IODINE AND SANITATION[1]

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One of the major objectives of organized and even unorganized community health has been environmental medicine which encludes environmental health and environmental sanitation. In industry, the emphasis on environmental sanitation is even greater, inasmuch as actual financial losses or gains due to keeping-qualities of materials are quickly apparent, depending upon low or high standards which may be in operation. The potential benefits of proper sanitization procedures have become a subject of intense interest to everyone and upon which the spotlight is strongly focused today. Direct and indirect benefits to all and monetary gains to many result from proper modern sanitary practices. There is sufficient evidence that effective sanitation assures better health. Public health authorities everywhere and especially in our country are increasingly insistent that we practice proper environmental sanitation. Environmental health needs have changed in recent years and there has been a steady broadening of the horizons of public health.

Sanitarians in these modern times must be trained so that they have a knowledge of all environmental influences as they affect health and well-being. They must be familiar with the basic principles and techniques dealing with environmental regulations and the control of environmental health hazards. But they must go beyond this; they must be prepared to teach others to establish proper sanitary and hygienic practices. And in addition, they must be prepared to educate the public. A significant contribution can be made if well-trained sanitarians will become familiar with the conditions wherein they work and then speak the language of that area with those who are to be trained and regulated. All workers must be made sanitation-conscious, be prepared to recognize unsound sanitary practices and appreciate the problems at hand. Health enforcement officials, on the other hand, must also understand the situations and approach them in a realistic practical perspective. Adequate sanitation is everyone's responsibility if we are to have clean, pleasant and sanitary surroundings. Too often, those in industry fail or even refuse to cooperate, indicating added expense. It should not require much effort to impress everyone with the fact that failure to pay in effort and slight monetary consideration for public health will mean greater losses in terms of inefficiency, disability, illness and even in loss of life itself. In this activity, it is possible to adopt an approach which at least does not bring about active opposition and conflict. It is important to establish desirable attitudes and to build intelligent lay opinion for good sanitary habits. We are dealing with all kinds of human beings, who must be made to understand, must even be convinced, and must be won over to the regulations we seek to further. Goals must be carefully defined and characteristics explained in all details. Cooperative action is the very essence of democracy and is productive. When health worker and lay worker and an informed and enlightened lay public work together to encourage better environmental sanitation, more is accomplished than if the health worker or sanitarian merely sits in judgment. Gathering the facts, familiarizing one's self with and interpreting them in an understandable manner and serving as an educator rather than as a policeman will bring about more marked and even, striking improvements. Better results will be obtained with a program stressing health education, leadership and health service rather than law enforcement alone.

An informed public opinion, educated to the advantages and values of environmental sanitation, and active co-operation on the part of all concerned are bound to result in an elimination of unfavorable environmental practices and the strengthening of the favorable. The magnitude of the problem is self apparent. This is likely to leave one at times discouraged and even frustrated. However, there is compensation in the fact that progress has been and is being made. Environmental sanitation has been improved in many places with appreciable returns in human and economic values.

The major emphasis of this presentation is placed upon the effectiveness of sanitization by chemicals and in the more recent use of free iodine solutions and iodine-liberating preparations in sanitization procedures. Employing these iodine solutions makes available a useful and effective means of quickly sanitizing suitable equipment as a necessity in modern environmental health practice.

The employment of suitable effective sanitizing chemical solutions as a final step in the practice of

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[1]Presented at the Laboratorian's Short Course, University of Florida, Agricultural Experiment Station, Gainesville, Florida, April 5, 1955.

sound sanitation is an additional safeguard, and is not to be used as an excuse for careless and insanitary methods in operation. Chemical sanitizers are effective, readily available and usually low in cost. Sanitization by chemicals is not intended nor can it be expected to take the place of overall sanitary control and proper supervision. However, we must recognize the frailties of humans and also that continuous careful inspection and supervision or policing if you please are not possible at all time. It, therefore, is of paramount importance to be assured that the final step in the overall operation should be the use of an effective sanitizing chemical compound. If the latter can provide for many purposes a detergency as well as a sanitizing action, the value of the sanitizing method is increased.

DEFINITIONS

It is important to understand and properly use various terms employed in sanitization procedures. A knowledge of their meanings as they reflect present-day usage is not only desirable for legal reasons, but much confusion and misunderstanding with resulting uncertainties will be avoided if they are employed properly. Certainly, sanitarians should not find themselves being criticized because all those in this profession do not always "speak the same language". With this in mind, the definitions of the following are presented.

A *disinfectant* is a chemical agent which destroys disease-producing or other harmful microorganisms, but not necessarily bacterial spores. The term is employed for substances used on inanimate objects. A *germicide* or *bactericide* is a chemical agent which kills bacteria but not necessarily bacterial spores; the term is used for substances applied to inanimate objects as well as living tissue. A *sterilizing agent* or sterilizing process is one which destroys *all* microorganisms including spores. Where a chemical possesses an unusually wide range in its destructive powers against microorganisms of all kinds including bacteria (lower and higher forms), fungi, viruses and protozoa, the term *"biocidal"* frequently is used. This term is especially applicable when referring to the effectiveness of free iodine solutions. A *bacteriostatic agent* prevents or inhibits the growth or development of bacteria . The term *"antiseptic"* is actually defined in the Federal, Food, Drug and Cosmetic Act of 1938. Section 201 (o) of the Act states: "The representation of a drug in its labeling as an antiseptic shall be considered to be a representation that it is a germicide, except in the case of a drug purporting to be, or represented as an antiseptic for inhibitory use as a wet dressing, ointment, dusting powder or such other use as involves prolonged contact with the body". The term is used especially for substances applied to the living body (humans and animals). As legalized in this country, an antiseptic is a substance, "which when applied to microorganisms, will render them innocuous either by actually killing them or preventing their growth, according to the character of the preparation or the method of application". Preparations "which remain in contact with the organisms in the affected part of the body for a long period of time, may properly be designated as antiseptics, if their action is merely to inhibit the growth of bacteria". Products "which are in contact with the affected parts for but a brief period of time, may be called antiseptics, only if they will destroy organisms if used as directed".

The term "sanitizer" is applied to an agent which reduces the number of bacteria to safe levels as may be judged or evaluated by public health requirements and regulations. It is used commonly in connection with cleaning operations on inanimate objects as on eating and drinking utensils, dairy and other food-handling equipment and the like. Its purpose is not only to safeguard public health by eliminating or reducing contact with disease-producing organisms, but also to reduce and eliminate microorganisms which may affect the quality of dairy and other food products.

Substances which during washing serve as cleaning agents, removing dirt, soil or foreign material are known as "Detergents". "Sanitizing Cleaners" or "Detergent Sanitizers" are dual-purpose compounds which serve both as cleansing agents and sanitizers. Detergents in weak aqueous solutions have the effect of lowering the surface or interfacial tension of water. Accordingly they have been or are also known as "surface tension depressors" or "wetting agents" or "surface tension depressants" or "surface active agents" and more recently as "surfactants". The ideal detergent is one possessing maximum or at least great, easy dirt-removing power, with effective performance in the shortest time, with no damage to the articles treated, and with a minimum of manual labor.

An almost limitless number of surface active substances is available on the market. They usually serve as effective detergents, or dispersing, emulsifying, spreading, penetrating, solubilizing or wetting agents. Their solutions may or may not produce frothing especially when shaken or agitated. They penetrate porous materials and usually produce foam when shaken or stirred. An individual surface-active compound or surfactant may possess at the same time one or several of these functions in varying degrees. Usually one property may predominate over the others and this property is responsible for the general name of the compound. It is usually necessary to carry out many practical studies to determine the requirements for effective use for its individual varied application. The commonly used surface active agents consist of molecules, one portion of which is a carboxylate or a sulfate, sulfonate, alcohol-ether or polyhydric alcohol. This portion, having an affinity for water and said to be hydrophilic or water-loving, is combined to make up the whole molecule with the other portion, which having an affinity for oleaginious substances, is spoken of as being lipophilic or oil-loving. The latter portion generally is a long hydrocarbon chain (as in fatty acids) or a cyclic hydrocarbon or a combination of both.

ELECTRIC CHARGE

It is common practice to classify surface-active agents or surfactants depending upon an exhibition of a particle charge of their colloidal solutions in water, so that we hear of ionic (or ionogenic) and nonionic compounds. The former are either cationic or anionic, depending on whether the surface-active portion of the surface-active agent has a positive electrical charge (cationic) or whether the effective portion of the molecule is in the anion (negative electric charge). There are some surfactants available which are bi-ionic (or amphoteric or ampholytic; the compound is also known as an ampholyte). They behave as anionic surfactants in an alkaline medium and as cationic surfactants in an acid medium; in other words the active portion of surfactants has a positive or negative charge depending upon the pH of their aqueous solutions. Ionic compounds are readily inactivated by many substances and especially by antagonistic surface active compounds.

Nonionic substances do not exhibit an electrical charge. They possess electrical neutrality (are not attracted to either cathode or anode). In general, nonionic compounds are compatible with other surface active agents (ionic and nonionic) and electrolytes, and are neutral, usually less irritating and less toxic. This inert character chemically, electrically, etc. is especially valuable in a surface-acting substance. The available marketed nonionics are heat-stable, non-volatile, usually complex mixtures, and water-miscible or dispersible in water.

CHEMICAL SANITIZERS

Among the more important chemicals employed in sanitization procedures, especially for food handling and processing equipment, we find chlorine and chlorine compounds, quaternary ammonium compounds and iodine and iodine compounds. Until recently, only the use of solutions of chlorine and chlorine-releasing compounds has had general acceptance. As an all-around sanitizing agent, there are certain drawbacks to chlorine and chlorine compounds. Among them are the fact that in use dilutions, they are not effective against tubercle bacilli and poliomyelitis and other viruses; they act as bleaches, thus affecting the clothing of operators, etc.; and it is necessary to test the use solutions to be assured that effective concentrations for effective sanitization still persist, inasmuch as the gross appearance of such use solutions does not give any indication of their potency. Solutions of the quaternary compounds also do not establish a "tell tale" as to potency. They are inactivated readily by many substances under practical use conditions, and they do not possess the broad antibacterial spectrum as displayed by the halogens, being more selective in their activity on different microorganisms.

IODINE

For more than a century, iodine, as tincture of iodine, was used in wounds, even before microbiology was introduced as a branch of science. Since 1881, when Koch reported on the antiseptic properties of iodine, the latter has been extensively used and considerable data have been presented extolling such virtues. The efficiency of free iodine solutions has been found to fulfill a function that many other antibacterial agents do not and cannot accomplish. Iodine (free) exerts its biocidal effect over a wide pH range, including the reactions apt to be encountered in practical routine. The concentration of free iodine necessary to disinfect does not vary greatly with different species of microorganisms and iodine being quite non-selective, covers a wide spectrum in its action. In a recent presentation (1), notation was made of the use of iodine as an antiseptic for the skin, wounds and mucous membranes of man and animals; for the sterilization of air and of inanimate objects; as a bactericide, fungicide, virucide, and protozoacide, (also killing thermoduric and psychrophilic bacteria, tubercle bacilli and poliomyelitis virus); for the disinfection of drinking water and swimming pool water, and for the sanitization of eating and drinking utensils and for equipment in bakeries, dairies and in food establishments. The introduction recently of new iodine-liberating compounds for the sanitization of dairy, food, eating and drinking utensils and equipment has resulted in even greater interest in the use of free iodine solutions. The latter continue to possess the many valuable, effective and useful properties possessed by iodine, but of special value in sanitization procedures is the so-called "built in" or self-controlled concentration indicator displayed by these solutions. The concentration or strength of the use-solution is readily detected, being indicated and the potency approximated by the color imparted by the free iodine. Even a few p.p.m. of free iodine, serving as a "tell-tale" indicator, will impart a yellow or pale amber tinge to the solution. The deeper the amber or brown color, the greater is the iodine concentration. It requires very little experience with these free iodine solutions for a user to quickly note when the strength of the latter is at or below minimum requirements for effective usefulness.

The over-all effectiveness exhibited by free iodine solutions has been detailed by the author (1) and others in numerous presentations and is recognized and accepted by all workers. In practice, the U.S.P. Iodine Tincture and the Strong Solution of Iodine (Lugol's Solution) are the two preparations of iodine readily available on the market and purchasable even at the corner drugstore. Other formulations of free iodine require individual or extemporaneous compounding and dispensing. This and other cognate factors including at times the stability factor and pH of such solutions have confined the scope of application of these two marketed solutions to comparatively limited use. It therefore appeared desirable to formulate solutions of free iodine which, in addition to any other application for their use, would be also practical for use as sanitizing agents in the dairy and food handling industries and for eating and drinking utensils and equipment sanitization.

Iodine even though in use for more than a century continues to serve as a most effective biocidal agent. The introduction of new iodine-liberating preparations enables it to continue to expand and even improve its usefulness as the changing needs of today require. It merits even wider use and application.

IODOPHORS

Iodine is sparingly soluble in water. Though the strength of a saturated solution is approximately one part in 3450 at 20° C, it is time consuming to make such a saturated aqueous preparation. Accordingly, soluble iodides (usually sodium or potassium iodide) are employed to make the iodine more readily soluble in water; however, this means added expense. Other inexpensive solubilizing agents have been used; and more recently various synthetic detergents or surfactants have been employed as solubilizing agents or iodine carriers. The resulting combination or complex possesses antibacterial as well as detergent and surface-activating properties. Such compounds are more generally referred to as "iodophors" (iodo-*iodine* and phor-*carrier*). A large variety of different ionic and nonionic detergents can serve as iodine-carriers. Other than their ionization characteristics, the synthetic surfactants have little in common structurally or functionally. The many detergents or surfactants in the various types or groups differ in respect to the amount of iodine which can be present in each, their stability, reactivity (amount of iodine liberated), their detergency and in other characteristics.

Of the various iodine-based sanitizers (combinations of iodine and surfactants) introduced to date, the nonionic detergents in general have been found most efficient and the most stable iodine carriers. The addition of a suitable buffering agent and certain acids to maintain the proper pH gives such an iodine preparation its maximum biocidal properties and makes available a more stable product. Not all nonionic detergents are suitable for the production of a nonionic-iodine "complex". Alkylphenoxypolyglycol ethers have thus far proved to be among the best. The available iodophors marketed as detergent-sanitizers retain all of the desirable properties of iodine, at the same time suppressing to a minimum many of the undesirable characteristics. The biotic properties of the iodine are unimpaired and, under certain conditions, enhanced. Present day improved laboratory techniques and modern stringent standards for biocidal agents have proved them most effective. Under conditions of use, solutions are not affected by hard water, are compatible with anionic, cationic and other nonionic compounds, do not stain permanently, are safe, non-toxic and noncorrosive (except on silver or silver-plated implements), effective dual purpose products (detergent and sanitizer), useful over a wide pH range, miscible with water in all proportions, and are practically free of flavor, taste and odor. Some individuals may detect a faint iodine odor. This odor can be masked with a flavoring agent. It is of interest to note that some people prefer the almost negligible odor, as it is not objectionable and serves as a "tell-tale" that a sanitizing agent has been or is being used. Milkstone formation is prevented by these iodine-sanitizing preparations, inasmuch as the compounds responsible for such residue are solubilized. The "wetting" properties provide a greater penetrating and spreading power, and aid in a quick draining without spotting or streaking or film production, this being useful when sanitizing eating and drinking utensils which are drain-dried. These preparations are economical. Though simple indicator papers or color comparison kits are supplied to check the potency of use solutions and thus be assured of biocidal action at all times, the concentration or strength of the use-solution is indicated by the color imparted by the free iodine. This so-called "built-in" concentration indicator or "tell-tale" indicator reveals a color which is an accurate measure of the potency of the use-solution. Even a few p.p.m. of free iodine will impart a yellow tinge or pale amber color to the solution. With but little experience, even the unskilled worker can learn to tell quickly by the color of the solution when the strength or concentration is below minimum requirements for effective usefulness. Thus the color of free iodine solutions and these iodophors indicates their biocidal effectiveness, serving as an important visual safeguard against the use of solutions of ineffective concentrations of the compound. The U.S. Public Health Service and various Health Departments concerned with environmental sanitation have indicated the acceptability of certain iodophor preparations for the sanitization of milk and food utensils.

IODINE IN SANITARY PRACTICE

As a sanitizing agent, iodine has been used for the treatment of water supplies for over a half century. In 1922 (1) "the United States Public Health Service recommended the disinfection of drinking water by the addition of the 7 per cent tincture of iodine in an amount approximately equivalent to 1 drop of the latter per quart of water and a time period of 10 to 30 minutes depending upon the clarity". The United States Armed Forces have at present adopted an iodine-releasing chemical, tetraglycine hydroperiodide, as a disinfectant for water in canteens. In times of floods and other emergencies when drinking water is at a premium, iodine treatment "will assure a safe potable water for human consumption" (1).

The sanitization of air-raid shelters with iodine was used in Great Britain as a prophylactic measure against influenza. Other workers reported on the effectiveness of iodine as an aerial disinfectant (1).

In a detailed study in our laboratory, we reported on the usefulness of free iodine as a sanitizing agent for treating eating and drinking utensils and its importance, especially when such utensils are used by the sick. Sanitization of dishes, cups, glassware, knives, forks and spoons was effected by a one-second immersion in iodine solutions (50 to 200 p.p.m.), having first scraped these utensils and having employed a preliminary 10 second rinse in water (3).

A presentation on iodine sanitizers was recently made (2). We have conducted and are continuing studies on various proprietary and non-proprietary preparations containing free iodine or iodine-releasing chemicals. A detailed report of a bacteriological study on such preparations and their effectiveness as compared to hypochlorite (available chlorine) is being presented at the forthcoming annual meeting of the Society of American Bacteriologists. At this time, I can report briefly the following:

Solutions containing free iodine are very effective preparations for the sanitization of hard, non-porous surfaces after first cleaning the latter. This includes the sanitization of eating and drinking utensils, dairy and food plant equipment, tank trucks, etc. Such iodine sanitizers can be combined with suitable detergents as in the available marketed iodophors. Some of these iodophors, all liquids, are marketed as a "Germicide for Dairy and Food Plant Sanitation"; or "Detergent-Germicide for Dairy Farm Sanitation; or "Triple Action-Cleaner, Sanitizer and Deodorant", or "Complete Germicide and Detergent for Eating and Utensil Sanitation". Another marketed iodophor is available as a "General Purpose Cleaner, Disinfectant and Sanitizer". Generally speaking, iodine-iodide solutions acid buffered to a low pH (2.5 to 3.0) are more effective than unbuffered iodine-iodide solutions (as in Iodine Tincture (2%) U.S.P. and Iodine Solution (2%) N.F.), inasmuch as the unbuffered solutions after dilution to the suitable free iodine content and admixed with material during cleansing tend to become alkaline. The effective concentrations of the acid-buffered iodine-iodide solutions used in practical sanitization procedures are approximately identical to the concentrations used for the available marketed iodophors used as sanitizers. These are usually dilutions for immediate use yielding from 25 to 75 p.p.m. of free iodine, the exact concentration depending upon the specific practical application. However even lower concentrations, as low as 10 to 12.5 p.p.m. may be effective under certain conditions of immediate use. On the other hand, if one intends to prepare a solution of free iodine to be used over a prolonged period of time during a working day, at least two to three times the concentration indicated above should be used, for the assurance of greater safety. As indicated previously, the United States Public Health Service, Health Departments and sanitarians all over the country have approved these iodine preparations for the sanitation of utensils between each usage

FORM OF IODINE

Recently, greater attention has been focused upon the kind or form of iodine present in aqueous solutions. The following variety of chemical forms may exist when iodine is dissolved in water: I_2, I_3^-, I^-, HIO, IO^- and IO_3^-. It now appears that each of these entities may possess different characteristics as to biocidal and even therapeutic properties. Data have been presented revealing that the biocidal property of such iodine solutions are due mainly to the activity of diatomic iodine (I_2). The biocidal activity of triatomic iodine (I_3^-) is almost nil. The biocidal effectiveness of HIO is difficult to evaluate as it is unstable, fleeting and generally present only in minimal amounts. It is possible that in the future, preparations of iodine intended for making aqueous solutions where the biocidal properties are desired will be formulated so that the diatomic iodine (I_2) will predominate. Since the various forms of iodine indicated above which may be present in aqueous solutions are difficult or impossible to distinguish titrimetrically and require a spectrophotometric analysis, the latter may be the method of choice for determining quantitatively the forms of iodine and especially the amount of diatomic iodine (I_2) present.

SUMMARY

A brief consideration is presented indicating the need for sanitarians to be trained so that they have a knowledge of all environmental influences as they affect health and well-being. Furthermore, it is important that cooperative action exist between health worker, lay worker and an informed and enlightened lay public, all to work together to encourage better environmental sanitation.

Acknowledgment of the meanings of various terms employed in sanitization procedures as they reflect present-day usage is needed by sanitarians. These definitions are herein presented.

The employment of suitable effective chemical solutions as a final step and an additional safeguard in the practice of sound sanitation is stressed. Among the more important chemicals employed in sanitization procedures, solutions of free iodine and iodine-liberating compounds play a leading role. They are highly effective as biocidal agents. Descriptions and many of the useful properties of iodophors and free iodine solutions used as sanitizers or sanitizer-detergents in sanitization procedures are given. Even the color of such solutions serves as a useful "tell-tale" or "built-in" indicator as to the potency or efficiency of the sanitizing solution.

Acid-buffered iodine-iodide solutions and available marketed preparations of iodophors are effective as sanitizing agents in concentrations from 25 to 75 p.p.m. of free iodine and even concentrations as low as 10 to 12.5 p.p.m., the exact concentration depending upon the specific practical application. If the solution is to be used over a prolonged period of time during a working day, from two to three times this concentration should be employed for the assurance of greater safety. The 25 p.p.m. free iodine concentration in the above is equivalent to at least 200 p.p.m. available chlorine concentration (diluted hypochlorite).

Attention also is directed to the fact that in the future, formulation for the preparation of free iodine solutions may be prepared to determine the I_2 (diatomic iodine) content, as this form of iodine appears to possess the greatest biocidal activity.

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