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THE RECENT CHLORINATION CONTROVERSY *

by

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ABSTRACT:

In 1974, while conducting the nationwide water quality surveillance program, the United States Environmental Protection Agency study has detected several organic compounds present in the drinking water of 79 U. S. cities. Since some of these organic chemicals are by-products of chlorination and are suspected of being carcinogenic (capable of causing cancer), these recent findings seem to have a great impact in creating a chlorination controversy among the water engineers, research scientists and concerned public all over the world. The set of arguments and counter arguments associated with such a controversy is the subject matter of this paper. In final analysis at this time, it appears that future extensive scientific research can only resolve such a critical and very important chlorination issue.

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INTRODUCTION:

From the beginning of the twentieth century, when treatment processes were developed and applied in the field, their performance was evaluated in terms of very few general parameters. For example, effectiveness of chlorination was examined primarily in terms of bacterial kills and residual chlorine; Filtration performance was checked by turbidity removal, length of filtration, backwash rate etc. etc. All these parameters and many more indicated in gross terms the working of these processes for making the water source adequate for drinking purposes. In recent years, due to the interactive pressures of urbanization and industrialization on the water bodies with multiple uses (water supply being one of them), there arose a need to understand the soluble, insoluble organics and inorganics released in the water. Simultaneously, the progress in instrumentation has provided numerous sophisticated techniques to detect on a micro and macro scale the chemical constituents of the water. As a result, there is an increasing number of nationwide surveys to monitor the water quality parameters in major water sources. Recently when these surveys with sophisticated modern techniques started, it was expected \longrightarrow that some of the findings of these nationwide programs could either substantiate what had been done in the past or provide brand new scientific information available to water engineers for the first time and which may possibly change the traditional philosophies underlying the widely used water treatment processes. The latter part was recently experienced in the U.S.A. when the United States Environmental Protection Agency (USEPA) study found, among many organic chemicals, the by-products of chlorination in the drinking waters of 79 cities of the United States (2) This paper is primarily designed to discuss the role of these recent findings in creating the chlorination controversy with associated arguments and counter-arguments.

RECENT INCIDENCES:

In November 1974, the Surveillance and Analysis Division of the United States Environmental Protection Agency reported that small quantities of 66 organic chemicals were detected in the drinking water supplies of New Orleans, Louisiana, U.S.A. and some of the compounds may be hazardous to human health (4).

During the same time, the Environmental Defense Fund of Washington, D.C. performed multi-regression statistical analysis of cancer death rates in Louisiana, and the results indicated the correlation between the Mississippi River water and New Orleans' high (i.e. 25 percent above the national average) cancer death rate (4,5).

To follow up the EPA findings in New Orleans' City waters, an extensive nationwide survey is currently underway to:

1. analyze in detail the water supplies of 10 U. S. cities
2. measure the concentrations of the six chemicals in the waters of 80 cities all over the United States. These selected six chemicals: chloroform, bromodichloromethane, dibromochloromethane, bromoform, carbon tetrachloride and 1, 2 dichloroethane are by-products of chlorination (2).

Using sophisticated instrumental techniques such as gas chromatography and mass-spectrography, Bellar, Lichtenberg and Kroner, three research scientists from the National Environmental Research Center of EPA, have detected chloroforms and trihalogenated methanes which are formed as a result of chlorination during the water and wastewater treatment (1). Although the concentrations of these organohalides (chlorinated organics) are well below the hazardous level to man, their chronic effects are unknown and thus, constant monitoring of finished waters and sewage effluents for these compounds are suggested (1).

NATURE OF THE CONTROVERSY:

Looking at these incidences, it is clear that the inhibitive or stimulatory effects of treatment processes on the trace quantities of residual organics present in the water are specific research areas, with the measurement of individual organics in municipal water supplies just starting on a large scale. Although carbon-chloroform extract (CCE) has been previously used to measure the general organic level of the water, it is a gross parameter and it does not identify the individual organic constituents. Thus, due to the recent discoveries of chlorinated residuals by the modern sophisticated chemical techniques, the basic foundation underlying the very old and useful method of chlorination was shaken at the outset. Basic questions that have come up recently as a result of the above incidences are:

1. Is the chlorination process as safe as it used to be for the last seven decades?
2. Is the formation of organohalides^a universal phenomenon or a coincidence reported in the above surveys?
3. Is there any treatment process equally effective, economical and accepted as the chlorination?
4. What are the chronic toxicological effects of trace amounts of chlorinated organic chemicals on man?
5. What are the supplemental means to alleviate the formation of chlorinated organics while still using chlorination process?
6. Are there any other significant pathways by which carcinogens are added to the source water and treated water?

Unfortunately, there is no unanimous agreement among the water engineers and research scientists regarding the answers to these questions. Conservative professionals cite more good points about chlorination than the possible pitfalls. Whereas, some authorities consider the recent evidence of the possibility of carcinogen formation during the chlorination much more serious than the advantages of chlorination. In addition, the lack of sufficient scientific data to approve or disapprove the points makes the situation more speculative. As a result, there exists a modern controversy with the chlorination issue. Although such controversy is going to remain with us for some time to come, it is a very interesting educational experience to first understand both sides of the coin at this preliminary stage of the issue and then to observe in the future how the controversy is settled with the advent of new evidence to favor a particular viewpoint. With this thinking, an effort is made in the following section to discuss the two sides of the controversy.

POINTS AND COUNTER POINTS:

1. When an experienced water engineer hears about the "chlorination under attack", the first question that comes to his mind is "why are we concerned about by-products of chlorination now when the process has been in operation more than a half century?" This point indeed favors the chlorination with great faith. However, the counterpoint deals with three arguments. Firstly, when in 1913 chlorine was effectively used in irradiating typhoid, cholera, dysentery and other water borne diseases, the water managers thought that the cure for all water problems was chlorine. As a result, during the years of industrial growth and urbanization, chlorine was added more and more without any major nationwide surveys of tap water until 1969 when, in the U.S.A., U.S. Public Health Service conducted a drinking water survey with

the conclusion that eight out of ten samples had not even been examined during the previous year (5). Secondly, due to the tremendous industrial growth during the last thirty years, complex types of industrial wastes were introduced into the water with no knowledge of the by-products of their interaction with chlorine. Thirdly, the advances in water technology has provided sophisticated instruments to detect the organics as small as parts per billion (ppb) instead of the previous level of parts per million (ppm). All these modern factors are collectively responsible for pinpointing recently trace amounts of the by-products of chlorination in water.

2. Although it is a general feeling that the chlorination controversy was developed recently because the by-products of chlorination were not detected before, the formation of chlorophenols (by-product of chlorination with the phenolic source water) is known to the water manager for the last several decades for their notorious odors. This argument leads us to the fact that water professionals in the past focused their attention to monitor specific by-products of chlorination. Although, as we know now, there seem to be other forms of by-products of chlorination which may have much more detrimental effect on man than the esthetic threat of the chlorophenols.
3. The multi-regression statistical analysis by the Environmental Defense Fund indicated the correlation of the drinking water and cancer death rates for white males (4). But, such analysis fail to establish the hypothesis for white females. Based on this fact, some professionals may claim that other factors such as age group, physiological strength, family history, working environment, quality of food and air could be equally responsible for the observed high cancer death rates of New Orleans. In the case of chloroform (which is a suspected carcinogen), it is argued

that tens of millions of Americans have been inhaling the chloroform for the last 60 years through cough medicine in larger quantities than found in the drinking water and it does not seem to have any reported detrimental effects (3).

4. Based on practical research, Bellar, Lichtenberg and Kroner speculated possible pathways of forming chloroform and carbon-tetrachloride along with other organohalides. For example, as they have reported, ethanol in the water gets oxidized first to acetaldehyde which reacts with chlorine to form chloral which in turn reacts with water to form chloral hydrate and finally chloral hydrate decomposes to chloroform (1). A very important counter point to such speculation is that there exist many other possible pathways which can add carcinogens to the source water. According to Dr. Morris of Harvard University, basic routes by which chlorinated organic matter can reach the water supplies are

1. nonpoint sources including rainfall and agricultural runoff,
2. industrial waste sources,
3. chlorinated sewage effluent, and
4. chlorination of relatively unpolluted water supplies (3).

Therefore, it is indicated that each source be investigated for each specific case before any generalization regarding the relative importance of these pathways are finalized although some water managers point their fingers to the "chlorination of sewage effluent" as being the most potential culprit in introducing noxious, carcinogenic chemicals to the receiving water used for drinking purpose. It is also speculated that if the water supply source does not receive directly or indirectly the chlorinated sewage effluent, then carcinogens would not be found in that water supply.

5. As mentioned earlier, the chlorination has indeed done a good job over the past years to prevent typhoid, cholera, dysentery and other waterborne

diseases. At the same time, scientific evidence has also been accumulating to demonstrate the adverse effects of chlorine to aquatic life, the spawning and the survival of game fishes. Recently, such adverse effect was heightened by the detection of trace quantities of chlorinated organics which may directly and adversely affect human safety.

6. The most dominant factor in creating the chlorination controversy relates to the failure of finding a substitute for chlorine, although several other disinfectants such as ultraviolet, bromine chloride, ozone are often suggested. The basic criteria of evaluating the final substitute are that in comparison with chlorine,
 1. It should be economical and readily available,
 2. It must have some residual value to be measured to provide added protection against chance contamination in the distribution system,
 3. It should not be toxic to the beneficial species in the water, and
 4. It should not develop any kind of disorder in man neither on a cellular level nor on a molecular basis.

Unfortunately, none of the suggested disinfectants satisfies these four factors simultaneously. As a result, the chlorination controversy continues.

7. In spite of unsuccessful efforts of finding an adequate replacement for the chlorination process, it was often suggested to use the combination of unit operations and unit processes to minimize the generation of organohalides in the treatment plant. One of such combinations is employed in a newly built water treatment plant of Manchester, New Hampshire, U.S.A. This particular 40 mgd plant uses dual filtration with carbon and sand beds along the the chlorination process. It has been speculated that organic matter can be adsorbed over the carbon beds so that, during chlorination, the adverse by-products of the chlorination may not be formed. Although such explanation

looks sound from a theoretical standpoint, enough scientific data was not collected so far,

1. to prove its usefulness in relation to the elimination of chlorination by-products, and
2. to confirm the position of carbon beds before or after chlorination.

The advantage of using activated carbon is that it can be used in both water and waste water treatment plants (if required) to extend the two sided protection to the source water. Another useful process which is currently in the experimental stage uses ozonation and sonication. It has been demonstrated to a limited extent that such a combination can eliminate the bacteria, viruses and other harmful micro-organisms from the water and wastewaters, although the lack of residual property of such a combination can be a significant disadvantage.

INSTITUTIONAL RESPONSE:

As can be seen from the previous discussion that chlorination controversy demands collective efforts in areas of large scale monitoring, analytical laboratory research, toxicological experiments and public health aspects of the issue. In the United States, the Congress has recently passed a safe drinking water act (PL93-523) which allows the utilities and states to take active part in water quality monitoring of public water supply. Similarly, the Environmental Protection Agency has continued its role in conducting a nationwide survey and stimulating the required research so as to help in resolving the existing chlorination controversy. The toxicological experiments and public health oriented cancer research is currently being carried out by the National Cancer Institute (NCI) and International Agency for Research on Cancer (IARC).

Until sufficient data is gathered to shift the controversy one way or other, it seems essential to consider current opinions of the following official authorities:

According to Russel E. Train, an administrator of USEPA, "Based on current knowledge, the benefits of chlorination far outweighs any potential harmful effects of compounds that may be created by the process" (4).

Erich Johnson, an Executive Director of AWWA writes that "At present there is insufficient information to justify any change in the disinfection practices. In fact, to discontinue disinfection of water with chlorine would result in great harm to the public" (4).

Gordon Robeck, Director of USEPA Water Supply Research Laboratory, has shown with calculations that, "drinking water with 133 ppb of chloroform would expose a man to 1.9 mg during a seven-day week whereas threshold limit is 48.9 mg of chloroform during 40 hour week" (4).

Similarly, the statements based on scientific research regarding carcinogenicity of chloroform and carbon tetrachloride are given in reference 4.

All these statements suggest "no panic" situation. However, there are reservations in the minds of some water professionals about such a conclusion because of very skimpy scientific data to support the issue one way or another.

SUMMARY:

Although modern instrumentations, sophisticated analytical measurement techniques and nationwide water quality surveys provide adequate information on the current level of the water quality of water resources, they can sometimes create controversies too. This is demonstrated by taking the case history of a recently raised chlorination controversy. After presenting two sides of the issue, it seems clear that it is too early to make any positive conclusions

since some major research studies and national surveys are still being done and are not complete at this date. It is hoped that such a key issue will be resolved in light of sufficient scientific evidence in the very near future.

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