Shattuck, Chadwick, and the Engineer In Public Health

By GORDON M. FAIR, Dr.Ing.

In the now remote spring of 1850, there fell from the hands of the State printer of the Commonwealth of Massachusetts in North America a "Report of a General Plan for the Promotion of Public and Personal Health." The recommendations contained in this report were eventually to become the charter of public health in America. Among them were recommendations that set the example for the participation of engineers in developing the public health policy of the country.

The principal author of this report was Lemuel Shattuck, a Boston bookseller, teacher, and public servant, who had written its more than 500 pages in slightly less than a year. This he had done, furthermore, with the expenditure of but $500. However, Shattuck could never have accomplished this task had he not been able to "drink deeply from the Pierian spring" that welled through the writings and reports of Sir Edwin Chadwick. Sir Edwin he acknowledged to be "the individual to whom, perhaps more than any other, the cause [of sanitary welfare and improvement of the people] was indebted" (*1*).

The substance of Shattuck's document was contained in 50 recommendations, 36 of which, according to an analysis by Winslow (*2*) in 1949, are now "universally accepted practice"; but 4 are "unimportant or, in some degree, unsound"; and 10 although "as sound as the 36 proposals that have been generally accepted" were sufficiently advanced in their objectives that "their importance has as yet not been fully recognized."

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The Need for Engineers

Among the half-hundred measures that Shattuck proposed was the creation of a general board of health composed, so far as practicable, "of two physicians, one counselor-at-law, one chemist or natural philosopher, one civil engineer, and two persons of other professions or occupations; all properly qualified by their talents, their education, their experience, and their wisdom" (*1*). Two reasons were given why the members of the board should not be selected exclusively from one profession. In the first place, Shattuck anticipated that "numerous questions requiring a knowledge possessed by different professions" would be presented to the board of health "for discussion and decision." Second, the promotion of public health, in Shattuck's mind, was a matter that concerned "every profession and every person." The services of medical men he rightly considered "indispensable, but the services of other professions, and of every person in their respective spheres," he was convinced, "must be put in requisition before reform can [could] be complete." According to Shattuck "the idea which too generally prevails, that everything relating to health belongs exclusively to one profession, operated against sanitary improvement."

The civil engineer member of the board, Shattuck suggested, should possess "competent knowledge to determine the best methods of planning and constructing public works, and the best architectural sanitary arrangements of public buildings, workshops, and private dwelling houses." Possession of such competence, Shattuck was convinced, would make the engineer an exceedingly valuable member of the board, and so he has proved to be.

The enunciation of the principle that engineers should have a part in public health had been anticipated by Sir Edwin Chadwick, who, in 1842, had suggested:

> That for the protection of the laboring classes and of the rate payers against inefficiency and waste in all new structural arrangements of the protection of the public health, and to insure public confidence that the expenditure will be beneficial, securities be taken that all new local public works are devised and conducted by responsible officers qualified by the possession of the science and skill of civil engineers (*3*).

The minds of Chadwick and Shattuck, as the minds of great men so often do, moving in much the same channels, therefore, appear to have assured the early participation of engineers in the public health work of their respective countries, but for each in its own way. In the older civilization of Britain, participation has during this past century of public health progress been confined perhaps more narrowly to the economic design of sanitary works as a peripheral contribution of the engineer to public health. In the more fluid civilization of America, engineering participation has been afforded somewhat wider scope in the formulation of public health policy and in its implementation. In this sense, perhaps, the American engineer has moved closer to the central core of public health, greatly to its ultimate advantage.

The Great Sanitary Awakening

That we may establish a base line for the accomplishments of the last century, let us turn to a few examples of on-the-spot reporting of sanitary conditions in the mid-nineteenth century and adjacent decades.

Lagging behind the renaissance in arts and letters, the scientific renaissance had begun to flower in the eighteenth century. An opportunity had been afforded thereby for its fusion with the spirit of humanitarianism which pervaded the end of the eighteenth and beginning of the nineteenth century in Britain. There resulted the great sanitary awakening that swept over the emergent democracies of the world.

The great sanitary awakening is associated, in particular, with the growth of cities, which was a necessary element of the industrial revolution. Scientific discoveries and engineering inventions had created centralized industries. To these, people flocked for employment. On the whole, this was a good thing. Certainly it advanced the standard of living of vast numbers of men. But absence of restrictive legislation soon led to the exploitation of labor, and absence of community organization created slums. Through these slums the apocalyptic horsemen of pestilence and death often rode their steeds unchecked.

The community facilities of the mushrooming industrial cities were generally overtaxed. In particular, the need for the abundant distribution of safe water, for the effective disposal of human wastes, and for the decent housing of swelling tides of humanity could not be met. The means and knowledge to cope with this new situation were not immediately at hand. Too often water was drawn from polluted rivers or from shallow wells in crowded sections of the community. It was then "distributed in courts by standpipes on intermittent days. The fatigue of fetching it was so great that they (the inhabitants of the courts) only used it for purposes which they deemed of absolute necessity, such as cooking; they rarely bestowed much of it on their clothes or persons" (*4*).

A single quotation from the report of the Poor Law Commissioners (*3*) gives a picture of housing conditions and of the need for sanitary sewerage in Britain a hundred years ago.

> Many dwellings of the poor are arranged "round narrow courts having no other opening to the main street than a narrow covered passage. In these courts there were several occupants, each of whom has accumulated a heap. In some cases, each of these heaps is piled up separately in the court, with a general

receptacle in the middle for the drainage. In others, a pit is dug in the middle of the court for the general use of all the occupants. In some the whole courts up to the very doors of the houses are covered with filth. Around this mass, the cottages of the residents are arranged, having no back outlet, no back windows, or other means of ventilation. The windows and doors of the houses open and look towards this mass; and all the air supplied to the inmates is obtained through these doors and windows. The residents were very frequently subject to fever, and were always regarded as the first to be affected by any epidemic disease.

To remedy conditions such as these, the discharge of human wastes into existing storm drains was permitted at the beginning of the nineteenth century. The system of combined sewerage was thereby initiated, and the earlier drainage works of most metropolitan communities were subsequently developed in accordance with this scheme. Terminating in nearby water courses, the drains discharged quantities of waste materials that more often than not overtaxed the receiving capacity of these waters. The nuisances that had apparently been so happily removed from dwellings by water carriage were then concentrated along the streams.

Rain to River, Sewage to Soil

First the smaller ones and then the larger water courses began to "seeth and ferment . . . in Augean foulness." As a remedy, many of the smaller streams were, therefore, converted into sewers; but the larger bodies of water had to remain open to view and other sensory disapprobation. I shall spare you a description of the Thames in the hot summers of 1858 and 1859 as recorded by Dr. Budd in his classical treatise on "Typhoid Fever, Its Nature, Mode of Spreading, and Prevention," and shall only recall the rhyme of Samuel Taylor Coleridge about the city of Cologne, which he visited about 1798.

"The river Rhine, it is well known,
Doth wash your city of Cologne;
But tell me nymphs! What power divine
Shall henceforth wash the river Rhine?"

Engineers would have done well to heed as early as 1847 the earnest recommendations of Sir Edwin Chadwick (*5*) for the introduction of the separate system of drainage whereby the storm flows would have reached the water courses unaffected by the wastes from habitations and industries, while the sanitary flows would have been led away in much smaller conduits to a point where they could be disposed of without nuisance, if need be, after suitable treatment. "The rainfall to the river and the sewage to the soil" was the phrase that epitomized the Chadwick doctrine.

In spite of such admonition and that of Chadwick's great engineering associate, Sir Robert Rawlinson, municipalities continued, on the grounds of expediency and short-range economy, to elaborate their storm-drainage systems into combined sewerage works, greatly to the disadvantage of ultimate amenities in the city plan. Even the capital city of Paris, which did not complete its sewerage until many years later, failed to take advantage of the hygienically and esthetically more desirable separation of sanitary and storm flows. Although Paris did not adopt the separate scheme, Sir Edwin Chadwick may well have promoted the speedier institution of sewerage in that city by his suggestion to Napoleon III in the winter of 1865–66 which is recorded by B. W. Richardson (*6*) as follows:

Sire, they say that Augustus found Rome a city of brick, and left it a city of marble. If your Majesty, finding Paris fair above, will leave it sweet below, you will more than rival the first Emperor of Rome.

It is evident from these descriptions that the foremost public health needs of the mid-nineteenth century were for adequate and pure water supplies, and for the safe removal of wastes from human habitations. These matters became the responsibility of civil engineers who were experienced in hydraulics. Sir Robert Rawlinson was in his day probably the leading practitioner in this field. But there were many others, particularly in Britain, among whom was John Roe. It was he who accepted Sir Edwin Chadwick's suggestion that vitrified tile pipe be used in sewer lines. In his report to the Harrow local board of health of 1854, Roe said:

The introduction of stoneware pipes for general drainage arose from a suggestion made by Mr. Chadwick to me, in his desire to obtain smooth interior surface; and the first sewer pipes made for that purpose in the metropolis were for the Holborn and Finsbury office.

It is understandable, therefore, that Sir Robert Rawlinson should have dedicated his Lectures, Reports, Letters, and Papers on Sanitary Questions (1876) "To Edwin Chadwick, Esq., C. B., as the Chief Promoter of Modern Sanitary Works and Appliances."

The Scientific Foundation

Although James Simpson had introduced the principle of sand filtration as early as 1829, in order to purify the waters gathered from the Thames by the Chelsea Water Co., and although Dr. John Snow had demonstrated by 1849 that fecal pollution of drinking water was a major factor in the dissemination of cholera, these were judgments, as it were, *ex pede Herculem.* Public health, and with it public health engineering, had to await the discoveries of Louis Pasteur before the full body of knowledge and the measures of sanitary accomplishment could become available. Thenceforward, the engineering objectives as well as the means for attaining them became clear.

Filtration for the sake of improving the palatability of water was tied to the more important use of filtration for the prevention of enteric disease. Sewerage for the purpose of avoiding nuisance was made ancillary to waste disposal for the safeguarding of water supplies, bathing places, and useful aquatic life. Sewage treatment for the utilization of the fertilizing ingredients of municipal sewage as well as its water value was made subservient to suppression of an ever-growing list of intestinal infections. In the course of time the *Index Expurgatorius* included, among causative agents, not only bacteria but also protozoa, worms of many kinds, and finally viruses.

In America, the need for sanitary reform led to the establishment, in 1886, of an engineering department in the Massachusetts State Board of Health. This department was given the responsibility to protect the purity of inland waters. By allying to itself not only engineers but also chemists and biologists and by meeting its responsibilities in a spirit of research and investigation, this department established itself firmly in public health service.

Today, no State or Territory of the United States is without its public health engineering organization; neither are the United States Public Health Service, the four medical departments of the Armed Forces and the Veterans Administration, the Atomic Energy Commission, and the Tennessee Valley Authority. Engineers sit on the committees of the National Research Council and are attached to the headquarters staff of the American National Red Cross. Engineers have been directors of the health and sanitation effort of the Institute of Inter-American Affairs, and an American engineer heads the environmental sanitation division of the World Health Organization.

The Chemist and Natural Philosopher

A word should be interpolated here about the chemist or natural philosopher whom Shattuck included in his proposed board of health. This member of the board, according to Shattuck, would have to answer many questions and make special investigations "relating to the influence of the elements on the production or prevention of disease." It is the happy alliance of the chemist, the biologist, and the engineer with the medical profession that has, in large measure, accounted for the progress that has been accomplished in the promotion of the public health by sanitation of the environment. Chemists and biologists have, indeed, had to answer many questions of fundamental scientific importance, and they have had to make many special investigations. Without these, it is only fair to say that the works of the engineer and their management would often have been ill-conceived and inadequate in performance.

The presence of hydraulic engineers in health departments led medical officers of health to seek their advice first of all in matters related to water, such as water supply, sewerage, the sanitation of swimming pools and other bathing places, the control of shellfish-laying areas, and, in certain parts of the country, the control of malaria and other insect-borne diseases in which the insect vectors can be attacked in their aquatic habitat by hydraulic and related operations.

Sanitation of the Environment

In the course of time, the familiarity of public health engineers with the control of environmental factors that were implicated in the spread of disease made them available to assist in the solution of numerous additional problems. Among them are the following: (*a*) the sanitation of the air both in and out of doors, in habitations and workshops, in airplanes and in vehicular tunnels; (*b*) the sanitation of food, in particular of milk during production, conditioning, storage, preparation, and distribution; (*c*) the disposal of solid municipal wastes, especially food wastes; (*d*) the control of animal and insect vectors of disease with special reference to their presence in dwellings and other structures; (*e*) the control of noise; and (*f*) the provision of adequate light. Many of these environmental factors are implicated in one way or another in the complex problems of housing, industrial hygiene, school sanitation, and town planning.

Given a high place in the formulation of public health policy and the development of measures for the preservation and promotion of public health, engineers have, however, not only been called upon to advise communities and private organizations and individuals about sanitary measures and needs. They have also been asked to give voice, in the halls of parliaments, to the public health requirements of municipalities and rural areas. They have, within public health bodies, been required to exercise such measure of police power as has been needed to enforce sanitary regulations. They have been instrumental in arousing public interest in sanitary progress. They have been put in charge of researches that have advanced the art and science of sanitation. They have become part of the public health team assigned to the suppression of sudden outbreaks of disease. Finally, they have been mobilized in time of disaster and war to coordinate the management of emergency and military sanitation.

Sanitation of the environment is indeed peculiarly a responsibility of the engineer, because his profession, more than any other, is fitted to direct the use of men, money, and materials to the purpose of securing the prosperity and well-being of mankind. The environment of modern man has, in fact, been created in large measure by the exercise of engineering skills. What has been asked of the engineer, therefore, in a material sense is that he hold in check, as well as apply, the fire which his protagonist Prometheus wrested from the gods.

Organization for Engineering

The Massachusetts Department of Public Health, which grew out of the recommendations of the Shattuck Report of 1850, stands as a leading example of governmental organization for the protection and promotion of the public health through engineering activities. In 1952, this department was serving a population of about 4.5 millions, including the large metropolitan area of Boston. It is directed by a commissioner of health who has the advice of a public health council and the aid of three deputy commissioners.

The third deputy commissioner is an engineer. He is director of the bureau of environmental sanitation. He is also the chief engineer of the division of sanitary engineering and supervises the division of food and drugs.

The division of sanitary engineering is concerned with water supply and water pollution control, with sanitary works at State institutions, with hydrology and hydrography, with housing and plumbing, with camps and other shelters, with offensive trades and nuisances, with cemeteries and mausoleums, and with shellfish sanitation. The division staff includes 26 engineers, 14 chemists, 2 bacteriologists, 2 biologists, 6 sanitarians, 1 supervisor of public health information, and 28 assistants and clerks. It includes a central analytic laboratory, a district analytic laboratory, and the well-known Lawrence Experiment Station.

The division of food and drugs is directed by a chemist. Its responsibilities include veterinary food inspection, other food inspections, and inspection of bedding and upholstery. Drugs are controlled through the food and drug laboratories. Since the sanitation of food is so much a matter of education of the workers in food industries and of food handlers of all kinds, a coordinator of environmental sanitation cooperates with the division of food and drugs. He is directly responsible to the chief sanitary engineer. His duties extend also to cooperation with the division of occupational hygiene of the Department of Labor and Industries. The division of food and drugs comprises 2 veterinarians, 9 chemists, 2 bacteriologists, 15 food and drug inspectors, and 13 assistants and clerks.

In Massachusetts, the division of occupational hygiene is attached to the department of labor and industries rather than to the department of health. Environmental sanitation being an important part of occupational hygiene, however, there is cooperation between the two departments of State government through the chief sanitary engineer. The division of occupational hygiene is directed by a physician, and includes a laboratory. The personnel of the division includes 1 physician, 2 engineers, 4 chemists, 2 nurses, and 5 assistants and clerks.

The Massachusetts pattern of engineering organization for public health is repeated in many other States and to some degree in the organization of the Public Health Service. In the latter, the chief engineer bears the title of Assistant Surgeon General. This is descriptive of the historical origin of the Public Health Service in the Marine Hospital Service rather than of the functions assigned to the chief engineer, which are engineering in nature.

Accomplishments—Direct and Indirect

Many of the contributions of engineering to public health cannot be measured by statistics of morbidity and mortality, for they are allied more closely to the enhancement of human comfort and well-being than to the direct prevention of disease and death. There is, however, clear evidence of the accomplishments of the engineer in public health in terms of reduced morbidity and mortality.

Historically, for example, the control of the water-borne enteric infections became the first concern of engineers associated with the new public health movement. In Massachusetts, deaths to the number of 1,333 were ascribed to typhoid fever in 1870, when the population of the State was 1.5 millions, and but 13, in 1937, when the population was almost three times as great.

Typhoid fever and diarrhea and enteritis in infants present another primary illustration. In Pittsburgh, prior to 1907, when the Allegheny River water supply for the city was first subjected to filtration, the annual typhoid fever death rate had stayed close to 120 per 100,000 population. Filtration was responsible for a dramatic drop of almost a hundred points. Chlorination subsequently eliminated the water supply as a source of typhoid fever, and pasteurization of the milk supply of the community undoubtedly contributed to the decline in this enteric disease. The principal contribution, however, was in the slow but sure elimination of diarrhea and enteritis as an important cause of death of infants and young children.

Accomplishments in magnitude similar to those cited for the enteric infections could be shown for the reduction of malaria, murine typhus, and silicosis, and for yellow fever and other mosquito-borne diseases, for hookworn disease, for food-borne epidemics, and for numerous industrial hazards.

What of the Future?

The record of the past inevitably invites us to "look upon the seeds of Time and say which grains will grow and which will not." Although engineers do not lay claim to the gift of prophecy, they are, by force of circumstance, called upon to look into the future in order that their works may meet not only contemporary needs but that these works may serve well for many years to come. The normal period of design for some of the great structures that serve the sanitary requirements of communities may well reach a half-century. It is in the forecast of the future that the soundness of engineering judgments is, therefore, often tested.

The population of the world doubled during the nineteenth century under the impact of the industrial revolution, the speeding of communication, the intensification of agriculture, the discovery of new sources of energy, and the improvement in public health. It may well treble or quadruple within our own century. The sanitary competition for the elements of human existence will thereby grow steadily more intense.

Although we have learned how to put the fresh waters of the earth to use for multiple purposes, we shall have to become ever more jealous of them, and husband them more carefully both as to quantity and quality. In spite of our great investment in drainage schemes, we must be ready to replan our cities not only for better surface amenities but also for that "sweet below" for which Sir Edwin asked Napoleon III. We shall have to combine the recreational use of water with its sanitary protection. In all of this we must not fail to acknowledge that progress in the control of waterborne diseases imposes upon us ever greater caution, for we are constantly raising the level of nonimmunity of our people.

The lowering of the ground-water table and the encroachment of the sea upon our subsurface waters makes for anxious thought. We must learn to conserve this important source of water. There are many places in the world where we may even have to turn brackish waters into sweet. The progress in ion-exchange methods for this purpose is most encouraging, but the possible use of solar energy for the production of fresh water must not be overlooked. We are learning to become rainmakers, and the greater comprehension of micrometeorology that is needed to this end may help us also to place under our command the movements of the atmosphere above great industrial cities.

Air cleanliness is becoming an ever greater challenge. In areas of great atmospheric stability the growing pollution of the atmosphere is, in fact, reaching frightening proportions. There must be no more Donoras. Neither must great cities be permitted to be blanketed by smog, which shuts out sunlight, deprives us of beneficent radiations, and reduces the standard of attainable cleanliness.

Although we know how to disinfect air, the great mobility and communality of this element makes the control of airborne, droplet-borne, and dust-borne infections very difficult. Were it not for the chemotherapeutic agents and antibiotics, our record of respiratory infections would be far less satisfying than it is.

Marvels have been accomplished in the preservation of food, in its sanitary production, storage, transportation, and distribution. Yet the number of food-borne epidemics remains extraordinarily high. From 1923 to 1945, for example, milk alone was responsible for almost a thousand recorded outbreaks of a variety of diseases affecting more than 40,000 people in the United States, a country that prides itself in particular on the sanitary quality of its milk supply. At that, many outbreaks undoubtedly were not reported. Education of the public in health will be found essential to the suppression of such occurrences.

Healthful housing remains one of the great challenges of the future. Solar heating of water and of dwellings may well come into use within our time.

It is true, finally, that the boon of sanitation has so far been vouchsafed to but a small fraction of the peoples of the world. As Wycliffe Rose, director of the Rockefeller Sanitary Commission which was to become the International Health Division of the Rockefeller Foundation, insisted, "Unless public health is conceived in international terms, the strategic opportunity of our generation will be lost."

REFERENCES

(*1*) Massachusetts: Report of a general plan for the promotion of public and personal health [Shattuck Report]. Boston, Dutton and Wentworth, 1850, 544 p. (Facsimile of the same by Harvard University Press, 1948, 321 p., available.)

(*2*) Winslow, C.-E. A.: Lemuel Shattuck—Still a prophet. Am. J. Pub. Health **39**: 156 (1949).

(*3*) Great Britain: Sanitary inquiry: England. Local reports on the sanitary condition of the labouring population of England, in consequence of an inquiry directed to be made by the Poor Law Commissioners. London, W. Clowes and Sons, 1842, 444 p.

(*4*) London Metropolitan Sanitary Commission. First report of the Commissioners. London, W. Clowes and Sons, 1848, 430 p.

(*5*) London. Health of London Association: Report on the sanitary condition of the metropolis. London, 1847.

(*6*) Richardson, B. W.: The health of nations. London, Longmans, Green and Co., 1887, 2 vols., vol. 1, p. LXVI.

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