

PHENOLIC CHARACTERISTICS IN BREWING II THE ROLE OF WATER

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Earlier this year we had the privilege of presenting a paper dealing with the general subject of phenolic or medicinal off-tastes in beer (15). It had been assumed that the subject would have a limited appeal to brewers as the majority of them probably had never encountered this problem. Apparently we had misjudged the situation, as a surprising number of persons have approached us in the past four months with descriptions of their own, or their competitors, phenolic off-taste problems. Most of these occurrences described to us were corrected by the brewing staff concerned and were of short duration. However, in isolated instances a mild phenolic off-taste has been more or less accepted as a normal beer characteristic. It is our hope that this present paper will enable other brewers to avoid some of the causes of this off-taste or possibly correct an existing condition.

Our previous paper was primarily intended to present an analytical method for determining total volatile phenols and chlorophenols in beer. It also contained data on the very small amounts of some of these compounds that will produce objectionable off-tastes and odors in water and in beer. The paper also presented evidence that certain Grain negative wort spoilage bacteria produce high levels of phenols and chlorophenols in wort and beer. Helm (6) noted the presence of phenolic off-tastes in a few continental beers and also traced the cause to wort spoilage bacteria. Gorbach, Dedic and Koch (4) have reported an instance of certain molds growing on wood that caused a phenolic taste. These references serve to point out the possibility of several causes for this type of off-character.

In the present paper we have principally limited the presentation to the role which brewing water from various sources may play in the development of medicinal or phenolic tastes in beer. Our references to phenols and related compounds refer only to those relatively volatile compounds which are determinable in water by the American Public Health Association Method (1) or in beer by our previously published procedure (15). Many of these compounds have very high flavor intensities. The large number of polyphenolic substances so frequently mentioned in the brewing literature (5) (10) (17) and generally ac

cepted as being contained in beer and brewing materials are not directly concerned in this presentation.

Phenols and Taste

What are the phenolic substances that we are concerned with and how objectionable are they in water and beer? To start with, let us realize that the Drinking Water Standards of the United States Public Health Service recommend less than one part per billion of extractable total phenols in potable water. This does not mean that all phenols are taste or odor detectable at this concentration. Some can be detected at less than one ppb while others require concentrations of 50 or more parts per million. The parent compound phenol, frequently called carbolic acid, is not one of the worst offenders as it requires a concentration of about 25 ppm in water to be noticeable. Table I, taken partly from a paper by Nesmeyanova (9) and partly from our own work, shows the threshold taste concentrations in water of some of the phenolics. The wide range of detectable concentrations of closely related compounds and the much more objectionable character of most of the chlorophenols is illustrated in this table.

TABLE I

Beer, with its complement of volatile flavor components, has a partial masking effect. The threshold taste

Organoleptic Thresholds of Phenols and Chlorophenols in Water

	<u>Phenols</u>	<u>Respective Chlorophenols</u>
Phenol	25 ppm	1 - 5 ppb
Cresol	2.5 ppb	0.2 - 1.0 ppb
Thymol	50 ppb	50 ppb
Resorcinol	40 ppm	No odor
Guaiacol	40 ppb	
Naphthol	7 ppm	500 ppb
Creosote	50 ppb	10 ppb

concentrations of the various phenols and chlorophenols in beer are greater than with water. A **number** of sets of beers with increasing amounts of phenol compounds were presented to our experienced taste panel to study threshold concentrations. The results of five of these tests are shown in Table II. From this table we observe the wide variations in detectable concentrations, of the

TABLE II
Perception and Recognition of Phenols Added to Beer
(Values expressed in percentages of panel members)

<u>Concentration</u>	<u>Phenol</u>		<u>Chlorophenol</u>		<u>Cresol</u>		<u>Guaiacol</u>		<u>Creosote</u>	
	<u>Percep.</u>	<u>Iden.</u>	<u>Percep.</u>	<u>Iden.</u>	<u>Percep.</u>	<u>Iden.</u>	<u>Percep.</u>	<u>Iden.</u>	<u>Percep.</u>	<u>Iden.</u>
<u>ppb</u>										
3			50	37						
5			50	50						
10			62	50	25					
20			75	50	50	12	12			
40			88	62	75	25	62	25	25	
80					75	62	75	62	62	25
100							88	75	62	62
150									88	88
<u>ppm</u>										
20	62	37								
40	88	62								
80	88	88								
100	88	88								

compounds, the fact that beer has a partial flavor masking effect, the variation in threshold levels for different tasters, the fact that some persons are almost totally insensitive to phenolic tastes, and, most important, the very small amounts of certain phenolic compounds that will produce off-tastes in beer. It is entirely possible that chlorinated derivatives of some of the simple phenols reported in the literature (10) as being in beer also will have objectionable flavors.

One point which bears emphasizing is that a fairly high percentage of persons are essentially taste insensitive to this type of flavor. We have seen this with brewery personnel as well as with people in our own organization.

Another point of interest is the taste impression made by amounts of some phenols too small for compound identification but causing variations in taste when compared with a control beer. The masking effect of beer is quite different for various phenols. Taste impressions such as harshness, astringency, woodiness, or a paper character are caused by some of the compounds.

In order to establish the analytical concentrations of volatile phenolics in both normal and abnormal testing beers we have made determinations on a wide range of commercial beers. The method used separates the phenol components into two groups, the normal phenols and the chlorinated phenols. The values to follow will in all cases show both of these groups of compounds. Table III presents a summary of this data. The separation of the beers into the two classifications is based solely on taste. Three of the beers with exceptionally high values were so objectionable to the consumer that the breweries were obliged to withdraw them from the market.

We have, as yet, never analysed a beer which gave zero readings for chlorophenols and phenols. From this it is assumed that all beers have a small concentration

of volatile phenolics as normal constituents and only when the amount is increased by some means or when a particularly odorous compound is introduced does it become noticeable to the taste.

When phenolic compounds are added to a brew with the

TABLE III
Phenol and Chlorophenol Values
for Beers of Normal Taste

	<u>Chlorophenol ppb</u>	<u>Phenol ppb</u>
High Value	11.8	16.9
Low Value	3.0	9.6
Average of 15 Beers	7.1	12.5

Phenol and Chlorophenol Values
for Beers with "Phenolic" or "Medicinal" Tastes

	<u>Chlorophenol ppb</u>	<u>Phenol ppb</u>
High Value	38.6	71.2
Low Value	4.0	19.0
Average of 15 Beers	13.9	27.1

raw materials they do persist through the brewing process and into the finished product. To verify this statement we prepared a series of pilot brews in which some of the more common phenolics were added with the mash water. A summary of the results is contained in Table IV.

The basic or control brew was prepared from a 70 - 30% extract basis mash using six-row malt and corn grits. Distilled water hardened and pH corrected with a commercial corrective salt was used in the cooker and main mash. Clear filtered wort was boiled for 1 hours with hops at the rate of 0.5 pounds per barrel added in three portions. The wort was filtered hot, then cooled, aerated and pitched with compressed yeast at the rate of 10,000,000 cells per milliliter or equivalent to that used in commercial practice. Approximately three liters of 10.6° Plato wort were obtained from each brew. Fermentations were carried out in pressure re-

TABLE IV
Pilot Brews Containing Added Phenolics

<i>Pilot Brews</i>	<i>Compound Added</i>		<i>Chlorophenol ppb</i>	<i>Phenol ppb</i>
Control	None	Wort	4	7
		Beer	4	6
# 1	20 ppb Phenol	Wort	10	9
		Beer	11	12
# 2	20 ppm Phenol 2 ppb Chlorine	Wort	11	12
		Beer	18	15
# 3	20 ppb Chlorocresol (4-Chloro-3-Methyl-phenol)	Beer	19	20
# 4	20 ppb O-Cresol	Beer	7	24
# 5	20 ppb O-Chlorophenol	Beer	22	8

lease vessels for five days at 20° C. The fermented beers were cooled to 2°C for three days, filtered and the determinations conducted on the clear beer. The other pilot brews were made in the same manner with additions as indicated.

A study of Table I V indicates varying losses of the added compounds during processing. No doubt there is some volatilization during the kettle boil and we would not Hazard a guess as to what reactions take place during mashing, boiling, and fermentation. However, a comparison of the test brews with the control indicates significant increases of phenols and chloro-phenol in both worts and beers.

Phenols in Brewery Water Supplies

Each brewer is very concerned with his brewing water supply. Some plants have extensive treatments to produce water of the right pH and chemical composition. Some have excellent daily or hourly or even automatic control checks to assure uniformity of composition. However, some forget to taste their brewing water to see if it is drinkable.

Some breweries' only source of water is surface water, others have only ground water available, while a good number of plants obtain water from both sources. Breweries using a municipal water supply may have either type but in general the larger cities use surface water for their municipal supply and the smaller towns have their own wells. Well water is normally much less likely to acquire a significant phenolic content in comparison with surface waters. Surface waters, that is waters obtained above ground in lakes, rivers, reservoirs, etc. are open to many phenol producing conditions. Industrial wastes containing phenols may be discarded into surface waters; decaying vegetation may produce phenols ; certain algae, bacteria and actinomycetes (14) produce phenols. Other sources are phenolic weed killers, insecticides, etc. that are sprayed directly on to surface waters or on land that drain; into the lakes and rivers. Of course, the city treatment plants are supposed to take care of these phenol conditions and deliver acceptable water to the consumer but how many regular users of city water have not noticed fluctuations in the odor intensity of their water' \ 1057 U.S. Public Health Service Survey (13) of water plants in cities over 25,000 population reported that 202' plants out of 570 employ corrective treatments for taste and

odor control. Of course not all of these were for phenols. Algae were the most frequent cause of off-odors and tastes, with decaying^{vegetation} second, and trade wastes third. 38 treatment plants reported problems with industrial phenol wastes while 61 plants reported the development of medicinal odors due to chlorophenols after chlorination in their own treatment facilities. Some others reported what they term chloralgal odors.

A Canadian survey (7) taken the same year also disclosed that over 50;0 of their municipal treatment plants have water odor problems. The same three causes of water odor and taste were given and again chlorination is noted as producing chlorophenolic odors in treated water.

These surveys also disclose that the treatments were generally only partially effective and, particularly during periods of high contamination or peak demand, phenols and other odor substances were being delivered to the consumer in excessive amounts. Our laboratory analyses of city water supplies frequently show a few ppb of phenol and on one occasion a good sized city on a large river was apparently delivering water with 21 ppb phenol to its customers: including a brewery. Fortunately the brewery was able to switch to a well water supply but did have to resort to more than mtheusual blending of a few brews.

Surface Water Contamination

Algae are recognized (13) as being the most common cause of odors and tastes in surface water. Algae produce many different odors and phenolic is noted among them. Algae are normal inhabitants of surface water and are found in every water supply that is exposed to sunlight. The number of algae present in a given water supply depends oil many factors such as water temperature, amount of sunlight, food supply, and presence of algicides and other chemicals. Algae counts of over 4,000 per ml of water have been found in Lake Michigan off Chicago and counts of over 100,000 per ml have been made in some rivers and shallow lakes. (11)

Algae counts of less than 500 per ml are generally recognized as beneficial in surface water because of their

ability to release oxygen into the water aid thus promote oxidation of organic matter. Algae do this because they contain chlorophyll which, in the presence of sunlight, enables them to combine carbon dioxide and water and release oxygen. This oxygen released into the water is very beneficial in promoting aerobic bacterial decomposition of organic matter and industrial wastes. (11) Aerobic bacterial decomposition is the most important manner in which organic matter and industrial wastes are removed from surface waters. If algae are not present in sufficient quantity or are unable to carry on their photosynthesis, the oxygen in the water will be depleted and anaerobic or septic bacterial decomposition may result. Anaerobic bacterial action generally results in the formation of decomposition products with high odor and taste intensity. Phenols and chlorophenols are usually prominent in these products.

Algae die as well as grow at tremendous rates and oft-times the majority of (lead organic matter in a surface water comes from algae. These decomposing algae are notorious for causing off-odors and tastes, including phenols, in water supplies.

From these brief statements we can conclude that algae may be beneficial in water or may be troublesome if they produce phenols themselves or lead to phenolic decomposition products. Some bacteria in water produce phenols as natural metabolic products and others will produce phenolic compounds when subjected to unnatural environmental conditions.

The persistence of industrial phenolic wastes in rivers has been studied several times (8) (3) (2). Depending upon conditions the waste phenols may persist anywhere from four to forty or more days. Type of phenol, water temperature, cleanliness of the water, sunlight, dissolved oxygen, algal and bacteria populations, etc. all play important roles. In four or five days river water containing the phenols will not have moved too far downstream but in 30 or 40 days the condition may be carried hundreds of miles. Studies (3) have shown that physical losses of phenols in flowing streams is negligible and that their loss is primarily due to bacterial action.

Phenols in clean water, i.e. water low in sewage and other organic matter, persist longer than in dirty or polluted water. This is due to the low bacterial population and growth in clean water.

Waters having a low dissolved oxygen content or a low algal population retain phenols for a longer time than waters with high oxygen. As algae are the prime source of oxygen in surface water, their absence will slow down the rate or extent of bacterial oxidation of the phenols. Low temperatures slow down bacterial and algal activity and phenols may persist up to ten times

longer in water at 4°C than at 20°C. A heavy ice and snow cover on rivers and lakes also prevents the access of sunlight to algae and slows down their release of oxygen which, in turn adversely affects the action of bacteria.

In our analysis of water for certain breweries we have found noticeable differences in phenol contents of their brewing water depending upon the season of the year. Table V shows this effect for three breweries. These water samples had all been in-plant treated and were being used for brewing. All three plants used city water obtained from rivers which last winter had a heavy ice and snow cover. The three breweries also have a history of sporadic medicinal or phenolic tastes in their beer.

A source of chlorinated and non-chlorinated phenolics in water supplies which has been receiving increasing attention are weed killers, insecticides and similar chemicals (12) (10).

TABLE V
Seasonal Variations of Phenol Content
in 3 Brewing Waters

<u>Brewery</u>	<u>Water Source</u>	<u>Month</u>	<u>Phenols ppb</u>
M	River	January	4
		July	0
S	River	February	5
		March	0
		May	1
		June	1
W	River	October	2
		January	9
		May	1

A few of these compounds are not phenols but several of the common ones, such as 2,4,5-T and 2,4-D, belong in this category. Some of them have taste thresholds in the order of a few parts per billion. Many are not easily degraded by bacteria and are quite persistent in both soil and water. The Public Health Service reports (16) finding concentrations of pesticides of from 1 to 20 ppb in rivers and lakes. They also report that these compounds are beginning to be found in well waters due to heavy use, porous soil and shallow water tables. These compounds may not be of immediate concern to the brewer in relation to his beer quality but their increasing presence not only in water but also in other raw materials may cause future problems.

The treatment of water for the removal of phenols is of concern to municipal water treatment plants and also to brewers who have these compounds in their water supply. The most commonly used treatment is purification with activated carbon. This method is generally successful as long as the carbon bed is in good condition and the flow rate is not too great for the bed.

size. However, we have seen instances where, with a poorly regenerated carbon bed, the influent and effluent waters had equally high phenol contents. Some phenolic waters containing trade wastes are reported (S) to be poorly or little effected by carbon purifiers.

Regular chlorination, as used primarily for killing microorganisms, is not usually satisfactory for destroying phenolics. As noted previously, this treatment often leads to more intense chlorophenol odors. Superchlorination is more satisfactory but is not frequently used in routine water treatment. Some treatment plants use a combination of ammonia with chlorine or chloramines to avoid formation of chlorophenols. This combined treatment partially inhibits the reaction of chlorine on organic matter and does not react with any phenols present.

Chlorine dioxide, a powerful oxidizing agent, is increasingly being employed to break down phenolic trade wastes and is reported (13) to be very successful.

Several industrial plants that formerly clumped phenolic wastes into surface waters are now using phenoldegrading bacterial cultures in their private treatments works to reduce the phenols to more acceptable levels.

Phenols in Steam Condensates

During the past two years we have become involved in several instances where a phenolic or medicinal off-taste in beer was caused by phenol compounds present in the steam condensates used as part of the brew water or in steams used for direct injection in the cooker and mash tub. The initial source of these phenols was in all instances the boiler treatment compound used in the boilers.

The instances referred to occurred in the United States, Mexico and Canada and from the trade names or numbers involved the compounds do not appear to have been all from the same manufacturers. However, it may be that the objectional ingredient was from a single source in several of the boiler compounds. These treatment compounds all contained tannins or mixtures of tannin and lignin extracts in a form which when mixed with the other compounds in the treatment and diluted with water produced distillates that both tasted and smelled of phenols.

The magnitude of effect on the user's beer would depend on the amount of treatment employed and the proportion of condensate in his wort. One of the resulting beers had 27 ppb chlorophenols and 39 ppb phenols and another contained 13 ppb and 24 ppb.

Table VI contains figures showing a brief case history of one of the condensate induced off-tastes. The beer character was harsh and slightly medicinal rather

TABLE VI

Case history of a Condensate Induced Phenolic Taste than pronounced phenolic but analyzed considerably,

<u>Phenolic Taste Beer</u>	<u>Chlorophenols ppb</u>	<u>Phenols ppb</u>
Beer	7-10	19-21
Wort	10-12	19-22
Brewing Water		Less than 1
Steam Condensate		85-90
Boiler Compound (calc. from distillate)	5200	5300
<u>Normal Taste Beer</u>		
Steam Condensate		2
Wort	3	10
Beer	4	7

above normal in phenolics. The wort also contained above average phenols but was very stable and not subject to bacterial spoilage. The brewery has been assured that their boiler compound was non-volatile and only after the condensate proved to have high phenol was the compound suspected. The boiler compound was of the general type that we had become familiar with previously. After changing boiler compounds and thoroughly flushing the steam lines and traps, the condensate was quite normal and subsequent worts and beers were back to normal:

TABLE VII

Pilot Brews Containing Phenolic Boiler Compound Condensate

		<u>Chlorophenol ppb</u>	<u>Phenol ppb</u>
Control	Wort	4	7
	Beer	4	6
Brew A	Condensate = 5% of Brew		
	Wort	17	14
Water	Beer	18	12
Brew B	Condensate = 5% of Brew		
	Wort	26	19
Water Plus 2 ppm Chlorine	Beer	24	16

In order to assure ourselves that the above incident and others like it were not coincidental, we produced pilot worts and beers containing condensate from the above mentioned compound. The results are contained in Table VII. The condensate, used at a rate of 5% of the total cooker and mash water, was obtained from a simple laboratory still. The figures for the wort and beer of Brew A indicate that the added condensate had a considerable effect. If chlorinated water, as in Brew B, were used with the condensate, the effect was accentuated.

Production of Phenols by Wort Bacteria

Wort spoilage due to the accidental introduction of coli-aerogenes type termo bacteria is known to every

brewer. These organisms are of many types and may be introduced into the brewing process by non-sterile water, poorly filtered air or other causes. Once introduced into wort handling equipment these bacteria multiply rapidly and are difficult to eradicate by routine cleaning methods. In our previous paper we reported on two instances where a phenolic taste in brewery beer was caused by wort infection. Cultures of the bacteria causing this condition have been preserved and used for some further tests.

These Gram negative short rods grow and produce gas in lactose broth, are indole negative and when inoculated into brewery or pilot plant wort grow and cause spoilage. While these two cultures, which apparently are identical, cause high phenol and chlorophenol concentrations in worts and in beers made from these worts, other isolates of wort spoilage bacteria do not have this effect. Brewery worts inoculated with the phenol producing bacteria, incubated for nine days, and then analyzed, gave values as high as 80 ppb for chlorophenols and 117 ppb for phenols. Similar worts infected with other strains of wort bacteria and incubated, spoiled in the usual manner but did not contain abnormal amounts of phenolics.

The breweries which had this phenolic wort spoilage condition have eradicated the infection and are producing normal tasting beers. However, we were still interested in the possible behavior of the bacteria in other environments and conditions and it was decided to work with pilot plant worts.

A summary of three wort spoilage experiments is found in Table VIII. Brew F was from a routine control brew with the culture added immediately after cooling. Chlorinated water was used with Brew G and chlorinated water with added phenol was used to prepare Brew IT. Phenols were determined immediately after cooling and adding bacteria and again after six days incubation at room temperature. In all three cases the incubated worts spoiled and showed fairly high phenolics. The addition of chlorine to the brew water had little effect but the addition of phenol and chlorine altered the proportion of chlorophenol to phenol in the spoiled wort. These pilot worts have a higher hop rate,

one-half pound per barrel, than most commercial worts and we believe that this may have lowered the degree of spoilage.

Another set of four pilot brews were made to ascertain the effect of duration of wort infection on amount of phenols in beer. The findings are contained in Table IX. All worts were inoculated with the culture bacteria immediately after cooling but not pitched with yeast until the designated number of hours. No effect is noted until eight hours after inoculation and then the increase is slight. At 24 hours the phenol and chlorophenol production was considerable and the resultant beers had distinct off-odors.

Summary

The occurrence of several commercial beers having medicinal or phenolic characters led us to investigate the causes of this condition. A previous paper had established a certain type of wort spoilage organisms as one source of volatile phenolics in wort and beer but other causes were either known or suspected. Water has long been known as a carrier of phenols and the literature contains many references to the emblems it creates for industry.

Less than one part per billion of some phenols are detectable by odor and taste in water and as water is the largest amount of raw material in beer manufacture it is logical to expect that phenolic water would have an effect on beer character. The addition of various phenols to beer and the use of phenol containing waters in pilot brews established that this was true. Phenols contained in brewing water are carried through the brewing process and remain in the finished product.

Phenols and chlorophenols may be introduced into surface water supplies by certain algae and bacteria, by the dumping of phenolic industrial wastes, by the decomposition of dead organic matter, and by the use of pesticides, weed killers, etc. on water and land. Water treatment to remove these aromatics may be satisfactory or in some instances may intensify the condition. Low water temperatures, lack of dissolved oxygen in the water, low bacterial and algal populations all may lead

TABLE VIII
Pilot Worts Inoculated with Phenol
Producing Bacteria

<i>Pilot Brew</i>	<i>Other Additions</i>	<i>Time of Determination</i>	<i>Chlorophenol ppb</i>	<i>Phenol ppb</i>
F	None	(a) immediately	4	7
		(b) after 6 days	25	31

TABLE IX
Pilot Brew Beers Produced from Infected Worts

<i>Pilot Brew</i>	<i>Time of Yeast Pitching*</i>	<i>Chlorophenol ppb</i>	<i>Phenol ppb</i>
J	Immediately	5	9
K	After 4 hours	5	9
L	After 8 hours	7	11
M	After 24 hours	32	32

*All worts inoculated with phenol producing bacteria when cooled.

to longer than expected phenol retention in surface waters.

The use of steam boiler additives containing polyphenolic compounds which change composition and volatilize during use has led to the introduction of easily detectable amounts of phenols into wort and beer. A brief history of one such occurrence was presented.

Limited experiments were made on the use of phenol and chlorine in brewing water in conjunction with phenol producing wort spoilage bacteria. These tests show that the use of such waters would increase the phenolics in wort.

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QUESTIONS AND ANSWERS

Q. Does sand and gravel or similar filtration have any effect on removal of phenol from water?

A. Sand and gravel filtration has essentially no effect on removal of phenols from water. Anthracite coal water filters also have essentially no effect on removal of phenols.

Q. In the condensate experiment, have you any theories why the phenol increased when two parts per million of chlorine were added?

A. This question refers to the values contained in Table # 7. The chlorophenols increased 6 ppb and the phenols 4 ppb. We are not able to give a positive answer to this question but we have noticed this same trend with other pilot brews (See Table #4). It may be that the chlorine is able to oxidize some compounds to simple phenols.

Q. At what temperature was the infected wort held at before pitching in the last slide (Table # 9) ?

A. Those worts were held at 12° Centigrade, which is about 53° Fahrenheit.

Q. How can phenol producing bacteria be identified?

A. The coli-form group of organisms, to which this species belongs, is an extremely complex one and nothing is to be gained in the control laboratory by setting up lengthy identification systems. If the predominating flora in a spoiled wort sample is a Gram negative, indole negative rod, the organism can be suspected as a producer of phenol-type compounds. If olfactory tests also point in this direction a chemical analysis of the sample for phenols and chlorophenols can be made and this will either confirm or eliminate the suspicion.

Q. Will activated carbon filtering the water safeguard against phenol taste?

A. If the phenolic compound is in your water supply and you have an activated carbon filter of adequate capacity and in good condition ; it should remove the phenols. We have knowledge of breweries where this is routine practice.

If the carbon filters are of inadequate size or the carbon bed is not regenerated properly, phenols will not be completely removed.

From the Audience: (Mr. Phil Gray) May I add something to that? I want to say there is at least one of the companies who regularly and as a matter of form takes the precaution of both superchlorinating the water and then puts it through activated carbon filters.

Mr. West: There is one further comment I would like to make on this subject. I believe the most effective method of getting rid of all phenolics is to use commercial chlorine dioxide. It is used much more frequently than it was two or three years ago.

Q. With increasing use of chlorine compounds for cleaning vessels and as a deodorant in many breweries and bottle shops, the latter where bulk pasteurization is practiced to reduce airborne contamination, what is the chance of picking up chlorophenolic tastes?

A. The greater the use of chlorine compounds, the greater the chance of its introduction into the brewing process. If chlorine is introduced into wort or beer, and phenols are present, there is a strong possibility of chlorophenol formation. This reaction is quite rapid and does not require elevated temperatures.

Q. What method was used for the determination of phenol in ^{water?} Is this method equally satisfactory for phenol, cresols and substituted phenols?

A. The method used for determining phenols in water is that of the American Public Health Association as contained in their "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes", 10th edition, p. 336-339 (4 aminoantipyrine method).

This method is applicable to phenols, cresols and so forth in which the para position is not blocked with an aryl, alkyl, nitro, benzoyl or carbonyl group. Para substituted halogens, carboxyl, sulfonic acid, hydroxyl, and methoxyl groups are expelled in the reaction and do not interfere.

Q. Do different yeasts have any effect on the phenols in beer?

A. We have done a very limited amount of work in this field. So far only three strains of brewers yeast have been tried and all produced nearly identical results when used to ferment normal or phenol containing wort.

Q. There has been a suggestion as to the possible uses of iodine compounds for brewery sanitation. Should there be any possible remaining amounts left in tanks, what combination would be made with phenols and what characteristics of taste?

A. We have done no work on possible effects of iodine and phenols.