UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
NATIONAL BUREAU OF STANDARDS • E. U. Condon, *Director*

Control of Odors

by Elmer R. Weaver

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Preface

The ability to smell is one of the traditional five senses on which we depend for all knowledge of our environment. Of the five it is the one that tells us most about the chemical nature of the things we encounter. Directly, of course, it tells us only what is in the air we breathe, but because a vast number of things are slightly volatile they betray their presence and character by odor. The importance of this is not always fully appreciated. It contributes to our pleasure, our health, and our safety in innumerable ways of which we are not ordinarily conscious unless our attention is directly called to them.

Some of the information acquired through our ability to smell is of a pleasant nature and some is unpleasant. As in other matters, we are inclined to take the pleasant for granted and give most attention to what we do not like. In consequence, we are always trying to get rid of bad odors rather than of the conditions that the bad odors indicate; and we are prone to feel that we have accomplished our purpose when the odor is no longer perceived, although the change often results from a reduction of our ability to detect any odor rather than from an effect on the odor itself.

The National Bureau of Standards receives many requests for information or advice regarding odors, especially their elimination by the use of "deodorants", atmospheric "fresheners", and the like, terms used for many widely different products used in numerous ways. The Bureau is not in position to discuss the merits of individual proprietary products of this kind, but there is no reason why we should not discuss the properties of well-known substances such as ozone, sassafras oil, and chlorophyll.

This Circular is intended to present general information that will be of practical use in the control of industrial and household odors. The discussion of industrial odors is limited to means for preventing a nuisance to the neighborhood. Nothing is said about the professional perfumer's job of making articles smell good nor about personal deodorants, which are properly to be considered in the field of medicine. Some of the information given may be useful in hospitals and in places of entertainment or business.

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I. Introduction

Beyond question, the most important method of gas analysis ever employed is the sense of smell. One compact, but amazingly intricate, apparatus for the purpose is possessed by every human being. Although smelling has important limitations, chief of which is that it is never quantitative, it has many advantages over other means of analysis. The apparatus is nearly always in position to obtain the sample of greatest immediate interest to the analyst, sampling is automatic, and the analysis is made and the results reported almost instantly. No other method of analysis is capable of distinguishing between and correctly reporting so large a variety of chemical substances by a single operation; and only modern electronic devices for the investigation of radioactivity can detect such minute quantities of the class of materials to which they are most sensitive. Many of the more powerful odors can be smelled even by the relatively insensitive human nose in amounts that are only a small fraction of the amount that can be identified by other means. We can only marvel at the keenness of smell of some insects or the discrimination of a dog who follows his master's footsteps along sidewalks traversed by hundreds of people.

The frequency with which tests are made by this method must be several million times as great as the frequency of analyses by all other methods combined. It is literally true that every breath we draw and the vapor from every mouthful of food we eat are given a qualitative test for a myriad of things. The fact that nothing of interest is usually reported should not make the service unimpressive.

Anything that can be detected by the sense of smell is called an odor. The National Bureau of Standards is called on to answer a large number and variety of questions relating to odors, and particularly to the elimination or control of those we prefer not to have reported by our ever-alert analytical sense. Many questions are outside the range of the Bureau's work and the knowledge of its personnel. Others are fairly simple and are as appropriate subjects of study as those relating to less important methods of gas analysis, or to the light and sound that affect different human senses. It is the purpose of this Circular to give information that will be useful to those who have common problems of the types most frequently brought to the Bureau's attention.

Probably the most important of these, and certainly those to which much attention was first given, have had to do with the satisfactory ventilation of public buildings, such as offices, schools, hospitals, and libraries. But the most numerous questions deal with undesired odors inside homes and restaurants and outside of factories, and have been so individual in character that it is impossible to give more than general principles that will promote an understanding that will help readers in the solution of their often difficult and unique problems.

II. The Sense of Smell and the Nature of Odors

The perception of odor has never been fully explained, or at least no one explanation has been universally accepted [1].[1] It is known that an odor is perceived by human beings only when some substance capable of exciting the nerves reaches the specialized tissues of the olfactory tract and dissolves in the film of liquid covering or constituting their exposed surfaces. What property of

[1] Figures in brackets indicate the literature references at the end of this paper.

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the dissolved substance causes the nerves to transmit a characteristic sensation to the brain is one of the unsettled questions. It is not certain whether it is a chemical reaction or is the result of vibrations within the molecules or parts of molecules such as give rise to spectral absorption and radiation of energy, or whether only some concept less familiar than either radiation or chemical reaction can be the basis of a satisfactory explanation. It is certain that the sensation depends on some of the substance reaching the olfactory tract. It cannot stay at a distance and still be perceived as we perceive objects that are emitting light or sound.[2]

The olfactory tract is so located that ordinarily only gas reaches it. Gas, of course, includes vapor. The sensitive areas are at the closed ends of channels that are readily penetrated only by diffusion, and the diffusion of solid and liquid particles of more than submicroscopic size is almost negligible. Accordingly, characteristic odors are rarely, if ever, produced by a smoke or mist, however fine, of solid or liquid particles except of materials volatile enough to be smelled when only the vapor comes from massive forms of them.

Practically, then, an odor is always a gas mixed with air, usually in small amount; but many gases have no odor. A substance may therefore be odorless either because it is not appreciably volatile or because it does not have the specific property, which we cannot otherwise define, of exciting sensation in the nerves of the olfactory tract when it reaches that tract. In spite of the fact that odors are gases, the usual problem that must be solved when unpleasant odors are encountered is not, as commonly supposed, to find something that will "destroy the odor" by chemical action or otherwise. The change of air even in a poorly ventilated room is sufficiently rapid that anything present as odor and not renewed, for example, ammonia, is quickly removed and presents no difficulty. What we are practically most concerned with are solid or liquid materials which, either because they are undergoing chemical changes or are evaporating, are the sources of odor. Sometimes they have been deposited from the air on walls or furnishings, but with the exception of tobacco smoke this is relatively rare. The principal factor in the control of odors is the removal of these liquid or solid sources, and in a real sense the most important deodorant for domestic or personal use is soap and water. The odor problems of industrial plants sometimes involve lack of cleanness, but more often they result from some process in which unpleasant-smelling vapors are unavoidably added to air, and the control and ultimate disposal of the odor-contaminated air is the principal factor to be considered.

[2] In experiments conducted by Miles and Beck [37, 38], insects were attracted to one or the other of two objects under conditions that "support the interpretation that the behavioral difference is due to increased heat losses from the insects' antennae." This has led to an outline of a theory of odor based on radiation, but any significance of the observations in relation to the sense of smell among mammals is far from clear.

III. Industrial Odor Control

With industrial odors will be included those produced in the public disposal of garbage and waste. There are several possible solutions to the problem of preventing or disposing of an industrial odor without nuisance to the community in which the plant is located. Roughly, they may be described as confinement, dispersal, incineration, adsorption, and solution, or combinations of these. For odorous dusts and mists, electrical precipitation or centrifugal separation, with or without the condensation of added steam, is often useful.

The first step is usually to make the building fairly tight and to provide fans that will produce a slight vacuum inside the building so that air enters at all accidental or momentary openings and goes out at only one opening. Usually a large volume of fresh air is provided for the comfort of the workers within the building, and the requirement of sufficient tightness is not difficult to meet; but in extreme cases it may be best to use windowless buildings with only artificial light, to cover walls as well as roofs with soldered metal sheets, and to provide entrance and exit, particularly for freight cars and trucks, through double-doored "locks", of which only one door is to be opened at a time. The second step is to confine the odor as much as practicable within definite channels in the plant itself by inclosing the equipment within which the odor principally originates and arranging ventilation so that air-flow is again outward at one point and inward at all others. When the odor has been confined to a single air stream, it is disposed of by dispersal, burning, or adsorption (sometimes by precipitation, solution, or chemical action).

In general, it is desirable to keep the volume of air passing through the odor-evolving equipment as small as possible without letting it outside the intended channels or interfering with necessary operations, such as the supply and removal of the products treated. If the process involves cooking or drying, it may be practicable to limit the confined atmosphere mostly to water vapor and to condense it with much of the odor before disposing of the remaining air.

The surest method of disposal of the odor in the foul air is to pass the air through a flame. If the air can be used as primary air (mixed in advance of combustion with the fuel) with gas or oil in a boiler or furnace, organic odors are destroyed completely and without difficulty. Only less certain is combustion by passing the air through a

bed of glowing coal. It is ordinarily too expensive to supply fuel for this purpose only, and in case the volume of contaminated air is greater than can be passed through the flame of fuel used for other purposes, it is necessary either to concentrate the odor still further or to depend on dispersing it by discharging to the upper air through a stack.

Except in a few cases, the most practicable method of concentrating the odor is by adsorption, usually by means of activated carbon. A good grade of activated carbon adsorbs most of the organic vapors, which comprise the worst odors, without difficulty. It is necessary only to force the air through a bed of the fresh adsorbent thick enough to insure intimate contact between the solid and all of the air. The material constituting the odor is not destroyed by this process, however, but is held in the porous solid much as water is held in a sponge, and the adsorbent soon approaches saturation with the odor at its entering concentration and is no longer effective. The adsorbed odor must then be driven off by heating the carbon and is obtained in concentrated form which can be burned without too much trouble. The "reactivated" carbon can then be used again. A continuous system is advantageous in which the fresh carbon and the air to be purified move in countercurrent flow in one part of the system, and the fouled carbon and a little air or steam move similarly in the heated zone of another part of the system.

When for any reason it is not found practicable to remove the odor from the air that must necessarily be discharged from the plant, the polluted air should be greatly diluted and discharged through as high a stack and at as high a temperature as practicable. If the air can be discharged at high velocity, it may flow upward as a fairly compact stream in still air to a height several times that of the chimney; and if it is hot and particularly if it is mixed with steam, which is lighter than air, it will continue to float upward after its initial momentum has been lost. In windy weather the odor is not likely to cause much trouble anyway.

The incineration of waste materials presents a great deal of difficulty, principally because, with simple arrangements for combustion, the material to be burned is heated gradually as it approaches the zone of combustion and all sorts of distillates and products of decomposition are driven off without reaching the temperature of ignition with the air. Probably in general the best treatment is preliminary drying by heating in a rotary dryer to a temperature above the boiling point of water, followed by the incineration of the dry residues, with or without added fuel. Incineration should take place under such conditions that the volatile products formed during preliminary heating must pass through the zone of active combustion. This is usually most easily accomplished in a downdraft furnace. Vapors from the preliminary drying should be condensed so far as practicable and uncondensed gases treated as already described.

In spite of the difficulties of incineration, the process is second in importance only to cleansing as a method of deodorization, which must always be kept in mind as means of getting rid of sources from which odors emanate. Without incineration it would be almost impossible to maintain a tolerable atmosphere in any large city.

It may be said in summary that the most important general feature for the control of industrial odors is the combination of an inside ventilating system within which odors are conveyed for disposal with a minimum of air and an outer ventilating system in which a large volume of air is used to keep working areas of the plant tolerable, and to dilute whatever odors remain after treatment in the inner system before discharging them to the outer atmosphere.

IV. Control of Odors in Households and Places of Business

1. The General Problem

The problems of control of odors in homes and places of business differ from those of industrial odors in many ways. They usually involve only slight odors within the walls of a few occupied rooms, but the complete elimination of unpleasant scents is always sought. These come from many sources, often at unexpected times, and their control cannot be planned in advance as in the case of an odor continuously produced from a single well-known source. Cleansing and the intelligent use of ventilation are principal elements of control in all cases, but the destruction of household odors either by burning or by chemical action is usually both impracticable and unnecessary. In the household, the use of adsorbents is also usually impracticable.

Restaurants, offices, stores, and places of amusement have odor problems of much the same variety and character as homes, and what is said of one can generally be applied to the others.

It is not possible to list all the sources of unpleasant household odors. They include tobacco smoke and partially burned tobacco; leather; rubber; some woolen fabrics; and a variety of plastics brought in as furnishings; fecal material from mice or pets; dead animals; sweat in unwashed garments; cleansing agents in washed ones; paint and some lubricants; material charred in some pre-

vious fire; food being prepared for the table; decaying food in storage or dropped on rugs or porous floors; food spilled in ovens or on burners and repeatedly heated; and food, particularly fat, that has been vaporized during cooking and condensed on walls and furnishings; mildew and decay of building and furnishings; and such things as naphthalene, coal tar, Lysol, and creosote used to prevent damage by insects, water, or decay. Trouble is caused not so much by volatile substances initially present in food, sweat, and animal excrement as by those produced later by the action of bacteria and mold.

The best solution of an odor problem is to find the material that is the source of the odor and remove it, if possible. When we cannot remove it, we can sometimes prevent its decay or change the rate of decay enough to make the condition tolerable. Since neither bacteria nor molds grow in very dry material, this can often be accomplished by drying out the contaminated area and stopping leaks or applying waterproofing to keep it dry. Hypochlorites, particularly in the form of "chloride of lime", have been used for generations, partially as cleansing agents but mainly as germicides, and have been considered important "deodorants." Sodium hypochlorite solutions are now more used than chloride of lime and are probably better. A class of compounds relatively new in commerce, the quaternary ammonium compounds, has value both as a detergent (cleansing agent), for which it is rather expensive, and for preventing the growth of bacteria and fungi. These compounds are almost nonvolatile and are not poisonous to human beings even in rather large quantities. The traditional unpleasant moth preventives, naphthalene and para-dichlorobenzene, can be replaced by a more effective and much less odorous spray of DDT or similar insecticide.

Next to cleaning up the sources of odor, the most attention should be given to ventilation. In most houses the sources of unpleasant odors are localized, for example, in the kitchen, bathroom, or a freshly painted bedroom. They may not even be considered objectionable in the room of their origin, but we do not like them throughout the house. Usually it is not difficult to limit the range of odors by controlling the direction of air-flow. Although exhaust fans are often installed in kitchens, even this may not be necessary. Always in the winter in a heated house and usually in the summer, air inside the building is warmer than outside. Air will enter at the lowest opening and leave at the highest, unless interfered with. The entry of air is usually largely under doors and through floor cracks. It may only be necessary to make kitchen and bathroom floors tight, to use impermeable floor coverings, and to open the windows a little at the top to insure that air will practically always flow into these rooms from the rest of the house, not in the reverse direction.

If we fail to remove the sources of odor, we often can cover them up successfully. Dead animals are buried in shallow graves that are far from airtight but are adequate, unless a dog with a sense of smell much keener than ours decides to investigate. Often the odors from old floors and walls can be confined by the use of tight floor coverings, new wall paper, or paint. Even a rat's nest in a wall may be made inoffensive by calking openings and painting or recovering porous plaster as in outdoor waterproofing. The covering up of sources of stench is not always successful and should be resorted to only when their removal is impracticable. In a building where fire has deeply scorched the woodwork or where casein paint is putrefying on a damp wall, repainting may not help much. Paint is very thin and is permeable to the tarry materials of partial combustion. Casein paint that cannot be kept dry should be removed by scrubbing with an alkaline solution, preferably ammonia.

Why not destroy household odors by incinerating them, say by a constantly burning candle flame? The reason is that it takes too long for any large part of the air of a room, with the odor it carries, to pass through, or "come into contact with," the flame. From a knowledge of what takes place in a flame and of the composition and weight of candle-wax burned, we can compute accurately the quantity of air that passes through the luminous surface of the flame. We find that if as many as 100 ordinary candles were burning in a living room of average size, 16 by 20, a volume of air equal to the volume of the room would pass through the flames in about 12 hours. But our homes are not tight; we do not want them to be. There is a continuous flow of air through all our rooms at all hours of the day and night, even if the doors and windows are closed. An average closed room has at least 20 changes of air during 12 hours.

Now, it is a well-established fact that the human nose is not sensitive to a change in the concentration of odor as small as one part in twenty. The limit is more nearly one in three. Then, since even 100 candle flames would not remove as much as one-twentieth of the amount of any constituent carried away by normal ventilation, it is certain that the odor removed by the flames would have *no* detectable effect on the odor in a room of ordinary construction. We are dependent entirely on ventilation for the renovation of the place.

This necessary conclusion is not limited to flames. We are frequently told that this contrivance or that will remove or destroy odors. But a candle flame is the center and cause of vigorous air movement, and it offers no obstruction to the flow of air right through its surface. In contrast.

a solid or liquid surface, even in a breeze, is surrounded by a nearly stationary layer of air through which molecules can reach the surface only by the slow process called diffusion. The difference from a flame is fairly comparable to the difference between the rate of passage of smoke through an electric fan with the current off and on. Insofar as the supposed action of a proposed deodorizer depends on an odor reaching its surface, it can do no more than destroy each molecule of odor that reaches it, and unless the active surface is several times larger than the combined luminous surface of a hundred candle flames, it is useless in comparison with the removal of odor by normal ventilation.

2. Adsorbents and the Control of Odors in Refrigeration

Actually, the activated carbon discussed in the section on industrial odors can do substantially what was assumed for discussion in the preceding paragraph; that is, when fresh, it removes from the air nearly every molecule of odor that reaches its surface, but it is impracticable to expose enough surface to do much good unless the air is forcibly circulated through a bed of carbon of considerable depth. Acting like a wet sponge, which, even after being well squeezed, will dampen dryer materials, the carbon does not adsorb much odor before it becomes a source of odor to air more nearly odor-free than that with which it was last in contact, and it must be "reactivated." Accordingly, it has been found more expensive to use it than to obtain equally good results by the circulation of fresh air, even under the unusually favorable circumstances presented by air-conditioned railroad cars. There the source of odors is concentrated in the smoking rooms, small volumes are involved, mechancial equipment for circulating the air is required anyway, additional power for its operation is almost a byproduct, and the routine reactivation of the carbon at terminals should present a minimum of difficulty. It seems certain that adsorption will never be of much value for deodorizing living spaces except where, as in submarines, adequate ventilation with outdoor air is impossible.

At intervals for at least 30 years, activated carbon has been sold, usually from door to door, for the control of odors in refrigerators. The object of the device is primarily to prevent the transfer of odor from one material, say, a fish, to another, say, butter. The odor of the fish cannot get into the carbon unless it is first present in the air, and while it is in the air some of it gets into the butter; hence, the deodorizer is only partially effective at best. If no "deodorizer" is in the refrigerator, the fish can be removed and fresh butter put on the shelves will remain fresh. But because the action of an adsorbent is merely to store odors, not to destroy them, any adsorbent present before the fish was removed becomes an odorizer afterward, and there is no such thing as keeping butter fresh in the refrigerator while it remains. Just so, there is no comfort in retaining a wet towel after a bath, and a towel becomes entirely useless after an application or two unless it is dried in the meantime. Of course it is possible to dry out a towel or to drive off accumulated odorous material from an adsorbent by heating it in the oven; but because of its porous structure the carbon takes long to become heated through and produces a concentrated stench while doing so. Fresh carbon is much too expensive to be used only once. It is not surprising that in spite of its long availability carbon has not become popular for this purpose.

Clay has the ability to adsorb vapors to a much smaller extent than activated carbon and is subject to the same limitations, but it has been offered for sale, sometimes in chips retaining its natural stratification. Tests at this Bureau and at the National Naval Medical Center [2] of similar but not identical mineral products of this type have shown them to be almost entirely useless.

For household refrigerators the practical means of preventing the transfer of odors is by inclosing each food in a substantially tight container. Fortunately, an abundance of excellent and inexpensive products for this purpose is available. Among them are glass, metal, and plastic dishes with well-fitting lids, plastic bags that are especially useful for melons and some vegetables, aluminum foil, and paraffin paper.

3. Air-Borne Deodorants

When we have done what we can to eliminate the sources of odors and to remove the odors themselves by ventilation, some disagreeable scents may remain. It is common practice to add something to the atmosphere of the house to make these odors less noticeable or less objectionable. The gases or volatile substances used for the purpose are commonly referred to as deodorants, particularly if they are a little on the unpleasant side themselves. Otherwise, they may be called perfumes. If they are liberated from solid materials by burning, they are called incense. With a few exceptions that are unimportant because they rarely involve unpleasant household odors, the use of volatile deodorants does not result in the presence of less odor in the air. Usually it results in more, because the deodorants themselves have odors. But the volatile deodorants do affect our ability to smell or at least to identify the unwanted odors. It will be convenient to classify the volatile deodorants as (A) substances that tend to produce insensibility of the olfactory tract, and (B) substances which themselves have odors that more or less completely "mask" other odors in the sense that they render them less noticeable. Put in terms of the introduction, substances of class A make our analytical

apparatus inoperative; those of class B merely affect our interpretation of the results of analysis. Materials of class A can be subdivided into anesthetics and irritants, of which the first produces insensibility only during the time the agent is present in the nasal tissues, whereas the second causes much more lasting physiological changes, particularly inflammation and exudation [3].

Perhaps the simplest method used in studying odors is to put small quantities of the materials from which they are evolved into dishes, place them in front of an electric fan, and move them toward an observer until he is able to detect or identify each scent. The distance at which this occurs is a measure of the apparent strength of the odor. By the use of various combinations of odors and volatile "deodorants," the effect of one material on the perception of another is easily observed.

The classification of the deodorant can be simply determined from the record of distances at which other odors are identified during a long exposure of the observer to the deodorant. With a simple "masking agent," other scents are as hard to identify immediately after the deodorant is introduced into the air as after it has been smelled for hours. In fact, the tendency is for the effect of a masking odor to diminish and at last to disappear entirely as we become accustomed to it. As soon as the masking odor is removed from the air stream our sensitivity to other odors returns to normal; we smell them just as well as before the masking substance was introduced, unless they are very much like it.

With an anesthetic the record is entirely different. When it is first encountered it has little or no effect on the perception of other odors. After 10 or 15 minutes of exposure the distances at which other scents can be recognized begin to shorten, and if enough tests are made their average shows a regular change (a "smooth curve" in the technician's dialect). If the concentration to which the observer is exposed is high, the anesthetic may be removed from the air stream after 15 or 20 minutes, but the ability to smell continues to decrease, perhaps for an hour, presumably because the anesthetic already dissolved in the outer tissues of the olfactory tract is gradually diffusing to the more deeply seated nerve centers. But usually within an hour recovery begins; and an hour or two later the perception of odor is again normal.

Irritants, of which ozone and chlorine are typical examples, differ from anesthetics much as they do from simple masking agents. In a concentration that can be safely tolerated for even a few hours, neither ozone nor chlorine has more than a barely detectable immediate (masking) effect. The loss of ability to perceive odors begins to be noticeable only after a half hour or more; but even if exposure to the deodorant is discontinued, it is several hours before the maximum effect is reached. The effect continues thereafter for days. It has been compared by physiologists to sunburn, which may go unnoticed during actual exposure but the effects of which develop and subside with painful slowness.

4. Ozone [3 to 32]

The lasting effect of an irritant has also been compared to that of a scab formed by a burn on the hand. Just as the scab desensitizes the area it covers to the perception of touch or temperature, the effect of irritants and particularly of ozone, the irritant most frequently used for deodorization, is to desensitize the organ of scent. The effect requires several hours to develop fully and may last for weeks.

The author believes this to be the only effect of consequence. A tolerable amount of ozone has very little anesthetic effect and almost no masking effect, although there is some disagreement on this point. Some investigators have reported that the introduction of ozone into a room inadequately ventilated for the number of occupants in it makes the air seem fresher [29]; others have found that at least to those just entering the room the air seems worse [9].

Ozone in even small concentrations is a dangerous substance. H. B. McDonnell of the University of Maryland [21], who has made the most extensive of the American investigations of its effects, reported that continuous exposure to one part per million of air shortens the lives of guinea pigs. Correspondingly, thorough British investigators, Hill and Flack [17], found that an exposure of 2 hours to as little as ten parts per million might result fatally to larger animals. More recently, different groups of physiologists have set one part in ten million, one in twenty-five million, and one in forty million as the maximum to which human beings should be exposed. This Bureau has gone to considerable trouble and expense to eliminate ozone, produced by laboratory equipment, from its buildings; and complaints from personnel that removal was not complete have occurred when only about one part in thirty million could be found by analysis. In contrast, three thousand times that concentration of carbon monoxide, which we are likely to think of first when a poisonous gas is mentioned, would have attracted no attention and done no harm.

Nearly 20 years ago Russian experimenters announced that certain ionized substances imparted desirable properties to the air. This was taken up and exploited in Germany, where anything with a "scientific" sounding description found the same ready market as in this country; but it was soon shown conclusively by L. B. Loeb of the University of California [33] and others in both America and Europe that ions as such could have none of the effects ascribed to them, and that the effects, if they existed at all, must be attributed to

the chemical nature of the materials, such as magnesium oxide dust used in the original experiments, to which the electric charges were attached. Two or three attempts were made to sell "ionizers" in the United States during the thirties, but they seem to have been unsuccessful. At the end of the war, however, a report was given wide circulation that the old Russian idea of the benefits of ions was a German wartime discovery that had been used with great benefit. This was sufficient to revive the sale of "ionizers" in this country. So far as they are capable of affecting odors or their perception, they are believed to be simply ozone generators of unknown capacity.

The disagreeable effects of mild exposure to ozone and the danger of severe exposures have been recorded from time to time for 70 years. Then why has it been employed as a deodorant of occupied spaces intermittently but extensively for 50 years? The writer believes that people who were conscious of mild but persistent bad odors in their usual surroundings found that after a day or two of exposure to a low concentration of ozone in the atmosphere they no longer noticed the familiar scents and thought they no longer existed. The observers had simply lost their awareness of odor and were unable to smell much of anything. Having no standard by which to judge this except their regular impressions of their disagreeable surroundings, they did not realize that the change was in themselves. If they noticed such effects as headaches and burning eyes, they probably ascribed them to hay fever or colds in the head. They almost certainly would not have attributed to ozone breathed on Friday the fact that the steak seemed "tasteless" on Sunday.

Probably the most important contribution of the sense of smell to our daily lives is the enjoyment of flavors. In the sense in which it is commonly used, a flavor is merely the odor of something that has been taken into the mouth,[3] and much of the pleasure of eating depends on the perception of delicate flavors, which is to say, on the ability to smell faint odors. How often do we hear people lament that peas or apples or maple syrup no longer have the flavor of former years. Actually food flavors cannot have changed greatly, but most people lose their native keenness of smell and, correspondingly, their perception of flavor just as, but to a greater extent than, they lose some of their ability to see and hear. It is generally agreed that the pleasure derived from eating, including the enjoyment of flavor, is an important element in the digestive process. When we sacrifice our olfactory sense, the comfort and health of good digestion may be affected at the same time.

Although the enjoyment of food is probably the greatest benefit derived from a normal sense of smell, it is by no means the only one. The sense is a protection from fire (we detect smoke, overheated materials, and escaping fuel), from asphyxiation (when we notice gases from house-heating equipment, refrigerating units, or automobile engines), and from food poisoning (when we detect decayed, soured, or molded food before it is eaten). It aids the housekeeper in her work by telling when things being baked, boiled, or toasted are done and when they are dry and likely to scorch. It tells when the laundry iron is too hot, and when the baby should be changed. It warns of needed ventilation, of decaying organic materials that should be removed, and of mildew and rot attacking clothing and building structures. It serves notice when the automobile clutch slips and the antifreeze is boiling away. It gives pleasure in gardens, woods, and fields, and contributes materially to the enjoyment of our vacations and to the interest of our daily lives. It is a social monitor that warns when our homes, our persons, or our clothing will make an unpleasant impression on others who can smell. If our noses are as keen as theirs, we will not have to depend for happy endings on the candid friend of so many advertisements. Certainly a great number of lives have been saved by the sense of smell, and to do anything that will impair it, even temporarily, is to risk an unnecessary hazard to life and health.

Among things less frequently introduced into air in connection with deodorization than is ozone, chlorine is primarily an irritant but has some masking effect; ammonia is an irritant with more masking ability; formaldehyde is both irritant and anesthetic; and turpentine combines considerable masking effect with anesthetic properties and produces only slight irritation.

Before leaving the subject of anesthetics and irritants, the following numbered statements will be made to summarize the experience of this Bureau and the information available to us from other sources.

1. A "deodorant" in the sense of something added to the air that affects our perception of other odors is either a masking agent, an anesthetic, or an irritant, or it combines the three properties in various ways.

2. Anesthetics and irritants affect the perception of pleasant odors as much as they do unpleasant ones. To the extent that anything destroys all unpleasant odors, it destroys all odors, including all flavors.

3. Probably the principal purpose of "deodorizing" a household or a place of business is to avoid giving offense to guests or customers. This is not accomplished by any air-borne deodorant except

[3] The term "flavor" is sometimes used to indicate the general sensory effect of something taken into the mouth, including taste and touch. To make the distinction clear, suppose we make solutions of sugar, cream of tartar, table salt, and baking soda and add to each a drop of oil of cloves. Under the first definition four solutions would have the same flavor; under the second they would not.

a masking agent, because the actions of both anesthetics and irritants are so delayed that they affect the perception of other odors scarcely at all during the first 5 or 10 minutes of exposure to them. But it is when we first enter the atmosphere of a room that our impressions of its odors are formed. We soon become unconscious of them unless they are particularly strong or are changing in strength.

5. "Odorless Deodorants"

A new class of "deodorants," not included in the preceding description, is used only in the form of sprays and, although the solutions may be perfumed, the principal action is apparently not entirely dependent on masking with another odor; hence these sprays are referred to as "odorless deodorants." Only one such preparation has been experimented with at this Bureau. It consists of a strongly perfumed oily solution of a chemical that has the property of causing the oil to spread over a moist surface. The solution is "atomized" into a very fine mist, the breathing of which almost instantly reduces the ability to smell by a large factor. It is probable that the action results from the formation of a film of oil over the olfactory tract. The combination of this action with the masking odor of the perfume causes the immediate disappearance, to the observer who inhaled the vapor, of weak odors initially present. Only the perfume of the deodorant is perceived thereafter. In the case of the one deodorant tested at this Bureau, the effect disappeared almost entirely in 15 or 20 minutes; and although there appeared to be a little irritation from repeated exposures to the spray, the effect was so slight that it could not be said with certainty to exist.

Receptacles that had contained fish or cigarette ashes were emptied but not washed and were then well sprayed with the deodorant. Although the amount of spray introduced per unit of volume was more than one thousand times that recommended for the deodorization of a room, both the fish and the tobacco odors could be subsequently identified. The decided diminution in their apparent strength seemed at first to justify the claim that the original odors had been destroyed by chemical action, but they were present again seemingly in their initial strength before the perfume of the deodorant had disappeared. A few crystals of menthol, the principal constituent of peppermint flavor, were then placed in each container, an amount of air not more than equivalent to the blast of gas used to produce the spray swept out most of the air, and the odors were again observed over a period of time. The menthol was found to be quite as effective as the commercial deodorant when used under conditions such that the mist is not directly inhaled by the observer.

Of course it is possible to determine whether the effect of the deodorant in a room is primarily on the odor or the observer by first noting carefully the character and intensity of odor in one room, going into another room to inhale the spray, and returning to the first room. The result can be checked by observing the odor in a room, letting someone else spray the room and, a few minutes later after the mist has settled or drifted away, returning to the room to see whether the original odor seems to have changed.

From such simple experiments it was concluded that, except for the masking effect of residual perfume, the deodorant is effective only for the person who has inhaled the mist. If one wishes to disguise the odors of a room from a guest or customer by this means, it is only necessary to spray him generously as he enters the door; but such a gracious gesture of hospitality might be misinterpreted if the visitor should mistake the deodorant for an insecticide.

6. Masking Odors and Their Uses

The application of masking odors would be more properly called counter-odorization than deodorization, since it usually results in the perception of more pleasant odors and frequently of stronger ones, not in the complete disappearance of odors. A large number of physiological and psychological effects are involved in the group of phenomena here referred to as "masking". Among perfumers and others professionally concerned with odors, some of these effects are differentiated and given various names to which precisely the same meanings are not attached by all observers. The phenomena themselves are hard to describe and correspondingly vague. One of them, about which much has been written, is referred to as the "cancellation" of odors, meaning that two odors when mixed in precisely the right proportion "remove all trace of one another". This phenomenon may be of value to the perfumer, who works to make acceptable a single malodorous object, but it is not an effect commonly encountered in everyday life. The writer of this circular, for example, has never experienced the effect of complete cancellation, although he has several times tried to observe it with odors alleged to cancel one another. In several cases, combinations have been observed that seemed to have less odor than either of the components, but in no case has a notable effect of this kind involved any of the commonly troublesome household odors except that of fuel gas, which we do not want to disguise. For the control of such odors, cancellation is of little use.

There are four facts of primary importance in connection with this subject: that weak odors are not perceived in the presence of strong ones; that sometimes odors of the same strength blend to

produce a combination in which one or both of the components is unrecognizable; that in the presence of odors of constant intensity we rather quickly lose awareness of any odor at all; and that our liking and dislike for an odor depends largely on association of the scent with pleasant or unpleasant experiences and impressions of the past.

The latter point is well illustrated by the answers of a group of people asked to name, among a variety of scents, those which they thought added "a desirable freshness" to the air. One man chose, of all things, smoked herring. A woman, in the same test, chose creosote. It developed that the man had spent every summer of his childhood "playing around smelly fish wharves" and that the woman's early playground had been the yard in which a railroad company treated its ties with creosote. An interesting division of taste occurs in the case of Lysol. To many people it is associated with the snowy linen and polished floors of hospitals and is therefore a peculiarly "clean" smell. To others, including the writer, it is associated with people and places that needed to be disinfected and is exactly opposite in its esthetic effect. As a constituent of soap, it is no more effective in masking the odors of perspiration than are such old favorites as lavender, geraniol, and pine tar, all of which are much preferred to it as individual odors when submitted to the judgment of a fair-sized group of people.

A sense of appropriateness also plays a large part in our reactions to odors. For example, most people like the odor of fried bacon at the breakfast table and that of lavender in soap, but they would not like the aroma of bacon in soap nor lavender with their eggs. The smell of eucalyptus or camphor leaves may be delightful in the open air and not objectionable in a sick room, but because of their association with medicine, they are unacceptable in living and dining rooms. On the other hand, the foliage odors of pine and fir, of many spices, and of the laurels, mints, and sages that are not used in food or medicine are usually pleasant anywhere. Probably the most important aspect of odor "masking" corresponds to the first half of the dictionary definition, "to disguise or cover up." Since our dislike for certain odors is so largely determined by association, the addition to one of them of something that makes an unfamiliar combination breaks the association and makes the odor no longer objectionable. It may be, even, that the unpleasant odor is still clearly recognizable but that the combination has agreeable associations.

An interesting combination of odors is that of smoked fish. It is not hard to identify the product for what it is; both the smoke and the fish odors are distinct enough to cause no confusion. The combined odor is not unpleasant to most people and may be thought appetizing. But if we breathe some wood smoke or even the odor of pine tar for a few minutes until our sense is fatigued with respect to the smoky part of the odor, smoked fish then smells like any other very stale fish and the effect is wholly altered. In this food the smoke has been an effective counter-odorant.

The popularity of highly spiced meat dishes in the Tropics has been explained by the fact that it is almost impossible to keep meat in such a climate without refrigeration, even for a day, without it acquiring a taint that would make it unpalatable except for the masking action of the spices. Indeed, the discovery of America may have been the byproduct of "deodorization" of this kind, for spices had become very popular in Southern Europe, where refrigeration was badly needed but not yet existent; and one of the stronger motives for the voyages of exploration of the fifteenth century was the profit to be obtained from the spice trade. It would seem ridiculous to call garlic a deodorant, but it is the poor man's masking agent for malodorous food in a large part of the world. Wood smoke, cloves, and garlic provide means for making palatable a vast quantity of food that is not fresh, and they are probably the most important "deodorants" of the masking type in the world, even today.

The "deodorization" of persons and of living quarters by similar means is possibly as ancient as the use of spices in food. The personal masking agent is usually called a perfume and may be used chiefly to enable someone to smell a pleasant odor; but certainly it has often been used to enable him to not smell an unpleasant one. The ancients lacked atomizers with rubber bulbs for the convenient spraying of perfumes in living quarters; but someone discovered that certain resins and spices could be combined into a slow-burning stick that dispersed their masking fragrances very effectively. Incense was badly needed in the hot country of its origin, where there was little water and no soap, and domestic animals frequently shared the habitations of their masters. Incense became a possession almost as precious as the allegedly seductive perfumes of present-day cosmetic counters. It acquired a fame greater than that of the part played by spice in the discovery of America when it was included by the Three Wise Men among the gifts of the first Christmas. Myrrh, another gift of the Magi, was likewise an odorant used both as a perfume and a seasoning.

In the limited but somewhat varied experiments that have been made at this Bureau, no new principles were discovered in connection with masking or deodorization. Not only is there no modern miracle, with the exception of the oil spray, there is not even a new trick in the conjurer's bag; for no odor or combination of odors was found that was more effective than those known to our great-grandmothers. Of the scents experimented with, sassafras seemed capable of masking the greatest

number and the most disagreeable of odors, but it has been used for generations with some of the vilest-smelling things used in the household, especially the glues of animal origin. The remarkable thing is that we still like it well enough to use it extensively in foods and beverages.

Even sassafras was not enough more effective as a masking agent than most other scents of the same strength to be outstanding. This is a fact of much importance, for it makes the selection of masking agents a matter of personal preference; it will make little difference, so far as concealing miscellaneous unpleasant odors is concerned, what pleasant one is used. The mingled odors of pine and cedar sawdust was the scent best liked by the greatest number of people among those with which we experimented, and it was satisfactorily effective. But if masking odors are to be used at all as household "deodorants," they should reflect individual tastes and be as varied as possible, for if the same odor is used generally to mask unclean bathrooms, uncovered garbage, unwashed ashtrays, mildew, moth balls, and neglected pets, it will soon acquire the associations that will make it to everybody the odor of bad housekeeping.

An acceptable masking agent should be fairly simple, or at least have a dominant fragrance that will direct attention from the odors that are to be concealed. The characterless stuffy atmosphere of a florist's showcase is a blend of the wonderful fragrances of roses, sweet peas, carnations, stocks, lilacs, and gardenias. What would be the effect of mingling in uniform mixture such delicious aromas as those of browned pork chops, coffee, buttered peas, strawberry jam, celery, peach pie, and vanilla ice cream, with a little pleasantly scented soap? The experiment is tried several million times a day, and the result is always dishwater.

In answer to a question frequently asked, we have no reason whatever to believe that chlorophyl ever has anything to do with deodorization. The chemical reaction, called photosynthesis, by which chlorophyl in sunlight converts the carbon dioxide of the air into plant substance is perhaps the most important in nature. On this reaction all life on the earth has depended for nourishment. It is the ultimate source of all our food and all our fuel. But the known action of chlorophyl on the air is limited to the removal of carbon dioxide and the liberation of oxygen. Carbon dioxide is not only odorless, but the sensation produced in nose and throat by a high concentration is enjoyed and considered refreshing by most people. On this fact the entire carbonated-beverage industry is based. But even if the substance removed from air by chlorophyl were unpleasant, the rate at which it acts would be wholly negligible. When the dry ice is taken from around a pint of ice cream, more carbon dioxide is released in a few minutes than would be removed by a roomful of the most active cholorphyl in a week. In any case, the extent to which a particular lot of chlorophyl has purified the air can be measured exactly by the weight of the new organic material synthesized. When it equals the weight of a matchstick, then the atmosphere has been "freshened" by the removal of just as much carbon dioxide as is produced by burning a match. If your specimen doesn't grow, it is not doing anything to the atmosphere.

V. Control of Odors in Sick Rooms and Hospitals

The control of odors in sick rooms and hospitals, mental hospitals in particular, is a special problem of considerable importance because there is a close connection between the perception of odors and the emotions. Thorough cleansing needs no emphasis, only because it is a part of the routine of every hospital. Arrangements for ventilation that will prevent the mingling of odors from various parts of the building are only less important but much less to be taken for granted. It has been found that a rubber tube introduced under the blankets of a bed and connected to suction—an inexpensive and usually convenient source for which is a jet pump connected to the plumbing system—is effective in controlling much of the odor from diseased patients. An air-flow that does not produce any sensation of a "draft" has been found satisfactory [34]. Counterodorants may be useful but should be chosen with attention to the associations likely to be produced. For example, familiar food odors may be stimulating to a hungry convalescent but extremely distasteful to a patient suffering from nausea.

VI. Sources of Materials

Quaternary ammonium compounds. The quaternary ammonium compounds suggested for trial in preventing decay of putrescible material are not sold, like soaps, under names that identify their chemical character. Most of their several manufacturers give them trade names under which they are sold to makers of solutions or solid cleansing agents, who rename them before they reach the retail market. Therefore those who wish to give them a trial with full knowledge of what they are using should write to the primary producers, either for the materials themselves or the names

under which they are sold. The following list of makers has been compiled from current sources:

Armour and Co., 1335 W. Thirty-first St., Chicago, Ill.
E. F. Drew and Co., 15 E. Twenty-sixth St., New York, N. Y.
Edean Laboratories, 10–20 Pine St., S. Norwalk, Conn.
The Edwal Laboratories, 732 Federal St., Chicago, Ill.
Emulsol Corp., 59 E. Madison St., Chicago, Ill.
Onyx Oil and Chemical Co., 15 Exchange Pl., Jersey City, N. J.
Paragon Testing Laboratories, 345 Henry St., Orange, N. J.
Parke Davis and Co., Jos. Campau Ave., Detroit, Mich.
R. S. A. Corporation, 690 Sawmill River Rd., Ardsley, N. Y.
Rohm and Haas Co., Washington Square, Philadelphia, Pa.
Winthrop-Stearns Inc., 1459 Broadway, New York, N. Y.

Masking agents. The following extensive but incomplete list is intended to represent sources of primary odorous materials rather than blends or products made from them. Probably it will be most useful to those who wish to undertake the solution of their own odor problems rather than to employ professional perfumers. However, many of the concerns listed are prepared to act as consultants or investigators as well as merchants, and probably most of them will advise how their own products can be used with advantage. Numerous formulas for various applications are to be found in the periodical literature [35, 36].

Barclay Chemical Co., 77 Varick St., New York, N. Y.
W. J. Bash and Co., 9 E. Thirty-eighth St., New York, N. Y.
Compagnie Parento, Croton-on-Hudson, N. Y.
Consumers' Import Co., Empire State Bldg., New York, N. Y.
Dodge and Olcott Co., 180 Varick St., New York, N. Y.
P. R. Drayer, Inc., 119 W. Nineteenth St., New York, N. Y.
T. M. Duche and Sons, 117 Hudson St., New York, N. Y.
Fulton Chemical Co., 599 Johnson Ave., Brooklyn, N. Y.
Florasynth Laboratories, 1533 Olmstead Ave., New York, N. Y.
Fritzsche Bros., 76 Ninth Ave., New York, N. Y.
Givaudan-Delawana, Inc., 330 W. Forty-second St., New York, N. Y.
Glogan and Co., 1910 W. Birchwood Ave., Chicago, Ill.
Gunning and Gunning, 601 W. Twenty-sixth St., New York, N. Y.
Jas. B. Homer, Inc., 215 Pearl St., New York, N. Y.
D. W. Hutchinson and Co., 162 Front St., New York, N. Y.
E. L. Laning Co., Irvington, N. J.
Magnus, Maybee and Reynard, 16 Desbrosses St., New York, N. Y.
Chas. Mathieu, Inc., 77 River St., Hoboken, N. J.
Naugatuck Aromatics Div., U. S. Rubber Co., 352 Fourth Ave., New York, N. Y.
New York Aromatics Co., 5 Beekman St., New York, N. Y.
Norda Essential Oils and Chemicals Co., 601 W. Twenty-sixth St., New York, N. Y.
S. B. Penick Co., 50 Church St., New York, N. Y.
Polska Fruital Works, 36 Thirty-fifth St., Long Island City, N. Y.
Robert and Co., 58 Broad St., New York, N. Y.
Roure-Dupont, Inc., 366 Madison Ave., New York, N. Y.
Sherwood Refining Co., Aromatics Div., Englewood, N. J.
Wm. G. Sibbach and Co., Maywood, Ill.
Synfleur Synthetic Laboratories, Monticello, N. Y.
C. Tennant and Co., Empire State Bldg., New York, N. Y.
Ungerer and Co., 161 Sixth Ave., New York, N. Y.
Volkart Bros., 60 Beaver St., New York, N. Y.

VII. References

(Abbreviations of references are those used in Chemical Abstracts, itself abbreciated C. A.)

[1] The present circular is intended for the information of the numerous individuals who are not professionally interested in the use and control of odors and who do not have problems too specialized for a hasty general treatment nor enough at stake to employ professional consultants or even to do much library work. Those who require more than this will find an extensive literature in libraries. Fortunately, there has just been published (1949) an authoritative treatise, "Odors, physiology and control," by Carey P. McCord and W. N. Witheridge, McGraw-Hill Book Co., New York, which not only discusses more fully most of the topics in this circular and many that could not be included, but contains a bibliography of 124 pages. For the present, at least, this bibliography will be available, by purchase or in libraries, to everyone who has sufficient need of it, and its references need not be repeated here. The principal headings and some of the subheadings of the bibliography are as follows:

A. Anatomy of the olfactory system.
B. Physiology of the olfactory sense.
C. Pathology and perversion of odor perception.
D. Body odors.
E. Chemical constitution and odors.
F. Classification of odors.
G. Odor detection, tests, and measurements.
H. Odors of food and water.
I. Industrial odors and general.
J. Perfumes and floral odors.
K. Odor control.
  a. Body deodorants.
  b. Food and oil.
  c. Water.
  d. Industrial and general.
L. Theories of odor stimulation and general treatments.
M. Legal cases involving odor.

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