with polyhydric phenols and amines. One kind removes anions, and the other kind removes cations, giving a water free from electrolytes. The process is comparable with distillation and the electro-osmose process.

(3) Closely related to water supply is sewage disposal. Historically, we have, first, disposal on the land, next, construction of sewers and disposal in the streams, and the various methods of purification as the streams were unable to carry the load of sewage from large cities.

Sewage farms, one of the first methods of sewage disposal, were used by Berlin, Paris and other large cities. In Berlin, when the farms were first established, the city attempted to sell the vegetables grown on these farms. Sewage farm vegetables could not be sold. The city then leased the farms to peasants, and peasant-grown vegetables readily sold in Berlin markets. There is a limit to the amount of sewage that can be handled on land, and a limit to the amount of land available near large cities. Therefore, various methods requiring less space for disposal have been developed. Sand beds require less area. Still less is required by filters of various types in which the sewage is sprayed over beds of stone or cinders in such a manner that air is carried into the interstices of the stones or cinders, to destroy the organic matter by aerobic bacteria. Settling tanks and the so-called septic tanks are used alone or supplementing other methods. In the septic tanks decomposition takes place without air. Various methods of aeration have been developed, including slate beds, through which sewage passes, and into which air is blown. This scheme led to the activated sludge process of Ardern and Lockett.

By blowing air into sewage a sludge rich in aerobic bacteria is developed. The sludge, when mixed with incoming raw sewage and stirred with air, accomplishes the purification very rapidly. The process has been so successful that many large cities, including Indianapolis, Milwaukee and Chicago, have adopted it.

In some states, notably Illinois, it is impossible to forbid the fouling of streams by sewage, on the ground that water supplies will be polluted and that human beings will be injured. It is possible, however, to prevent the dumping of an excess of sewage or industrial wastes into Illinois streams, if it can be shown to be detrimental to fish life.

An injunction against the Sanitary District of Chicago and the Corn Products Refining Company was threatened by the Illinois Rivers and Lakes Commission. The waste from the factory was proven equivalent to the sewage from a city of 380,000 people. The wastes could not be economically treated as sewage, but it was possible to use the waste within the plant in such a way that the load was reduced from the equivalent of 380,000 to 10,000 people. This was done with profit to the company. To-day practically all corn products factories in the country are "bottled up."

Cities located on sea-coasts might dispose of sewage by dilution in the ocean without injury to drinking water supplies. Where the outlets are near seaside resorts, the wastes pollute the beaches, and these cities are being compelled to treat their sewage. At present New York City is constructing an immense sewage disposal plant to prevent the pollution of the Hudson River and the water of the beaches of the Long Island and New Jersey coasts. Lake cities have the same serious problem, but augmented by the fact that often it is necessary to obtain water supplies from the lakes into which sewage must be dumped. As a result, disposal is further advanced in the lake states than in the coastal states.

Cities on large streams like the Ohio, Missouri and Mississippi Rivers have so much dilution that the oxygen dissolved in the water serves to destroy the organic matter and bacteria of the sewage, and there is less need for treatment. Minneapolis and St. Paul have a Sanitary District to treat the sewage which will have its organic matter so reduced that the upper Mississippi will be able to oxidize it and eliminate any nuisance to the cities down stream.

CONCLUSION

We have told of what has been done in past years. What of the future? About 25 years ago, I heard the statement that a certain organization 25 years before had done all that need be done, and it was only necessary to adopt their findings. Even to-day, I am not willing to say that any branch of water, sewage and sanitation is perfect. We know what a pure drinking water is and we know how to procure it. The water chemist in the future will develop still better methods, better control and a more economical procedure. We may find new coagulants or new and better sterilizing media. For example, if ozone can be made more cheaply and if a metal or other conductor can be found that will withstand corrosion, ozone might well replace chlorine, which is so universally used to-day. Ultra-violet light and the catodyn (silver) process are on trial.

Better methods of treatment of water for industry will be found. We have seen the Clark process, lime, widely used. The base exchange process is practical for use in industry, though it is not used in many municipal plants. The electro-osmose is being more used, and I am told that the new process being developed at Teddington, England, may be placed on a practical basis and that we may have a development in water treatment that will be comparable to the previous advance made by the base exchange.

I think great progress will be made in the disposal of sewage and trade wastes, resulting in the better protection of our streams. A way will be found to conserve the values that are now being wasted. Trade wastes are of special interest. The nitrogenous and other wastes of the organic chemical industries may furnish compounds which some day may be of future value.

SCIENTIFIC EVENTS

MEDICAL FELLOWSHIPS IN ENGLAND

THE London *Times* states that the Medical Research Council has decided to institute a series of studentships and fellowships to encourage young British medical graduates of special ability and original mind towards becoming investigators in those branches of medical science which are concerned directly with disease as it occurs in human beings. This field of research includes investigations into disease or manifestations of disease in patients, together with experimental work of an immediately relevant kind.

Six post-graduate studentships are therefore offered for medical graduates who have already held house appointments and are strongly inclined to a career in clinical science or experimental pathology. Each selected student will receive an inclusive grant at the rate of £200 a year, during a period not exceeding twelve months, for personal maintenance while undertaking approved courses of study in England such as may be regarded as best calculated to advance the student's training in methods of research. This study may include modern languages and such advanced physiological, pathological and special clinical work under recognized teachers as may be regarded as forming a suitable preliminary to serious research work to be undertaken later; but the approved course may not include studies of which the purpose is to enable the student to pass further examinations.

The council also offers four research fellowships for candidates of similar qualifications who have already had some experience in the use of research methods. Each fellowship will be tenable for one year at the value of £250 a year, and will be renewable in approved instances at the rate of £300 a year for a second year. These fellowships are intended as probationary appointments for research in clinical science