A FUNDAMENTAL STUDY OF AN INFECTION RISK CAUSED BY THE COMPOUND DISASTER OF A GREAT EARTHQUAKE AND FLOOD IN METROPOLITAN AREAS

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In this study, the risk assessment technique of pathogens was applied to the compound disasters of a great earthquake and flood, and the infection risks of some pathogens were calculated quantitatively. As for the results, even if the metropolitan area where functionality is normally high, when it suffers a compound disaster, such as being hit by a great earthquake and a flood, it was found that the infection risk increases remarkably. Thus, not only care of physical externally caused injuries, but also that of infectious diseases is vital in such compound disasters.

Keywords: compound disaster; flood; heavy rain; metropolitan area; microbial risk

Introduction

The Great East Japan Earthquake (magnitude 9.0) occurred on Friday, March, 11, 2011, and the sewage systems were intensely damaged. As a result, the condition of the hygienic situation became inferior, and the risk of exposure to pathogens was considered to be increased in the disaster area because the flushing toilets which need a sewage treatment system were unusable. On the other hand, in addition to torrential rainfall and typhoon damage which occur frequently, the possibility of the occurrence of a massive earthquake, such as a metropolitan direct-hit earthquake, has been increasing in the Tokyo metropolitan area in recent years. In other words, the risk of a compound disaster generated by heavy rain and a flood after a big earthquake is high in the Tokyo metropolitan area. In this case, the situation that the raw sewage from a drain pipe flows out by the destruction of a sewer pipe network and the filth in a temporary lavatory installed after a massive earthquake flows out by a flood are expected. In these cases, it is considered that the infection risk increases remarkably.

Therefore, in this study, the risk assessment technique of pathogens was applied to the compound disaster of a great earthquake and flood and the infection risks of some pathogens were calculated quantitatively. As for the results, even in the metropolitan area where functionality is normally high, when it suffers a compound disaster, such as being hit by a great earthquake and a flood, it was found that the infection risk increases remarkably. Thus, not only care for physical externally caused injuries, but also that of infectious diseases is vital in such compound disasters.

Microbial risk assessment methods

Risk assessment is a powerful tool for evaluating the influence of agents on humans. From the 1970s to the 1980s, the current method of risk assessment was developed mainly by the National Academy of Sciences (NAS). This method consists of 4 parts: Hazard identification, Dose-Response assessment, Exposure assessment, and Risk characterization. Hazard identification is description of the features of infection, such as condition, incubation period, and duration of the pathogen evaluated in the risk assessment. Dose-response assessment is characterization of the relationship between various doses administered and the incidence of health effects. Exposure assessment is determination of the size and nature of the population exposed and the route, amount and duration of the exposure. Also, risk characterization is integration of the formation from exposure, dose-response and health steps in order to estimate the magnitude of the public health problem and to evaluate variability and uncertainty.

Microbial risk assessment caused by the compound disaster of a great earthquake and flood

In this study, microbial risk assessment was applied to the compound disaster of a great earthquake and flood according to the procedure mentioned above.

Hazard Identification

Paying attention to enteric pathogens, enterovirus, rotavirus, norovirus, shigella spp., salmonella spp., and vibrio cholera, which have high concentration in the feces of the infected people, were selected for the reference pathogens. According to the literature, the concentration of pathogens in sewers and feces are shown in Table 1 and Table 2, respectively. Regarding Table 1, the influent of the public sewerage plants in the metropolitan area in Japan were selected.

Table 1: Concentration of enteric pathogens in wastewater

Pathogen	Concentration (/L)	Reference
Enterovirus	$10^{4.78}$～$10^{6.16}$	(Katayama *et al.* ,2008)
Rotavirus	10^{3}～10^{5}	(Saito,2011)
Norovirus	$10^{6.96}$～$10^{8.22}$	(Katayama *et al.* ,2008)
Shigella spp.	10^{3}～10^{4}	(Kaneko,1996)
Salmonella spp.	10^{3}～10^{4}	(Kaneko,1996)
Vibrio cholerae	10^{1}～10^{3}	(Kaneko,1996)

Table 2: Concentration of enteric pathogens in feces

Pathogen	Concentration (/g)	Reference
Enterovirus	$10^3 \sim 10^7$	(Haas *et al.* ,1999)
Rotavirus	10^{10}	(Haas *et al.* ,1999)
Norovirus	$10^5 \sim 10^9$	(Ozawa *et al.* ,2007)
Shigella spp.	$10^5 \sim 10^9$	(Haas *et al.* ,1999)
Salmonella spp.	$10^4 \sim 10^{11}$	(Haas *et al.* ,1999)
Vibrio cholerae	$10^8 \sim 10^9$	(Yamamoto,2009)

Dose-response assessment

Several models that show the relationship between the intake dose of the pathogen and the microbial risk have been proposed by Haas (Haas, 1983) and Rose (Rose *et al.*, 1991); the appropriate infective model, shown in Table 3, was used. Furthermore, Figure 1 shows these dose-response relationships according to the model and parameters shown in Table 3.

Table 3: Dose-response model and parameters used in the study

Pathogen	Dose-response model	Parameter					Reference
		α	β	γ	μ	σ	
Enterovirus	Lognormal				5.523	4.291	(Cooper *et al.* ,1984)
Rotavirus	Beta	0.232	0.247				(Rose *et al.* ,1991)
Norovirus	Exponential			0.0069			(Masago *et al.* ,2006)
Shigella spp.	Beta	0.16	155				(Rose *et al.* ,1991)
Salmonella spp.	Beta	0.33	139.9				(Rose *et al.* ,1991)
Vibrio cholerae	Beta	0.164	0.149				(WHO,2006)

Exposure assessment

In this study, two scenarios were assumed considering the exposure route to the pathogens during the compound disaster as follows.

Scenario 1: Being hit by a flood while the sewer is overflowing by damage to the drain pipes, a person intakes the sewer by mistake during the flood.

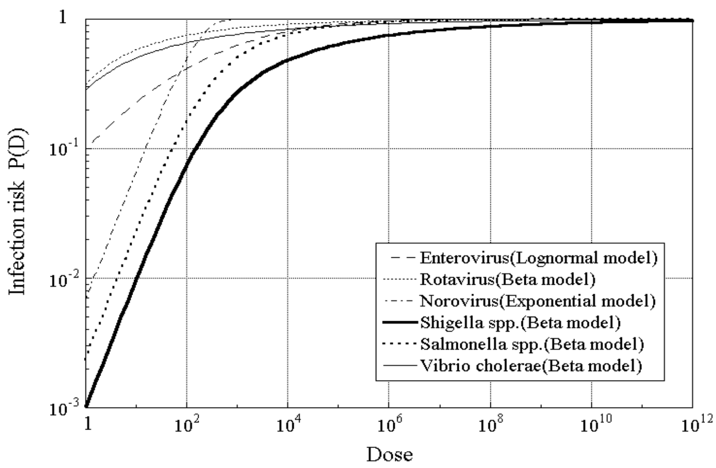

Figure 1: Dose-response relation of each pathogen

Scenario 2: Being hit by a flood while using a temporary outdoor lavatory, the filth in the toilet flows out and a person intakes it by mistake during the flood. In this case, it was assumed that there is an infected person among the temporary lavatory users and the amount of the feces per day per capita was assumed as 150 g.

The source of infection of scenarios 1 and 2 is mainly human excrement. It is assumed that various viruses and bacteria are contained in the sewer in scenario 1, and on the other hand, they exist in the filth of the temporary lavatory in scenario 2. The infection risk to a pathogen arises by drinking them by mistake. Especially in scenario 2, when the infected person exists among the users of a temporary lavatory, it is considered that an infection risk becomes very high.

Risk characterization

According to the results of the dose-response and exposure assessment, at first, risk calculation in exposure case 1, which is considered to be the worst case, and cases 2-4, which are considered to be the actual cases, as shown in Tables 4 and 5, were performed. In addition, risk calculation was performed stochastically using Monte Carlo techniques. The data generated stochastically were the concentration of the pathogens in the sewer, the concentration of the pathogens in the feces, and the dilution rates of the flood as log normal distributions which defined the median and standard deviation as follows, respectively. The median and standard deviation of the concentration of the pathogens in the sewer and the feces were set to be the values in Tables 1 and 2, respectively, and that of the dilution rates of the flood was set to be $10^{2\pm2}$. According to these conditions, assuming a 10 mL intake, the infection risk was calculated in scenarios 1 and 2.

Table 4: Conditions in scenario 1

case	Dilution by flood (times)	Amount of intake (mL)	Concentration of pathogen in wastewater (/L)
1	1	100	Maximum value in Table 1
2	100	10	Maximum value in Table 1
3	100	10	Median value in Table 1
4	100	10	Minimum value in Table 1

Table 5: Conditions in scenario 2

case	Dilution by flood (times)	Amount of intake (mL)	Concentration of pathogen in feces (/g)
1	1	1g of infected person's feces	Maximum value in Table 2
2	100	10	Maximum value in Table 2
3	100	10	Median value in Table 2
4	100	10	Minimum value in Table 2

Results and Discussion

Figure 2 shows the result of the risk calculation in the exposure case 1, which is considered to be the worst case, and cases 2-4, which are considered to be the actual cases, as shown in Table 4, according to scenario 1. As shown in Figure 2, there is a difference between the infection risk of viruses and that of microorganisms. This is because the concentration of the viruses in the sewer is much higher than that of microorganisms, as shown in Table 1. The selected microorganisms as the reference pathogens have had few symptom examples in Japan in recent years. Therefore, its pathogen concentration in a sewer is also low. On the other hand, the concentration in a sewer of each virus is higher than that of microorganisms, including norovirus and rotavirus, the viruses which mainly expand in the winter season, and enterovirus, which causes summer colds. Figure 3 shows the result of the risk calculation in exposure case 1, which is considered to be the worst case, and cases 2-4, which are considered to be the actual cases, as shown in Table 5, according to scenario 2. As shown in Figure 3, in the case of scenario 2, there is less of a difference between the infection risk of viruses and microorganisms compared to that of scenario 1. The reason of this is that the assumption of one infected person among the temporary lavatory users in the case of scenario 2.Therefore, the concentration of the pathogen in the feces and the power of the infection of it directly affect the result of the risk. Thus, both of the infection risk of viruses and the microorganisms are high, especially, the pathogen of high concentration in feces and the high power of the infection problem.

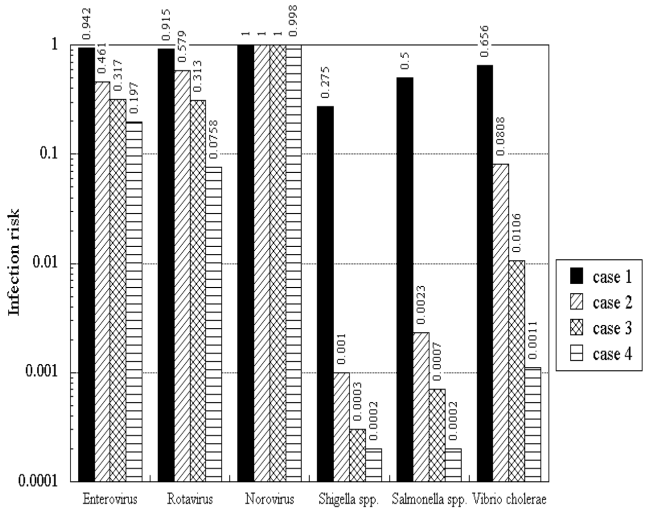

Figure 2: Result of the risk calculation according to scenario 1

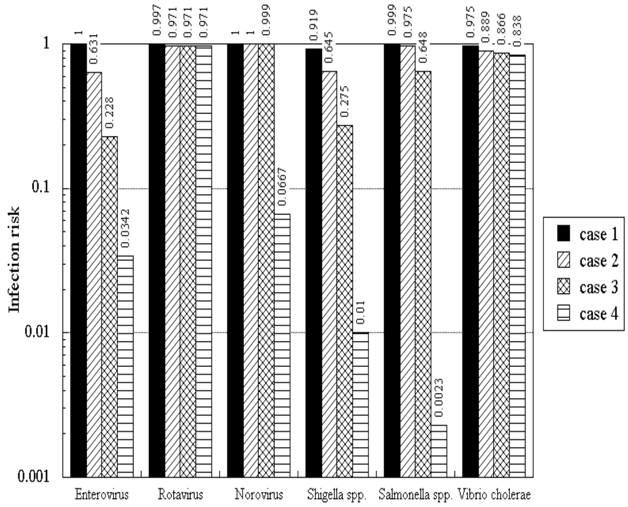

Figure 3: Result of the risk calculation according to scenario 2

In addition, the 95% confidence interval of the infection risk median to each pathogen according to scenarios 1 and 2 are shown in Figures 4 and 5, respectively. As shown in Figure 4, the infection risk of viruses is higher than that of microorganisms as the concentration of the viruses in the sewer is higher than that of microorganisms. In addition, as shown in Figure 5, it was found that both viruses and microorganisms have high infection risk because they have a high concentration in the feces of the infected person, and it was assumed that there was one infected person among the temporary lavatory users.

Therefore, this indicates that infection may be expanded even if there is one infected person of a pathogen which seldom exists in the urban areas of Japan, such as vibrio cholera, if the sanitary conditions worsen during a compound disaster.

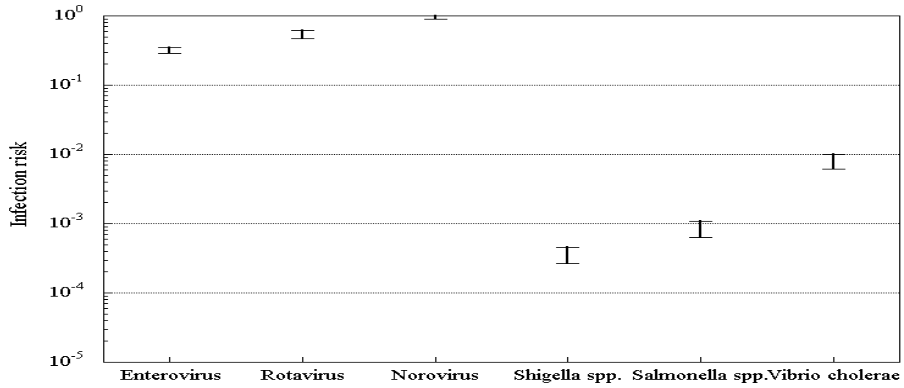

Figure 4: 95% confidence interval of the infection risk median to each pathogen according to the scenario 1

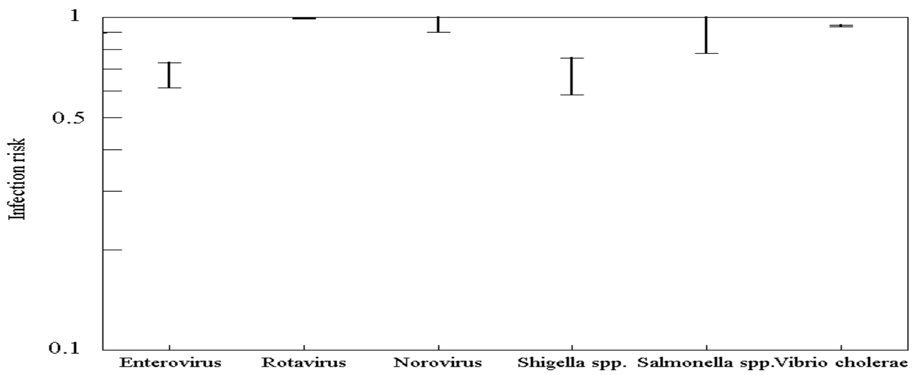

Figure 5: 95% confidence interval of the infection risk median to each pathogen according to the scenario 2

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