MANAGEMENT OF CHEMICALS IN DRINKING WATER:

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ABSTRACT

The Japanese Drinking Water Quality Standards(DWQSs) were throughly reviewed and revised in 2003. As a result, the number of standard parameters increased from forty-six to fifty. The new DWQSs are to be enforced from 1 April 2004. Chemical constituents newly included in the DWQSs are boron, 1,4-dioxane, bromates, chloroacetic acid, dichloroacetic acid, trichloroacetic acid, formaldehyde, aluminum, geosmin, nonionic surfactant, 2-MIB (methylisoborneol) and TOC. On the other hand, several chemical constituents were excluded from the DWQSs. Regulations related to the DWQSs including the Technical Standards of Water Supply Facilities and the Standards of Structure and Materials of Service Equipment for Water Supply have already been revised or are to be revised in due course. The revision may give a significant impact on the Environmental Water Quality Standards and other water quality standards.

KEYWORDS

Water supply, drinking water quality standards(DWQSs), chemical constituents, health risk assessment, regulation

INTRODUCTION

Water supply is one of the most important social infrastructures supporting our daily life and social activities. We cannot do without continuous supply of safe and good-quality water. In Japan, raw water contamination with chemical constituents aw well as microbial constituents due to industrialization and urbanization is still a serious problem in water supply, and proper water quality management is indispensable for ensuring drinking water safety. On the other hand, deregulation, decentralization and information disclosure towards social structure reformation are key issues in water supply administration. Considering such circumstances surrounding water supply, the current Drinking Water Quality Standards(DWQSs), established in 1992, were thoroughly reviewed and revised in 2003. Regulations related to the DWQSs were also reviewed.

In this paper, the Japanese regulatory framework on chemical constituents in drinking water is introduced and discussed focusing on the revision of the DWQSs. Detailed information on the revision as well as the regulatory framework of water supply administration can be obtained

through the homepages of the Ministry of Health, Labor and Welfare(MHLW)[1] and Water Supply Division of MHLW[2].

CHEMICAL CONSTITUENTS IN DRINKING WATER AND THEIR REGULATORY FRAMEWORK

Basic considerations

Today a variety of synthetic chemicals are produced for our daily consumption and industrial use, and some of them are introduced into water environment. Raw water for drinking water supply is inevitably contaminated with synthetic chemicals depending on human activities in a watershed although measures for preventing raw water contamination are taken. This is the reason why proper water quality management is important in water supply.

Major requirements for ensuring drinking water safety may be summarized as follows:
  (1) To select water sources of good quality and to maintain them in good conditions.
  (2) To operate water treatment facilities properly along with the changes in raw water quality.
  (3) To prevent water quality deterioration in its treatment processes and distribution network.

The first priority for ensuring drinking water safety is to select water sources of good quality. However, there are actually many cases where raw water is contaminated and contaminant removal by water treatment is indispensable. Drinking water contaminants are also derived from its treatment processes and distribution network. The release of lead from lead pipes is one of typical examples. So we should take those matters into account when considering measures for ensuring drinking water safety.

Regulatory framework and present status of drinking water contamination with chemical constituents

In Japan, the Ministry of Health, Labor and Welfare(MHLW) has established the Drinking Water Quality Standards(DWQSs) and the Technical Standards of Water Supply Facilities based on the Waterworks Law. The DWQSs are directly related to drinking water safety with specifying minimum quality requirements of drinking water. Every water utility should regularly examine the parameters listed in the DWQSs and observe the DWQSs. The DWQSs may not be exceeded all the time. The Technical Standards of Water Supply Facilities specify the requirements of water supply facilities from the viewpoints of stable supply of drinking water meeting the DWQSs. The Technical Standards include the standards of materials and chemicals used for water supply for the purpose of preventing drinking water contamination in its treatment and distribution. Moreover, the Standards of Structure and Materials of Service Equipment for Water Supply have been established for the purpose of preventing the release of chemical contaminants from pipes and fittings used in household water supply equipment.

The current DWQSs on chemical constituents were established in 1992 based on latest scientific information at that time so that the consumption of drinking water throughout a lifetime may not give a significant adverse health effect. Drinking water is chemically safe so

long as the DWQSs are observed.

Drinking water quality examination for compliance is regularly being undertaken by water utilities at more than 5,000 stations, mainly at consumer taps, all over Japan. Its result is reported to the MHLW and also disclosed to the public every year. In fact, the DWQSs on chemical constituents have well been observed in Japan. The chemical DWQSs are rarely exceeded, and so far no cases of adverse health effects caused by chemical contamination of drinking water have been reported.

Table 1 shows a basic principle regarding chemical constituents in establishing the three standards, i.e. the DWQSs, the Technical Standards of Water Supply Facilities, and the Standards of Structure and Materials of Service Equipment for Water Supply. The total concentration of a chemical constituent derived from water treatment chemicals, materials used for water supply, and materials used for service equipment may not exceed 30% of its standard value, which means the concentration of a chemical constituent derived from raw water may not exceed 70% of its standard value.

Table 1 Basic principle on chemical constituents in establishing the three standards

Derivation	Allowable level
Raw water	<70% of DWQSs
Water treatment chemicals	<10% of DWQSs
Materials used for water supply	<10% of DWQSs
Materials used for service equipment	<10% of DWQSs

We have no raw water quality standards for drinking water supply in Japan. Instead, the Environmental Water Quality Standards(EWQSs) have been established. One of the purposes of establishing the EWQSs is to conserve drinking water sources. Furthermore, there are the Law of Execution of Preservation Project of Water Resource for Water Supply(Project Execution Law) and the Law Concerning Special Measures to Preserve Water Quality of Water Resource for Drinking Water(Special Measures Law) for the purpose of raw water protection.

REVIEW AND REVISION OF THE DWQSs ON CHEMICAL CONSTITUENTS

Background and consequence of review

The current DWQSs were established more than ten year ago. Since then, the circumstances surrounding water supply have changed very much. For example, the contamination of drinking water with dioxins and endocrine disrupting chemicals is a matter of great concern. Contamination with chlorine-resistant pathogens, like *Cryptosporidium*, is also a serious problem for water utilities. On the other hand, new scientific information on drinking water contaminants has well been accumulated. In addition, the latest edition(i.e. second edition) of the WHO Guidelines for Drinking-water Quality, which were referred to when establishing the current DWQSs, are going to be revised. Those are the main reasons of reviewing the current

DWQSs.

The MHLW organized a Drinking Water Quality Management Committee under the Health Science Council for the purpose of reviewing the current DWQSs in 2002, and the council submitted its report[3] on the result of review in April 2003. The new DWQSs accordingly revised were promulgated on 30 May 2003, and they are to be enforced from 1 April 2004. New regulations related to the DWQSs have already been revised or are to be revised in due course.

Basic principles of reviewing DWQSs

The basic principles of reviewing the current DWQSs are as follows:
(1) All the parameters, which do not often occur in drinking water but may have a potential of adverse health effects or cause troubles in its daily use other than drinking purpose depending on location, type of water source and water treatment system, should be included in the DWQSs.
(2) All water utilities should implement drinking water quality examination for compliance on essential parameters at a specified frequency, but they may be allowed to minimize the frequency of examination for compliance on the other parameters depending on their own situations.

In total, approximately 200 chemical constituents have been reviewed, and standard parameters were selected according to the principles as described above. A reference value had been established for each chemical constituent prior to selecting a standard parameter and establishing a standard value. The criteria of selecting a standard parameter are that a chemical constituent has a potential of adverse health effects or cause troubles in its daily use other than drinking purpose, and that it has occurred in drinking water at concentrations exceeding 10% of its reference value. Chemical constituents, that do not satisfy both criteria, have not been selected as standard parameters even if they may have a potential of adverse health effects.

A reference value of a chemical constituent with a potential of adverse health effects was derived based on its health risk assessment. Basic considerations in health risk assessment remained unchanged as before. Chemical constituents with potential health risks were classified into two groups according their carcinogenicity and genotoxicity. A health-based reference value of each group of chemical constituents was calculated as described below. Dose-response relationships of carcinogens and non-carcinogens can be assumed as shown in Figure 1.

(1) Non-carcinogens(including carcinogens without genotoxicity)
   Reference value = TDI $\times$ body weight(50kg) $\times$ AF / water consumption(2 liters/day)
      where TDI = NOAEL / UF
         TDI: Tolerable daily intake in mg/kg/day
         NOAEL: Non-observable adverse effect level in mg/kg/day
         UF: Uncertainty factor(100 or more)
         AF: Allocation factor for water(10% or 20% for most chemicals)

(2) Carcinogens(excluding carcinogens without genotoxicity)

Reference values were calculated setting a health risk level at 10^{-5} in principle.
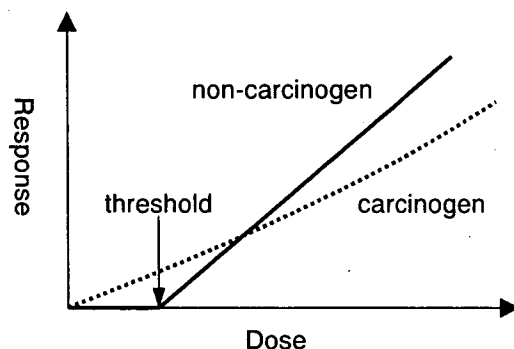

Figure 1 Dose-response relationship

If necessary, a reference value of a chemical constituent obtained as described above was slightly modified taking its analytical achievability and treatability into account when establishing its standard value.

A reference value of a chemical constituent, which cause troubles in daily use of water other than drinking purpose, was established considering a level at which difficulties may arise. Analytical achievability and treatability were also taken into account when establishing its standard value.

Revision of the DWQSs

As a result of the revision, the number of standard parameters increased from forty-six to fifty as shown in Table 2. Chemical constituents newly included in the DWQSs are boron, 1,4-dioxane, bromates, chloroacetic acid, dichloroacetic acid, trichloroacetic acid, formaldehyde, aluminum, geosmin, nonionic surfactant, 2-methylisoborneol(2-MIB) and TOC. On the other hand, several chemical constituents were excluded from the DWQSs.

Table 2 Revision of the DWQSs and guidelines related to drinking water quality

Category			Status of specified value	Number of parameters	
Revised standards/ guidelines	Standards	Relating to human health	Standard value	30	50
		Relating to basic water quality		20	
	Guidelines on Parameter relating to Drinking Water Quality Control		Target value	27	
Current standards/ guidelines	Standards	Relating to human health	Standard value	29	46
		Relating to basic water quality		17	
	Guidelines on Parameters relating to Acceptability		Target value	13	
	Guidelines on Monitoring Parameters		Guideline value	35	
	Guidelines on Pesticides used in Golf Courses		Target value	26	

In addition to the DWQSs, the Parameters relating to Water Quality Control, together with their target values, were newly established, instead of the Parameters relating to the Acceptability, the Monitoring Parameters and the Pesticides Used in Golf Courses. They include twenty-seven chemical constituents that are not so important as standard parameters

but occur or likely to occur in water environment and attention should be paid to in drinking water quality control.

Table 3 shows the revised DWQSs. Scientific information used for the revision of the DWQSs are summarized in a document[4], and authorized analytical methods on standard parameters are described in a notice of the MHLW. The Technical Standards of Water Supply Facilities and the Standards of Structure and Materials of Service Equipment for Water Supply will be revised according to the revision of the DWQSs in due course, and their revised standards are to be enforced from 1 April 2004. It has also been decided that a new system of rolling revision of the DWQSs will be introduced as the WHO Guidelines for Drinking-water Quality.

Table 3 New Japanese Drinking Water Quality Standards(To be enforced from 1 April 2004)

No	Parameter	Standard value	No	Parameter	Standard value
1	Standard plate count	< 100 /ml	26	Total trihalomethanes	< 0.1 mg/l
2	E. coli	Not detected	27	Trichloroacetic acid	< 0.2 mg/l
3	Cadmium	< 0.01 mg/l	28	Bromodichloromethane	< 0.03 mg/l
4	Mercury	< 0.0005 mg/l	29	Bromoform	< 0.09 mg/l
5	Selenium	< 0.01 mg/l	30	Formaldehyde	< 0.08 mg/l
6	Lead	< 0.01 mg/l	31	Zinc	< 1.0 mg/l
7	Arsenic	< 0.01 mg/l	32	Aluminum	< 0.2 mg/l
8	Chromium(VI)	< 0.05 mg/l	33	Iron	< 0.3 mg/l
9	Cyanides and cyanogen chloride	< 0.01 mg/l	34	Copper	< 1.0 mg/l
			35	Sodium	< 200 mg/l
10	Nitrate- and nitrite-nitrogen	< 10 mg/l	36	Manganese	< 0.05 mg/l
			37	Chlorides	< 200 mg/l
11	Fluorides	< 0.8 mg/l	38	Hardness	< 300 mg/l
12	Boron	< 1.0 mg/l	39	Total suspended solids	< 500 mg/l
13	Carbon tetrachloride	< 0.002 mg/l	40	Anionic surfactant	< 0.2 mg/l
14	1,4-Dioxane	< 0.05 mg/l	41	Geosmin	< 0.00001 mg/l[1]
15	1,1-Dichloroethylene	< 0.02 mg/l	42	2-Methylisoborneol	< 0.00001 mg/l[1]
16	cis-1,2-Dichloroethylene	< 0.04 mg/l	43	Nonionic surfactnt	< 0.02 mg/l
17	Dichloromethane	< 0.02 mg/l	44	Phenols	< 0.005 mg/l
18	Tetrachloroethylene	< 0.01 mg/l	45	Organic matter(Total organic carbon)[2]	< 5 mg/l[2]
19	Trichloroethylene	< 0.03 mg/l			
20	Benzene	< 0.01 mg/l	46	pH	5.8 - 8.6
21	Chloroacetic acid	< 0.02 mg/l	47	Taste	Not abnormal
22	Chloroform	< 0.06 mg/l	48	Odor	Not abnormal
23	Dichloroacetic acid	< 0.04 mg/l	49	Color	< 5 units
24	Dibromochloromethane	< 0.1 mg/l	50	Turbidity	< 2 units
25	Bromates	< 0.01 mg/l			

Note 1) Both standard values on Parameter 41 and 42 shall be 0.00002 ng/l, instead of 0.00001ng/l, until the day of 31 March 2007.

2) The standard value on total organic carbon(TOC)(Parameter 45) of 5 mg/l shall be replaced with that on permanganate consumption of 10 mg/l until the day of 31 March 2005.

Bromates have newly been included in the DWQSs. Their cancer risk is 2B according to the classification by the International Agency for Research on Cancer(IARC). The causes of their existence in drinking water are raw water contamination, formation in ozonation as by-products and contamination of a sodium hypochlorite solution. Bromates formation potential in ozonation is higher at higher raw water bromides concentration. Bromates in a

sodium hypochlorite solution are derived from impurities(i.e. bromides) in sodium chloride as its raw material.

1,4-Dioxane has also newly been included in the DQWSs. Its cancer risk is 2B which is the same as bromates. 1,4-Dioxane has widely been used as a stabilizer for organic solvents, e.g. 1,1,1-trichloroethane. It has been found that 1,4-dioxane sometimes occur in groundwater at very high concentrations.

Total organic carbon(TOC) is a good water quality index of total organic substances in water. Although we continued to use permanganate consumption for such a purpose for many years, it is evident that TOC is far better than that. The standard value of 5mg/l on TOC may be reviewed after several years. If necessary, permanganate consumption can still be used, instead of TOC, until 31 March 2005. Its standard value is 10mg/l in that case.

Aluminum was newly selected as a standard parameter from the aspect of discoloration but not from the aspect of its potential health effects. Whether its standard value should be 0.1 or 0.2mg/l was a point of discussions. Its standard value may be strengthened from 0.2 to 0.1mg/l in near future.

Both 2-MIB and geosmin are the causes of musty odor of drinking water. Both of their standard values are 0.1ng/l but provisionally 20ng/l until 31 March 2007. Many water utilities, having a problem of musty odor due to eutrophication of source water, will be compelled to adopt activated carbon treatment.

The standard value of lead was already strengthened from 0.5mg/l to 0.1mg/l in March 2002, and the new standard was enforced from 1 April 2003. Lead contamination of drinking water is due to its release mainly from lead service pipes. The replacement of lead pipes is being undertaken, but it may still take many years.

Table 4 shows the Parameters relating to Drinking Water Quality Control as well as their target values. Pesticide contamination of drinking water is of great concern. Although no pesticides were selected as standard parameters, they were included in the Parameters relating to Drinking Water Quality Control, where it is required that the sum of a ratio of a detected value to a target value on each of 101 specified pesticides will not exceed 1.

Regulations related to the DWQSs

According to the revision of the DWQSs, existing regulations related to the DWQSs have been revised and some regulations have newly been introduced. Important ones are as follows:

(1) Sampling points and frequency of regular water quality examination

Water utilities are required to examine drinking water quality on standard parameters at consumer taps, but they are allowed to examine drinking water quality at the outlet of a water treatment plant on some parameters whose concentration will not increase in a distribution

network. The new regulation requires a water utility to select one or more sampling point(s) in each distribution area.

Table 4 Parameters relating to Drinking Water Quality Control

No	Parameter	Target value	No	Parameter	Target value
1	Antimony	< 0.015 mg/l	17	Hardness(Ca, Mg)	10-100 mg/l
2	Uranium	< 0.002 mg/l(p)	18	Manganese	< 0.01 mg/l
3	Nickel	< 0.01 mg/l(p)	19	Free carbon dioxide	< 20 mg/l
4	Nitrite-nitrogen	< 0.05 mg/l(p)	20	1,1,1-Trichloroethane	< 0.3 mg/l
5	1,2-Dichloroethane	< 0.004 mg/l	21	Methyl-t-butyl ether (MTBE)	< 0.02 mg/l
6	Trans-1,2-Dichloroethylene	< 0.04 mg/l			
7	1,1,2-Trichloroethane	< 0.006 mg/l	22	Organic matter (Permanganate consumption)	<3 mg/l
8	Toluene	< 0.2 mg/l			
9	Di(2-ethylhexyl)phthalate	< 0.1 mg/l			
10	Chlorites	< 0.6 mg/l	23	Threshold odor number	< 3 TON
11	Chlorates	< 0.6 mg/l	24	Total suspended solids	30-200 mg/l
12	Chlorine dioxide	< 0.6 mg/l	25	Turbidity	< 1unit
13	Dichloroacetonitryl	< 0.04 mg/l(p)	26	pH	Around 7.5
14	Chloral hydrate	< 0.03 mg/l(p)	27	Corrosiveness(Langelier's index)	> -1
15	Pesticides	< 1*)			
16	Residual chlorine	< 1 mg/l			

*) As the sum of a ratio of a detected value to a target value on each of 101 specified pesticides.

The requirement of examination frequency was reduced from once a month to four times a year in principle. The new regulation also allows a water utility to reduce examination frequency on some specified standard parameters that are not important to it, e.g. carbon tetrachloride in the case of taking surface water.

(2) Quality assurance/control(QA/QC) of water quality examination

Water utilities are allowed to entrust their duty of compliance examination to a third party, including private laboratories. Since the drinking water quality examination is a very important task for ensuring its safety, laboratories engaged in the examination should well be qualified. Laboratories other than those of water utilities are required to get an approval of the Minister of Heal, Labor and Welfare at present, but they will be required only to be registered in the new regulation. Laboratory qualifications for registration will be established in due course.

(3) Water Quality Examination Plan

Each water utility are required to develop a Water Quality Examination Plan including such information as written below according to the new regulation. Water utilities are also required to disclose the plan to their consumers.

1) Water quality profile from a source to consumer taps, causes of drinking water contamination, and priority parameters in water quality control
2) Parameters regularly examined, sampling points and examination frequency together with the basis of frequency setting
3) Parameters not regularly examined together with the basis of their selection

4) Extra examination of drinking water quality

5) Whether drinking water quality will be examined by their own or by a third party

6) Others(evaluation of examination result, review of the plan, QA/QC of water quality examination, and information exchange with stakeholders)

Subjects to be further reviewed

The report[3] of the Health Science Council suggests that remaining subjects to be further discussed are as follows:

(1) DWQSs on aluminum, unpleasant microorganisms and viruses(to be reviewed in the rolling revision processes)

(2) Measures against *Cryptosporidium*

(3) Drinking water quality management practices

(4) The necessity of including the parameters relating to basic drinking water quality in the DWQSs

CONCLUSIONS

The new DWQSs and related regulations are to be enforced from 1 April 2004. They will give an impact to drinking water quality management practices in water utilities. The most important point in the revision of drinking water quality regulations including the DWQSs is that a water utility will partly be allowed to select standard parameters to be regularly examined on its own responsibility. Such flexibility will favor water utilities. Furthermore, a Water Quality Examination Plan will surely become a good tool for a water utility to communicate with consumers and other stakeholders.

The DWQSs are the key water quality standards that are closely related to other water quality standards, e.g. the Environmental Water Quality Standards. The inclusion of new standard parameters such as TOC, 1,4-dioxane, nonionic surfactant, 2-MIB and geosmin as well as *E. coli* may give a significant impact on those other standards.

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