衞生防護中心
Centre for Health Protection

Scientific Committee on Enteric Infections and Foodborne Diseases

Epidemiology, Prevention and Control of Shiga toxin-producing *Escherichia coli* Infection

Purpose

This paper serves to provide an overview on the epidemiology of Shiga toxin-producing *Escherichia coli* (STEC) infection and its prevention and control strategies.

Introduction

Bacteriology

2. *Escherichia coli* (*E. coli*) is a diverse group of gram-negative, rod-shaped, facultative anaerobic bacterium. Most *E. coli* strains harmlessly colonize the gastrointestinal tract of humans and animals as a normal flora.[1] However, some strains are pathogenic and can cause severe foodborne disease.[2]

3. STEC is an important type of *E. coli* that can cause severe diseases, including haemorrhagic colitis and haemolytic uraemic syndrome (HUS), and is responsible for many foodborne outbreaks worldwide.[3] It produces the verocytotoxin, Shiga toxin, which is similar in structure and function to the Shiga toxin produced by *Shigella dysenteriae*. The terms verocytotoxin-producing *E. coli* (VTEC) and enterohaemorrhagic *E. coli* (EHEC) are often used interchangeably with

STEC.[4] STEC can be classified into serotypes based on the O antigen found on the lipopolysaccharide layer of the cell wall and the H antigen which is a major component of flagella.[5] *E. coli* O157:H7 is the most important serotype in relation to public health; however, other serogroups, which are referred to as "non-O157 STEC", have also frequently been involved in sporadic cases and outbreaks.[2]

4. Cattles are the major reservoir of STEC and the reservoir host is usually asymptomatic. Other ruminants (e.g. sheep, goats and deer) are considered significant reservoirs, while some other mammals (e.g. pigs, horses, rabbits, dogs, and cats) and birds (e.g. chickens and turkeys) can also be infected.[1, 2]

Transmission

5. STEC is transmitted from animals to humans primarily through consumption of contaminated foods, such as raw or undercooked meat products and unpasteurised milk, or direct contact with animals on farms or at petting zoos.[2, 5] Ground beef is the most common vehicle for STEC O157 outbreaks, as beef products may become contaminated during slaughter, and the process of beef grinding may transfer pathogens from the surface of the meat to the interior, increasing the likelihood of bacteria survival if the meat is undercooked.[1] STEC can grow in temperatures ranging from 7°C to 50°C, with an optimum temperature of 37°C, and will be destroyed at temperatures of 70°C or higher.[2]

6. Faecal contamination of water and other foods, as well as cross-contamination during food preparation by beef and other meat products, contaminated surfaces and kitchen utensils, will also lead to infection. An increasing number of outbreaks are associated with the consumption of fruits and vegetables (e.g. sprouts, spinach, lettuce, coleslaw, salad) whereby contamination may be due to contact with faeces from domestic or wild animals at some stage during cultivation or handling.[2]

7. Person-to-person transmission through the oral-faecal route can occur directly within households, child care centres and institutions, or indirectly through contaminated drinking or recreational water.[5, 6]

Clinical Presentation

8. The incubation period ranges from three to eight days, with a median of three to four days.[2] Adults typically excrete STEC O157 for up to a week, while up to one third of children will excrete the pathogen for as long as three weeks. Prolonged carriage, though uncommon, can also occur.[5]

9. Symptoms of STEC infection often include abdominal pain, vomiting and diarrhoea that may in some cases progress to bloody diarrhoea (haemorrhagic colitis).[3] Fever is generally absent or low-grade in contrast to other bacterial enteric infections.[5]

Complications

10. Most patients recover within 10 days. However, in a small proportion of patients, especially young children and the elderly, the infection may lead to complications including thrombotic thrombocytopenic purpura (TTP), haemolytic uraemic syndrome (HUS) and pancreatic injury.[3]

11. HUS is estimated to develop in up to 10% of patients with STEC infection. It most frequently affects children under five years of age and is less common in non-O157 STEC infections. Onset typically occurs seven days after initial symptom onset when the diarrhoea is improving. It is characterised by acute renal failure, microangiopahic haemolytic anaemia and thrombocytopenia. In addition, there is increased risk of neurological complications such as seizure, stroke and coma in 25% of HUS patients. About half of HUS survivors will continue to suffer from mild chronic renal sequelae after recovery. The case fatality rate of HUS ranges from 3% to 5%.[2, 3, 5]

Epidemiology

Global Situation

12. STEC has been associated with large-scale outbreaks affecting hundreds of people reported over the past two decades.[3, 7]

13. In 2006, the World Health Organization (WHO) launched an initiative to estimate the global burden of foodborne diseases, which was carried forward by the Foodborne Disease Burden Epidemiology Reference Group (FERG) and used 2010 as the reference year. It was estimated that 2.5 million new STEC cases occurred worldwide, resulting in 3,330 HUS cases, 200 end-stage renal failure cases, 269 deaths and 27,000 disability-adjusted life years (DALYs). Foodborne STEC accounted for more than 1 million illnesses, 128 deaths and approximately 13,000 DALYs annually.[8] The highest disease burden in absolute numbers occurred in the South-East Asia region, followed by the European and American regions. Across all sub-regions, about half of the STEC disease burden was estimated to be foodborne.[8, 9]

14. Despite a high incidence, both the probability of developing significant sequelae and the case-fatality ratio were relatively low, resulting in a low population-level disease burden. However, due to globalization and international trade, STEC still has the potential to become a risk management priority in countries in which it is not currently a human health priority and poses a worldwide health burden as well as an economic impact in terms of disease prevention and treatment.[8]

United States

15. STEC is estimated to cause more than 265,000 illnesses each year, with more than 3,600 hospitalizations and 30 deaths. STEC O157 causes about 36% of these infections, with the remaining caused by non-O157 STEC.[3, 4]

16. STEC O157 was put under surveillance since 1996. Between 1996 and 2017, the reported incidence of STEC O157 ranged from 0.6 to 1.3 per 100,000 population; the trend was relatively stable. Incidence of non-O157 STEC, on the other hand, has been on an increasing trend from 0.01 in 2000 since it was put under surveillance to 1.09 in 2017. The overall incidence of STEC infections has also been on an increasing trend, from 0.71 in 1996 to 1.81 in 2017.[10]

17. According to FoodNet, which conducts surveillance at 10 US sites and includes 15% of the US population, the incidence of STEC was higher during 2022 compared with the average annual incidence during 2016-2018. The case fatality rate was 0.4% (n=11), which was comparable to the average

rate during 2016-2018.[11]

18. The US Centers for Disease Control and Prevention (CDC) reported three multistate foodborne outbreaks in 2022. Two of the outbreaks were due to STEC O157, involving contaminated ground beef (n=7) and an unknown food source (n=109) respectively. The remaining outbreak was due to STEC O121 and involved frozen falafel (n=24).[12]

United Kingdom

19. A total of 402 confirmed cases of STEC O157 were reported in England and Wales in 2020, with a crude incidence rate of 0.68 per 100,000 population, which has been on a downward trend since 2015. Children aged five to nine years had the highest incidence of infection with 1.5 per 100,000 population, unlike in previous years where the highest incidence was in children aged one to four years. HUS occurred in 10 (3%) confirmed cases, where two cases were under five years of age with a median age of 13. Two deaths were reported among confirmed STEC O157 cases.[13]

20. In 2020, 843 non-O157 STEC cases were confirmed in England, with 557 culture positive cases. The increase over the last 10 years was likely due to the increasing number of local hospital laboratories in England that have adopted a PCR approach to GI diagnostics, facilitating their capacity to detect non-O157 STEC serotypes. The five most common non-O157 serogroups isolated were O26 (n=103, 18%), O146 (n=80, 14%), O91 (n=51, 9%), O128ab (n=37, 7%) and O145 (n=24, 4%). HUS occurred in 28 confirmed cases, with the most frequently isolated serogroups being O26 (n=10, 36%) and O145 (n=4, 14%). HUS cases ranged from 10 months to six years of age and 70% (n=10) were between one and four years of age. There were three deaths reported among cases of non-O157 STEC.[13]

Europe

21. Following a decrease in 2020 due to the COVID-19 pandemic, the EU/EEA trend in confirmed STEC cases increased in 2021. In 2021, 6,534 confirmed cases of STEC infection were reported by 30 countries. The EU/EEA notification rate was 2.2 cases per 100,000 population, representing a 37.5% increase compared with the previous year. The highest numbers of confirmed

cases were reported by Germany and Ireland, which together accounted for 38% of all reported cases in the EU/EEA.[14]

22. Among the 4,625 cases with known outcome, 18 deaths were reported, resulting in a case fatality of 0.4%. Most of the deceased cases were aged over 65 years (61%). From a total of 365 HUS cases, the majority were in the youngest age groups of 0-4 years (64%) and 5-14 years (20%). There were four fatal cases with HUS, all being in the youngest age group of 0-4 years.[14]

23. The five most commonly reported serogroups were O157 (15.1%), O26 (14.7%), O103 (8.4%), O145 (4.6%) and O146 (3.7%).[14]

Australia

24. STEC became a nationally notifiable disease in Australia in 2001. Notification rates of STEC have trended upwards between 2001 and 2015. The peak observed in 2013 was related to a zoonotic outbreak in Queensland. In June 2016, the only laboratory in South Australia conducting STEC testing began testing all faeces for STEC, instead of only bloody stool samples, resulting in a sharp increase in notifications.[15]

25. In 2017, 496 cases were notified giving an incidence rate of 2.0 per 100,000 population. Notifications peaked in children aged 0-4 years (n=68, 14%), followed by those aged 50-59 years (n=43, 9%).[15]

26. HUS is rare in Australia. In 2017, only 14 cases were reported. Consistent with previous years, HUS was most commonly reported in children aged 0-4 years (n=6, 43%).[15]

27. Most STEC cases are sporadic, though outbreaks have been reported. Foodborne outbreaks are relatively rare; the implicated foods in confirmed and probable STEC outbreaks reported in Australia since 2000 include potato salad consumed at a camp in rural South Australia in 2009 (n=31; no HUS cases) and kangaroo meat consumed in a remote Northern Territory community in 2012 (n=5; no HUS cases). Outbreaks due to contaminated tank water and zoonotic transmission have also been reported, with the largest STEC

O157 outbreak reported following contact with animals at a petting zoo in Queensland in 2013 (n=57 cases; no HUS cases).[15]

28. The distribution of STEC in Australia differs from the Northern hemisphere in that not all of the prevalent global serotypes were highly represented. Instead, STEC in Australia comprised a diverse range of lineages, with the most common lineage of O157 STEC emerging in the mid-nineteenth century.[16]

Large-Scale Outbreaks

29. Between 1998 and 2016, 27 countries spanning the Region of the Americas (AMR), European Region (EUR) and Western Pacific Region (WPR) reported 919 STEC outbreaks. The large majority was reported in AMR (77%), whereas 19% and 4% were reported in the EUR and WPR, respectively.[8]

30. Several large outbreaks of STEC O157 infection were recorded in various countries in the past three decades. In the early 1990s, an outbreak of more than 700 cases and three deaths took place in western US which was linked to consumption of undercooked hamburger meat (ground beef) at a fast-food chain.[7] The largest STEC O157 outbreak ever recorded occurred in Japan (Sakai city) in 1996;[17] more than 10,000 people were affected after white radish sprouts had been served at school canteens and the outbreak resulted in 12 deaths.[7] In the same year, another outbreak occurred in Scotland involving 512 people and 17 deaths due to contaminated meat products.[7]

31. Apart from foodborne outbreaks, there have been large STEC O157 waterborne outbreaks involving tap water, well water and drinking water in 1995, 1999 and 2000 in Scotland, New York and Canada (Walkerton) affecting 633, more than 1000 and 2300 people respectively.[7]

32. In recent years, a large outbreak of STEC O157 with 165 cases occurred in the summer of 2016 in the UK. Among the cases, 66 people attended hospitals, nine had features of HUS and two adult cases died. Consumption of mixed salad leaves, particularly from catering establishments such as cafes and restaurants, was associated with the infection.[18, 19]

33. Compared with STEC O157, there are relatively few large outbreaks of STEC non-O157 recorded worldwide.

34. In August 2008, a large outbreak of STEC O111:NM (non-motile) infections associated with a buffet-style restaurant in rural Oklahoma was identified. Out of 341 cases with gastroenteritis, 70 patients required hospitalization, 25 (7.3%) developed HUS and one died. The epidemiological evidence suggested cross-contamination of restaurant food from food preparation equipment or surfaces, or from an unidentified infected food handler.[20]

35. In 2011, there was an outbreak of STEC O104:H4 in Europe, which mainly centered in Germany and France with some cases found in 15 other countries, almost 4,000 cases were reported with 50 deaths. Adults and the elderly were disproportionately affected, and there was a high rate of HUS (> 20%) with a preponderance of female cases. Fenugreek sprouts were the most likely causative agent in the outbreak.[21, 22]

Local Situation

36. All STEC (both O157 and non-O157) infections have become statutorily notifiable since 10 June 2011. From June 2011 to 2023 (as of 31 October 2023), the Centre for Health Protection (CHP) has recorded 40 cases of STEC infections (Figure 1). The annual number of cases ranged from zero to eight while the incidence using mid-year population of the corresponding years ranged from 0 to 0.11 per 100,000 population. The overall incidence in Hong Kong is low compared to the US, EU countries, Australia, New Zealand and Canada (Table 1).

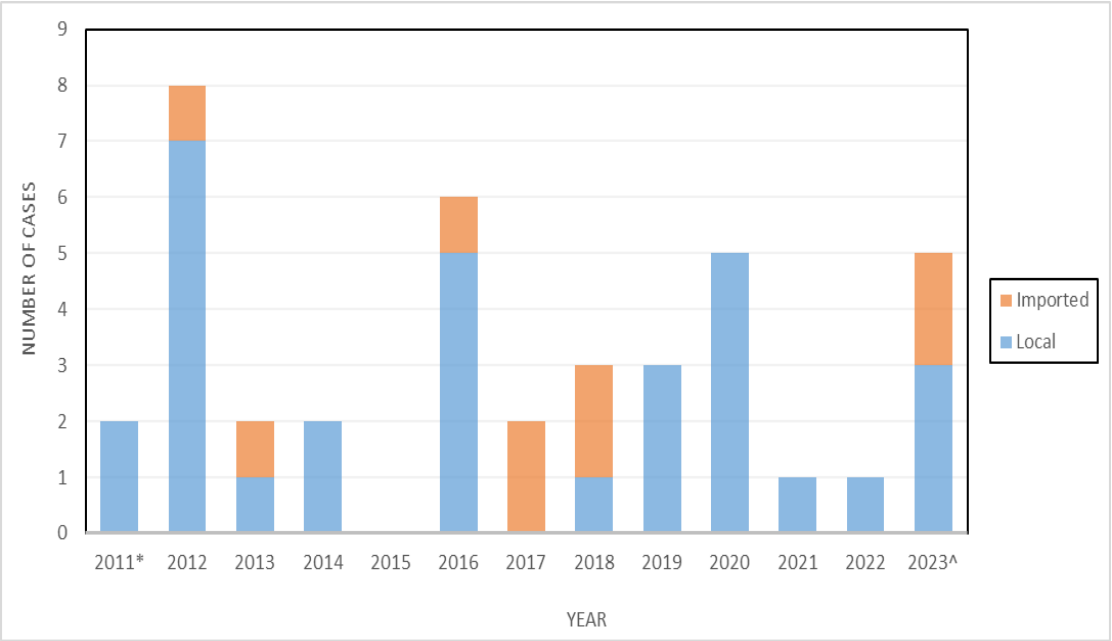
Table 1: Incidence Rates of STEC Infection in Hong Kong and Other Countries/Areas

Country/Area	**Period**	**Incidence Rate (Per 100,000 Population)**
Hong Kong	June 2011 – 2023^	0 – 0.11^
United States (US)[10]	2017	All serogroups: 1.81 O157: 0.71 Non-O157: 1.09

United Kingdom (UK)[13, 23]	2006-2020	O157: 0.68-2.10
European Union (EU)/European Economic Area (EEA)[14]	2016-2021	1.6-2.4
Australia[15]	2001-2017	0.2-2.0
New Zealand[24]	2006-2020	2.2-22.2
Canada[25]	1991-2021	1.60-9.81

^ *Data from 2023 are preliminary as of 31 October 2023*

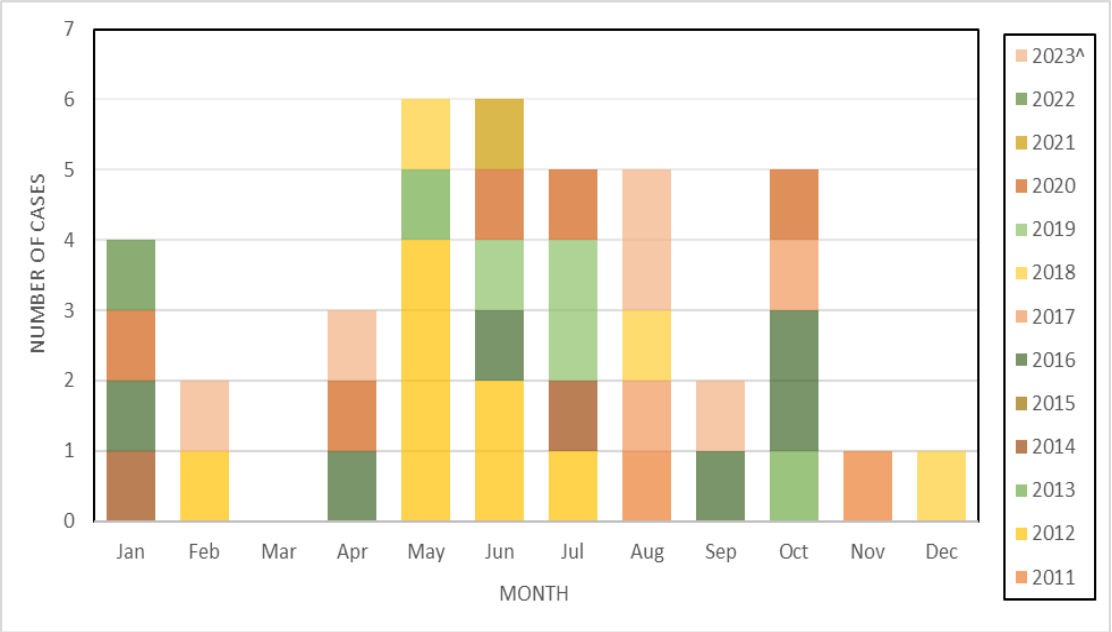
Figure 1: Number and Classification of Confirmed Cases of STEC Infection in Hong Kong from June 2011 to 2023



^ *Provisional data as of 31 October 2023.*

37. Most of the cases acquired the disease locally (n=31, 77.5%), while nine were imported cases (22.5%). All reported cases were sporadic. Majority (55.0%) of the cases occurred during the summer months of May through August (Figure 2).

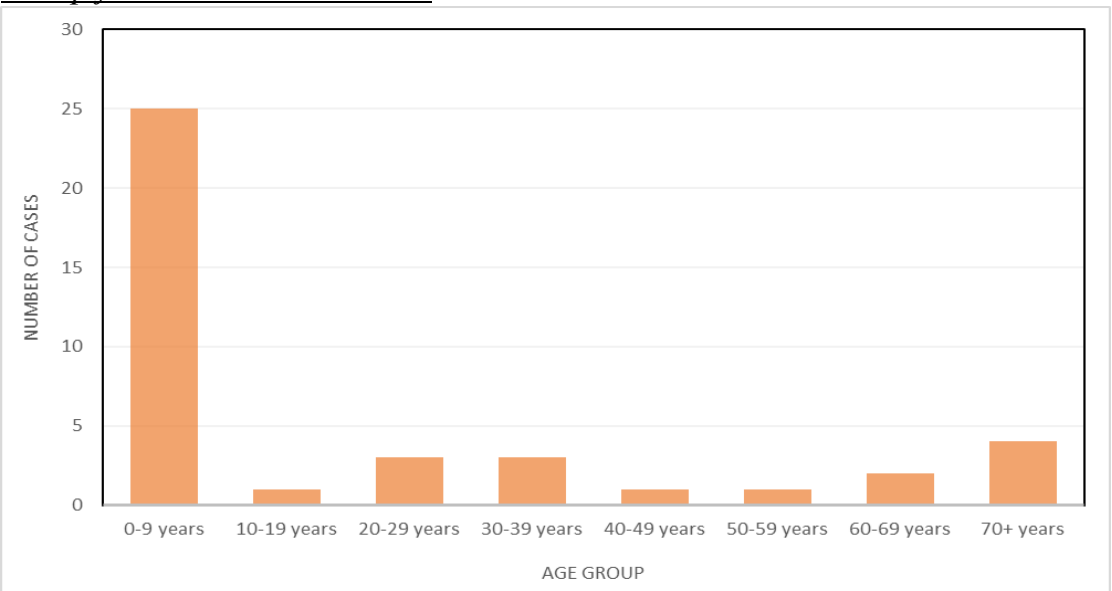
Figure 2: Number of Confirmed Cases of STEC Infection in Hong Kong by Month of Onset from June 2011 to 2023



^ *Provisional data as of 31 October 2023.*

38. Among the 40 cases, there were 23 (57.5%) male and 17 (42.5%) female with age ranging from 16 days to 80 years (median=4 years) (Figure 3). The majority (n=25, 62.5%) were less than 10 years of age and most of them enjoyed good past health. Four (10.0%) of the affected persons were elderly with age ranging from 71 to 80 years, and all had underlying medical conditions such as hypertension, diabetes, hyperlipidemia, malignancy and bronchiectasis.

Figure 3: Number of Confirmed Cases of STEC Infection in Hong Kong by Age Group from June 2011 to 2023



^ *Provisional data as of 31 October 2023.*

39. Among the 40 patients, most (n=34, 85.0%) presented with diarrhoea including eight (20.0%) with bloody diarrhoea. Over half (n=21, 52.5%) of the patients were febrile on presentation. Hospitalisation rate was high (85.0%) with the known duration of stay ranging from one to 10 days (median=3 days). None were complicated by HUS. No fatal cases have been recorded.

40. The source of infection could not be ascertained in most cases. For cases reported to have consumed high-risk foods during the incubation period, the foods included undercooked minced beef congee, minced-meat burger, raw lettuce and fresh fruit juice. One child had a history of visiting farms with animal contact and one child had a history of feeding wild monkeys.

41. Regarding the serogroups, 17 (42.5%) cases were associated with *E. coli* O157:H7. For the eight non-O157 STEC cases, the involved strains included O124:H19 (2), O26:H11 (2), O8:H19 (1), O128:H2 (1), O55:H12 (1) and O18:H7 (1). The remaining 15 cases were untypable. Concomitant infection with other bacteria and viruses are not uncommon (n=7, 17.5%). Enteroaggregative *E. coli* (EAEC), *Campylobacter* species, *Salmonella* species, *Vibrio parahyaemolyticus*, *Aeromonas hydrophila*, *Plesiomonas shigelloides*, norovirus, rotavirus, astrovirus and sapovirus have been detected in stool specimens in addition to STEC.

Prevention and Control Strategy

42. Effective surveillance and epidemiological investigation systems, together with food safety control measures at all stages of the food chain are the basis for prevention and control for foodborne diseases such as STEC infection.[10] In Hong Kong, there are established systems for STEC disease surveillance, epidemiological investigation, food surveillance and food incident surveillance. There are also various statutory requirements and health promotional initiatives in safeguarding and promoting food safety.

Disease Surveillance

43. The CHP has an established structured mechanism for surveillance of *E. coli* O157:H7 infection, which became a statutorily notifiable disease under the Prevention and Control of Disease Ordinance (Cap. 599) in July 2008. Available data prior to this date was provided by voluntary notification. Subsequent to the severe outbreak of non-O157 STEC which occurred in Europe in 2011, the CHP broadened the surveillance to include all STEC infections since June of the same year. The CHP also sent letters to doctors to inform them about the latest situation including the legislative amendment and change involved, and to implore them to report suspected/ confirmed cases to the CHP in accordance with the statutory notification system.

44. In addition to local disease surveillance, the CHP also monitors for overseas STEC outbreaks. In response to large outbreaks overseas (e.g. the 2011 STEC O104:H4 outbreak in Europe) and detection of local cases, the CHP would issue press releases to inform the public and remind them to be vigilant against STEC infection.

Epidemiological Investigation

45. Upon receipt of notification of a suspected STEC case, epidemiological investigation is initiated and public health control measures are implemented immediately. Food history, including the epidemiological information of the food collaterals, and other risk factors such as animal or case contact would be explored in order to identify the source of infection. Close contacts such as household contacts and travel collaterals would be traced. Health education on disease transmission, personal, environmental and food hygiene would be provided to the patients and their close contacts.

46. Health information and advice are given to infected persons and their caregivers regarding effective hand washing, particularly after using the toilet, changing diapers, and before preparing or eating food. Children should be excluded from playgroup, day-care/preschool nursery or child care centre/kindergarten until diarrhea has ceased for at least 24 hours and two successive negative stool cultures taken not less than 48 hours apart, after recovery. Food handlers, health care workers and child care workers should refrain from duties until they become asymptomatic and have two negative stool

specimens. Infected persons may continue to be infectious for several weeks after diarrhoea resolves and should be cautioned accordingly especially with regards to hand washing. They should also refrain from using recreational water venues (e.g. swimming pools, water parks) until two weeks after symptoms resolve.

47. The patients' close contacts with symptoms compatible with STEC infection should be referred for further investigation. In case of close contacts who work as a food handler, healthcare worker or child care worker, or who attend child care centres, testing for STEC would be offered even if they are asymptomatic.

48. If food premises are suspected to be the source of infection, the case will be referred to the Food and Environmental Hygiene Department (FEHD) for further investigation. The FEHD will conduct field investigation and collect relevant food samples, environmental samples and clinical samples from food handlers for laboratory analysis. Health advice will be given on food safety practices, and enforcement of environmental and food hygiene will be carried out as appropriate. If there is suspected incriminated food potentially available in the market, the FEHD will trace its source and distribution, and take action to halt the import or sales of the affected products if necessary. Food handlers with STEC infection will be ordered to refrain from food handling duties.

49. For laboratory confirmation, the Public Health Laboratory Services Branch performs microbiological analysis to support epidemiological investigations. Diagnosis can be confirmed through laboratory testing on stool specimens by culture and serological typing of STEC O157:H7, or detection of Shiga toxin-encoding genes.

Food Surveillance Programme

50. The Food Surveillance Programme of the Centre for Food Safety (CFS) of the FEHD is designed to identify, control and prevent food hazards along the food supply chain. Food samples are taken at import, wholesale and retail levels for microbiological, chemical and radiation testing. Checking for the presence of STEC O157 is included in microbiological testing for ready-to-eat food. From 2013 to 2022, none of the food samples collected was tested positive for STEC O157.

Food Incident Surveillance System (FISS)

51. The Food Incident Surveillance System (FISS) of the CFS is an important tool for monitoring food incidents with potential food safety implications around the globe. The FISS collects information from multiple sources so that the CFS can react rapidly to global food incidents relevant to Hong Kong and safeguard the health of the local community.

52. From 2018 to 2022, the CFS identified several incidents associated with STEC-contaminated food overseas via the FISS. Prompt risk assessment and risk management actions have been carried out. No local occurrence of STEC infection associated with these food incidents was reported in the corresponding period.

53. There are also statutory requirements in place for foods that are imposed for food safety and public health reasons. For example, certain high-risk imported food such as milk and meat are regulated by subsidiary legislation of the Public Health and Municipal Services Ordinance (Cap. 132). Importation of meat is confined to sources recognized by the FEHD. Milk and milk beverages available in the market are ensured to be effectively pasteurized or sterilized to prevent related foodborne diseases including STEC infection.

Health Promotion

54. Promulgated by the WHO, the CHP and the CFS regularly promote "Five Keys to Food Safety" to prevent foodborne diseases. The CFS also organises food safety training, health education and health promotional activities targeted to the food trade industry, food handlers and the general public. Besides, the CFS has issued a food safety guideline on beef burgers, and published articles related to overseas STEC-contaminated food incidents, to educate and advise food businesses and the public on associated food safety risks and measures that can be implemented to reduce the risk of foodborne diseases.

55. The CHP and the CFS have prepared a variety of health education materials such as fact sheets on STEC[26], pamphlets and posters on hand hygiene, food and water safety, and ways to prevent foodborne diseases, to raise

awareness of the general public and the food trade industry, and relevant information is dissemination through various channels such as press releases and the media. Furthermore, updated travel health news can be found on the website of the Travel Health Service of the DH along with relevant health tips for travellers.

56. In addition, the CHP has published feature articles on STEC in its on-line publication "Communicable Diseases Watch" to provide healthcare professionals and members of the public with up-to-date information and related health advice.

Conclusion

57. The number of reported cases of STEC infection in Hong Kong has remained steady over the years. STEC-associated morbidity and mortality are much lower compared with other developed countries.

58. Systems and measures are in place for the prevention and control of STEC infection. The CHP and the FEHD have also been working closely in communicating information on disease surveillance, food surveillance and food incident surveillance. Health promotional activities have been conducted over the years to educate and empower the general public, care-givers, food trade industry as well as food handlers to practice food safety and adopt good hygiene practices to prevent the disease.

59. Although the local incidence of STEC infection is not high compared to other countries, there is no cause for complacency. To safeguard public health, people should always be vigilant against foodborne diseases; government departments, the food trade and various stakeholders should continue to work together and protect the health of the community, in particular the young children, from serious STEC infection.

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December 2023

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