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The Ecological Risk Assessment of Foodborne Disease Outbreaks in Yazd Province, Iran

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ABSTRACT

Background: Ecological conditions can change infection routes and increase the risks of outbreaks. The aim of this study is risk assessment of foodborne disease outbreaks based on dispersed regional climatic and demographic variables in Yazd Province, Iran. **Methods:** In this cross-sectional study, data of temporal climatic parameters and regional demographic factors linked to bacterial foodborne diseases were addressed. A multi-level regression analysis model was used to detect associations between the risk of outbreaks and ecological risk factors; the relationships were verified using (P<0.05). **Results:** Significant associations were observed between the outbreaks and age (P<0.001), community type (P<0.001), temperature (P=0.04), rainfall (P=0.03) and dust pollution (P<0.001) in scattered parts of the province. The maximum rate of outbreaks was seen in spring, while the frequency of the outbreaks increased during April and October, compared to other months of the year (2012–2016). **Conclusion**: Consequences have revealed interventions of the environmental exposures in transmissions of microbial agents by complex ecological processes that caused the outbreaks.

Keywords: *Climate; Environment; Disease outbreaks; Risk; Iran.*

Introduction

Ecological conditions such as environmental parameters and human behaviors affect public health and contribute to multiple hazards (Cao *et al.*, 2017, Jenerette, 2018, Siziba, 2017). The effects of environmental variations on disease transmissions linked to seasonal warming of sea-surface temperature are significant reasons for enhancing the growth of microorganisms and their transfer routes (Shi *et al.*, 2020, Wei *et al.*, 2020). Severe annual flooding of extreme weather plays an important role in shigellosis outbreaks in some regions, as the seasonal surveillance data of dysentery in Shandong Province of China were associated with El Nino-Southern Oscillation (ENSO) (Chen *et al.*, 2019, Wu *et al.*, 2020). Seasonal climatic patterns and ecological

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conditions have affected foodborne disease outbreaks among Vietnamese and Australian young children and females during the summer of the warmest states (Ghazani *et al.*, 2018, Vo *et al.*, 2014). Temporal climatic patterns is one of the important reasons for the spread of microbial contaminants via vegetables and herbs (Pradhan *et al.*, 2018, Ssemanda, 2018). Lack of rainfall in drought seasons can cause dust storms which decrease infectious particles in farms and increase infectious diseases by carrier insects in warm and dry weather (Aik *et al.*, 2020, Soleimani *et al.*, 2020). Another reason for pathogen preservation is the humidity that affects environmental contents and wildlife habitats such as the roles of raccoons in *Salmonella* outbreaks in Ontario, Canada, 2011–2013 (Bondo *et al.*, 2016). The rise in ambient temperature associated with monthly non-typhoidal *Salmonella* outbreaks in international travelers is known as significant evidence for ecological risk factors in developed countries (Dallal *et al.*, 2020, Savage *et al.*, 2019, Wong *et al.*, 2019). Other effective ecological factors include population density, human lifestyle and the community's inadequate sanitation facilities such as low volumes of water supplies, which are known as important reasons for enteric disease transmissions and foodborne outbreaks (Brouwer *et al.*, 2018). Due to patient sensitivity and private nature of specific communities, *Shigella* outbreaks spread in Orthodox Jewish community of Antwerp, Belgium, from the beginning of April 2008 caused endemic shigelloses in Israel (De Schrijver *et al.*, 2011).

The increased population density in high-temperature provinces of China was associated with global warming and irregular climatic variations that affected transmission of communicable diseases in high population densities (Deb, 2018, Levy *et al.*, 2018). Moreover, spatial circumstances may change during human land use and settlement, road construction, and water sanitation plants such as dams, canals, irrigations, and reservoirs which can affect transmissions of etiologic agents (Mas-Coma *et al.*, 2018). Unsanitary conditions after disasters can increase the rate of enteric diseases, especially in the hot weather of desert areas, as marine gastroenteritis outbreaks increased in Iraq, in 2003, and *Shigella* caused serious health concerns by non-sanitary facility controls (DuPont and Whichard, 2017, Williams *et al.*, 2017). Yazd Province, with cold humid winters and arid warm summers, is located in central desert of Iran. In this desert province, a particular lifestyle can be seen due to the specific climate as the climatic conditions affect people's eating habits. Therefore, this study was carried out in Yazd Province (Iran) with more than 1,138,533 populations and 131,575 km² area; the natural geomorphologic phenomena in Yazd have caused climatic diversities between its various regions. This ecological study investigates possible associations between foodborne disease outbreaks and environmental risk factors such as temporal patterns of climatic parameters and demographic factors in various ecosystems of Yazd Province, Iran.

Materials and Methods

Study design and setting: This study was based on the most important goals of national development in the Fourth Economic Social and Cultural Development Program in Iran. Therefore, the criteria were used to ensure that the collected data were prepared based on the standardized World Health Organization (WHO) questionnaire guidelines on foodborne disease outbreaks by all the personnel at all times, places, and levels. Furthermore, data on foodborne disease outbreaks from Yazd province climatic database were compared with those from Iran Meteorological Organization (IRIMO). A multivariate regression analysis model was used for surveillance data, and hypothesis records were formulated based on the nature of foodborne disease distributions in various cities of the province. Moreover, foodborne disease incidence rates (IR) were assessed in various regions of Yazd province, which were at high risk of outbreaks.

This cross-sectional study was carried out based on two essential elements of effects, and thus, exposures and available information on

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sources, stressors, effects, ecosystems, and the risk characteristics used in the risk assessment were integrated. Sources included water or food, and climatic parameters acted as stressors and foodborne diseases known as effects during the outbreaks. While exposures were known as microbial infectious agents, cities of the Yazd province were considered as various ecosystems, and outbreak rates were considered as risk characteristics.

Data collection: Demographic information regarding Yazd province was provided by the Statistical Centre of Iran (SCI) (https://www.amar.org.ir/) and was classified based on age, sex, and the community's type as instituted social groups and household groups. Climatic data, such as mean monthly temperature, rainfall, relative humidity, and dust conditions were provided by IRIMO (www.irimo.ir). In this study, the inclusion criteria were demographic information, clinical symptoms, climatic variables, and geographic characteristics. The exclusion criteria were the participants who were involved with non-infectious gastroenteritis diseases that could interfere with the success output.

Sampling: People suspected of foodborne diseases were diagnosed based on clinical symptoms described by the surveillance system of the Iran Ministry of Health and foodborne disease outbreak guidelines. Totally, 729 rectal swabs from patients living in Yazd Province were sent to the Reference Laboratory of the School of Public Health, in Tehran University of Medical Sciences, Tehran, Iran, 2012–2016. The patients' questionnaires were assessed based on WHO's foodborne disease outbreak tools; and the patients verbally agreed to participate in the study (World Health Organization, 2008). Questionnaires included patients' age, sex, address, job, visiting care centers or admission types, and clinical symptoms and laboratory-diagnosed etiological agents (Dewey-Mattia *et al.*, 2018). In this study, bias was decreased by skilled questioners in surveillance systems, and hence, the over-representation of unknown gastroenteritis or non-foodborne disease diarrheal cases that might underestimate the true contributions of sporadic illnesses, were omitted. Furthermore, travelling diarrheal patients who referred to clinics and laboratories were suggested as the confounders, and the patients who suffered from foodborne diseases and lived in various cities of the province, were considered as the target populations.

Ethical considerations: This study was ethically approved by the Department of Disaster and Emergency Health, from the International Campus of Yazd Shahid Sadoughi University of Medical Sciences, in Yazd, Iran (IR.SSU.MEDICINE.REC.1395.127) and was a part of a research project from Food Microbiology Research Center in Tehran University of Medical Sciences, Tehran, Iran.

Data analysis: Collected information, including climatic variables, clinical symptoms, patients' age, sex, and the community type regarding the outbreaks, were coded using Excel 2007 spreadsheets. Multilevel regression analysis method was used to quantify the magnitude and extent of the links between the foodborne disease outbreaks, climatic parameters (temperature, humidity and dust condition), demographic factors (age, genus and community type), and regional cities. Poisson regression analysis was used to assess the associations between the IR of outbreaks and the environmental conditions of the province. Factors involved with all the applicable levels of a hierarchy were assessed using multivariable random intercept models by identical sequences to the one described for province-level analyses. In this statistical method, significant associations were tested using likelihood ratio tests, and analyses were carried out using Stata Software v.14 (Stata, USA). The multilevel regression analysis model was used to identify the relationships between the environmental stressors as independent variables and the foodborne disease outbreak risk characteristics as dependent variables. Relations were reported when (P-value < 0.05).

Results

From 2012 to 2016, 161 outbreaks have been

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reported in Yazd Province, from which, 664 bacterial foodborne diseases were identified within 729 samples using differential assays. Most foodborne diseases have been associated with environmental stressors such as temperature, humidity, rainfall, air dust condition, and temporal pattern of exposure to infectious agents in various regional cities. The most frequent outbreaks occurred at temperatures higher than 24.51 ˚C, the humidity of lower than 22%, and 0 ml of rainfall in summer. In isolated areas of the province, statistically significant correlations were seen between the outbreaks and age (P<0.001), community type (P<0.001), temperature (P=0.04), rainfall (P=0.03), and dust pollution (P<0.001). In comparison to other months of the year (2012–2016), the rate of outbreaks was maximum in the spring and increased between April and October. Moreover, a high frequency of outbreak risk characteristics was observed in Yazd City of the province in May and October (**Table 1**). In addition, significant associations of dust, temperature and rainfall with bacterial exposures were reported during outbreak events using approaches of various risk characteristics. Statistical analysis revealed that the inner dust was more effective than external dust in outbreaks. Furthermore, temperature and rainfall demonstrated similar relationships with the IR of outbreaks since the IR of outbreaks in Ashkezar, Mehriz, and Behabad increased in May and October 2013, compared to that of the other regional ecosystems (**Table 2**).

In various ecosystems of the province, relationships were shown between the IR values of foodborne diseases, beginning with types of microbial exposures, and demographic factors of various cities. Therefore, the effects of risk factors such as age, sex, and community type on various exposures such as *Salmonella*, *Shigella*, *Citrobacter freundii* and enterotoxigenic *Escherichia coli* (ETEC) were assessed. In all foodborne diseases except ETEC, the most vulnerable age groups were ≤5, and sex only was linked to shigellosis IR, while the community type was an important risk factor only in *Salmonella* foodborne diseases (**Table 3**).

Table 1. Frequency of the outbreaks based on temporal patterns, regions, and climatic parameters.

Variables	Outbreak	95% CI	
		Lower	Upper
Temperature(C°)			
≤ 13.90	14.00	5.86	22.14
13.91–24.50	66.00	44.50	87.50
24.51≤	81.00	56.91	105.09
Humidity(%)			
≤ 22.00	91.00	65.89	116.11
22.01–38.00	53.00	32.93	73.07
38.01≤	17.00	8.29	25.71
Rainfall(mm)			
0.00	88.00	63.73	112.27
0.01–3.70	37.00	20.65	53.35
3.71≤	36.00	19.12	52.88
Climate			
Normal air	57.00	38.67	75.33
External dust	41.00	25.57	56.43
Inner dust	63.00	41.35	84.65
Season			
Spring	60.00	38.50	81.50
Summer	54.00	34.51	73.49
Fall	36.00	20.57	51.43
Winter	11.00	4.09	17.91
Month			
January	3.00	0.00	6.41
February	3.00	0.00	6.41
March	5.00	0.00	10.17
April	18.00	4.36	31.64
May	23.00	9.60	36.40
June	19.00	8.03	29.97
July	21.00	7.60	34.40
August	17.00	5.37	28.63
September	16.00	6.81	25.19
October	23.00	10.23	35.77
November	6.00	0.53	11.47
December	7.00	0.58	13.42
City			
Yazd	88.00	67.33	108.67
Ashkezar	14.00	2.46	25.54
Mehriz	13.00	4.88	21.12
Taft	11.00	3.73	18.27
Meybod	7.00	1.23	12.77
Abarkooh	8.00	2.69	13.31
Khatam	7.00	1.23	12.77
Ardekan	11.00	4.95	17.05
Bahabad	2.00	0.00	6.00

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Table 2. Incidence rate ratios (**IRR**) of the outbreaks based on the temporal and regional patterns of the climatic stressors.

Variables	IRR	95% CI Lower	95% CI Upper	*P*-value[a]
Climate				
Normal air	Ref.[b]			
External dust	2.22	1.43	3.46	< 0.001
Inner dust	3.79	2.48	5.78	< 0.001
Temperature	1.08	1.00	1.17	0.04
Humidity	0.99	0.95	1.03	0.63
Rainfall	1.06	1.00	1.11	0.04
Season				0.32
Spring	1.55	0.65	3.71	
Summer	1.05	0.37	2.97	0.93
Fall	1.90	0.89	4.03	0.10
Winter	Ref.			
Year				
2012	Ref.			
2013	3.49	1.86	6.53	< 0.001
2014	2.91	1.56	5.43	< 0.001
2015	2.45	1.33	4.55	< 0.001
2016	1.80	0.94	3.45	0.08
Month				
January	Ref.			
February	1.00	0.20	4.95	1.00
March	1.67	0.40	6.97	0.48
April	6.00	1.77	20.37	< 0.001
May	7.67	2.30	25.53	< 0.001
June	6.33	1.87	21.40	< 0.001
July	7.00	2.09	23.47	< 0.001
August	5.67	1.66	19.34	0.01
September	5.33	1.55	18.30	0.01
October	7.67	2.30	25.53	< 0.001
November	2.00	0.50	8.00	0.33
December	2.33	0.60	9.02	0.22
City				
Yazd	Ref.			
Ashkezar	2.93	1.66	5.14	< 0.001
Mehriz	1.92	1.07	3.45	0.03
Taft	1.70	0.91	3.17	0.10
Meybod	0.55	0.25	1.18	0.12
Abarkooh	1.14	0.55	2.36	0.72
Khatam	1.35	0.63	2.92	0.44
Ardekan	0.90	0.48	1.69	0.75
Bahabad	0.16	0.04	0.67	0.01

[a]: Multilevel regression analysis method ; [b]: Reference

Discussion

This study was the first ecological risk assessment regarding the effects of regional climatic and demographic parameters on IR of foodborne disease outbreaks in Iran. Adverse outcomes of the risks were identified in target populations to complete problem formulation by defining outbreak problems and solving the problems based on ecological assessment frameworks (Suter II, 2016). Effects of temporal climatic variables on the exposing effects of foodborne disease agents were assessed with respect to the regional characteristics of the populations. A similar quantitative study was carried out by Semenza and Smith on the roles of environmental conditions and climate changes on the growth of foodborne disease agents and their outbreak incidences (Semenza *et al.*, 2017, Smith and Fazil, 2019). In the planning stage, the regional scope in outbreak complexity extents was estimated using IRs of the outbreaks in various cities of Yazd Province and multilevel regression analysis (**Table 2**). Regarding problem formulation, at first, information was collected to show at-risk populations such as old people (> 60 years old) and children (≤ 5 years old) after contact with contaminated foods or water (**Table 3**). A similar quantitative microbial study regarding risk assessment focused on aspiration and inhalation of contaminated water in *Legionella* spp. outbreaks as the role of exposure in enteric diseases during foodborne and waterborne disease outbreaks (Bentham and Whiley, 2018). At the end of problem formulation stage, potential areas of disease outbreaks were identified in regional cities, and Ashkezar was reported as an important hot spot for the outbreaks (Suter II, 2016).

In all the regions of the world, effects of foodborne diseases on communities vary significantly based on demographic parameters; however, IR of shigellosis and salmonellosis and ETEC foodborne diseases have been reported to be higher in children ≤ 5 years of age compared with other age groups. The current study showed significant relationships between ≤ 5-year-old groups and outbreak rates regarding *Salmonella* and *Shigella* outbreaks using multilevel regression analysis models, which was in line with studies from NZ did (On *et al.*, 2011, Sukted *et al.*, 2017). The IR of ETEC foodborne diseases in patients ≥ 60 years of age were significantly linked to the outbreaks in Yazd Province (**Table 3**).

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Table 3. Incidence rates of various foodborne diseases based on the demographic factors.

Foodborne disease agent	IR	95% CI		*P*-value[a]
		Lower	Upper	
Salmonella				
Age ≤ 5 y	8.37	3.07	18.21	< 0.001
Family	0.31	0.201	0.45	< 0.001
Social[b]	72.20	51.09	99.1	> 0.05
Shigella				
Female	1.77	1.2	2.52	0.018
Male	1.13	0.796	1.56	> 0.05
Age ≤ 5 y	15.64	7.15	29.7	0.005
Age ≤ 60 y	4.78	1.55	11.15	< 0.001
Enterotoxigenic *Escherichia coli (ETEC)*				
Age ≥ 60 y	4.78	1.55	11.15	< 0.001
Citrobacter				
Age ≤ 5 y	3.06	1.23	6.3	0.002

IR: the incidence rate of foodborne diseases per 100,000 populations; [a]: Multilevel regression analysis method; [b]: A community that used prepared food from restaurants or organizational foods

Collected information and outcomes of multilevel regression revealed that the older people in ETEC outbreaks who lived in Mehriz Sanatorium were further vulnerable to outbreak incidents. In the analysis step, associations of various infectious agents and harmful ecological stressors with foodborne diseases were assessed using the framework of data to show effective relationships between the stressors, infectious agent exposures, and various regional ecosystems of outbreaks (**Tables 1** and **3**). Therefore, critical modes of stressor effects were investigated as climatic variables on endpoints of the microbial contaminant effects during outbreaks. Most investigations on climate change revealed climatic parameters such as temperature, humidity, and dust pollution as risk factors in IR of disease outbreaks, showing significant associations with disease outbreaks worldwide (Wu *et al.*, 2020). Due to the roles of dust conditions in the spread and survival of pathogens in dry weather, increased rates of outbreaks in falls might be linked to such environmental conditions in Yazd Province. Based on the analysis results, atmospheric dust condition was significantly associated with foodborne diseases and IR of the outbreaks increased in various cities of the province in summer.

Increased IR could be associated with etiologic agents of diseases since most of the infectious disease agents were reported as clinically-relevant bacteria with warning-worth occurrences in dust particles (Wei *et al.*, 2020). Recent studies demonstrated that the effects of high temperature and low humidity could be controlled by dietary habits, which affected the IR indirectly (Clark *et al.*, 2019, Rushton *et al.*, 2019). Assessed exposures in the analysis stage of risk assessment revealed that high contingency of outbreaks might be associated with tourism attractions or potentials of specific cities, compared to other cities of the province (Aminharati *et al.*, 2018). Furthermore, waterfalls that caused prosperity of the city regions could provide opportunities for microbial survival and transmissions (Wang *et al.*, 2018, Weiskerger *et al.*, 2019). In the ecological stage of risk assessment, the roles of the precipitation on IRs of outbreaks were unclear or reversed since rainfalls had various effects on foodborne diseases such as salmonellosis in various regions of the world (Lee *et al.*, 2019, Wang *et al.*, 2018). In risk characterization stage, the weight of exposing effects on the most sensitive variables of the host such as age, sex and community type was assessed based on spatial/temporal trends of climatic variables using *P*-values of ≤ 0.05 (**Table 3**). In the present study, females were reported as a sensitive group with respect to shigellosis, which was different from other studies.

In a social community, ≤ 5-year-old groups were more vulnerable with regard to *Salmonella* outbreaks. These different results could be linked to demographic conditions in different communities or environmental variations, nutrition recourses, and food habits of populations in scattered geographical regions. Moreover, the IR of foodborne disease outbreak regarding salmonellosis increased in social groups compared to the family groups, possibly due to *Salmonella's* latent carriers or infection spread by employees (Bonardi, 2017). A similar study was carried out in US Carolina State (2008–2015) to find the effects

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of environmental exposures on foodborne disease outbreaks. Relevant exposures were reported using logistic regression models, which showed that most outbreaks occurred in urban areas in females of ≥45 in August and those of ≤45 in May (Alianell, 2017). In the current study, significant relationships were observed between the outbreaks and demographic parameters of scattered regional cities, while females were more vulnerable to the risk of shigellosis, possibly due to cooking traditions in Yazd province. Similar to other cross-sectional studies, this study included multiple variables at the time of data snapshots which was used to prove or disprove assumptions; however, these could not be used to analyze behaviors such as traditional cooking over a while and did not help constantly determine causes and effects. Larger sample sizes and longer study periods could lead to a better understanding of the problem.

Conclusion

Weather variations can affect local vulnerabilities, surveillance activities, and community's resiliencies, which need to be considered in preparedness activities and anticipating response plans. Furthermore, spatial/temporal trends of climatic variations can affect functions of health infrastructures by changes in magnitude and frequency of the outbreaks. Therefore, healthcare facility infrastructures must be maintained and activated in the response and recovery phases. In general, understanding possible climatic risks and the way they can be most efficiently managed are critically necessary.

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Authors' contributions

Ehrampoush MH designed the study; Aminharati F carried out the research; Soltan Dallal MM, Dehghani Tafti AA, and Yaseri M provided the materials and reagents; and, Mazaheri Nezhad Fard R revised the manuscript.

Conflict of interests

The authors declared no conflict of interests.

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References

Aik J, Ong J & Ng L-C 2020. The effects of climate variability and seasonal influence on diarrhoeal disease in the tropical city-state of Singapore–A time-series analysis. *International journal of hygiene and environmental health.* **227**: 113517.

Alianell AT 2017. Analysis of Food Exposures in Foodborne Disease Outbreaks. University of South Carolina.

Aminharati F, et al. 2018. Enterotoxigenic Escherichia coli Food-Borne Disease Outbreaks in Yazd Province of Iran during 2012-2016. *Journal of food quality and hazards control.* **5 (4)**: 154-160.

Bentham R & Whiley H 2018. Quantitative microbial risk assessment and opportunist waterborne infections–are there too many gaps to fill? *International journal of environmental research and public health.* **15 (6)**: 1150.

Bonardi S 2017. Salmonella in the pork production chain and its impact on human health in the European Union. *Epidemiology & infection.* **145 (8)**: 1513-1526.

Bondo KJ, et al. 2016. Impact of season, demographic and environmental factors on Salmonella occurrence in raccoons (Procyon lotor) from swine farms and conservation areas in southern Ontario. *PloS one.* **11 (9)**: e0161497.

Brouwer AF, Masters NB & Eisenberg JN 2018. Quantitative microbial risk assessment and infectious disease transmission modeling of waterborne enteric pathogens. *Current environmental health reports.* **5 (2)**: 293-304.

Cao Z, et al. 2017. Individual and interactive effects of socio-ecological factors on dengue fever at fine spatial scale: A geographical

[DOI: 10.18502/jnfs.v9i2.15429]

detector-based analysis. *International journal of environmental research and public health.* **14 (7)**: 795.

Chen C-C, Lin C-Y & Chen K-T 2019. Epidemiologic features of shigellosis and associated climatic factors in Taiwan. *Medicine.* **98 (34)**.

Clark J, Crandall P & Reynolds J 2019. Exploring the influence of food safety climate indicators on handwashing practices of restaurant food handlers. *International journal of hospitality management.* **77**: 187-194.

Dallal MMS, et al. 2020. Associations between climatic parameters and the human salmonellosis in Yazd province, Iran. *Environmental research.* **187**: 109706.

De Schrijver K, Bertrand S, Gutierrez Garitano I, Van den Branden D & Van Schaeren J 2011. Outbreak of Shigella sonnei infections in the Orthodox Jewish community of Antwerp, Belgium, April to August 2008. *Eurosurveillance.* **16 (14)**.

Deb P 2018. Environmental Pollution and the burden of Food-Borne Diseases. Elsevier.

Dewey-Mattia D, Manikonda K, Hall AJ, Wise ME & Crowe SJ 2018. Surveillance for foodborne disease outbreaks—United States, 2009–2015, https://www.cdc.gov/mmwr/volumes/67/ss/ss6710a1.htm.

DuPont HL & Whichard JM 2017. Antimicrobial resistance of Shigella spp., Typhoid Salmonella, and non-typhoid Salmonella. Springer.

Ghazani M, FitzGerald G, Hu W, Toloo G & Xu Z 2018. Temperature variability and gastrointestinal infections: a review of impacts and future perspectives. *International journal of environmental research and public health.* **15 (4)**: 766.

Jenerette GD 2018. Ecological contributions to human health in cities. *Landscape ecology.* **33 (10)**: 1655-1668.

Lee D, Chang HH, Sarnat SE & Levy K 2019. Precipitation and salmonellosis incidence in Georgia, USA: interactions between extreme rainfall events and antecedent rainfall conditions. *Environmental health perspectives.* **127 (9)**: 097005.

Levy K, Smith SM & Carlton EJ 2018. Climate change impacts on waterborne diseases: moving toward designing interventions. *Current environmental health reports.* **5 (2)**: 272-282.

Mas-Coma S, Bargues M & Valero M 2018. Human fascioliasis infection sources, their diversity, incidence factors, analytical methods and prevention measures. *Parasitology.* **145 (13)**: 1665-1699.

On S, Lim E, Lopez L, Cressey P & Pirie R 2011. Annual report concerning foodborne disease in New Zealand. In *Enviromental science and research limited*, p. 130.

Pradhan AK, Mishra A & Pang H 2018. Relevant pathogenic and spoilage microorganisms in vegetable products. In *Quantitative Methods for Food Safety and Quality in the Vegetable Industry* (ed. F. Pérez-Rodríguez, P. Skandamis and V. Valdramidis), pp. 29-58. Springer.

Rushton SP, et al. 2019. Climate, human behaviour or environment: individual-based modelling of Campylobacter seasonality and strategies to reduce disease burden. *Journal of translational medicine.* **17 (1)**: 1-13.

Savage RD, et al. 2019. Direct medical costs of 3 reportable travel-related infections in Ontario, Canada, 2012–2014. *Emerging infectious diseases.* **25 (8)**: 1501.

Semenza JC, et al. 2017. Environmental suitability of Vibrio infections in a warming climate: an early warning system. *Environmental health perspectives.* **125 (10)**: 107004.

Shi P, et al. 2020. The impact of temperature and absolute humidity on the coronavirus disease 2019 (COVID-19) outbreak-evidence from China. *MedRxiv.* 2020-2003.

Siziba N 2017. Effects of damming on the ecological condition of urban wastewater polluted rivers. *Ecological engineering.* **102**: 234-239.

Smith B & Fazil A 2019. Climate change and infectious diseases: The challenges: How will

[DOI: 10.18502/jnfs.v9i2.15429]

climate change impact microbial foodborne disease in Canada? *Canada communicable disease report.* **45 (4)**: 108.

Soleimani Z, et al. 2020. An overview of bioaerosol load and health impacts associated with dust storms: A focus on the Middle East. *Atmospheric environment.* **223**: 117187.

Ssemanda JN 2018. Towards microbial safety of fresh vegetables in Rwanda. Wageningen University and Research.

Sukted N, et al. 2017. Reducing risk of campylobacteriosis from poultry: a mini review. *International journal of food processing technology*. **4 (2)**: 41-52.

Suter II GW 2016. Ecological risk assessment. CRC press.

Vo TH, et al. 2014. Applying standard epidemiological methods for investigating foodborne disease outbreak in resource-poor settings: lessons from Vietnam. *Journal of food protection.* **77 (7)**: 1229-1231.

Wang P, Goggins WB & Chan EY 2018. Associations of Salmonella hospitalizations with ambient temperature, humidity and rainfall in Hong Kong. *Environment international.* **120**: 223-230.

Wei M, et al. 2020. Effects of aerosol pollution on PM2. 5-associated bacteria in typical inland and coastal cities of northern China during the winter heating season. *Environmental pollution.* **262**: 114188.

Weiskerger CJ, et al. 2019. Impacts of a changing earth on microbial dynamics and human health risks in the continuum between beach water and sand. *Water research.* **162**: 456-470.

Williams VF, Stahlman S & Oh G-T 2017. Incidence of nontyphoidal Salmonella intestinal infections, active component, US Armed Forces, 2007–2016. *Age.* **20 (100)**: 12.10.

Wong W, et al. 2019. The first Canadian pediatric case of extensively drug-resistant Salmonella Typhi originating from an outbreak in Pakistan and its implication for empiric antimicrobial choices. *IDCases.* **15**: e00492.

World Health Organization 2008. Foodborne disease outbreaks: guidelines for investigation and control. World Health Organization.

Wu X, Liu J, Li C & Yin J 2020. Impact of climate change on dysentery: Scientific evidences, uncertainty, modeling and projections. *Science of The Total Environment.* **714**: 136702.

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