



ORIGINAL ARTICLE

# Emerging Pathogens and Vehicles of Food- and Water-borne Disease Outbreaks in Korea, 2007–2012

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**Abstract**

**Objectives:** Food- and water-borne disease outbreaks (FBDOs) are an important public health problem worldwide. This study investigated the trends in FBDOs in Korea and established emerging causal pathogens and causal vehicles.

**Methods:** We analyzed FBDOs in Korea by year, location, causal pathogens, and causal vehicles from 2007 to 2012. Information was collected from the FBDOs database in the Korean Centers for Disease Control and Prevention.

**Results:** During 2007–2012, a total of 1794 FBDOs and 48,897 patients were reported. After 2007, FBDOs and patient numbers steadily decreased over the next 2 years and then plateaued until 2011. However, in 2012, FBDOs increased slightly accompanied by a large increase in the number of affected patients. Our results highlight the emergence of norovirus and pathogenic *Escherichia coli* other than enterohemorrhagic *E. coli* (EHEC) in schools in 2012. We found that pickled vegetables is an emerging causal vehicle responsible for this problem.

**Conclusion:** On the basis of this study we recommend intensified inspections of pickled vegetable manufacturers and the strengthening of laboratory surveillance of relevant pathogens.

## 1. Introduction

Food-borne diseases are an important public health problem [1]. Although it is impossible to estimate the worldwide burden of food-borne diseases [2], numerous

food-borne disease outbreaks have been reported to the national surveillance and reporting systems in diverse countries such as the USA, European countries, China, and Japan [3–6]. In Korea 200–300 food- and water-borne disease outbreaks (FBDOs) are annually

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reported to the national surveillance and reporting system. However, there is little information to describe epidemiological characteristics of FBDOs in Korea including causal pathogens, causal vehicles, and outbreak places. Therefore, identifying epidemiological characteristics of FBDOs in Korea can provide additional epidemiological information of FBDOs in eastern Asia and contribute to finding global trends of FBDOs. Furthermore, considering that the epidemiological information is essential to make more efficient national policy to prevent infectious diseases, identification of epidemiologic characteristics of FBDOs is significant. Thus, this study aimed to identify the epidemiologic characteristics of FBDOs in Korea by analyzing epidemiologic data on FBDOs reported to the Korea Centers for Disease Control and Prevention (KCDC) during 2007–2012.

## 2. Materials and methods

### 2.1. Data collection

A total of 253 local public health centers are responsible for most of the epidemiological investigation of outbreaks caused by infectious diseases [7] in Korea. However, when large-scale outbreaks occur that cannot be controlled by local public health resources, Epidemiological Intelligence Service officers from the 16 provincial offices or KCDC usually conduct the epidemiological investigation [8]. Most epidemiological investigation reports and all the reports about FBDOs by microorganisms are submitted to the database electronically. All FBDOs reports were reviewed by EIS officers in KCDC to decide official results. The official results regarding causal pathogens and causal vehicles are based on the KCDC investigation report *Epidemiological Investigation Guideline for Water and Food-borne Disease* [7]. The database, the official results, and the epidemiological investigation summaries of the FBDOs are all available on the Internet [9]. In this study, we excluded FBDOs that occurred outside Korea.

### 2.2. Definition

An FBDO is defined as the occurrence of two or more cases of a similar illness resulting from a common food [7]. The causal pathogen is confirmed by standard laboratory confirmative criteria. If the laboratory results do not meet the confirmative criteria, the causal pathogen is suspected by reasonable assessment of the relevant epidemiological investigations such as checking incubation period [10,11]. The causal vehicle is confirmed when the same microorganism is isolated from the vehicles and illnesses. If the microorganism is not isolated from the illnesses, the causal vehicles are suspected by the results of statistical analysis or the laboratory results of the vehicles with an appropriate incubation period.

Because most foods contained diverse ingredients, we simplified the causal vehicles into six groups by the main ingredient: meat, seafood, fresh vegetables, pickled vegetables, water, and others. In this study, positive results include both confirmed cases and suspected cases.

## 3. Results

### 3.1. National surveillance during 2007–2012

A total of 2862 FBDOs were reported between 2007 and 2012. Of these, 1794 FBDOs affecting 48,897 patients occurred domestically and 1068 FBDOs occurred outside Korea. During 2007, 440 FBDOs and 9830 patients were reported. Thereafter, FBDOs and patient numbers steadily decreased over the next 2 years and then plateaued until 2011. However, in 2012, FBDOs increased slightly accompanied by a large increase in the number of affected patients: 350 FBDOs with 8543 illnesses in 2008; 224 FBDOs with 6827 illnesses in 2009; 256 FBDOs with 7259 illness in 2010; 236 FBDOs with 7039 illnesses in 2011; and 288 FBDOs with 9408 illnesses in 2012.

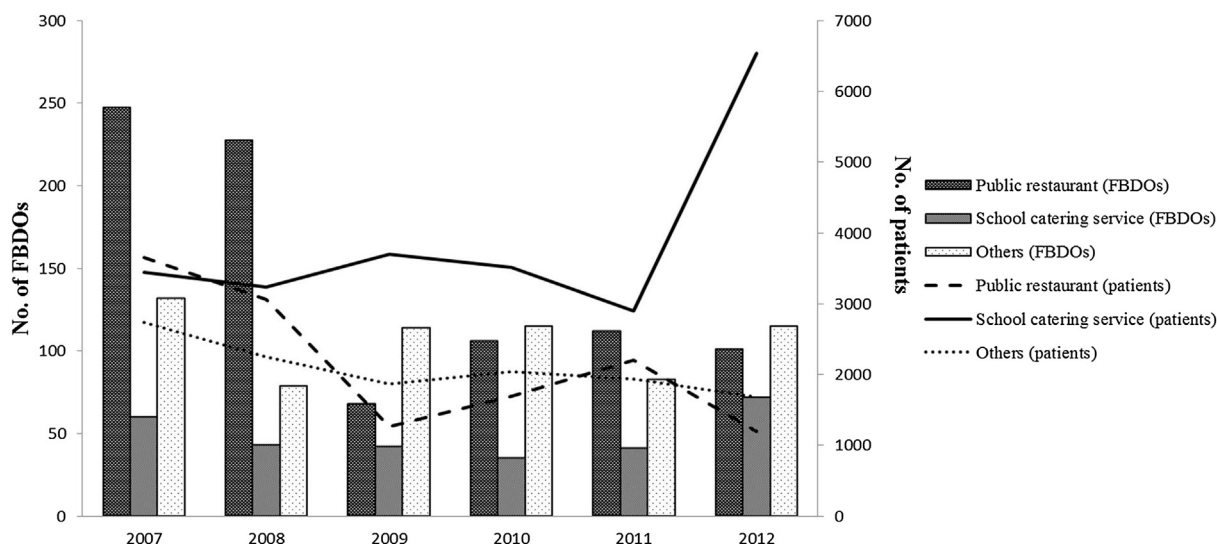
### 3.2. Epidemiological characteristics of the places where the FBDOs occurred

Over the study period FBDOs occurred most frequently in public restaurants (881 FBDOs with an average of 16.1 patients/outbreak). However, school catering services caused the greatest number of patients. Although only 293 FBDOs were reported in schools over the 6 years, the scale of FBDOs was much higher at 79.6 patients/outbreak. Reports of FBDOs in public restaurants decreased dramatically after 2009, whereas FBDOs in schools increased gradually with the largest numbers of patients occurring from 2010 onwards (Figure 1).

### 3.3. Causal pathogens

The causal pathogens were identified in 1025 of the 1794 FBDOs (57%) over the 6 years. The main causal pathogens were as follow: norovirus, pathogenic *Escherichia coli* other than enterohemorrhagic *E. coli* (EHEC), *Salmonella* species, and *Vibrio parahaemolyticus*. The most common causal pathogen was norovirus, followed by pathogenic *E. coli* other than EHEC, *Salmonella* species, and *V. parahaemolyticus*.

In public restaurants, norovirus, which caused 28 FBDOs in 2007, became the most common causal pathogen in 2008 (33 FBDOs). However, it decreased rapidly and caused fewer than 10 FBDOs/year after 2009. Pathogenic *E. coli* other than EHEC caused 21 FBDOs in 2007 but after 2008 caused approximately 10 FBDOs/year. *V. parahaemolyticus* was the most common causal pathogen in 2007 and drastically decreased



**Figure 1.** Total numbers of food- and water-borne disease outbreaks and illnesses by location and year during 2007–2012.

after 2008. *Salmonella* caused 10–20 FBDOs/year over the study period showing a fluctuation pattern.

In schools, norovirus outbreaks increased rapidly after 2010 and became the most common pathogen found in FBDOs. Pathogenic *E. coli* other than EHEC caused 5–15 FBDOs/year showing a fluctuation pattern during 2007–2011. Outbreaks caused by pathogenic *E. coli* other than EHEC rose to 25 FBDOs with a large number of patients in 2012. No outbreaks of *V. parahaemolyticus* were reported over the 6 years. *Salmonella* species, which caused four FBDOs in 2007, caused fewer than two FBDOs after 2008 (Table 1).

### 3.4. Causal vehicles of FBDOs

The causal vehicles of FBDOs were identified by epidemiological investigation in 24.1% of the FBDOs over the 6 years.

In public restaurants, FBDOs caused by seafood and meat were reported frequently. During 2007–2008, seafood caused more than 50 FBDOs. However, this number decreased by more than half after 2009. Meat caused approximately 5–10 FBDOs showing a fluctuating pattern. Water caused nine FBDOs during 2007–2008 and then decreased by two FBDOs during 2009–2010 and one FBDO during 2011–2012. Fresh

**Table 1.** Total numbers of food- and water-borne disease outbreaks (FBDOs) and illnesses by causal vehicle, location, and year during 2007–2012

Causal pathogens	Total No. of FBDOs by year (total patients)					
	2007	2008	2009	2010	2011	2012
<b>Total FBDOs</b>						
Norovirus	72 (1704)	64 (2465)	28 (553)	28 (1918)	26 (1300)	50 (1784)
Pathogenic <i>Escherichia coli</i> other than EHEC	64 (2615)	27 (1911)	34 (2460)	22 (1857)	32 (2088)	34 (4390)
<i>Vibrio parahaemolyticus</i>	27 (542)	28 (377)	9 (88)	17 (297)	8 (130)	12 (195)
<i>Salmonella</i> species	38 (1213)	21 (376)	17 (455)	26 (669)	23 (937)	10 (157)
Others	51 (1553)	63 (1753)	32 (1947)	65 (1558)	50 (1509)	47 (1672)
<b>Public restaurants</b>						
Norovirus	28 (316)	33 (532)	5 (33)	6 (159)	2 (17)	8 (139)
Pathogenic <i>E. coli</i> other than EHEC	29 (996)	13 (539)	4 (88)	8 (321)	10 (315)	3 (32)
<i>V. parahaemolyticus</i>	21 (485)	19 (288)	7 (77)	9 (186)	6 (112)	12 (195)
<i>Salmonella</i> species	20 (708)	10 (219)	8 (279)	20 (510)	18 (910)	7 (102)
Others	23 (333)	35 (675)	8 (447)	24 (278)	19 (463)	15 (189)
<b>Schools</b>						
Norovirus	15 (475)	18 (1120)	9 (388)	8 (1280)	12 (970)	27 (1366)
Pathogenic <i>E. coli</i> other than EHEC	16 (1222)	6 (1030)	18 (2130)	9 (1369)	10 (933)	25 (4182)
<i>V. parahaemolyticus</i>	0	0	0	0	0	0
<i>Salmonella</i> species	4 (164)	0	2 (28)	0	1 (2)	0
Others	9 (865)	9 (604)	7 (856)	9 (569)	10 (564)	11 (862)

EHEC = enterohemorrhagic *E. coli*.

vegetables were responsible for six FBDOs during 2007–2008 and decreased by three FBDOs in 2009–2010 and two FBDOs during 2011–2012. Pickled vegetables, which caused two FBDOs in 2008, did not cause any further FBDOs in public restaurants for the remainder of the study period (Table 2).

In schools, approximately one to three FBDOs were reported annually as being caused by seafood, meat, water, and fresh vegetables. One pickled vegetable-associated FBDO was reported during 2007–2008 but this number increased rapidly (Table 2). In 2012, a total of 18 pickled vegetable-associated FBDOs occurred: 13 FBDOs caused by pathogenic *E. coli* other than EHEC with 3152 illnesses, four FBDOs caused by norovirus with 427 illnesses, and one FBDO caused by *Clostridium perfringens* with 90 illnesses. Seven food factories that supplied pickled vegetables to schools were responsible for these FBDOs. Four out of the seven food factories caused pickled vegetable-associated FBDOs in more than two schools simultaneously.

#### 4. Discussion

The number of FBDOs increased gradually in Korea until 2006 [12] and tended to decline after 2008. It was presumed that the decline of the FBDOs was associated with improved hygiene and continuous national efforts [13]. However, the number of illnesses by FBDOs increased drastically again in 2012 and we found that school catering service-associated outbreaks were responsible for that. It was interesting that public restaurant-associated outbreaks decreased at the same time. The pathogens involved in school catering service-associated outbreaks showed an increase in norovirus and pathogenic *E. coli* other than EHEC.

Norovirus is the main causal pathogen of FBDOs in the USA, European countries, China, and Japan. Norovirus was also reported as one of the most common causal pathogen of the FBDOs in Korea during 2007–2012. The norovirus outbreaks in public restaurants and schools decreased dramatically after 2009. It was presumed that the decline of the norovirus outbreaks was due to the national efforts to prevent the norovirus outbreaks including intensified inspection of seafood such as raw oysters and the norovirus surveillance system in underground water sources [14]. However, in 2012, the norovirus outbreaks emerged again in schools. The increases in norovirus outbreaks were also reported globally. Especially in the USA, UK, France, Australia, and Japan, the emergence of the new norovirus strain GII4, named the Sydney type, was reported as a cause of the increase of the norovirus outbreaks [15,16]. In Korea, norovirus GII-4 Sydney type was also detected in some of the norovirus outbreaks. However, more study is needed to establish whether the norovirus GII-4 Sydney type was a cause of the increase in norovirus outbreaks in schools in 2012.

Pathogenic *E. coli* other than EHEC has become a significant causal pathogen in Korea. Its significance is greater than norovirus because the scale of FBDOs caused by pathogenic *E. coli* other than EHEC was much larger than the scale of FBDOs caused by norovirus in school catering services. This is a unique epidemiologic characteristic of FBDOs in Korea compared with the USA, European countries, Japan, and China [3–6]. It has not been definitively established why pathogenic *E. coli* other than EHEC was the cause of such large-scale FBDOs in Korea.

It was presumed that pickled vegetables was an emerging causal vehicle in Korea. Most school catering

**Table 2.** Total numbers of food- and water-borne disease outbreaks (FBDOs) and illnesses by location and year during 2007–2012

Causal vehicles	Total numbers of FBDOs by year (total patients)		
	2007–2008	2009–2010	2011–2012
Public restaurants	476 (6708)	174 (2961)	213 (3397)
Pickled vegetables	2 (222)	0	0
Fresh vegetables	6 (141)	3 (136)	2 (17)
Seafood	54 (814)	17 (211)	15 (337)
Water	9 (131)	1 (54)	2 (66)
Meat	11 (480)	11 (516)	14 (512)
Others	32 (494)	21 (838)	17 (826)
Unknown	362 (4426)	121 (1206)	163 (1639)
Schools	103 (6685)	77 (7213)	113 (9435)
Pickled vegetables	0	4 (216)	21 (4300)
Fresh vegetables	1 (467)	3 (572)	3 (122)
Seafood	3 (498)	4 (232)	4 (174)
Water	8 (1135)	2 (759)	6 (261)
Meat	1 (84)	4 (497)	2 (445)
Others	6 (368)	7 (663)	4 (277)
Unknown	84 (4133)	53 (4274)	73 (3856)

services usually serve pickled vegetables sourced from food factories. One catering factory may supply pickled vegetables to a large number of schools, so that, if the pickled vegetables are contaminated in the factory, FBDOs can occur in multiple schools simultaneously. In the epidemiological investigations of food factories providing pickled vegetables in 2012, the causes of contamination were identified in only three of the seven factories. Underground water contaminations occurred in two factories and ingredient contamination in one. In Korea, 1077 food factories providing pickled vegetables were legally registered in 2013 and 228 catering factories used underground water [17]. Furthermore, where tap water is available, the catering factories still prefer to use underground water because of its low cost. According to national research in 2011, 16.2% of the underground water specimens tested was not safe for use [18,19]. Therefore, political support is needed to ensure that the factories use tap water instead of underground water. Although underground water is suspected as one of the main causal factors of pickled vegetable contamination, there are still factors that remain unknown. Epidemiological investigations and current monitoring of underground water in the food factories were not sufficient to control pickled vegetable-associated FBDOs. Hence, taking strong and specific actions including intensified inspection of the ingredients and monitoring of the cooking process of pickled vegetables are needed. For this, the Ministry of Food and Drug Safety recommends the application of Hazard Analysis and Critical Control Points (HACCP) for food factories and has a plan to apply mandatory HACCP to factories that make some kinds of pickled vegetable [20].

This research was significant in identifying emerging pathogens and causal vehicle using the analysis of FBDOs from 2007 to 2012. However, we acknowledge a number of potential limitations. First, it is easier to identify causal pathogens and causal vehicles in large-scale than in small-scale FBDOs. It is therefore possible that the pathogens and agents causing small-scale FBDOs may have been underestimated. Second, small-scale FBDOs may also be under-reported. Third, most human specimens collected were not stool samples but rectal smear samples. Therefore, rigorous tests for parasites could not be conducted in most of the FBDOs. Fourth, this study excluded FBDOs experienced in Korea but caused by exposure in other countries.

In conclusion, the decrease in the total number of FBDOs over the study period can be attributed to national efforts and general improvements in hygiene. However, large-scale FBDOs in schools increased rapidly in 2012. This increase was associated with pickled vegetable, an emerging causal vehicle, which has led to the emergence of norovirus and pathogenic *E. coli* other than EHEC. We recommend intensified inspections of food factories that supply pickled

vegetables, including monitoring of underground water, ingredients, and the cooking process, as well as the strengthening of laboratory surveillance for norovirus and pathogenic *E. coli*.

## Conflicts of interest

None of the authors have any conflicts of interest to disclose.

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