6. Conclusion

We summarize the results of our investigations about the quality of water in the Hashemite Kingdom of Jordan in conjunction with the Zay Water Purification Plant.

In accordance with the measurement data about the quality of water furnished by the Water Authority and Jordan Vallay Authority, we studied various characteristics about the quality of the water which makes changes in flow down and by season along the East Ghor Canal, a source of water for the Zay Plant.

When a view is given to the section of the Canal from Inlet to Yabis, the water quality is more or less constant from Inlet. However, it is variant from Yabis to Deir Alla. When the mean values of the two sections are compared, we notice that the latter shows a tendency of increase.

The concentrations of calcium, magnesium and other substances attributable to geological features are relatively high throughout the Canal and a little higher down from Yabis. We presume that this phenomenon emerges from such conditions that the Canal water is repeatedly used and more waste water is discharged from human activities as a consequence of higher utilization of the land between Yabis and Deir Alla.

As regards sodium, potassium, chloride ion, sulfate ion, etc. the mean values are considerably high and the variation widths are large between Yabis and Deir Alla. This is indicative of heavy contamination deriving from vigorous human and agricultural activities in this region. From this it is known that throughout the Canal and particularly the downstream basin of it the ingress of contaminated human waste water is intensive, though part of the water is naturally purified.

Yarmuk and Deir Alla are nearly the same in the rate of potassium permanganate consumption value. The information we have obtained about the Canal is not sufficient, however, judging from the fact that the degree of contamination on the downstream is notably high, we assume that the rate of potassium permanganate consumption value of the water running from Inlet into the Canal through the system of underground water development is considerably low. About the concentration of bicarbonate ion found to be very high throughout the Canal, we presume that it is due to the feature of the soil. This, however, constitutes a factor for increasing the alkalinity of the water, which suggests that deliberate care be made about pH adjustment in the coagulation process at the Zay water purification plant.

From the foregoing, we emphasize that the personnel of the Zay Plant should be careful in a series of water purification processes including coagulation, for the water taken from Deir Alla is considerably contaminated by the human and agricultural waste water. For this reason, the presence of some hazardous organic matters in the water is undeniable, and also THM precursor is expected to be high.

Further, according to the analytical results of the water respectively at the Water Quality Laboratory of the Water Authority of Jordan and in Japan by ourselves, it is found that there is little difference in the quality of water from those given above.

As to the problem of trihalomethane formation potential, the test methods used in Jordan and in Japan are different, hence difference in measured values. However, it is recognized in common from both test results that the THM formation potential is increasing as the Canal flows down. This is obvious from the Jordan test result that the THM formation potential is approximately 170 μg/ℓ at Addasiyyeh and approximately 280 μg/ℓ at Deir Alla. In this conjunction we gave an explanation based on the papers by Magara et al. to such an effect that the test methods involved were to obtain a value as close as to the peak of THM formation potential.

Of the water sample brought back to Japan, we conducted a variety of simulation tests under different settings with partial alterations in the water purification process and in the trihalomethane reducing process at the Zay Plant. According to the test results, the total THM is 143 μg/ℓ after the lapse of 96 hours, an anticipated point of time for the supply of drinking water to Amman in case the water is processed in the standard sequence from prechlorination to coagulation-sedimentation to rapid sand filtration. On the other hand, it is so good as 109 μg/ℓ at the same point of time when the water is processed in a different sequence from injection of powdered activated carbon to coagulation-sedimentation at low pH (about 6.5) to intermediate chlorination to sand filtration.

Incidentally, the powdered activated carbon used at the Zay Plant is inferior in the adsorption property to the THM precursor. If this is changed for a better one, a higher removal efficiency could be obtained.

Further, basing on the analysis results of the quality of the raw water sample and on the simulation tests regarding water purification processes, we presented our ideas in favor of low pH coagulation, the adding of powdered activated carbon, the filtration by granular activated carbon, the blending with the available water and change of water intake point, and, moreover, described characteristics of these cases one by one and presented our cost estimates.

From an economic point of view, it is known that the cases of blending with the available water and of changing the water intake point are the most in the initial cost, and the cases of PAC application and of GAC filtration are the most in operating cost. By comparison of the latter two cases, it is obvious that if PAC is dosed in excess of 20 ppm throughout the year, the case of GAC filtration would eventually become cheaper in two to three years even though GAC life cycle is 30 days.

The low pH coagulation is the method which turned out to the most effective in the simulation tests. Another effect which could be expected from this method would be a reduction in the coagulant dose subsequent to the lowering of pH in dealing with the high alkaline raw water.

Intermediate chlorination is feasible without altering any part of the existing equipment, by which a THM reduction can be expected.

Neither of the low pH coagulation nor the intermediate chlorination is so expensive, and both can be put into practice at any time. Each is expected to reduce the THM concentration to about 100 μg/ℓ. Therefore, both seem to be ideal for implementation for the time being. However, neither is effective for thoroughly removing pesticides or THM, a matter unavoidably present in water, or any other chlorinated organic substance. For this reason, ideally the method of PAC application or of GAC filtration should be used.

With regard to the method of trihalomethane monitoring, we proposed an appropriate method in the followings which suitable for the prevailing water conditions in Jordan, according to our analysis results of the various tests concerned.

As the water in Jordan contains much of bromide ion, the ratio of brominated THM in the THM formed through chlorination must be high. And, as the analytical methods which are currently used in Jordan make no effective to cease a hydrolyzing process of trihalomethane intermediate to trihalomethane, the values obtained by measurement become high and the values obtained by analysis become likewise.

In view of this, we are of the opinion as a result of careful appreciation of all the problems involved that the solvent extraction method is most suitable. In this method, the extraction process of THM is simple and there should be no complicated procedure for the given THM, for it is simply put directly into the gas chromatograph after detaching the head space assembler which exists in the Water Quality Laboratory.

Finally, judging from the present conditions of water resources in Jordan, we conclude that the Zay Water Purification Plant and the East Ghor Canal are capable to fulfill their functions for the supply of drinking water to the Amman population. Our reasoning in this connection is that the quality of the purified water obtained by the above-mentioned treatments such as low pH coagulation and intermediate chlorination would be same as the quality of the tap water which is processed from a very severe water source condition in Japan and that the people drinking this quality of water would tolerate any health risk involved.

As the concentration of trihalomethane is relatively high and, although our investigations has not be able to implement, the possibility of the presence of agricultural chemicals can not be denied, we think it ideal for the Zay Plant to upgrade its efficiency by adopting advanced technology such as introduction of activated carbon treatment.

In addition, selection of a new water intake point up from the present one along the Canal where the influence by human activities is considered much less seems to be worth considering.

In connection with all the suggestions and propositions given in the foregoing, we hope continuously cooperation with the Jordan Authorities concerned in the fields of investigation, planning and designing for development of the present undertaking.

[Appendix 1]

Countermeasures for Total Trihalomethane in Drinking Water

Water Supply Division,
Water Supply and Environmental Sanitation Department,
Ministry of Health and Welfare, Japan

Following the pollution of the sources of drinking water by various factors and the development of water analyzing technology, recently, trace organic chemical substances which have not been detected before in drinking water have been defected indicating the necessity for management of the quality of drinking water from a new standpoint.

In 1974 US Environment Protection Agency (EPA) reported that many organic substances were detected in drinking water in New Orleans, and since then trace organic chemical substances in drinking water have drawn people's attention. Especially, there has been much discussion in many countries and international organizations on how to control trihalomethane which is produced by reaction between organic substances in raw water such as humic substances and chlorine which is used in public water supplies.

In Japan, the Ministry of Health and Welfare began the research into analytical methods for trihalomethane in 1976, as well as to research the mechanism of its production and how to remove it; in August 1980 the Ministry entrusted the work on countermeasures for trihalomethane contamination to the Water Quality Technical Group of the Water Quality Division, Environmental Health Council (chairman, Toshiaki Osawa, Professor of Tokyo University). The Group published a report entitled "On the Problem of Trihalomethane in Drinking Water" (Attached paper No. 1) in January in 1981. The report states that, though the concentration of trihalomethane in drinking water can be decreased by discontinuing the use of chlorine, chlorine is remarkably effective in controlling water-borne infections, and there is no substitute for it. The report's basic concept is that it is reasonable to practice various countermeasures to trihalomethane continuously such as using chlorine in water purification facilities. It also proposes countermeasures based on the following, (1) setting of a tentative target level for control of trihalomethane, (2) monitoring of trihalomethane, and (3) a method and a long-term policy to decrease trihalomethane.

The Ministry notified local governments of the countermeasures to be taken for trihalomethane in drinking water based on the report; by issuing, "Countermeasures for Trihalomethane in Drinking Water" and "Cautions on Trihalomethane Countermeasures for Water Supply."

The former notification from the director indicates (1) the target level for control of total trihalomethane is to be 0.10 mg/ℓ or less of the annual average, determined by gas chromatography using head space method, (2) the guidelines for monitoring and the arrangement of monitoring systems, and (3) means to decrease trihalomethane in water supply systems when the level in drinking water is high. The latter notification indicates cautions on testing methods, monitoring sites, frequency of determination, planning of monitoring systems, methods and policies to decrease trihalomethane.

Till now, trihalomethane in drinking water has been determined mainly in a few large cities, and according to the data available, almost all of waters tested are assumed to be under the target level of the notification. However, it relates to human health over a very long term and it is expected that for the maintenance of the safe quality of drinking water, the water works body shall arrange a monitoring system early along the lines of the notification and begin to monitor trihalomethane as well as to research and undertake some means for decreasing it, if necessary.

(Attached paper of Appendix No. 1)

The Problem of Trihalomethane in Drinking Water

Water Quality Technical Group
in Water Supply Division,
Environmental Health Council

1. Introduction

The primary purpose of water supply is to supply clean and safe drinking water. Now that over 90 % of the population receive the public water supply service, the responsibility of the water works body is increasing, and greater efforts in various aspects of water supply such as clean water sources, adequate water purification and good management of water distribution systems are required.

Now, about 70 % of the source of water in Japan is surface water; though water pollution is being improved in the aspect of the total average of the national environmental quality standard station, it tends to be worse in some water areas.

Following the recent development of analytical techniques such as instrumental analysis, various trace organic chemical substances which have not been detected before have been detected in drinking water, indicating the necessity for water quality management from a new standpoint.

In the USA and other countries, various organic chemical substances such as organic chlorine compounds have been detected in drinking water, and their chronic effect on human health is drawing people's attention. Particularly, trihalomethane has become a subject of investigation as its concentration is rather high and the chlorination in water purification processes appears to contribute to trihalomethane formation.

Under such conditions, some international organizations have begun to discuss countermeasures for trihalomethane and other organic chemical substances in drinking water.

In June 1979, the Water Management Group of Organization for Economic Cooperation and Development (OECD) began to research contents, potential toxicities, formation mechanisms, and removal of organic chemical substances in drinking water, and it published a report on countermeasures for organic chlorine compounds mainly consisting of modifications of the chlorination process.

The World Health Organization (WHO) is also investigating treatment of organic chemical substances including trihalomethane in its work to revise the standards for the quality of drinking water.

In US Environmental Protection Agency (EPA) regulated the total trihalomethane level in drinking water to under 0.10 mg/ℓ for water supplies of a given scale in November 1979; in Canada, the guideline for total trihalomethane level is fixed at 0.35 mg/ℓ. In West Germany, there is a movement to control trihalomethane and also the UK is trying to decrease trihalomethane in practice, though standards have not been established.

The Water Quality Technical Group of the Water Supply Division, Environmental Health Council, has investigated the countermeasures for the problem in Japan and come to the conclusion on monitoring and decreasing methods for trihalomethane, which is reported here.

The Group further intends to collect domestic and foreign data and to revise the report if necessary.

2. Tentative Target Level of Trihalomethane

When deciding a tentative target level for control of trihalomethane in drinking water, not only the evaluation of its effects on human health but also the possibility of its control shall be considered.

A tentative target level for control of trihalomethane was discussed considering the practical controls in foreign countries, and it was decided that an adequate total trihalomethane level (the sum of the levels of chloroform, bromodichloromethane, dibromochloromethane, and bromoform) should be under 0.10 mg/ℓ for Japan.

3. Monitoring of Trihalomethane

(1) Basic matters

Since trihalomethane is produced in the relation between the quality of raw water and its purification process regardless of the scale of the water supply facilities, it is preferable to monitor it in all the water supplies in which monitoring will be necessary. The annual average of the test results of trihalomethane shall be discussed, since the result of its intake for a long time is important in the influence of trihalomethane.

The frequency of monitoring shall be decided in practice based on the test results for raw water quality which have significant correlation with trihalomethane, as the analyses will require much time and skill.

(2) Planning of monitoring program

The monitoring program for trihalomethane is adequately planned according to the following:

Reference figure: Flowchart for monitoring of trihalomethane

1) Raw water quality and evaluation based on water quality criteria

The total trihalomethane formation potential has a correlation with the potassium permanganate consumption value or the color units of raw water, and prescribed values for these items are used as water quality criteria. According to previous investigations, adequate criteria are 12 mg/ℓ for the potassium permanganate consumption value for surface water and 20 units for the color for ground water.

Average values in the past 5 years have been obtained once a year for raw water (when a plural number of raw water are used, as to each of them), and the monitoring program is planned according to the water quality criteria.

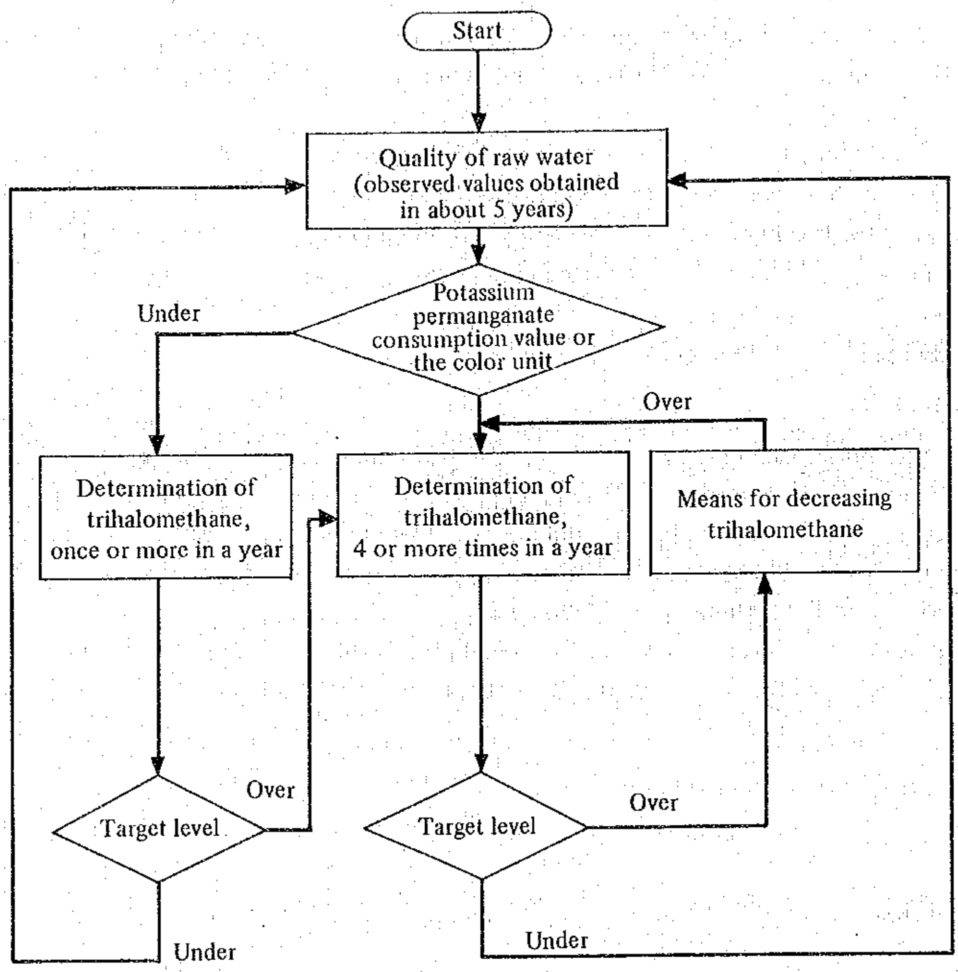
2) Monitoring of trihalomethane

(i) When the average value is over the water quality criteria described in the above 1):

The total trihalomethane is monitored 4 or more times a year according to "the method of monitoring the total trihalomethane in drinking water" attached here.

When the annual average is over the target level of trihalomethane, countermeasures for decreasing it are established and enforced such as repeating the trihalomethane monitoring.

Reference figure: Flowchart for determination of trihalomethane



(ii) When the average value is under the water quality criteria described in the above 1):

The total trihalomethane is monitored once or more a year at a similar place to that described in (i) above to get an annual average approximation of the trihalomethane level.

When the obtained value is over the target level of trihalomethane, the procedure described in (i) above is employed.

When the obtained value is sufficiently under the target level, it will be practicable to reduce the frequency of monitoring to that which appears to be adequate, considering the scale of the water supply facilities.

3) Miscellaneous

Even when the color unit of raw water is over the water quality criteria, and if it is revealed to be due to iron, manganese and the like, but not due to organic substances which seem to be precursors of trihalomethane based on the measurements of trihalomethane and the like, it is adequate to treat it as described in (ii) of 2).

(3) Method for monitoring

Monitoring is performed according to "the method of monitoring the total trihalomethane in drinking water" attached here.

(4) Arrangement of the monitoring system

For monitoring trihalomethane smoothly, it is indispensable to arrange the monitoring system well. However, the gaschromatograph with an electron capture detector which is required for trihalomethane monitoring has not been necessary to the monitoring of water quality standards regulated in the Water Works Law, and the device requires trained operators. Therefore, operators must be trained for maintenance and analytical work of the gaschromatograph with an electron capture detector as early as possible in each water works body. It is also reasonable for the analytical work to be entrusted to the water quality testing facilities of local governments, as well as creating a test system in the water works body itself.

4. Decreasing of Trihalomethane

(1) Basic matters

When an annual average of the total trihalomethane in drinking water is found to be over the target level of its control by monitoring trihalomethane in drinking water, a trihalomethane decreasing program must be planned to enforce countermeasures for decreasing trihalomethane in drinking water to under the target level.

This will involve methods to decrease the formation of trihalomethane such as eliminating its precursors and methods to remove formed trihalomethane which may be used alone or in combination. It may be also considered best to change the water source for another purer one.

The trihalomethane decreasing program shall be planned comprehensively with an understanding of the real state of trihalomethane formation and other conditions.

As great efforts are required for decreasing trihalomethane, the main emphasis must be to ensure good water quality when new water sources are employed.

(2) Decision of decreasing program

1) Research on trihalomethane behavior

For deciding the trihalomethane program adequately and effectively, it is fundamentally important to know as precisely as possible the trihalomethane levels in the water supply system from raw water to tap water and related items of water quality. Thus, the total trihalomethane level and the total trihalomethane formation potential and the like shall be measured at adequate points in each process to see the variation in a year. It is also necessary to research important matters for trihalomethane control such as addition of chemicals and operation of water supply and distributing facilities. It is also necessary to analyze the obtained results sufficiently to know the behavior of trihalomethane.

2) Understanding of conditions surrounding the water supply

When practising a decreasing plan, it is of course necessary to understand the conditions of each water supply.

Particularly, understanding of future trends in the quality of the water source is important to select adequate countermeasures, as well as understanding of the possibility of changing the intake point of the raw water itself to improve the quality.

It is also necessary to discuss the possibilities of acquiring space for the requisite water treating facilities or to arrange its maintaining system and the like.

3) Selection of decreasing program

The present state of technology thought to be available for decreasing of trihalomethane is described later in (3): as well as the properties of the technology, the results of the research described in 1) above and the conditions revealed in 2) above shall be considered to select the most adequate countermeasures for individual water supplies.

On deciding countermeasures, a variety of plans are to be evaluated as to their effect in decreasing trihalomethane, based on the results of experiments and research, as well as revealing the treating capacity, the effect on disinfection, required maintaining and managing systems in currently existing facilities; it is also necessary to consider various costs for a total evaluation.

(3) Current state and problems of trihalomethane decreasing technology

The technology for decreasing the trihalomethane level in drinking water roughly consists of the depression of trihalomethane formation and removal of the formed trihalomethane, and there are various methods for both; when decreasing the trihalomethane level practically, these may be used in combination.

1) Depression of trihalomethane formation

(i) Combined chlorine treatment can almost completely inhibit the formation of trihalomethane in water supply and distribution systems because of the absence of free chlorine. However, as the disinfecting power of combined chlorine is lower than that of free chlorine, the effect on bacteria is not always complete. It is supposed that a water system having a high level of trihalomethane precursors will have a high level of pollution with bacteria and the like, and thus this aspect must be carefully researched.

(ii) Coagulation/sedimentation process is effective for removing precursors which have rather large molecular weight, and can decrease considerably the formation of trihalomethane. thus, this will be one of the most effective methods to decrease trihalomethane.

(iii) Intermediate chlorination is a process in which after removing precursors as much as possible by coagulation/sedimentation, chlorine is added before introducing the water into a filter. It is as effective as the coagulation/sedimentation process described in (ii), but this process must be carefully employed because it affects adversely the removal of iron or manganese if ammonia nitrogen is present in the raw water.

(iv) Potassium permanganate and ozone may substitute for chlorine as an oxidizing agent. These oxidizing agents can remove products formed by chlorination and depress the formation of trihalomethane. However, they may make the water purification operation complicated and expensive, and also may produced unknown by-products. Moreover, if there is ammonia nitrogen in raw water, chlorine is difficult to remove.

(v) Powdered activated carbon treatment is a process in which powdered activated carbon (PAC) is added to raw water to adsorb and remove trihalomethane precursors. Good results can be expected when there is sufficient contact time, but it gives rise to various problems in sludge treatment and maintenance.

(vi) Granular activated carbon treatment is a process in which after coagulation/sedimentation, the water is filtered through granular activated carbon to adsorb and remove trihalomethane precursors. It has various cost problems such as the need for remodeling of existing facilities, land and the like.

2) Removal of formed trihalomethane

(i) Aeration is a process to decrease the trihalomethane level in drinking water by aeration of water containing trihalomethane: it has proved to be effective experimentally, but as it requires a large gas/liquid ratio, it is difficult to use practically.

(ii) Adsorption with granular activated carbon is to decrease trihalomethane in drinking water by filtration: it requires regeneration of activated carbon in a rather short period, and has various problems of maintenance and cost.

3) Basic direction of decreasing of trihalomethane

When comparing the process to depress the formation of trihalomethane and the process to remove formed trihalomethane, the former is more adequate for decreasing trihalomethane in drinking water.

Consequently, such combinations of trihalomethane decreasing processes as shown below can be considered to be practicable.

(i) Use of combined chlorine instead of free chlorine for disinfection

(ii) Use of intermediate chlorination in stead of prechlorination

(iii) Removal of precursors by powdered activated carbon or granular activated carbon

(iv) Removal of precursors by a combination of ozonation and granular activated carbon filter

When employing these processes, it is important to understand their properties and evaluate them rationally considering each water purification plant.

5. Decreasing Policy from a Long-term Standpoint

The currently used water purification for drinking water mainly consisting of sedimentation, filtration and chlorination has been developed primarily for removing of turbid substances in raw water and disinfection, and consequently, it is said to be inadequate to treat this new problem of decreasing organic substances such as trihalomethane and its precursors. However, at present, trihalomethane can be decreased by some processes among those which are described above.

From the long-term aspect, it will be necessary to maintain good quality water sources to control the formation of trihalomethane and the like; and to develop a new water purification system, considering the water treating methods for drinking water.

(1) Maintenance of water quality in the source of drinking water

Organic substances which are precursors of trihalomethane will be mainly humic substances. Some of them exist naturally, but in some rivers a considerable part originates from human activities. Chlorination is used for disinfection of drinking water and it is very effective in prevention of water-borne infections, and is highly evaluated at present. The advantages of chlorine, that is, its effectiveness, the residual effect and the economic usefulness in the countermeasures for aquenous microorganisms, have been well evaluated, and thus, research and development of its substitution by an effective disinfecting method for drinking water will require a very long time.

It is an urgent problem calling for, in addition to conventional methods to control organic substances in public water areas based on chemical and biological oxygen demand, a management system for organic substances including precursors of trihalomethane and the like to be established in the public water quality management system, for the purpose of keeping good water quality at the sources of drinking water.

The development of measures to maintain good water quality by control of organic substances from the above-described new aspect will also be greatly expected to contribute to decrease in organic chemical substances which are produced by various organic substances existing in public water bodies and by water treatment for drinking water.

Prechlorination is unavoidably employed for maintaining good drinking water quality and maintaining the function of water supplies against the increase of ammonia nitrogen, iron, manganese and the like, and contamination by bacteria and algae in raw water. Therefore, to develop and carry out measures for keeping good water quality and decreasing these substances and organisms in the water source of drinking water as early as possible will reduce the necessity of prechlorination, and subsequently, depress the formation of trihalomethane.

(2) Review of the water purification system

Even if the above-described countermeasures are promoted for maintaining good water quality in the water source, it will require a long time until the effects appear in practice: also, considering the present utilization of the water areas, it will be difficult to decrease sufficiently precursors of trihalomethane in all water sources. Therefore, from a quite novel standpoint, it will be important that the water purification system for drinking water is reviewed and that new systems are introduced.

As a process to decrease trihalomethane by changing the water purification process, there will be removal of precursors, ozonation without prechlorination, and removal of trihalomethane, and these have been considerably clarified, as previously described. However, even when these can be incorporated with conventional water purification systems which have been designed mainly for removal of turbid substances and disinfection, it will not always be the most efficient water purification system from economic or technological standpoints.

It is required not only to make efforts to develop and practice effective water purification processes for removal of organic substances such as precursors but also to develop water purification system which can treat most efficiently the above-described organic substances as well as conventional subject materials. At that time, it will be carefully noted whether any problem similar to the trihalomethane problem may be caused by introduction of a new treating process for removing such organic substances.

6. Summary

The Water Quality Technical Group discussed the tentative target level and technical countermeasures for trihalomethane control for drinking water based on domestic and foreign findings which are now available, and the results are reported here.

As for trihalomethane in drinking water, considerable amounts of research on determination, removal, and its effects on health are available, but some facts remain unknown. In future, it shall be further studied and also the current process shall be discussed based on the results of the studies.

Control of organic chemical substances such as trihalomethane which are contained at low levels in drinking water is an important matter in control of various substances in the environment. Consequently, it is necessary to make efforts to research their existing state in the water supplies, the effects on human health, and control methods and to arrange the management system of water supplies. However, such efforts alone are not sufficient. With the cooperation of the water supplies and wider environmental control, it is indispensable to establish a basic and comprehensive policy for these substances.

It is necessary to consolidate the strengths of various fields and also it is hoped to establish a consolidated research institute for water supply and financial support to water works.

Comparison test results of two types of powdered activated carbon (PAC) to be used at the Zay Water Purification Plant, Jordan, and being used for deodorizing at the Kunijima Water Purification Plant of Osaka City concerning trihalomethane precursor removability.

Jordanese PAC: NORIT W-20 (Moisture Content: 2 %)
Japanese PAC: KINTOL of KIYATARA Kogyo (Moisture Content: 35 %)

PAC	Dose of PAC* (mg/ℓ)	Dose of Cl (mg/ℓ)	Free Cl. in 24 hrs.	THM Formation Potential (μg/ℓ)					Ultraviolet Absorption	Fluorescene Strength	Total THM Removability (%)
				$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	TTHM			
NORIT W-20	0	12	2.0	31	8	3	0	42	0.035	33	0
	9.8	11	2.0	27	8	3	0	38	0.034	28	15
	19.6	11	2.0	28	8	4	0	40	0.032	24	27
	29.4	11	2.0	25	8	3	0	36	0.030	24	27
	39.2	11	2.5	22	7	4	0	33	0.028	23	30
	49.0	11	2.5	16	7	4	0	27	0.025	19	42
	58.8	11	3.0	13	6	4	0	23	0.033	16	52
Kiyatara Kogyo Kintol	6.5	11	2.5	25	8	3	0	36	0.031	26	21
	13.0	11	2.5	21	7	4	0	32	0.026	21	36
	19.5	11	2.5	16	6	3	0	25	0.022	18	45
	26.0	11	2.5	10	5	3	0	18	0.020	14	58
	32.5	11	2.5	9	5	3	0	17	0.020	14	58
	39.0	11	3.0	9	5	3	0	17	0.010	12	64
W-20**	49.0	20	1.6	7	1	0	0	8	0.010	9	
Kintol**	32.5	20	2.0	8	2	0	0	10	0.006	9	

* Note 1: PAC dose is given at dry rate. ** Note 2: Formation potential of PAC solution

Test Methods

1. Title: THM Precursor Removability Test
   Sample: Water of Yodo River at Kunijima Water Purification Plant

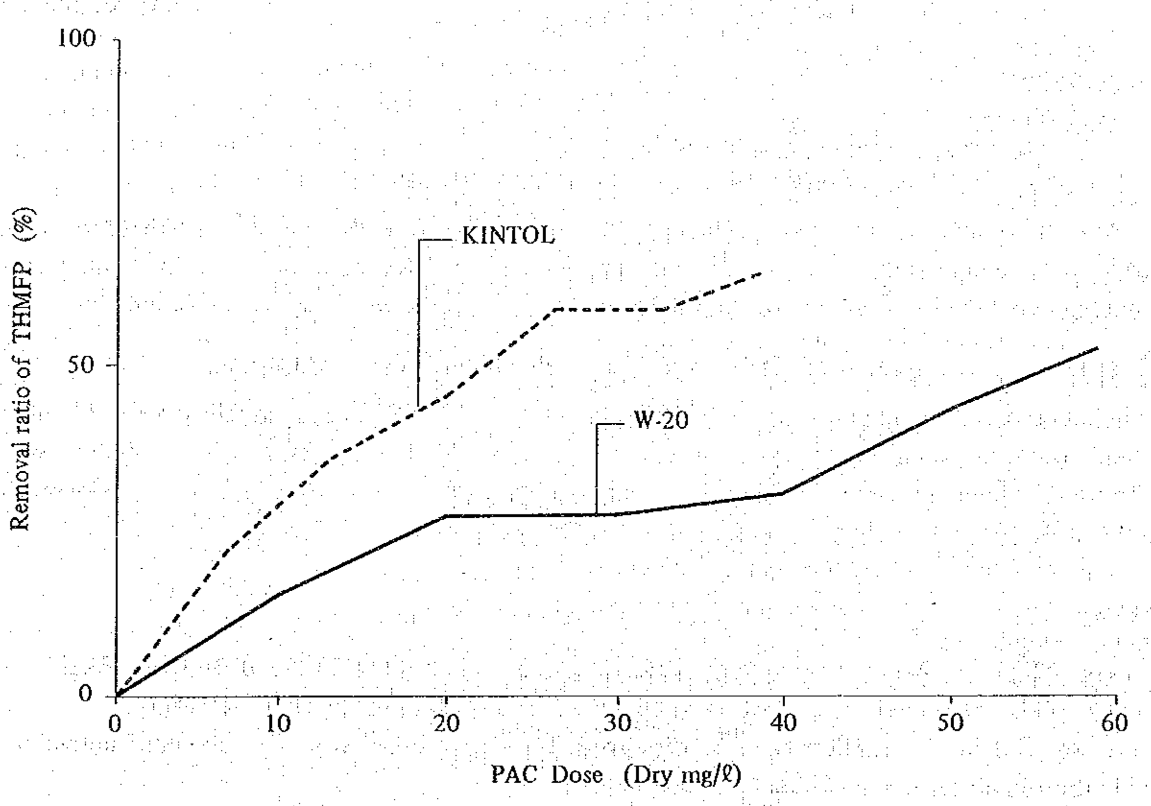
Powdered activated carbon was injected into the sample, and the sample was stirred slowly at 50 rpm for two hours, and then filtered by glass fibre filter of approximately 1 μm pore diameter. After this, the THM formation potential in the filtered water was measured.

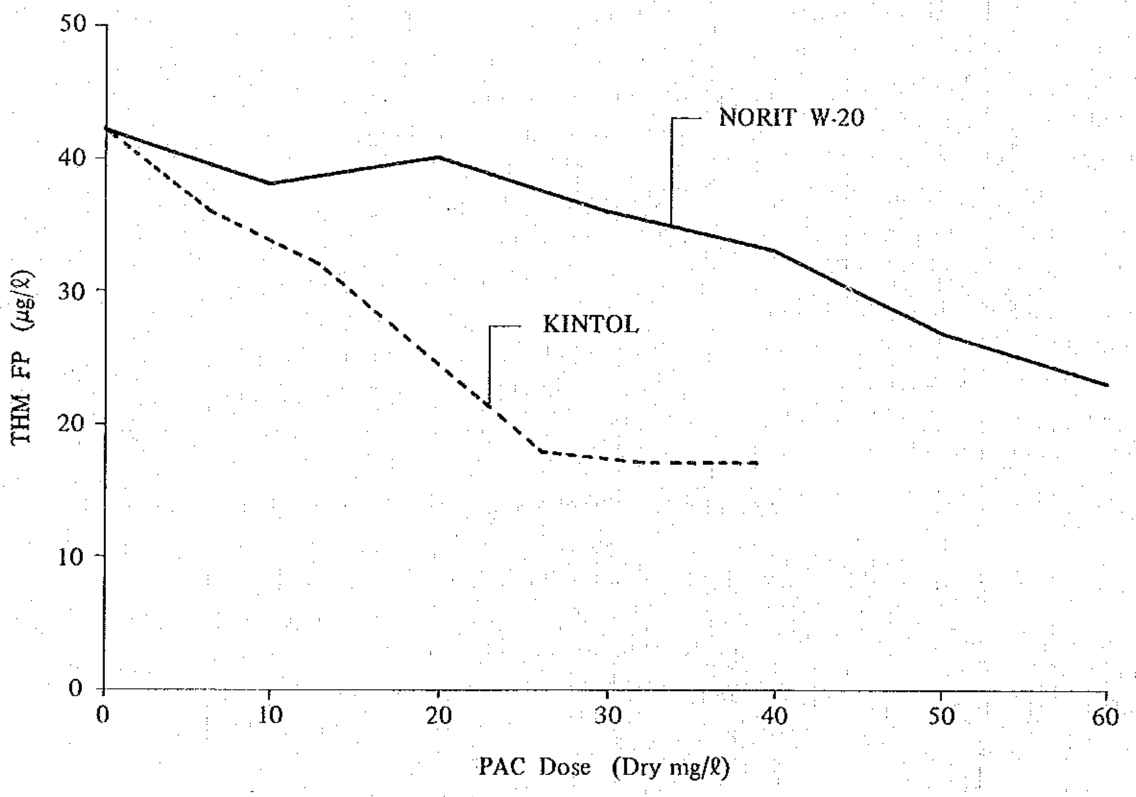
2. Title: Measurement of THM Precursor in Powdered Activated Carbon

Powdered activated carbons of NORIT W-20 and KINTOL were added separately into purified water samples at a rate of 49.0 mg/ℓ and 32.5 mg/ℓ, respectively, to obtain two different solutions. To each of these, added chlorine water at a rate of 20 mg/ℓ and measured the THM formation potential.

Results

1. The THM precursor removal rate of KINTOL is almost double that of NORIT W-20.
2. The ultraviolet absorbability of NORIT W-20 is less diminishing than KINTOL.
3. There is little exudation seen of dissolved THM precursor from the powered activated carbon in either case. (Considered as 'blank')


100
50
0
Removal ratio of THMFP (%)
KINTOL
W-20
0
10
20
30
40
50
60
PAC Dose (Dry mg/ℓ)


50
40
30
20
10
0
THM FP (μg/ℓ)
NORIT W-20
KINTOL
0
10
20
30
40
50
60
PAC Dose (Dry mg/ℓ)