The Present Situation and Countermeasures of Groundwater Contamination in Japan

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Abstract

Since 1982, thousands of groundwater pollution cases have been found in Japan. In order to improve the groundwater quality, Japan has developed strategies for protection of groundwater. In this paper, authors try to explain the present of groundwater use, groundwater pollution and remediation methods in Japan. From the results shown in this paper, it can be found that groundwater pollution problem has become very serious in Japan. Even many efforts have been made to improve the situation in past 15 years, there is still a long way to go to reach the goal since the characteristics of subsurface water movement and limitations of remediation technologies. Finally, groundwater pollution situation in Tokyo was discussed in more detailed.

Key words: Groundwater pollution, Remediation, Groundwater management

1. Introduction

Groundwater is immensely important for human water supply in both the urban and rural areas in Japan. Groundwater is naturally of excellent microbiological quality and generally of adequate chemical quality. According to results of census in 1994, 1.577×10^{11} m^3 of groundwater have been used for urban (4.05×10^{10} m^3), industry (6.04×10^{10} m^3) and agriculture (5.68×10^{10} m^3), which means that about 17.0% of water used in Japan comes from groundwater. Especially, 38.3% water used for industry, and 25.7% for urban life are groundwater. Figure 1 shows the variations of groundwater uses from 1974 to 1993. It was found that groundwater use increased for urban life, decreased for industry and kept constantly for agriculture in this period. It is clear that the demand of groundwater use now is the same as before.

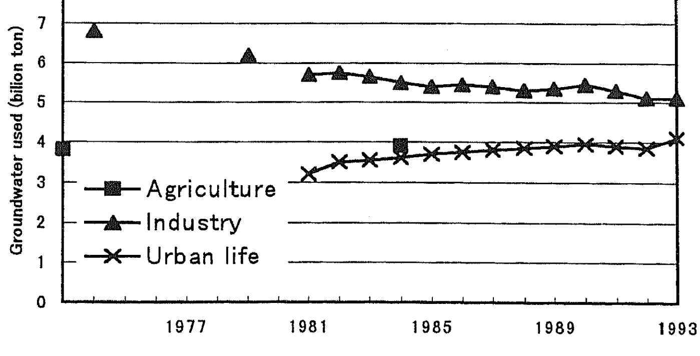

Figure 1 Variations of yearly groundwater used from 1974 to 1993.

2. Groundwater quality

Groundwater pollution due to volatile organochlorine like trichloroethylene and tetrachloroethylene has become a great environmental issue in Japan as well as in many developed nations. Comparing with surface water pollution, groundwater pollution was found later, but in larger regional scale, even contaminants had been put into subsurface at the same time. The nation-wide groundwater pollution survey for organochlorines started in 1982, and so for 2 through 5 percent of groundwater samples every year cannot meet the standard for drinking water of trichloroethylene and tetrachloroethylene. Figure 2 shows the variations of groundwater pollution cases found in the period of 1975 to 1995. In this period, 1,151 groundwater pollution cases have been found, and only 24.9% have been treated to meet Environmental Standard at the end of 1995. Most of contaminants found in groundwater were tetrachloroethylene, trichloroethylene, arsenic, 1,1,1-trichloroethane and cis1,2-Dichloroethane. About 67% of cases, the pollution area kept constant or expanded (Figure 3). It means that the groundwater pollution is a long-term problem. From viewpoint of groundwater use, 25% of pollution cases were found in the wells for drinking, and 75% for industry. However, only half cases of groundwater polluters have been identified. Also more than 50% of heavy metals pollution in groundwater occurred in nature.

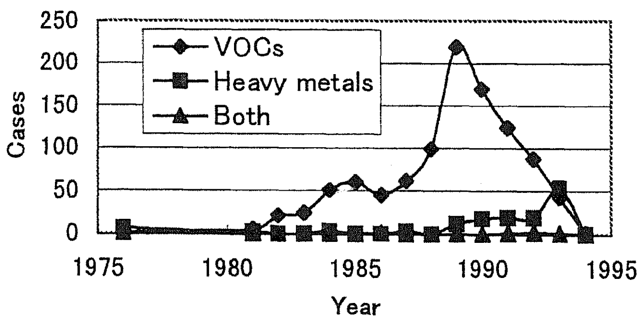

Figure 2 Variations of groundwater pollution cases found from 1975 to 1995.

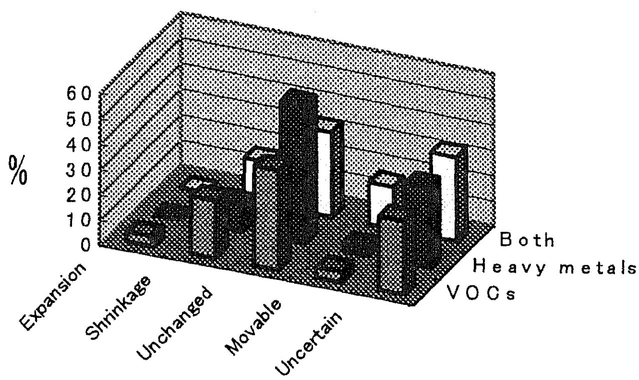

Figure 3 Variations of pollutants plume distribution.

3. Monitoring

As well known, VOC contaminants present underground can be in following four phases, i.e. gas, liquid, dissolved or sorbed.

A. As gas phase
   1. Contaminant vapors as a component of soil gas in the unsaturated zone

B. As liquid phase
   1. Liquid contaminants adhering to "water-dry" soil particles in the unsaturated zone
   2. Liquid contaminants in the pore spaces between soil particles in the saturated zone
   3. Liquid contaminants in the pore spaces between soil particles in the unsaturated zone
   4. Liquid contaminants floating on the groundwater table
   5. Liquid contaminants in rock fractures in either the unsaturated or saturated zone

C. As dissolved phase
   1. Contaminants dissolved in groundwater
   2. Contaminants dissolved in the water film surrounding soil particles in the unsaturated zone
   3. Contaminants that have diffused into mineral grains or rocks in either the unsaturated or saturated zone
   4. Contaminants dissolved in the mobile pore water of the unsaturated zone

D. As sorbed phase
   1. Contaminants sorbed to "water-wet" soil particles or rock surface (after migrating through the water) in either the unsaturated or saturated zone
   2. Contaminants sorbed on to colloidal particles in water in either the unsaturated or saturated zone
   3. Contaminants sorbed onto or into soil microbiota in either the unsaturated or saturated zone

According the above classification, there are three kinds of pollution cases. Firstly, pollutants move in unsaturated zone and have not reached to the groundwater. Secondly, pollutants can be found both in unsaturated zone and saturated zone. Thirdly, pollutants can only be found in groundwater. Clearly, the first type is an evil omen of groundwater pollution, the second type is usual case found in pollution points, and the third one can be found in the area around the pollution point. As a result, the monitoring methods used are strongly depended upon the pollution cases.

The success of remedial operation totally depends on how much information concerning the contaminants existing form and location in subsurface environment and the areal extent of pollution can be obtained. Therefore, groundwater monitoring is very important. Since 1989, groundwater qualities have been monitored throughout the country based on the revised "Water Pollution Protection Law". There are two kinds of monitoring systems, i.e. the routine monitoring and extraordinary monitoring. During the monitoring, pollution source, leakage, pollutant plume distribution should be checked. Based on the monitoring results, the assessments of groundwater pollution, groundwater remediation and environmental impacts can be carried out.

4. Solutions

The organochlorines have several insidious features to be little soluble in water and to be strongly resistant to biodegradation in subsurface environment. Such physic-chemical properties prolong the groundwater pollution once the undiluted liquids intrude into soil and groundwater zones. In addition, the groundwater pollution incidents involve difficulties to be solved, for example, not easy to identify the contaminant source and existing form in subsurface environment because of various usage in many industries, insufficient number of wells in existence to delineate the contaminant plume boundary in regional groundwater, etc.

Generally, the following steps will be taken for groundwater remediation.

a. Identification of pollution area and its sources;
b. Identification of pollution situation (in unsaturated zone or saturated zone);
c. Selection of suitable remediation technology;
d. Operation of remediation; and
e. Assessment of remediation result to meet the environmental standard.

Table 1 shows the remediation technologies used in Japan. It was found that single technology can not have a satisfying remedial efficiency, since no one can cover all steps for groundwater remediation. The most urgent problem at present to be solved is how long the remedial operations should be done because each technology has its own limitation for remediation. In this context, the suitable standard to finish the operation and the method to evaluate the effects of the remedial operations are desired.

5. Case Study

Table 2 shows the highest concentrations of trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, 1,1-dichloroethane and cis1,2-dichloroethane found in the groundwater of Tokyo area. In many pollution cases, it was found that 1, 1-dichloroethane and cis1,2-dichloroethane had close relationships with trichloroethylene and tetrachloroethylene. As a result, both have been checked since 1995. From Table 1, the highest concentrations of trichloroethylene and tetrachloroethylene have decreased since 1992, especially in the area where groundwater remediations were on operation. On the other hand, the highest concentrations of 1,1,1-trichloroethane, 1,1-dichloroethane and cis1,2-dichloroethane increased slowly.

Figure 4 shows the variations of percentage of groundwater samples that could not meet the environmental standard in Tokyo area. It was found that groundwater quality had been improved greatly from 1986 to 1990, when groundwater remediation began. However, groundwater pollution by VOCs has not decreased, in spite of many efforts made to get contaminants out from groundwater after 1990. Here, we found that there are some limitations for the present remediation technologies. As a result, the groundwater pollution is a long-term problem.

Table 1 In-situ technology comparisons

In Situ Technology	Design Basis	Operational Mechanism	Applicability	Scale	Expected Efficiency	Commercial Availability
Aerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot/ Available
Anaerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot/ Available
Electro-Osmosis	Theoretical	Treatment/ Recovery	Dissolved phase only	Pilot	Low	Available
Electroacoustic Soil Decontamination	Empirical/ Theoretical	Treatment/ Recovery	Dissolved phase only	Labor atory	Low	Emerging
Slurry Walls	Empirical	Containment	Dissolved and separate phase	Full	High	Available
Grouting	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/ High	Available
Hydraulic Gradient Control	Theoretical	Containment	Dissolved phase only	Full	Intermediate/ High	Available
Stabilization/ Solidification	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/ High	Available
Permeable Treatment Walls	Empirical/ Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/ High	Pilot
Alkali Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/ High	Pilot/ Available
Cosolvent Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Labor atory	Intermediate	Emerging
Surfactant Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/ High	Pilot/ Available
Water Flooding	Empirical/ Theoretical	Recovery	Dissolved and separate phase	Full	Low/ Intermediate	Available
Air Sparging	Empirical	Recovery	Dissolved phase only	Full	Intermediate/ High	Available
Vacuum Vaporizer Wells	Theoretical	Recovery	Dissolved phase only	Full	Intermediate	Available
Steam Enhanced Extraction	Theoretical	Recovery	Dissolved and separate phase	Pilot	High	Pilot/ Available
Radio Frequency Heating	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate	Pilot
Vitrification	Empirical	Treatment/ Recovery	Vadose Zone only			

Table2 The highest concentrations detected from groundwater from 1992 to 1996

Year	trichloroethylene	Tetrachloroethylene	1,1,1-trichloroethane	1, 1-Dichloroethane	Cis1,2-Dichloroethane
1992	1.6	7.4	0.45	Unavailable	Unavailable
1993	1.2	4.7	0.11	Unavailable	Unavailable
1994	0.63	0.83	0.087	Unavailable	Unavailable
1995	0.81	0.93	1.5	0.058	0.22
1996	0.77	1.6	3	0.38	0.36

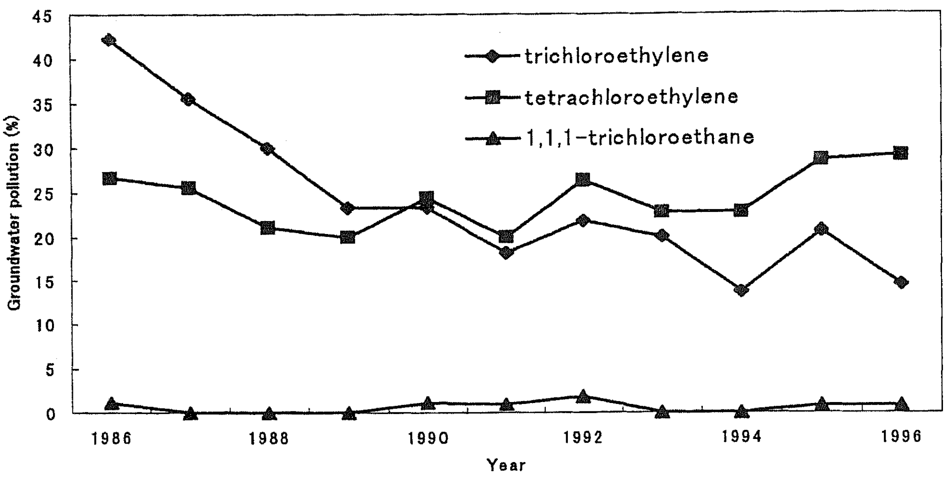

Figure 4 Variations of percentage of groundwater samples that could not meet the environmental standard in Tokyo area.

6. Conclusions

Management of our groundwater systems of necessity should be underpinned by sound science. By nature, management strategies should also be evolutionary and adaptive. There has been a very strong interest in groundwater in relation to environmental management generally, and more specifically to combat land degradation, for maintenance of healthy ecosystems, as well as for protection and maintenance of potable water resources.

From hydrological point of view, groundwater movement is one of slower parts in water cycle. At the same time, contaminants such as VOCs can remain in soil or aquifer for a long time. From the results shown in this paper, it can be found that groundwater pollution problem is very serious in Japan. Even many efforts have been made to improve the situation in past 15 years, there is still a long way to reach the goal.

The existing form and concentration of contaminant in the subsurface environment will change with local water movement and remediation processes. Moreover, the application of a single technique to the contaminated site is limited to reach the final goal, in which the subsurface contamination is repaired to meet the regional groundwater usage. From the cost-beneficial point of view, it is of great significance to pick the suitable techniques up or combination of techniques, and in particular to keep the flexible operation in changing remediation techniques, corresponding to the existing form of contaminant in the subsurface environment.

References

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