PHENOL COEFFICIENTS

F. W. TILLEY, M. D.,
Senior Bacteriologist, Biochemic Division,
U. S. Bureau of Animal Industry,
Washington, D. C.

The author states that a phenol coefficient indicates relative germicidal efficiency under laboratory conditions only, and has no practical value. Users of disinfectants ordinarily "follow directions," and employ the dilutions recommended by the manufacturers. This author suggests that we make certain that the recommended dilutions are efficient, and cast aside the coefficient.

THE standardization of disinfectants by means of a carbolic acid coefficient, or phenol coefficient as it is more commonly called nowadays, was originally proposed by Rideal and Walker in 1903. At the time when they published their original article in the *Journal of the Royal Sanitary Institute*[9] a considerable amount of information regarding disinfectants had been made available by the work of many investigators. But the methods used varied so much and so little attention had been paid to establishing standard conditions that it was difficult to compare the results obtained. So, in order to facilitate such comparison, Rideal and Walker devised a method of standardization in which disinfectants are tested alongside of carbolic acid under certain specified conditions, and their relative germicidal values estimated in terms of carbolic acid.

This method was investigated by the Disinfectant Standardization Committee of the Royal Sanitary Institute and in 1906 was recommended by them "for general purposes of standardization."[11] Since then the method has been improved in various ways until now we have the much more exact and accurate method described by Rideal and Walker in 1913 in their article published in the *American Journal of Public Health*.[10]

Although many workers have been able to obtain good results with the R-W method many others, both in England and in this country, have found difficulty in obtaining satisfactory results. Much of this difficulty has been due to failure to observe strictly the standard conditions of the test, and in this country much additional difficulty has been caused by uncertainty in regard to the official standing of the technique described by Partridge[8] in 1907.

On account of the difficulties experienced with the R-W method the Lancet Commissioners devised a method called the Lancet method, which is described in detail in their report published in the Lancet[6] in 1909.

In 1911 Anderson and McClintic, working in this country, brought out a method based on the Lancet method, which they designated the "Hygienic Laboratory" method. This method is described in their original article published in the Journal of Infectious Diseases[1] and also in Hygienic Laboratory Bulletin 82.[2]

The H-L method was investigated by the Disinfectant Standardization Committee of the Laboratory Section of the A. P. H. A. and adopted as an official method, with some modifications made by the Committee. This modified method is described in their report published in the *American Journal of Public Health*[3] in 1912.

The latest phenol coefficient method is that recently devised by another Disinfectant Standardization Committee of the Laboratory Section of the A. P. H. A., the full details of which are given in their report published in July, 1918, in the *American Journal of Public Health*.[4]

The method is based on the H-L method as adopted by the previous A. P. H. A. Committee but a number of modifications have been made. The most important change is the use of an unadjusted culture medium. J. H. Wright made a special study of this matter and the full details of his work are reported in his article published in the *Journal of Bacteriology*.[16] Attention will be given here only to the significance of the change from media adjusted in the usual way to the unadjusted culture medium, as shown by the work of the Committee.

In 1915 a comparative test was made whereby 5 different laboratories undertook to test two special disinfectants by both the R-W and H-L methods, using first the ordinary procedure then in vogue in each laboratory, and second the two methods exactly in accordance with the published technique, using the same strain of typhoid bacillus and the same sample of synthetic phenol for all the laboratories.

In regard to the results, the Committee's report states that the average deviation from the mean with one disinfectant (having a coefficient of about 5), was 10% for the H-L method and 18% for the R-W method, while with the other disinfectant (having a coefficient of about 15) the deviations were 6¼%, for the H-L method and 14% for the R-W method.

As a member of the Committee the writer had occasion to note also the extent of the extreme variations and as these are rather striking they will be mentioned briefly. Using the H-L method with standard technique, the same strain of typhoid bacillus and the same synthetic phenol, coefficients obtained by different laboratories varied from 4.0 and 11.8 respectively, up to 5.4 and 14.8. Using the R-W method in like manner, with standard technique, the same strain of typhoid bacillus and same phenol, one laboratory reported the coefficients of the two disinfectants as 3.3 and 11.00, while another laboratory reported coefficients of 7.0 and 20.0.

In 1916 another comparative test was made, using the R-W and H-L methods with standard technique in all respects, except for the use of the unadjusted culture medium. The difference in results was most marked; the average deviation from the mean in all H-L tests was 6¾% and in all R-W tests 4.6%. The extreme variations of coefficients for the low coefficient disinfectant were from 3.8 to 4.4 by the H-L method and from 3.8 to 4 by the R-W method. For the high coefficient disinfectant the variations were from 12.2 to 14.8 by the H-L method and from 11.1 to 13 by the R-W method.

In view of the results obtained in this second comparative test and the results of Wright's investigations, the Committee adopted the unadjusted culture medium and recommended that its H-ion concentration be determined by the colorimetric method of Clark and Lubs. The most favorable pH is 6.5, but the medium may be used with the pH anywhere between 6.0 and 7.0.

In connection with the Committee's consideration of the results of the second comparative test, Wright called attention to some work which he had been doing which indicated that the really important factor to be considered is not so much the H-ion concentration of the original culture medium as the H-ion concentration of the typhoid cultures used in making the tests. He stated that the coefficient obtained seemed to depend on the length of time the organism had been subjected to any given H-ion concentration. When a typhoid culture is carried along by successive

daily transfers from one broth to another, which is the method followed in all standard methods, the H-ion concentration of the cultures varies with the number of daily transfers that have been made in any particular medium.

Wright found that, for example, with H-L broth having an initial pH of about 5.2 the first one or two daily transfers will show a pH of 4.9 or 5. As the number of transfers is increased the pH increases gradually up to about pH 6.2, after which it remains very constant, this point being reached in from seven to eight days. With Witte's peptone in unadjusted media he found that the pH became uniform in from 4 to 5 days at about pH 6.8 and with Armour's peptone becomes uniform in about 7 to 8 days at approximately pH 7.2. As far as coefficient tests were concerned he stated that the most uniform results were obtained only after the test cultures have been transferred a sufficient number of times to attain the final comparatively uniform H-ion concentration.

The writer has recently made some experiments along this line, the results of which will be mentioned briefly. In the first place, cultures of *B. typhosus* in an unadjusted culture medium made with Armour's peptone if left undisturbed grow steadily more alkaline. For example, in one experiment with four different strains of *B. typhosus* in an unadjusted medium whose pH was 6.7, the pH of the four cultures after three weeks growth was as follows: 9.0, 8.8, 8.8. and 8.3.

On the other hand, where a typhoid culture was carried along in this same culture medium by successive daily transfers, the pH of the cultures after ten transfers remained constant at approximately 7.0.

In another experiment, using an unadjusted culture medium containing more Liebig's extract, the pH of which was 6.3, the pH of four typhoid cultures after 17 successive transfers was as follows: 6.3, 6.1, 6.2 and 6.2. And in a similar experiment with R-W standard broth made with Witte's peptone, the initial pH being 7.3, the pH of the typhoid culture after 14 transfers was 7.1.

In using these cultures in making coefficient tests there were noted perceptible changes in the resistance of the cultures to phenol coincident with changes in the H-ion concentration and uniform resistance when the H-ion concentration remains unchanged.

And now let us ask ourselves "What is the real value of a phenol coefficient as determined under present conditions?" In answer I should say that at the present time a coefficient has no practical value whatever, except as a means of preventing the use of positively worthless preparations and as an aid to the disinfectant manufacturer in maintaining the uniformity of his product.

In the first place, on account of the multiplicity of "standard" methods, any given disinfectant will have as many coefficients as there are methods, and on account of modifications which have been made in the R-W and H-L methods the number of possible coefficients is even greater. The R-W method as now used in England[7] differs from the method as used in this country and the H-L method as now used at the Hygienic Laboratory[14] differs from that described in Bulletin 82. Indeed, lacking any authoritative definition of what "R-W" and "H-L" mean any one is at liberty to use any one of several different forms of these methods and say that the resulting coefficient was obtained by the R-W method, or H-L method.

A much more serious source of trouble is found in the fact that all of these standard methods, except the R-W method now used in England, specify the use of Witte's peptone. As we all know, Witte's peptone is hard to obtain and the English peptone used in the English R-W method is hard to obtain in this country.

But it may be said: "Why use Witte's exclusively? There are lots of other pep-

tones and the exclusive use of Witte's is only a superstition anyhow." In answer to this may be adduced the conclusion reached by Wright[16] who, after examining a number of brands of American peptone found only one that could safely be substituted for Witte's peptone. Furthermore, according to an article appearing in the *Journal of State Medicine* in Feb., 1919,[5] English investigators working in the Research Laboratory of the Royal Institute of Public Health, employing the R-W method with various peptones substituted for Witte's found the coefficient of the same sample of disinfectant to vary from 7.7 to 15.

And, although Witte's peptone has, perhaps, been more uniform in quality than other peptones, it has hardly warranted the implicit trust that has been placed in it. In the English article above mentioned there is the following quotation from the *Lancet* (1916, p. 9): "Even before the war the preparation of a standard broth for bacteriological purposes was a matter of considerable difficulty, since different samples of Witte's and other peptones exhibited such marked variations when employed in nutrient media that the cultural features of an organism were apt to vary with each sample used."

It may seem extravagant to speak of the exclusive use of Witte's peptone as a superstition. But what else can you call our usual practice of employing a certain ingredient in our culture media simply because the label says "peptone" and has some man's name on it, when, as a matter of fact, peptone is only a name which as generally used stands for an indefinite mixture of proteoses, peptones and polypeptides varying enormously in composition, depending on the materials employed and the method of manufacture. It is to be hoped that in due course of time we shall become scientific enough to insist on knowing the real composition of our culture media and prepare them so as to meet the food requirements of the organisms we wish to grow.

The reasons already given are, however, not the only reasons that exist. From the legal standpoint and also by common practice, a phenol coefficient signifies only the relative germicidal value of a disinfectant against *B. typhosus,* and that determined in the absence of organic matter under narrowly limited conditions as to temperature and proportion of culture to disinfectant.

The facts already known in regard to differences in the resistance of various species of bacteria to disinfectants, are almost enough in themselves to make it obvious that no general conclusions can be drawn from a test made only against the typhoid bacillus.

Walters, in an article published in the *American Journal of Public Health*[15] has considered this phase of the problem in a very interesting and able manner. Besides discussing the work done by Churchman and others, he gives the results of his own work with Pine Oil Disinfectant. Stated briefly, these results were as follows: A sample of Pine Oil Disinfectant having a phenol coefficient of 3.8 was found to have so little value against *Staph. aureus* that a 4% solution required an hour or more to destroy that organism, while in contrast to this a 5% solution of phenol killed *Staph. aureus* under the same conditions after exposures of from 5 to 10 minutes.

To the examples of specific action of disinfectants given by Walters I will add the following examples taken from some recent work of my own: Tested under identical conditions Chloramine T was found to kill *B. typhosus* in 10 minutes in a dilution of 1-500, while the same dilution required 30 minutes to kill *B. pyocyaneus*. On the other hand, a dilution of 1-1000 was sufficient to kill *Staph. aureus* in 10 minutes and a dilution of 1-2000 killed it in 30 minutes. Expressed in the form of phenol coefficients the varying activity of Chloramine T against these organisms is as follows: The coefficient with *Staph. aureus* is approximately 23, with *B. pyocyaneus* 2.1, and with *B. ty-*

phosus 16.6. So far as the tubercle bacillus is concerned neither Chloramine T nor any other chlorine disinfectant, is worth very much. For example, a 1-50 dilution of Chloramine T failed to kill the tubercle bacillus in 10 minutes, or diminish its pathogenic power so far as guinea pigs were concerned.

The specific action of disinfectants is discussed in the report of the A. P. H. A. Committee[4] along with two other important factors which influence the action of disinfectants. These are concentration and temperature.

The efficiency of a disinfectant measured by the time required for it to kill a given number of organisms is not proportional to its concentration but to some power of that concentration. For example, with phenol the concentration exponent is six, while with mercuric chloride it is one. The significance of this is shown by the fact that the germicidal value of phenol increases rapidly with increasing concentration, and decreases with equal rapidity with increasing dilution, while mercuric chloride increases and decreases in germicidal power much more slowly.

The effect of temperature may be expressed by saying that while the temperature increases in arithmetical progression the velocity of disinfection increases with geometrical progression.

Since phenol coefficients are determined under certain carefully specified conditions of concentration and temperature while the conditions as to concentration and temperature in practical disinfection vary a great deal and are quite likely to be entirely different from the conditions under which the coefficient was determined, it is evident that a coefficient cannot furnish any reliable indication as to the practical value of any given disinfectant.

In recognition of these facts the Committee has recommended that in addition to the ordinary coefficient the following should be determined: First, the coefficient against other organisms than *B. typhosus;* second, the temperature coefficient; and, third, the concentration exponent or "time ratio."

It might seem from all this that the examination of a disinfectant has become entirely too complicated and yet it seems to me that unless another factor is also taken into consideration all the factors previously mentioned will, in many instances, completely fail to measure the real value of disinfectants. This added factor is the influence of organic matter upon the germicidal power of disinfectants.

It is true that Sommerville and Walker[13] have devised a modified R-W technique for use in determining coefficients in presence of organic matter, although this is not officially a part of the R-W method, and the H-L method includes a modified technique for the same purpose. But in practice these are entirely ignored and when we speak of a phenol coefficient we ordinarily mean a coefficient determined without organic matter.

As a single example of possible error due to ignoring the effect of organic matter I will refer to a disinfectant which I once had occasion to examine. The coefficient of this disinfectant by the H-L method was 10, but it was so seriously affected by organic matter that the additional .4 (4/10) cc. of culture used in the R-W method brought the coefficient down from 10 to 3. Of what value would the coefficient be in this case, even though determined by the A. P. H. A. method, with due reference to other organisms than *B. typhosus* and due reference to the time ratio, concentration exponent, and temperature coefficient?

Finally, a phenol coefficient doesn't tell the user of a disinfectant what he really wants to know. Whether he be householder or public health official what he wants to know is what dilution of any given disinfectant to use for his own particular purpose. And even if the A. P.

H. A. method were in general use, and, in accordance with the Committee's recommendations, coefficients were furnished showing relative efficiency against other organisms than *B. typhosus* and the time ratio, concentration exponent and temperature coefficient were included for good measure, unless the user happened to be a disinfectant expert, and a mathematician as well, he would be none the wiser in regard to the question of what dilution to use.

What the ordinary citizen really does is not to look for a coefficient but rather for the directions furnished by the manufacturer, which he proceeds to follow without question.

What the public health official does I will not attempt to say, although it may be surmised that in many instances he imitates the ordinary citizen and follows directions without question. At any rate, W. G. Savage, in an article published in the *Journal of the Royal Sanitary Institue*,[12] makes the following statement: "I have been surprised in the course of enquiries to find how largely those who use disinfectants for practical public health work, and spend large sums of public money on them, have very little exact knowledge at their disposal to enable them to judge as to the kinds to use, the specific purposes for which to employ them, and the methods of application. They frequently rely upon the statements of the vendors of these substances, statements which cannot be always relied upon."

If this is true for the public health official it is not surprising that the ordinary citizen, with his profound ignorance of disinfectants and their use, relies entirely upon the directions given by the manufacturer, no matter how absurd they are. As an example of such directions I will cite the following, taken from the label on a sample of disinfectant: "For purifying the air of houses, schools, hospitals, etc., dilute one teaspoonful of the fluid with one quart of water and sprinkle about freely." As a matter of fact the dilution recommended would not be sufficient to kill the typhoid bacillus under the conditions of the Rideal-Walker test, a dilution of 1 to 165 being required to kill the typhoid bacillus in 10 minutes under these conditions, while the dilution given is approximately 1 to 236. And, of course, it is all nonsense to expect such a procedure to purify the air.

Since the way we really do things, then, is to follow directions instead of bothering with phenol coefficients it might not be a bad idea to recognize the fact officially and abandon the use of the phenol coefficient. Instead of this, manufacturers of disinfectants could be required to have their products tested against the germs of the various diseases they mention in their literature, the tests being made under conditions simulating natural conditions as nearly as can be done in the laboratory, and they should be required also to recommend the use of dilutions of their products consistent with such tests. A guarantee that any given product had thus been tested and found efficient in the dilutions recommended would be worth more than any coefficient.

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