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2－1 The Cost of Anti-Risk Measures and Perceptions of Risks

○ Katsuyoshi TOMONO
Japan Water Works Association
Yasumoto MAGARA
Hokkaido University

1. Introduction

No anti-risk measures will be implemented where no risk is perceived. It is obvious that earthquakes had not been perceived by people as a great risk in Hanshin area prior to the Hanshin-Awaji earthquake. It was a surprise for the aid forces, who were sent from Kanto area after the earthquake, to see very few fire cisterns in Kobe city. If the risk of an earthquake had been properly perceived there, and more measures against earthquakes had been made, the damage caused by the earthquake would have been much lighter. This notion will surely apply to water supply.

When weighing a particular risk, we often compare it with risks we know well. For example, one may perceive the risk of being hit by an automobile while walking in a sidewalk in comparison with that of flying a passenger airplane. He may weigh both risks to be almost equal since the former is as rare as the latter as he reads news of pedestrians hit by an automobile on the sidewalk as frequently as reports of airplane crash. As evidenced by statistics, the truth is that walking in a sidewalk is some 40 times riskier than flying a passenger airplane.

For such a comparison, the ladder of risk drawn by Hammitt [1)] presents easy reference as reproduced in Fig. 1. Referring to it, one will know that perceptions of a risk can be considerably higher or lower than the actual one. For example, the risk of lung cancer and heart disease from cigarette smoking is as high as the risk of an amateur pilot. It is interesting to know that the death rate caused by home accidents is comparable to that of suicide and homicide. As these figures are obtained in the U.S., some of risk rates may be much lower in Japan; for instance, the risk of homicide is about one tenth of that in the U.S. according to the Police Agency.

Risk management starts from perceptions of risks. Then, the size of each risk will be estimated so one judges whether or not any measure against the risks should be undertaken. Since a risk can occur at various magnitudes, the greater the magnitude of a risk envisaged, the higher the cost of measures against the risk. However, funds available for new investments are almost always limited. We should implement the most cost-effective anti-risk measures applying available funds. The final, most important process is the assurance that the anti-risk measures are supported by consumers who will finally pay the cost of such measures.

2. Strategy Against Risks

There may be three principal means to cope with possible risks:

1) Risk prevention,
2) Risk abatement, and
3) Post-risk measures

Risk prevention, if perfect, means no occurrence of risk. A typical example is cancellation of an airplane trip to avoid an airplane accident. In regard to water supply, the change from the disinfection system with chlorine gas into the one with sodium hypochlorite solution so as to avoid gas leak accidents.

Risk abatement is based on the concept that a certain risk is considered impossible to be prevented from happening. Therefore, the next best way to cope with the risk is to reduce the magnitude of the risk by a measure against it. One such example is a project to raise the height of a dike in prevention of a flood even though the dike may collapse if a greater flow comes into the river. Another example is an airbag to be installed in an automobile. In relation to water supply, the replacement of asbestos cement pipe with ductile iron pipe is a risk abatement measure. All the same, the airbag cannot prevent the passenger from an injury if the car collide in higher speed than anticipated. Likewise, the ductile iron water mains may not withstand an earthquake stronger than the one envisaged at the time of laying.

Post-risk measures are designed to recover the cost of the risk consequences as much as possible. A typical example is an insurance policy to hedge the cost of damage to facilities to be caused by a risk event. In the case of water supply, the water utility may store an extra amount of materials to be used for repair of leaks on water mains. The provision of emergency cisterns and water tank lorries for emergency water service is another form of post-risk measure. Some water utilities will opt for establishing a cooperation agreement with neighboring utilities for restoration works required after such major risks as earthquakes. Insurance policies to be taken by water utilities are rather common internationally whereas they are rather rare in Japan except for fire insurance on office buildings.

3. Risks Related to Water Supply

Risks related to water supply may be classified into 1) natural risks, 2) social risks, and 3) humanly risks. [2)] Natural risks include earthquake, lightning, flood, draught, heavy snow, etc. Social risks consist of such events as power failure, burst of water mains, chlorine leakage, and deterioration of financial operation of water utilities. Humanly risks comprise accidental water source pollution, cross connection, erroneous handling of instruments, terrorism on facilities, etc. Those who are engaged in the water supply industry only tend to regard direct hazards to water utilities such as earthquake, draught, water pollution and floods as a risk. However, the consumers also consider such other hazards as carcinogens in tap water as a risk.

4. Anti-Risk Measures Related to Consumers

Consumers may consider the carcinogens the major risk to them. Then the feasibility study of risk abatement measures against the risk of carcinogens in tap water is an important subject. The most popular method for reducing the risk of carcinogens such as trihalomethanes in tap water is to introduce extra treatment processes in addition to the conventional ones. The most common processes are ozonation and activated carbon adsorption. If both processes are to be installed, what will be the cost of installation and operation, and the benefits? It is assumed that the concentration of trihalomethanes in treated water, unless any additional treatment processes are installed, is 150 micro g/liter, and that it can be reduced to 75 micro g/liter by the additional treatment processes.

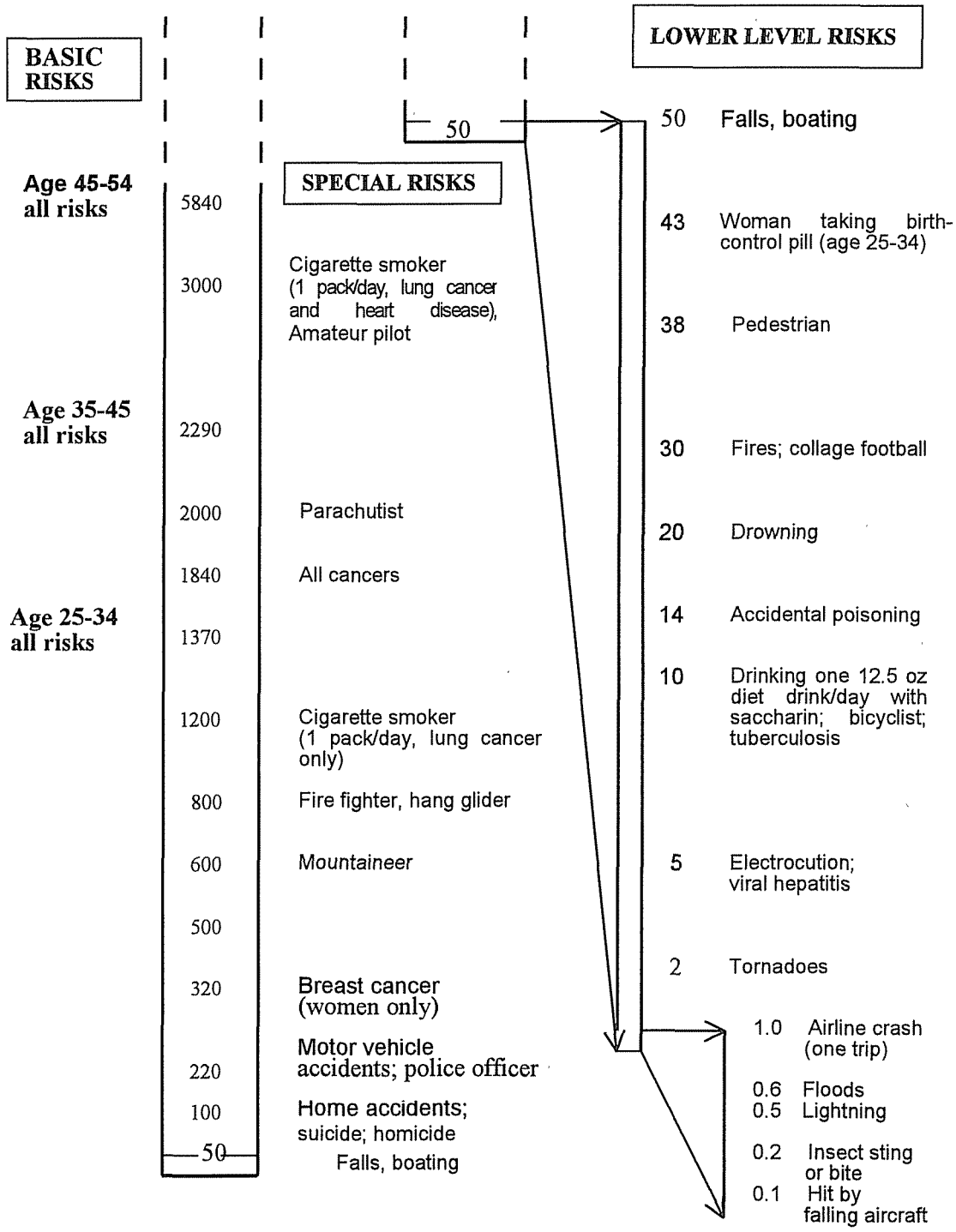

Fig. 1 Risk ladder indicating annual mortality probabilities from various risks
(Hammitt 1990)

Referring to the general concept of the water quality standards, it is assumed that the rate of additional cancer cases is one per 100,000 persons if a person drinks every day 2 liters of water containing THMs at the concentration of 100 micro g/liter for 70 years, which is tentatively considered the average life of man. If there is a group of population of 1,000 persons at age of 70, who have consumed the above water, the number of cancer cases will be 0.01 persons (1,000 times one 100,000th) (more precisely, in the marginal one year when he becomes 70; or commonly speaking, during one year from when he is 69.5 to when he is 70.5). Accordingly, if the THMs concentration is 150 micro g/liter or 75 micro g/liter, the number of the cancer cases will be 0.015 or 0.0075, respectively. Since the rate of cancer contraction is considered to be proportional to the time period of exposure, for a person at the age of N years, the probabilistic rate of his cancer contraction will be N/70.

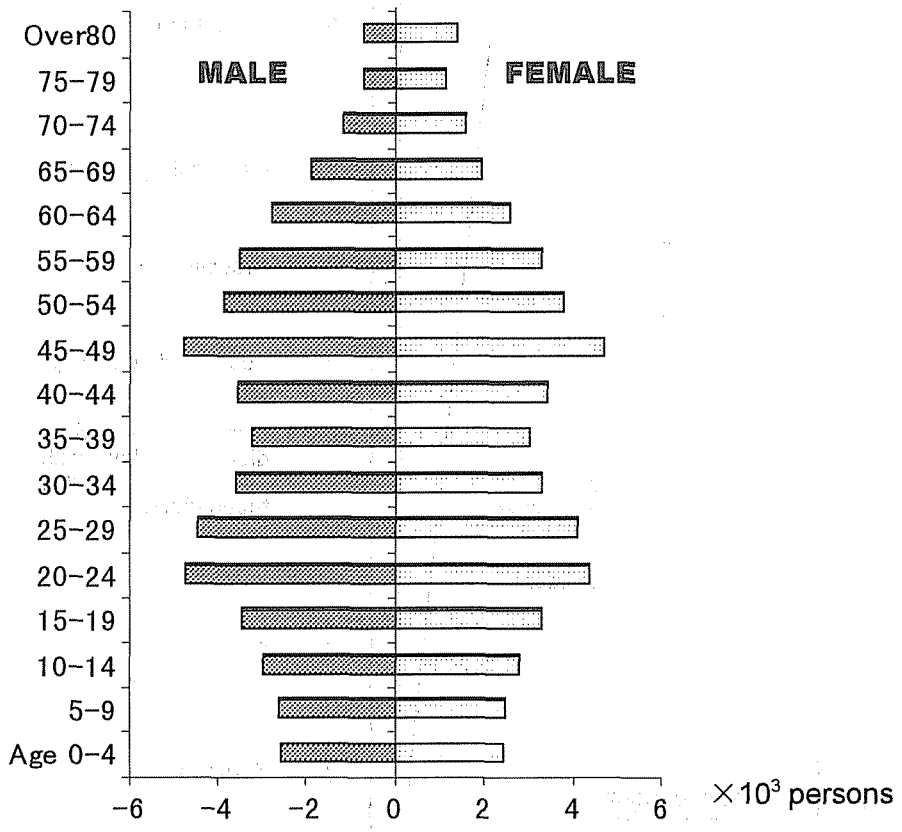

Fig. 2 Population Pyramid in Model City

5. Population Model

The Bureau of Statistics of Japan supplies demographic data through the Internet. Using such data on the population distribution by age group of Saitama Prefecture, a model city with a population of 100,000 persons is created. The population pyramid of the Model City is illustrated in Fig. 2.

6. Cancer-Afflicted Population

As illustrated in Fig. 2, the total population is divided into the age groups with the age range of five years. As an example, as the population in the 40-44 age group is 6,960 persons, the cancer-afflicted population due to the THMs in the above setting in this group is approximately computed as follows:

$$\frac{40+44}{2} \times \frac{1}{70} \times 10^{-5} \times 6{,}961 = 0.0417$$

Likewise, the total population afflicted by cancer is calculated as follows:

$$P_C = \sum_{i=1}^{n} \left[\frac{Y_{iL} + Y_{iU}}{2(70)} \cdot 10^{-5} \cdot P_i \right] \quad \text{.....(1)}$$

where,

P_C is the total population contracted by cancer,

Y_{iL} is the lower limit age in the i th age group

Y_{iU} is the upper limit age in the i th age group

P_i is the population in the i th age group

In conclusion, the incremental population afflicted by cancer due to 100 μg/liter of THMs in the Model City will be 0.533 persons per annum. By interpolation, the additional affected population in the case of 150 μg/liter will be 0.800 persons; and 0.400 persons in the case of 75 μg/liter. By multiplying these values with the value of social costs per person, the total cost of the population group due to cancer is computed.

7. Cost and Benefits of Anti-Risk Measures

The per-capita social cost of deaths due to cancer in a population group is considered to be equal to the total product of that population to be realized if the population are fully engaged in production for the rest of their lives. Since its accurate calculation is difficult, however, it is assumed that the base of the cost is equivalent to the average life insurance money to be paid to the people in their most productive age.

Summing up the costs for all the age groups in the above Model City, the total costs for the city will be 21 million yen per annum. Further, the costs shall be summed for the life of the above water treatment facilities. However, using certain discount rate, the future expenditures must be discounted. As the money, e.g., ¥10,000, to be received one year later is to be valued less than the same amount to be received now, the future costs are less valued than ones to incur at present. In conclusion, with the assumed discount rate of 3 % per annum and the life of the project to be 30 years, the total present value of the cost due to the cancer cases in the city will be 412 million yen as shown below:

$$21{,}000{,}000 \times 19.6 = 412{,}000{,}000$$

where, 19.6: the uniform series present worth factor F_P, which is computed as follows:

$$F_P = \frac{i(1+i)^n}{(1+i)^n - 1} \quad \text{.....(2)}$$

where,

F_P is the uniform series present worth factor,

i is the discount rate, and

n is the life of the project (years)

This will be the benefit to be realized by constructing facilities to remove 75 μg/liter of the carcinogen

THMs contents from the tap water.

This is equivalent to 1.65 yen/m^3, which is much smaller than the cost of the facilities per cubic meter at 18.1 yen/m^3. Nonetheless, the benefit may be doubled if the cost of medical care of the cancer patients is taken into account. Furthermore, the benefits will expand if the fact is taken into consideration that not only THMs but also other cancer causing substances are removed at the same time.

So far the general concept prevailing at the moment is to construct the facilities for removal of such carcinogens whatever the cost be. Then, after decision what method should be employed, efforts should be made to make the cost as low as possible. In this paper, brief analyses were made on not only the cost of risk abatement measures but also their benefits. Since water supply is an extremely important public service, even if the benefits of such measures are no much to their cost, it is important to compare the benefits from alternative measures.

8. Conclusions

Anti-risk measures will be effectively planned and implemented only where the risk is properly perceived. Although risk perception is made in different ways from person to person, people often perceive a new risk after comparing it with another risk known to him.

To evaluate the effectiveness of the project for a risk abatement measure, a model city with a population of 100,000 persons was created. The purpose of the project is to reduce the cancer risk caused by THMs in tap water. The THMs concentration of 100 μg/liter in drinking water is considered to cause 1 case of cancer in 100,000 persons if it is drunk for 70 years. At this level of THMs contents, the number of cancer cases in the Model City will be 0.533. It is assumed that the tap water in the model city contains 150 μg/liter of THMs. Under the project, the THMs contents will be reduced down to 75 μg/liter. The reduction in the cancer cases will be 0.400, namely, from 0.800 to 0.400.

Totaling the benefits, i.e., the balance of damage "with and without " the anti-risk measure from all the age groups, the total annual benefits of the project is calculated at 21 million yen per annum. Hence, the total benefits for the life of the water treatment facilities will be 412 million yen. Therefore, the benefits from the project per cubic meter of water is 1.65 yen, which is less than one-tenth of the cost of the treatment facilities at ¥ 18.1/m^3. [3] However, the water utility may have to implement an anti-risk measure even if the cost is very high to entertain strong consumers' demand for safe tap water.

Due to relatively small amount of financial benefits, the internal rate of return of the anti-risk measures related to carcinogens in tap water may be quite small. However, the principal motive for implementing anti-risk measures shall not be the magnitude of financial benefits, but the provision of safe water to be secured even at the time of major risk events.

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