A fundamental goal of research in this field is to provide bases for the formulation of public health policy. Using examples of research undertaken at the Robert A. Taft Sanitary Engineering Center and elsewhere, the author discusses the role of statistical concepts in providing these bases.

Statistics Applied to Research in Environmental Sanitation

By EUGENE K. HARRIS, Ph.D.

PROBABLY the most valuable application of statistical concepts in the environmental sanitation field is in determining the extent to which a given situation represents a public health problem. Another job, almost as important, is that of analyzing objectively the technical procedures on which much of public health policy and action is based.

The second task is often the easier. Two investigations, one on milk and the other on shellfish pollution carried out by personnel of the Robert A. Taft Engineering Center, may serve as examples. The first of these, an analysis of variation in the direct microscopic clump count on milk, has been mentioned briefly by Black and Myers (*1*). The study was small in scale, yielding results which are only indicative. Its purpose was to analyze variation in milk counts into two broad components: variation in the counts of a single observer and variation attributed to differences between observers.

Dr. Harris, an analytical statistician with the Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio, presented this paper before a joint session of the laboratory and epidemiology sections of the Western Branch of the American Public Health Association, meeting in Seattle, Wash., May 11, 1954.

The Milk Clump Count Study

The most interesting part of the milk clump count study concerns the examination of milk with 100,000 to 200,000 bacteria per milliliter (the upper half of the grade A range in raw milk to be pasteurized). Cooperation was obtained from four men, all with long experience in the direct microscopic count. Each man prepared five replicate films from the same lot of milk, following the procedures of 1948 Standard Methods for the Examination of Dairy Products (*2*). The number of fields read was determined by each observer on the basis of his counts on the first film examined, using the table in standard methods as a guide.

In this way, 20 counts were generated. Analysis revealed that the variation (standard deviation) attributable to differences between observers amounted to 63 percent of the mean count, while variation "within" the average observer amounted to 34 percent of the mean count.

Variation between observers probably arises chiefly from differences in ability to distinguish bacterial clumps when examining a film.

Nevertheless, a test was made of the possibility that mixing of the original sample was incomplete so that readers received portions of varying density or that individual differences in preparing films resulted in varying mean counts. Each observer examined one slide selected at random from each of the sets prepared by his colleagues. In no case did the mean or the variances of the counts on these films differ significantly from the corresponding statistics on his own slides. Apparently, some individuals tend to read "high" and others "low."

For 3 of the 4 readers, the observer variation was about as much as would be expected on the basis of a random distribution of bacterial clumps over a film. The fourth reader, who reported the lowest mean count—about 100,000 per milliliter—showed significant nonrandom variation, due most likely to fluctuations in judgment, attention, and other personal factors.

This small milk count study has been described partly to illustrate a simple statistical design for analyzing the precision of a laboratory method, but more especially to emphasize the importance of the subjective, personal factor in laboratory diagnosis. Improvements in mechanical technique, or in the composition of materials, will be of little worth if the persons applying the methods remain highly variable in their interpretation of what they see.

Finally, what administrative use can be made of these results? They indicate that a single direct microscopic count may not be too reliable a measure of bacterial density, chiefly because of great variation among observers. On the other hand, 3 of the 4 observers exhibited a high degree of internal consistency. It seems, therefore, that from a practical standpoint, the direct count will be most effective when used by a single experienced observer in judging the continuing quality of milk produced over a long time by a given dairy farm. Once the observer has established his own baseline of quality for a certain milk, the direct count will enable him to detect gross deviations from that baseline (that is, counts averaging at least 50 percent greater than his usual observations) regardless of whether he is by nature a "high" or a "low" reader. The fact that well-operated dairy farms are able to keep raw milk counts far below the grade A limit adds weight to the argument that the direct count is more efficient as a measure of continued quality control than as a criterion for grading any one lot of milk.

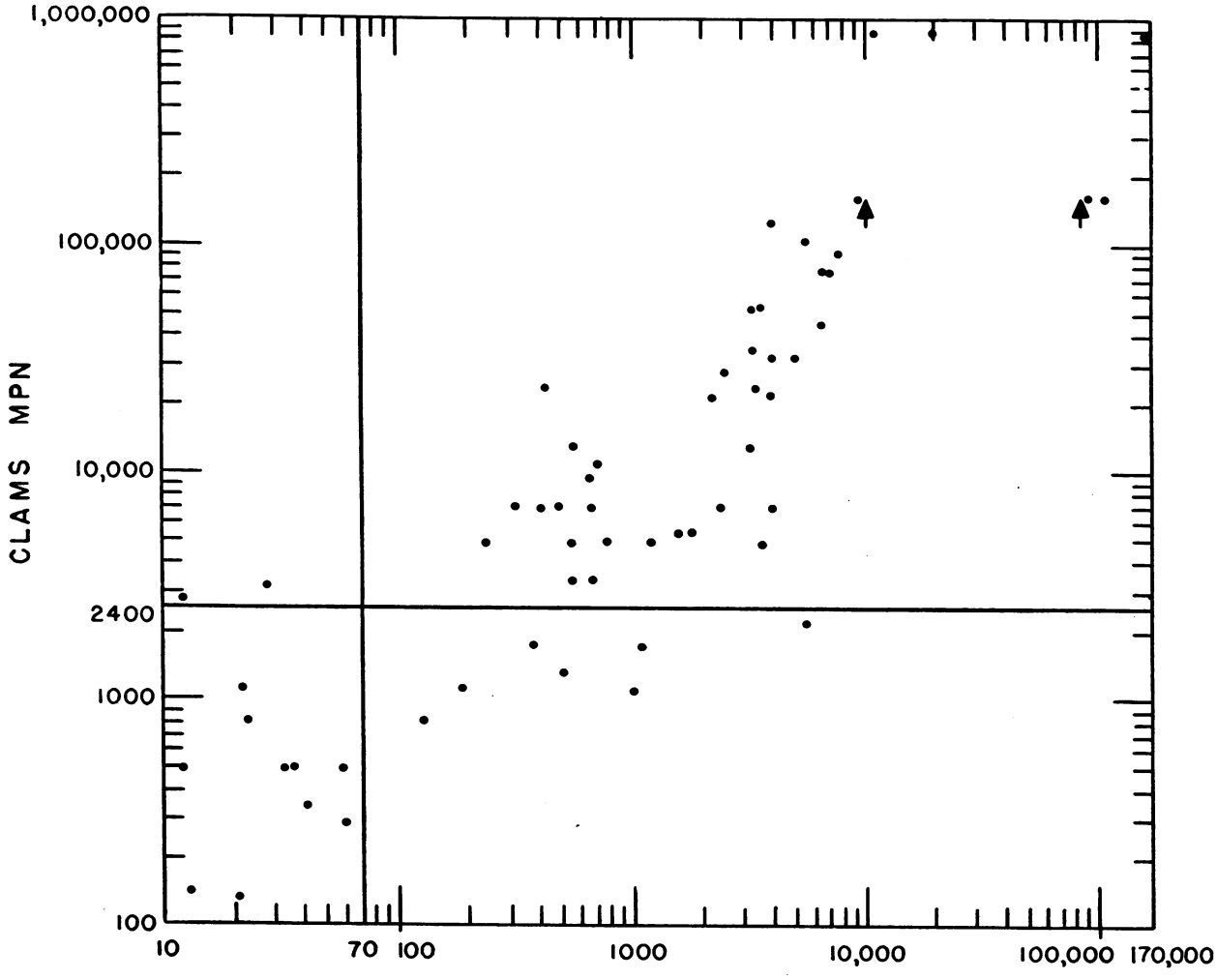
Shellfish Pollution Study

Another study which offers some interesting concepts to the health official desiring an objective basis for policymaking is that by the Shellfish Sanitation Laboratory operated as a field station under the center. It concerns the relationship between the density of coliform organisms in water overlying shellfish beds and the coliform density in the shellfish themselves. The data obtained in this investigation are now in the process of final analysis for publication and hence will not be discussed in detail. The study is mentioned here for illustrative purposes only.

The Manual of Recommended Practice for Sanitary Control of the Shellfish Industry (*3*) classifies shellfish growing areas according to the median most probable number (MPN) of coliform organisms in water samples collected during the harvesting season. A median less than 70 per 100 milliliters defines an approved area; between 70 and 700, a restricted area; and greater than 700, an area closed to shellfish growing. Of course, this is not the only basis for judging shellfish quality; the sanitary survey is doubtless the most effective guide. Nevertheless, numerical standards have a powerful attraction, and, in order to justify certain water standards, we should know the effect on the shellfish of a given level of pollution in the overlying water.

In the laboratory study, hard-shelled clams (*Venus mercenaria*), soft-shelled clams (*Mya arenaria*), and oysters were studied in laboratory flats under widely varying water pollution loads at temperatures ranging from 4° to 23° C. Most probable number determinations were made on both water and shellfish samples at frequent intervals, according to the procedures recommended by the American Public Health Association (*4*). Most of the experiments ran from 3 to 4 days, some from 2 to 3 days, and one or two slightly longer than 4 days. Since a

Water and clam MPN's in moderate temperature range (8°–17° C.). Arrows designate MPN's not precisely determined but greater than the charted values.



great many more water than shellfish samples were taken, each shellfish MPN was matched with a geometric mean MPN in water based on samplings made during a prior 12-hour period.

Water and shellfish MPN's were plotted as abscissa and ordinate, respectively, on a logarithmic grid for each species of shellfish in each of three temperature ranges. The resulting scatter diagrams may be subjected to a number of different analyses. Before proceeding, it is well to emphasize that the data of this particular study were obtained from relatively small numbers of shellfish subjected to controlled pollution under laboratory conditions. Nevertheless, this type of data, namely, matching water-shellfish coliform indexes must arise when studying the relation between water pollution and the sanitary quality of shellfish.

The following plan for analysis of such data appears to be the simplest and probably the most useful to the public health official. For example, from one of the graphs for soft-shelled clams, let us select some prominent MPN's per 100 milliliters in water and clams, say 70 and 2,400. The manual suggests that an MPN of 2,400 or more coliform organisms per 100 milliliters occurring in clams taken from the growing area indicates unfavorable conditions or practices surrounding the production of these clams and necessitates further investigation.

A vertical line is drawn intercepting the X-axis at $X=70$ and a horizontal line intercepting

the Y-axis at $Y=2,400$. As shown in the figure, these lines cut the scatter diagram into four blocks, which may be labeled northeast, southeast, southwest, and northwest.

Let us assume that the sanitary quality of clams in which the MPN exceeds 2,400 coliform organisms per 100 milliliters should be regarded with suspicion. Then, the northwest and southeast blocks represent risks incurred in operating at a mean MPN of 70 for approved waters. The proportion of northwest points to all western points estimates the probability that clams of suspicious sanitary quality will be harvested, while the proportion of southeast points to all eastern points estimates the probability that satisfactory clams will not be accepted immediately but will at least have to undergo further purification. We can reduce the risk of harvesting suspicious clams by lowering the permissible MPN in water, but this increases the risk of rejecting acceptable clams. It becomes necessary to define quantitatively the relative importance attached to each risk.

Suppose, however, that some number other than 2,400 is decided upon as a critical point with respect to the sanitary quality of clams. Then, the numerical estimates of the risks change and with them the bases for a decision of permissible water pollution. The question of proper limits is a very complicated one. This type of analysis merely offers the health official one quantitative criterion by which to estimate the effects of proposed limits.

Hazard Indicators

We have mentioned that statistical concepts achieve their greatest value in public health research when they can be used to determine to what extent a given environmental situation represents a public health problem. This statement needs further definition. As a rule, official recognition of a health hazard results from an outbreak of disease followed closely by epidemiological investigation. However, in order to translate mere recognition of a health hazard into an effective program for its control, two basic conditions must be met. One or more variables must be selected to serve as indicators of the hazard, and the variables must be calibrated so that by measuring them we may measure the severity of the hazard. This latter condition implies that quantitative research is necessary to determine, at least approximately, that point on the scale at which the hazard becomes sufficiently great to merit official action.

As examples of attempts to measure the relationship between indicator variables and health hazards, two investigations will be summarized briefly. The first consists of a series of studies by A. H. Stevenson and R. S. Smith of the center and T. D. Woolsey of the Division of Public Health Methods, Public Health Service, on the relation between bathing water quality and health (*5*).

Natural Bathing Water Quality

Three different classes of natural bathing water were studied: a great lake, an inland river and nearby swimming pool, and a coastal water. Selected in each study were two swimming areas which appeared on the basis of past records to differ markedly in bacterial quality but which were used regularly by families of similar socioeconomic levels.

Illnesses recorded during the study were eye, ear, nose, and throat ailments, gastrointestinal disturbances, and skin irritations. The two occurrences of significant positive correlation between illness incidence rate and bathing water quality are of particular interest since in each case the comparison was between extremes of bacterial quality, namely, median MPN's of 2,700 and 2,300 on the one hand, and less than 3 and 43 on the other. In one instance, only gastrointestinal illness rates were concerned; in the other, the correlation extended to all types of reported illness. In view of the general lack of correlation found between illness rates and variations of coliform density in the range up to about 700, the authors believe that "some of the strictest bacterial quality requirements now existent for natural bathing water might be relaxed. . . ."

Apart from the value of the findings, these studies are noteworthy because of the manner in which the data were collected. Each participating family maintained a daily diary of swimming and illness experience, recording the information on a calendar form according to a special code. This way of gathering information is in contrast to the interview method

whereby a trained investigator calls upon the family at scheduled times, eliciting information on morbidity during the preceding interval. The interview method suffers from the disadvantage that frequent visits are required in order to avoid the dangers of bias due to lapses of memory on the part of the respondent, especially for minor illnesses which were of chief concern in the bathing water studies.

On the other hand, a morbidity survey which requires the cooperating family not only to supply but also to record the data is subject to the risks of illegible and inadequate information. These difficulties were avoided in the bathing water studies by providing a simple code printed below the calendar; by carefully reviewing the diary form with the housewife; and, finally, by maintaining contact with the family during the study through telephone, mail, and an occasional personal visit.

Meteorological Factors and Air Pollution

The second example of quantitative research into the effects of environmental factors on health is in the field of air pollution. This project is the first step in a search for the possible health effects of minor changes in weather and atmospheric pollution. With respect to the effects of weekly variations in weather factors, an early study by L. J. Reed (*6*) of Johns Hopkins University, using statistics of England and Wales for the years 1865 to 1914, is of interest.

Weekly mortality records from the city of Cincinnati are being examined to find out if a pattern of variation exists which may be correlated with local meteorological factors and especially with some measure of air pollution. The mortality data on punchcards have been made available through the cooperation of the city health department. This study initiated by Dr. K. H. Lewis of the center and now being carried on under the writer's immediate supervision is the sort of work which may be undertaken by State or city health departments.

Progress to date of the Lewis study may be outlined as follows. Mortality during the period from January 1952 to December 1954 has been tabulated for 22 causes of death by age group and week of death. From these tabulations, four causes, comprising a group of cardiovascular diseases, have been selected. The successive weekly totals for all ages have been plotted on graphs for each year. The same has been done with deaths from respiratory causes and total deaths from all causes, but so far analysis has been confined to the cardiovascular group.

The general trend of cardiovascular deaths in any year could be fitted very well by a simple curve. Selected in each year were short periods of time during which significant deviations from the curve were apparent—either peaks or dips. The same techniques are now being applied to various weather factors (temperature, pressure, percent of possible sunshine, and so on) for which weekly medians or totals may be calculated from publications of the Cincinnati office of the United States Weather Bureau, and to a continuous measure of air pollution—the intensity of staining of filter paper in a Hemeon automatic smoke sampler. Information on this variable has been obtained through the cooperation of the Cincinnati Bureau of Smoke Inspection. It is possible that obvious deviations from the general mortality trend will be clearly associated with similar deviations in one or more environmental factors. More likely, in order to reveal any correlations, it will be necessary to analyze all weekly deviations observed in mortality, weather, and air pollution pictures.

Summary and Conclusions

This discussion has implied the need for careful research in defining the nature and content of control programs in environmental sanitation. Nevertheless, it is a common experience of health officials to be called upon for action in an emergency situation and to have to devote to the operation of an untested control program resources that might otherwise be spent on research leading to a more efficient program. There can be no criticism of this when the need is obvious and when at least the qualitative aspects of the necessary control procedures are known. Eventually, however, every such procedure calls for reevaluation, sometimes in terms of errors of measurement but always in terms of health significance. By means of specific examples, I have tried to illustrate the ways in which research based on

statistical concepts may aid in the evaluation of current sanitation programs and in the planning of new ones.

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Harold R. Sandstead, 1904–1955

Dr. Harold R. Sandstead, nutrition expert on the staff of the National Institute of Arthritis and Metabolic Diseases, was killed in the November 1, 1955, airplane crash in Colorado. Dr. Sandstead held the rank of medical director in the commissioned officer corps of the Public Health Service. For the past year he was executive director of the Interdepartmental Committee on Nutrition for National Defense. He joined the Service in 1934.

Dr. Sandstead was honored in 1945 by the Netherlands Government for his work on nutrition in Holland. He also received the Bronze Star for this work from the United States Army. In 1954, the Army awarded him the Bronze Star with Oak Leaf Cluster for his work on nutrition in South Korea. A memorial fund for medical students has been established in Dr. Sandstead's name by Vanderbilt University, Nashville, Tenn., where he served as assistant professor of medicine during 1940–53.

Printed in a recent issue of the Netherlands *Tijdschrift voor Sociale Geneeskunde* (*Journal of Social Medicine*) was a tribute to Dr. Harold Sandstead. Excerpts from this tribute, freely translated, are published below at the request of Dr. C. Banning, chief medical health officer of the Netherlands.

"Dr. Sandstead's name transports us directly back to the first months after the liberation. In our memories, we see this outstanding American laboring day and night to assist in the rebuilding of the Netherlands.

"On the SHAEF mission, he was prominent among those who hastened to help our country. He was particularly interested in the problem of starvation and malnutrition. Sandy, as many friends called him, took an important part in investigating malnutrition, especially in the western part of our country.

"With the late Sir Jack Drummond and Prof. G. C. E. Burger, he completed a report on Malnutrition and Starvation in Western Netherlands. In the introduction to this report, our Minister of Social Affairs thanked the composers, calling them the international 'triumvirate.' Concerning Dr. Sandstead, the Minister says that Lt. Col. H. R. Sandstead, as head of the health section of the SHAEF mission to the Netherlands, contributed much to the recovery of the health of the population of our country and to the relief activity.

"No wonder that in October 1945 our Queen honored Dr. Sandstead as Officier in de Orde van Oranje-Nassau met de Zwaarden (Officer of Orange-Nassau with the Swords).

"His more intimate friends know that Sandy not only gave material help and took care of the supply of food, medicine, and equipment, but he was a man of warm feelings who also gave moral support and assistance. This American officer understood and participated in the sorrow the occupation had caused us.

"From my personal experience, I know that Holland had a special place in Sandy's heart. He was deeply interested in everything happening in Holland, and he rejoiced in the swift rebuilding of our country. Holland has lost a great American friend. To his very many friends here, his death has left a great vacuum."

technical publications

Public Sewage Treatment Plant Construction, 1954

Public Health Service Publication No. 453. 1955. 18 pages. 20 cents.

Public Sewage Treatment Plant Construction for the calendar year 1954 supplements and brings up to date the information contained in the reports for 1952 (PHS Pub. No. 291) and 1953 (PHS Pub. No. 409). The report indicates the progress made by municipalities during 1954 in providing the sewage treatment facilities necessary to prevent pollution of water resources on which downstream water users depend.

Contracts were awarded for 716 projects costing $227.5 million, an increase, after adjustment for cost index fluctuation, of 21 percent over 1953 construction. Of the 1954 contracts, 366 were for new plants, costing $143.2 million, and 350 were for additions, enlargements, or replacements of existing plants, costing $84.3 million. The appendix to the report lists individual projects, by State, giving type of construction and cost of each.

Venereal Disease Clinics Directory

Public Health Service Publication No. 257. Revised 1955. 144 pages. 70 cents.

Names and addresses of the Nation's venereal disease diagnostic and treatment facilities, days and hours of service, and fee basis for use of each facility are listed in this directory.

It is published biennially by the Public Health Service Venereal Disease Program to provide the latest information on these clinics and other facilities. The material included in the 1955 edition has been compiled from information supplied by the health departments of the 48 States; the Territories of Alaska, Hawaii, Puerto Rico, and the Virgin Islands; and by the Division of Hospitals of the Public Health Service.

Summaries of premarital and prenatal laws as they pertain to venereal disease are given for each State and Territory having such laws, and laboratory facilities available in each State are described.

The current directory shows that 40 States and 3 Territories have premarital laws requiring blood tests and physical examinations for venereal disease, while 42 States and 3 Territories have prenatal laws requiring blood tests for pregnant women.

Nutrition and Healthy Growth

Children's Bureau Publication No. 362. 1955. 36 pages. 20 cents.

Quantities as well as kinds of food that will contribute most to good nutrition during pregnancy and throughout childhood are presented in this pamphlet, which is addressed primarily to teachers, nurses, social workers, and other personnel working with parents. Sample meals for children at varying stages of development are given. Common foods and the contribution each makes to good nutrition are listed in an appendix.

A Comprehensive Program for Water Pollution Control

Lower Portion of Upper Mississippi Basin

Public Health Service Publication No. 450. Water Pollution Control Series No. 71. 1955. 53 pages; illustrated.

Developed in cooperation with water pollution control agencies of Iowa, Minnesota, and Wisconsin and adopted by the Public Health Service, this program is based on data available as of November 1, 1954.

Among the recommendations for municipalities are: sewage treatment plants for 26 municipalities and institutions now discharging untreated sewage to the basin watercourses; replacement of 9 existing plants; enlargement or additions for 33 plants; and connection to existing municipal sewers of 1 plant. For industries, requirements include: 66 new treatment plants; enlargement or additions for 33 existing plants; replacement of 2 plants; and connection to existing municipal sewers of 4 plants.

Industrial Waste Guide to the Wool Processing Industry

Public Health Service Publication No. 438. 1955. 14 pages; illustrated. 15 cents.

Third in a series of Industrial Waste Guides, this one is intended primarily to aid operators of woolen mills and commission processors in using, reducing, and otherwise suitably disposing of their wastes. Like its predecessors in the series (the first was for the milk processing industry, and the second, for the meat industry), it is based on two premises. First, the greatest possible recovery, use, and reduction of wastes is necessary for the most economical production; and, second, protection of the Nation's limited

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This section carries announcements of all new Public Health Service publications and of selected new publications on health topics prepared by other Federal Government agencies.

Publications for which prices are quoted are for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Orders should be accompanied by cash, check, or money order and should fully identify the publication. Public Health Service publications which do not carry price quotations, as well as single sample copies of those for which prices are shown, can be obtained without charge from the Public Inquiries Branch, Public Health Service, Washington 25, D. C.

The Public Health Service does not supply publications issued by other agencies.

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water resources for maximum use is necessary in order to bolster our national health and economic growth.

The guide was prepared for the Public Health Service by the Stream Pollution Abatement Committee of the American Association of Textile Chemists and Colorists under the sponsorship of the National Technical Task Committee on Industrial Wastes.

The Halogenated Hydrocarbons, Toxicity, and Potential Dangers

Public Health Service Publication No. 414. 1955. By W. F. von Oettingen. 430 pages; illustrated. $2.50.

Intended for physicians, entomologists, engineers, and persons interested in agriculture, this publication deals with the toxicity and potential dangers of various halogenated hydrocarbons—aliphatic, olefinic, cyclic, aromatic, and aliphatic-aromatic. It covers, therefore, a great number of industrial solvents, refrigerants, fumigants, and insecticides.

Directions are included for the prevention and treatment of poisoning in humans by these chemicals.

PHS Films

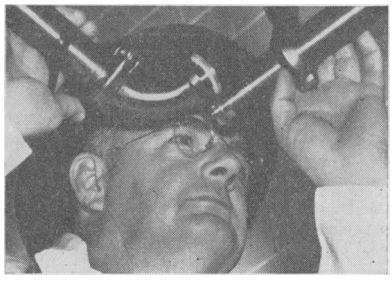
Milk Sanitation Series: Cleaning-in-Place for Pasteurization Plants

35 mm. Filmstrip, color, sound, 12 minutes, 63 frames. 1955.

Audience: Sanitary engineers, sanitarians, and dairy science students.

Available: Loan—Public Health Service, Communicable Disease Center, 50 7th St. NE, Atlanta 23, Ga.

The cleaning-in-place method of cleaning milk lines by recirculating a cleaning solution throughout the piping system is the subject of this filmstrip.



This method is represented, through contrast, to be superior to the manual cleaning method, whereby pipes and connections are cleaned individually. A typical installation for the cleaning-in-place method, consisting of the milk line, separate recirculation unit with return line, and solution tank and pump are shown. In addition, a step-by-step cleaning-in-place operation, from preparation of cleaning solution and checking flow velocity through post-rinsing with lukewarm water and bactericidal treatment of the entire system before starting the milk flow, is followed.

Installed glass and metal cleaning-in-place piping, fittings, gaskets, and welded connections are pictured. Among the check-points depicted are removable fittings, slopes and supports of pipes, accumulated charts, and the recording thermometer, which gives temperature and circulation time.

Basic Use of Levels by Sanitarians

35 mm. Filmstrip, color graphics, 8 minutes, 45 frames. 1954.

Audience: Sanitary engineers and sanitarians.

Available: Loan—Public Health Service Communicable Disease Center, 50 7th St., NE, Atlanta 23, Ga. Purchase—United World Films, Inc., 1445 Park Avenue, New York 29, N. Y.

The basic uses of engineer's, string, carpenter's, and hand levels and the transverse hose filled with water are pictured in this filmstrip.

To accomplish this, the installation of a septic tank is demonstrated. A specific demonstration relates to the grade board in one section of a drain field. Any one of the five methods demonstrated can give satisfactory results if sufficient time and care are taken. A knowledge of the use of at least one instrument is essential in sanitation work.

Serving Food

16 mm. Film, color, 10 minutes. 1954.

Audience: Sanitarians and public health workers.

Available: Loan—Public Health Service, Communicable Disease Center, 50 7th St., NE, Atlanta 23, Ga. Purchase—United World Films, Inc., 1445 Park Avenue, New York 29, N. Y.

The fundamentals of orientation and induction training to be given a waitress by a restaurant hostess are stressed in this film.

Correct ways of clearing tables and the proper storage of cups, dishes, and glasses are portrayed. Safeguarding against disease through the development of satisfactory personal habits and periodic physical examination are advocated to protect the health of the waitress as well as the customer.

The waitress avoids touching the rims of glasses to protect herself and the customers.

U. S. GOVERNMENT PRINTING OFFICE: 1955