

ENVIRONMENTAL MICROBIOLOGY AND ENVIRONMENTAL HEALTH¹

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Any person who has an appreciation of history must stand amazed today at the phenomenal advances which have occurred and are presently taking place in public health. Within the span of our own lifetime, our original goal of simply fighting a "holding action" against disease and illness has changed to one of taking the offensive. We are talking about nothing less than the actual elimination of most infectious diseases, and the start of massive programs to deal with such dread afflictions as cancer, heart disease, and stroke. Although there is still some distance to go before these goals are reached, the recent history of public health suggests that they are not at all unrealistic. Indeed, any consideration of the current progress in preventive medicine, surgery, chemotherapy, mental health, nutrition, health education and environmental health leads to the recognition that such aims as those of the World Health Organization are not simple Utopian pipedreams: "A state of complete physical, mental, and social well being, and not merely the absence of disease or infirmity".

Not the least of the contributing factors to the progress of the past, and certainly one of the more important considerations in the anticipated progress of the future, is the ability of environmental health workers and sanitation specialists to evaluate and adjust their position in and potential contribution to the over-all public health program. In fact, the successful pursuit of the expanded goals of public health mentioned above depend to a large extent on a concurrent expansion of the scope and goals of environmental health.

A complex and shrinking world, a rapid and uncontrolled urbanization, a proliferating and expanded industrialization—all of these are factors which have caused environmental health specialists to take a second and third look at their specialties and society's needs. It is no accident that the simple and relatively uncomplicated job definitions for sanitarians and sanitary engineers of the past have suddenly been expanded to "the control of all of those factors in man's physical environment which exercise or may exercise a deleterious effect on his physical development, health and survival". It is no accident that we suddenly find that environmental health encom-

passes such diverse specialization as water supply, waste handling, insect control, rodent control, food and milk sanitation, plumbing, atmospheric pollution, heating, ventilation and air conditioning, lighting, housing, institutional sanitation, occupational health, swimming pool and bathing places sanitation, nuisance eradication, radiological protection, and accident prevention. It is also no accident that in an age of such specialties as mentioned above, there is a greater demand for environmental health "generalists"—these environmental health workers who have a broad view of community needs and a sufficiently broad spectrum of skills and knowledge to perform jobs which cross the borders of several disciplines.

ENVIRONMENTAL HEALTH AND ITS SUPPORTING SCIENCES

It is obvious to all who work in environmental health that this is a field of applied science which draws upon a wide array of basic scientific disciplines. Not only do the "generalists" cross interdisciplinary lines, but even the specialists depend upon skills and knowledge derived from other sciences. Thus, a sanitarian must be familiar with chemistry, biology, and physics; an occupational health worker must be familiar with physiology, psychology and toxicology; a health physicist must understand mathematics, chemistry, nuclear physics, and physiology; and air pollution engineers must know their particle technology, analytical chemistry, biochemistry, and meteorology. In essence, environmental health workers draw together knowledge from a great number of sciences and apply these principles toward the specific purpose of making the human environment safe and healthy.

In the past, one of the major supporting disciplines of environmental health has been microbiology. Sanitation specialists had to be familiar with the various microbial agents of disease—the bacteria, viruses, fungi, rickettsiae, algae, protozoa, and helminthic parasites. He had to have more than an academic knowledge about the transmission of these agents whether by direct or indirect contact, by inanimate vehicles, by living vectors, or by airborne dust or droplet nuclei. Above all, the environmental health worker had to know a great deal about the control of infectious disease transmission—pasteurization, disinfection, sterilization, asepsis, and so forth.

In the "good old days" of classical microbiology

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and classical public health, the communication lines between environmental health and the bacteriology lab were clean and well defined. The only people interested in quantitative microbiology were the dairy, food and water workers and to this end many editions of standard methods provided answers. Sterility and disinfection concepts were nearly catechismal, and dealt usually with small units like dilution blanks, dishes, milk bottles and meat cutting boards. Air was sampled by open petri dishes and surfaces were sampled by swabs and since the significance of environmental organisms was not completely understood, the inadequacy of sampling really didn't make any difference. The difference between a pathogen and non-pathogen was clearly defined in text books, and the difference between infection and contamination was the responsibility of the medical profession. All too often the sanitarian degenerated into a sample collector for the bacteriologist and this laboratory insulated person didn't always know the difference between blood, milk and water, or between skin, tile floors, and milk cans—or at least he didn't always appreciate the significance of microorganisms in and on these materials.

However, there is no doubt that the combined efforts of environmental health workers and classical microbiologists were adequate for the job society demanded. For example, milk-borne typhoid, paratyphoid, scarlet fever, diphtheria, dysentery, and brucellosis in the United States during the last decade were responsible for less than 2 dozen cases and no deaths. Similarly, those other areas of environmental health which depend on classical microbiology have served as well. It is in some of the fringe areas of environmental health that our laboratory sources cannot provide the microbiological answers we need, mainly because of a frustrating lack of good data and no real system of theory upon which to base predictions.

For example, when the outbreaks of hospital staphylococcus infections became the subject of popular newspaper and magazine articles, both environmental health specialists and the bacteriology laboratories were embarrassed because they didn't know very much about the bacteriology of the hospital environment or about the role of the environment in the transmission of these infections. Similarly, when the National Aeronautic and Space Administration (NASA) decided to sterilize its spacecraft and turned to environmental health for help, all we knew about was autoclaving, and we didn't know how to determine the sterility of anything bigger than a gallon of water, anyway. The problems faced by workers in biological warfare defense also needed answers that should have been provided by environmental health—problems related to protective cloth-

ing, and masks, and large scale disinfection. But these answers were not forthcoming from classical bacteriology labs and the military had to develop their own answers, which incidentally, are proving most useful in other environmental health areas. The areas of deficiency in knowledge about environmental health microbiology would make a rather extensive list. The list would include things like transmission of virus diseases by fomites, the use of chlorine foot baths in army barracks, the outbreak of paratyphoid in a community water supply that had satisfactory coliform tests, the significance of airborne bacteria in food plants, and the spread of encephalitis from pet turtles.

ENVIRONMENTAL MICROBIOLOGY DEFINED

It can be seen, therefore, that although classical bacteriology has been able to provide environmental health workers with sufficient support for their routine missions, there are some grave deficiencies in our knowledge and skills which might prove critically limiting when we try to expand the scope of environmental health in response to the demands made on it. It is now being recognized that there are unique and related microbiological problems associated with environmental health endeavors that are not being considered in a systematic fashion by any other discipline. These problems, in essence, deal with the types and numbers of microorganisms in air, on inanimate surfaces and living creatures, in foods, on clothing, and in soil, and with their determination, survival, control, and significance to public health.

During the last five years, a number of formal and informal conferences have been held by people interested in the above-mentioned problems. The backgrounds of the participants ranged from epidemiology to architecture, to aerospace technology, and included representatives of university schools of public health, hospitals, microbiology departments, the National Institutes of Health, the Army Biological Labs, NASA, colleges of engineering, the Technical Development Labs of the U. S. Public Health Service, and the Robert Taft Sanitary Engineering Center.

There has never been any intention to establish environmental microbiology as an independent discipline with clean lines of demarcation between it and other subdivisions of bacteriology and public health. Rather, the participants at the conferences envisioned environmental microbiology as an interdisciplinary science, drawing together information from the fields of microbiology, engineering, statistics, chemistry, particle technology and physics and focusing this information toward the practical solution of problems in environmental health. A working definition of environmental microbiology might consequently be:

"The systematic quantitative and qualitative study of microorganisms in man's physical environment, the effect of the environment on these organisms, and the role of the environment in the transmission of infectious disease agents".

AREAS OF ENVIRONMENTAL MICROBIOLOGY

Although nobody has yet taken the time to do so, the broad and expanding field of environmental microbiology can be subdivided into five recognizable areas: (a) basic microbiology; (b) technology; (c) survey work; (d) control work; and (e) specialized applications.

Basic Microbiology

Studies in basic environmental microbiology deal essentially with such problems as the survival of different microorganisms in the environment, the influence of environmental exposure on infectivity of virulent strains, the source of microorganisms that are encountered in the environment, their generation from living and inanimate reservoirs, their dissemination and transportation, and ultimately, with their significance. It has been recognized that an organism which has been exposed to the stresses of the environment (e.g. temperature, humidity, oxygen, radiation, etc.) is not always the identical creature that was freshly isolated from a host or freshly grown on an artificial medium. Thus, the simple discovery of staphylococci in air does not necessarily mean that an epidemic is imminent. Similarly, the presence of a "carrier" of pathogenic bacteria in an operating room does not always mean that this person is shedding and transmitting the infectious agents.

As work progresses in this area, more and more is being learned about the complex interactions of environmental conditions on microbial viability and infectivity. And we are not always as sure of ourselves as we used to be when we try to incriminate inanimate surfaces and air as reservoirs of infectious disease. There still is no doubt that complete absence of bacteria will lead to absence of any hazard. On the other hand the converse of the statement, namely that presence of bacteria does constitute a hazard, must be qualified. We feel that studies of this nature will go a long way in aiding epidemiologists in assessing the significance of indirect routes of disease transmission, as well as aiding sanitary scientists in the establishment of realistic bacteriological standards.

In very recent years, a great deal of interest has been displayed in the phenomenon of virus survival in the environment. This interest encompasses such studies as the transmission of infectious hepatitis

through water supplies and non-sterile syringes and, closer to home, the dissemination of bacteriophages in cheese factories. About the only thing we have learned so far is that there is a diversity among viruses, and that some are more resistant than others to drying, heat and radiations. In this field we are at about the same stage as classical bacteriology was when it found that different strains and species of bacteria displayed different degrees of resistance to environmental stress. So far, no one has found a "sporeforming" virus. But we have found some phages that are difficult to kill, and we have only scratched the surface in these studies.

Technology

A great deal of work has been done in the last decade relative to the technology of sampling. Today there are available a whole battery of instruments for quantitative air sampling of microorganisms. This includes liquid impingers, impaction devices, thermal and electrostatic precipitators, and a number of filtration devices. Instruments are available for sampling very heavily contaminated air as well as for extremely clean air; instruments are available for size classifying airborne contaminants; and instruments are available for continuous monitoring of an environment. The problem is not so much availability of a sampling device as it is of choosing the appropriate device to answer the questions one may have. Thus, certain sampling techniques which were useful in a hospital operating room might be inapplicable to a dairy plant situation, or an instrument designed for an industrial clean room might be out of place outdoors.

Concurrent with the work in air sampling has been the work on surface sampling. There are now available such devices as soluble swabs, disposable direct agar contact plates (RODAC) and "water pressure and suction rinsing" methods for assay of surface contamination.

Of greater importance than the technological advances in this field, however, has been the interest displayed by the statisticians in the problems of environmental sampling. In the last five years some very good work has been generated relative to data reliability and data interpretation in the environmental microbiology field. We will find, ultimately, that many of our previous problems became problems because we did not formulate our questions in terms meaningful to a statistician, and that consequently our answers did not really have any validity.

Some questions still remain the property of bacteriologists. Decisions about the type of media to use and the incubation conditions to choose for environmental microbiology studies never seem to dis-

appear. These questions become more and more acute when one starts to work with smaller samples, or with expensive samples, or with very clean samples. In these circumstances it is often impossible to divide the sample and run replicates on several media or at several temperatures. The whole sample might contain just one or two organisms, and the decision about incubation is irrevocable.

In this regard, mention should be made about studies in the field of rapid detection. In certain cases (e.g. biological warfare defense and warning) the investigator does not have the luxury of a twenty-four incubation period. Similarly, he must detect extremely minute (i.e. sublethal) quantities of agent or his research becomes of historical benefit only. Unfortunately, the two conditions are mutually contradictory; low levels of contamination usually take much longer to find. Nonetheless, research in this field of rapid detection is progressing quickly and some ingenious concepts being developed in this area of technology promise us some major benefits in our routine works in the near future.

Survey Work

Although microbiological surveys of the environment are as old as microbiology itself, this activity was greatly stimulated by the above-mentioned advances in sampling technology and statistics. Surveys have been conducted and reported upon for any number of inhabited and uninhabited areas including operating rooms, classrooms, industrial clean rooms and the stratosphere. Perhaps the most pertinent surveys that concern this association were conducted in a dairy plant by several investigators at Michigan State University. It was found that the mean airborne bacterial count in packaging areas was less than 6 bacteria and 2 yeasts per cubic foot. Although this is considerably less than the contamination level of many hospital areas, similar factors seemed to influence the rise and fall of bacterial counts in both places: number of people and extent of their activity. An interesting observation made during the dairy plant survey was that flooding floor drains seemed to increase the airborne count significantly. This suggests that floor drains are an important reservoir of organisms which become displaced into the air during flooding. Application of high concentrations of chlorine sanitizer (800 ppm) to the flooding water controlled the airborne count during subsequent trials.

Control of Environmental Contamination

It is axiomatic that environmental health workers are interested in microbiology mainly because they would like to control the microbes and their dissemination. Consequently, a great deal of environ-

mental microbiology effort is devoted to the problems of contamination control. The effort includes study of sterilization and disinfection techniques and systems; concepts of asepsis and gnotobiology; and the use of ventilation design to control the movement of airborne microorganisms from "dirty" to "clean" areas.

The advent of adequate sampling techniques has made control work much easier, or at least has enabled us to measure adequately whether or not we are doing a good job. For example, before employing the RODAC plate and statistical controls it was extremely difficult to evaluate the effectiveness of different germicides "in use". Employing these two advantages, however, some investigators at the University of Minnesota were able to show that the type of germicide was not as important as the frequency with which it was applied. Similarly, it was difficult at one time to ascertain sterility of large volumes of fluid. This led to the anomaly of recording a count as $<1/\text{ml}$ and presuming that every milliliter was as clean as the next. Now, with membrane filters, one can measure counts down to <1 organism per gallon or 10 gallons or any other sample which might represent a tank car.

Research in contamination control is bearing significant fruit in the field of asepsis and germ-free work. It is now possible, by combining our knowledge of ventilation and air cleaning with our knowledge of chemical and physical germicidal treatment to render an environment truly sterile and to maintain it that way for extended periods of time.

Applications of Environmental Microbiology

During the course of this dissertation, allusions have been made to the different areas of public health which require environmental microbiology answers. We have seen that there is an application of this type of information to hospitals and to food plants. We have touched briefly on the field of biological warfare defense and germ-free research. It should be pointed out that this is only a beginning. Once hospitals have solved their present problems of control of routine infections, they will want to provide a sterile environment for patients whose treatment includes destruction of all phagocytes and antibody producing mechanisms. Once food and dairy plants are done with coliform counts and mold spoilage, they will want sterile, unheated products and absolute asepsis. The detection and protection people of the biological warfare labs really have set no limit to the precision and speed of their detection devices and their rapid decontamination procedures.

And all of this is taking place on this planet. The challenge of the exobiology program literally staggers

the imagination. They want to send a sterile capsule to Mars; then they want an automated sterile laboratory to sample the Martian environment and to detect any living microorganisms in it!

And, ultimately, all of these problems are problems in environmental health and environmental microbiology. Are we, as environmental sanitarians, ready to meet this challenge?

RADIATION-PASTEURIZATION OF FISHERY PRODUCTS

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The U. S. Bureau of Commercial Fisheries Technological Laboratory at Gloucester, Mass., under a contract with the U. S. Atomic Energy Commission, has conducted research on radiation-pasteurization of fresh fish as a means of extending its shelf life. Results indicate that a number of economically important Atlantic fishery products can be held refrigerated in an acceptable condition for at least one month after treatment with low doses of gamma radiation without significant nutritive losses. The method seems to be practical even when 50% of the shelf life of the fish has been used up.

The value of fishery products as a source of protein is well known and since man's dependence on them is anticipated to increase, it is inevitable that he supply his latest technology to the sea. In general, fishery products are relatively perishable and, consequently, distribution of fresh fish and shell fish is limited to coastal areas. Wider distribution is possible when those products are either heat-processed or frozen; however, in most cases fresh fish and shellfish, like fresh fruits and vegetables, command a higher consumer preference and a higher selling price than their frozen counterparts.

Since the discovery that ionizing radiations can be used to preserve food, much work has been done, especially in recent years, on the use of this energy for sterilization of many foods including fish and shellfish. The application of high levels of energy to these products resulted in significant quality loss from irradiation-induced flavors and odors. However, early research indicated that the refrigerated storage life of fishery products could be significantly extended without objectionable quality changes when irradiated with pasteurizing doses of ionizing radiations (less than one megarad).

Results of the study at Gloucester indicate that clam meats and haddock, cod, pollock, and ocean perch fillets can be held refrigerated in an acceptable condition for at least one month after treatment with low doses of gamma radiation (150-450 kilorads). The effect of irradiation on amino acids and B-vitamins was relatively insignificant and certainly not greater than the effects of cooking or of seasonal variations.

Data have been obtained to show that radiation-pasteurization of haddock fillets has practical application even when the fillets have been stored in ice for more than half their normal shelf life prior to irradiation.

It was found that the bacterial numbers in fresh haddock fillets were reduced by at least 99% by irradiation with 250,000 rads. An investigation of the chemistry of fish flavors and odors has not, thus far, uncovered any evidence that irradiation causes the formation of aberrant or unusual compounds.

The study also included a review of packaging. Because of the many advantages offered by flexible packaging materials, tests were initiated to determine the suitability of available plastics to hold irradiated fish and shellfish. Results showed that many commercially available plastic materials are suitable for packaging radiopasteurized fishery products and that in most cases unsuitability was apparently due to high oxygen permeability rates and poor sealing characteristics. Films tested (polyethylene, polypropylene, polyester, nylon-11, and others) were found to be resistant to bacterial penetration. They were also relatively free from pinholes and their seams were adequately strong.

EMERGENCY WATER MANAGEMENT MANUAL

A manual on the use of emergency water supplies and equipment in a disaster, entitled "Water Supply Management in the Packaged Disaster Hospital," has just been published by the Public Health Service Division of Health Mobilization.

This new publication covers such predisaster considerations as estimating water requirements, determining emergency sources, establishing conservation measures, and training personnel. The manual covers the use of all water supply equipment in the PHS Packaged Disaster Hospital, including a 1500-gallon water tank and 10-gallon per minute pump with pressure tank. It also gives detailed assembly instructions, illustrated with schematic diagrams and photographs.

Packaged Disaster Hospitals, pre-positioned across the country for use in national emergency or major natural disaster situations, are complete 200-bed hospitals which can be set up to replace destroyed local facilities or to expand existing hospitals.

Some state sanitarians and water supply managers are planning training seminars based on this new manual. It is designed as a guide to help community leaders in preparing emergency water supply plans and as a training tool for personnel assigned to operate Packaged Disaster Hospital emergency equipment.

The manual is available at State health departments, or may be obtained by writing the Division of Health Mobilization, Public Health Service, Washington, D. C. 20201.