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Ministry of Health, Welfare and Sport

Disease burden of **food-related** pathogens in the Netherlands, 2022

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Colophon

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Synopsis

The burden of disease of food-related pathogens in the Netherlands in 2022

Each year, RIVM investigates how many people become sick or die from gastrointestinal infections. To this end, we look at 14 pathogens that can cause such infections. They are mainly transmitted through food (around 41 per cent). People can also come into contact with these pathogens in the environment (through surface water, for example) or through animals or other people.

The burden of disease of these 14 pathogens was higher than in 2021 and 2020, but still a bit lower than in 2019, the year in which the COVID-19 pandemic began. This increase means that the burden of disease is almost back to pre-COVID-19 levels.

The burden of disease is expressed in Disability Adjusted Life Years (DALYs), an international measure for the number of healthy years of life that are lost due to disability or premature mortality. The total number of DALYs resulting from these 14 pathogens in 2022 (10,000 DALYs) was higher than in 2021 (9,100 DALYs) and 2020 (7,300 DALYs). However, the number of DALYs was slightly lower than in 2019 (11,000 DALYs). The fraction of the burden of disease attributable to foodborne pathogens in 2022 was estimated to be 4,300 DALYs. This was somewhat higher than in 2021 (4,200 DALYs) and 2020 (3,600 DALYs), but slightly lower than in 2019 (4,600 DALYs).

The total cost associated with the burden of disease in 2022 was estimated at 478 million euros. This was much higher than in 2021 (397 million euros) and 2020 (317 million euros), but slightly lower than in 2019 (480 million euros). The estimated cost includes the direct medical costs, for example in hospitals, as well as the costs incurred by the patients and families, such as travelling expenses. It also includes the costs incurred in other sectors, for example as a result of work absenteeism. The cost due to gastrointestinal infections resulting from foodborne pathogens in 2022 (201 million euros) was higher than in 2021 (189 million euros) and 2020 (173 million euros), but slightly lower than in 2019 (208 million euros).

The Ministry of Health, Welfare and Sport commissioned this research. The results provide policymakers with insight into the burden of disease and the various ways in which people can acquire an infection with food-related pathogens. This research also allows to monitor possible trends in time of the burden of disease caused by foodborne infections, as well as of the associated costs.

Keywords: food-related disease, burden of disease, DALY, costs

Publiekssamenvatting

Ziektelast van voedseloverdraagbare ziekteverwekkers in Nederland in 2022

Het RIVM brengt elk jaar in kaart hoeveel jaren mensen een slechte gezondheid hebben of eerder overlijden (ziektelast) door een infectie van de maag of darm. We hebben hiervoor naar 14 ziekteverwekkers gekeken die deze infecties kunnen veroorzaken. Ze worden vooral via voedsel overgedragen (ongeveer 41 procent). Mensen kunnen er ook via het milieu, zoals via oppervlaktewater, via dieren of andere mensen mee in aanraking komen.

De ziektelast door de 14 ziekteverwekkers was hoger dan in 2021 en 2020, maar nog wel iets lager dan in 2019, het jaar voordat de coronapandemie begon. Deze stijging geeft aan dat de ziektelast bijna terug is op het niveau van vóór COVID-19.

Voor de ziektelast wordt een internationale maat gebruikt: DALY's (Disability Adjusted Life Years). De bijdragen van de verschillende routes waardoor mensen besmet raken, verschillen per ziekteverwekker. Het totaal aantal DALY's dat deze 14 ziekteverwekkers in 2022 (10.000 DALY's) veroorzaakten, was hoger dan in 2021 (9.100 DALY's) en in 2020 (7.300 DALY's). Het was wel iets lager dan in 2019 (11.000 DALY's). Het deel van de ziektelast dat in 2022 aan voeding wordt toegeschreven, is geschat op 4.300 DALY's. Dat is wat hoger dan in 2021 (4.200 DALY's) en in 2020 (3.600 DALY's), maar iets lager dan in 2019 (4.600 DALY's).

De totale kosten van deze ziektelast in 2022 zijn geschat op 478 miljoen euro. Dat is veel hoger dan in 2021 (397 miljoen euro) en in 2020 (317 miljoen euro), maar iets lager dan in 2019 (480 miljoen euro). De geschatte kosten omvatten de directe medische kosten, zoals voor ziekenhuisopname, en de indirecte kosten die de patiënten en families maken, zoals reiskosten. Hieronder vallen ook de kosten die in andere sectoren worden gemaakt, bijvoorbeeld door ziekteverzuim. De kosten als gevolg van maag-darminfecties via voeding waren in 2022 (201 miljoen euro) hoger dan de 189 miljoen euro in 2021 en de 173 miljoen euro in 2020 maar iets lager dan in 2019 (208 miljoen euro).

Het ministerie van VWS heeft de opdracht voor dit onderzoek gegeven. De resultaten bieden beleidsmakers handvatten om meer zicht te krijgen op de ziektelast en de manieren waarop mensen met de ziekteverwekkers in contact komen. Ook geeft het een beeld hoe de ziektelast van voedselinfecties en kosten ervan zich door de jaren heen ontwikkelen.

Kernwoorden: voedsel-gerelateerde ziekte, ziektelast, DALY, kosten

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Introduction

Foodborne infections encompass acute and chronic syndromes with varying duration and severity, as well as mortality. Risk-based food safety management (i.e. decisions on control, prevention and surveillance) requires a consistent, quantitative assessment of the relative public health importance of foodborne diseases [1]. As such, we express the public health impact of foodborne pathogens in burden of disease (BoD) and cost-of-illness (CoI). The methodology that is used to estimate the burden of disease (in terms of Disability Adjusted Life Years (DALY)) is described in detail in another study [1], and in the disease burden report of food-related pathogens over the year 2015 [2].

Since 2008, the RIVM regularly publishes estimates of the number of incident cases, burden of disease, and costs of food-related infectious disease on its webpages¹, and since 2010 in publicly available reports (e.g. [3, 4]). In the current report, trend information on disease incidence, demographics, and consumer price index (a measure for changes in price levels of consumer goods and services) were used to update the information to the year 2022. From 2019 onwards, the BoD and CoI for toxin-producing bacteria *Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus* were no longer estimated due to the absence of recent national surveillance data for these pathogens. However, these three pathogens were included in the tables and figures regarding the overall estimates (based on data from previous years [4]), to ensure comparability of the total burden and costs with previous years.

¹ <https://www.staatvenz.nl/kerncijfers/voedselinfecties-aantal-verloren-gezonde-levensjaren>

1 Methods

1.1 Trend information

Data on the size and age distribution of the Dutch population (Table 1), as well as mortality risks and the number of live births and stillbirths (Table 2) were obtained from Statistics Netherlands².

Table 1 Population in the Netherlands by age group, 2018-2022.

Age group	2022	2021	2020	2019	2018
0	179,133	168,270	169,497	168,443	169,566
1-4	685,520	689,356	691,975	697,619	698,533
5-11	1,288,551	1,281,948	1,293,205	1,294,145	1,303,023
12-17	1,184,960	1,171,648	1,182,568	1,197,548	1,214,974
18-64	10,764,428	10,706,658	10,677,785	10,610,404	10,555,872
65+	3,313,251	3,457,535	3,392,555	3,314,004	3,239,116
Total	17,415,843	17,475,415	17,407,585	17,282,163	17,181,084

Table 2 Live births by age of mothers in the Netherlands, 2018-2022.

Age of mother	2022*	2021	2020	2019	2018
-19	635	715	876	915	950
20-24	9414	9899	10,015	10,685	11,223
25-29	44,741	45,289	43,666	45,300	45,974
30-34	78,488	75,904	70,258	69,205	68,110
35-39	40,339	39,153	35,868	35,732	34,715
40-44	8296	8007	7,571	7,356	7,089
45+	450	474	427	487	464
Total	182,362	179,441	168,681	169,680	168,525

* Estimates based on observed trend data from 2019-2021

Trend information on the incidence of gastro-enteritis (GE) by pathogen in the general population and consulting the general practitioner was obtained from the following sources:

- *Campylobacter* spp.: RIVM ISIS-AR laboratory surveillance.
- Non-typhoidal *Salmonella* spp.: RIVM laboratory surveillance.
- Shiga-toxin producing *Escherichia coli* O157 (STEC O157): mandatory notification and laboratory surveillance.
- Perinatal and acquired listeriosis: mandatory notification and laboratory surveillance.
- Norovirus: estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance.
- Rotavirus: RIVM laboratory surveillance.
- Hepatitis A virus: mandatory notification and laboratory surveillance.
- Hepatitis E virus: RIVM laboratory surveillance.
- *Cryptosporidium* spp.: RIVM laboratory surveillance data since 2013 until 2018, for 2019 the incidence is estimated based on observed trend from 2016-2018. The incidence in 2020 is based on observed (2017-2018) and estimated (2019) trend data from 2017-2019. The incidence in 2021 is based on observed (2018)

² [Birth; key figures](#); accessed February 3rd 2020

and estimated (2019-2020) trend data from 2018-2020. The incidence in 2022 is based on estimated trend data from 2019-2021. Although nationally representative data are not available anymore, the incidence data for *Cryptosporidium* spp. from three peripheral diagnostic laboratories is available and shows a strong decrease in 2020 compared to previous years. We used this rate of decrease (i.e., COVID-19 rescaling factor for 2020) to rescale the estimated 2020 incidence. As incidence data from the three peripheral diagnostic laboratories was not available for 2021 and in 2022, we looked at the increase in *Salmonella* incidence from 2020 to 2021 and from 2020 to 2022 and assumed the same increase for *Cryptosporidium* spp. (i.e., COVID-19 rescaling factor for 2021 and for 2022).

- *Giardia* spp.: a stable incidence was assumed since 2007 (i.e. the last year of RIVM laboratory surveillance data for *Giardia* spp.). Because the incidence of *Giardia* spp. follows similar trends as the incidence of *Cryptosporidium* spp., we assumed for *Giardia* spp. incidence in 2020, 2021 and 2022 the same trend as the one observed for *Cryptosporidium* spp. in 2020, 2021 and in 2022.
- No trend information was available for the GE toxin-producing bacteria (*Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus*), and toxoplasmosis. For the latter, trends in reported fatalities are included.

Trends in hospitalizations for gastro-enteritis as primary cause (ICD codes 20-93; 558.9) were obtained from the Dutch Hospital Data (DHD) for 2011-2014. Since 2015 the number of hospitalized patients is indirectly estimated from the observed time series of RIVM laboratory surveillance data on rotavirus, norovirus, campylobacteriosis, and salmonellosis. Because a substantial part of the estimated hospitalisations is due to other pathogens than those four, we corrected the baseline number of hospitalizations (i.e. hospitalizations due to other pathogens). This was done by downscaling the baseline with the average decrease in the number of cases of rotavirus, norovirus, campylobacteriosis and salmonellosis.

Excess mortality risks from campylobacteriosis and salmonellosis were assumed constant across the years. Fatalities due to listeriosis and STEC O157 were obtained from surveillance data based on mandatory notification to RIVM. Age-specific case fatality ratios for norovirus and rotavirus, originally obtained from German surveillance data, and for protozoan pathogens, originally obtained from the international literature, were assumed constant throughout the years (changes in years of life lost therefore reflect changes in incidence on which mortality is based).

1.2 Burden of disease

The method for the burden of disease calculations, in terms of Disability Adjusted Life Years (DALYs), was not changed since 2018 (i.e. reporting over 2017) [3].

1.3 Cost of illness

The method for CoI estimates was not changed since the 2019 report [5-7]. The cost prices used for the different resources were updated to 2022 euros using consumer price indexes as provided by Statistics Netherlands³.

1.4 Attribution

The fraction of human cases of enterically transmitted illness by five major pathways (food, environment, direct animal contact, human-human transmission, and travel) and by 11 groups within the food pathway was estimated using structured expert elicitation and is described in detail in Havelaar et al. [8]. For four pathogens (i.e. *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp. and STEC O157) we did not use the estimates from the aforementioned expert elicitation, but we used the average attributable fractions estimated by a novel Bayesian statistical model that integrates the attribution estimates from the expert elicitation with attribution estimates based on empirical data from microbial subtyping and case-control studies [9]. To allow for comparison with earlier results, we also updated the attribution estimates of previous years for the four aforementioned pathogens by applying the same novel Bayesian statistical model.

³ [Consumer prices](#); accessed at February 2th, 2021

2 Results

2.1 Trend information

Trend information for the last five years for specific pathogens is presented in Table 3. For trend information since 1999 for the 14 pathogens, see Annex - Table A.1.

A summary of trends is discussed below:

- The incidence of campylobacteriosis (laboratory confirmed cases) is slightly higher in 2022 than in 2021 and in 2020, i.e. 27 cases per 100,000 inhabitants compared to 24 cases per 100,000 inhabitants and 23 cases per 100,000 inhabitants in 2021 and in 2020 respectively.
- The incidence of salmonellosis (laboratory confirmed cases) is with 7 cases per 100,000 inhabitants slightly higher than in 2021 (6 cases per 100,000 inhabitants) and in 2020 (5 cases per 100,000 inhabitants).
- The estimated incidence of *Cryptosporidium* spp. in 2022 resulted in 6 cases per 100,000 inhabitants which is slightly higher than in 2021 (4 cases per 100,000 inhabitants) and in 2020 (2 cases per 100,000 inhabitants).
- The incidence of gastroenteritis by rotavirus (laboratory confirmed cases) in 2022 (21 per 100,000 inhabitants) was higher than in 2021 (13 per 100,000 inhabitants) and much higher than in 2020 (5 per 100,000 inhabitants).
- The incidence of gastroenteritis by norovirus (laboratory confirmed cases) was with 27 cases per 100,000 inhabitants much higher than in 2021 (19 cases per 100,000 inhabitants) and in 2020 (11 per 100,000 inhabitants).
- The incidence of acquired listeriosis (laboratory confirmed cases, active surveillance) was with 94 cases in 2022 higher than in 2021 (82 cases) but equal to 2020 (94 cases). The recorded fatalities increased from 11 cases in 2021 to 12 cases in 2020, but they were much lower than in 2020 (18 cases).
- The incidence of perinatal listeriosis (laboratory confirmed cases, active surveillance) decreased from 12 cases in 2021 to 8 cases in 2022. The incidence in 2022 was much higher than in 2020 (2 cases). The number of fatalities also decreased from 4 cases in 2021 to 2 cases in 2021. The number of cases of perinatal listeriosis in 2022 was higher than in 2020 (0 cases).
- The incidence of STEC O157 (laboratory confirmed notified cases, surveillance) in 2022 was 71 cases, of which 17 were hospitalized, and was higher than in 2021 (55 cases, 22 hospitalized) and in 2020 (36 cases, 13 hospitalized). The number of patients with HUS was with 3 cases in 2022 lower than in 2021 (4 cases) but higher than in 2020 (0 cases).
- The incidence of hepatitis A virus (notified cases, surveillance) was 93 reported cases and 30 hospitalized cases in 2022. This is higher than in 2021 (78 reported cases and 23 hospitalized) and in 2020 (50 reported cases and 12 hospitalized).
- With 1 case per 100,000 inhabitants, the incidence of hepatitis E virus (laboratory confirmed cases) in 2022 was equal to the

incidence reported in 2021 but was lower than the incidence reported in 2020 (2 cases per 100,000 inhabitants).

- The number of patients that were admitted to the hospital due to GE was estimated to be 21.224 which was higher than the 15.824 estimated in 2021 and the 10.838 estimated in 2020.

Table 3 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 2018-2022.

		2018	2019	2020	2021	2022
<i>Campylobacter spp.</i> ^a (x 100,000 inhabitants)		35	35	23	24	27
<i>Salmonella spp.</i> ^a (x 100,000 inhabitants)		9	9	5	6	7
<i>Cryptosporidium spp.</i> ^a (x 100,000 inhabitants)		10	8	2	4	6
Rotavirus ^a (x 100,000 inhabitants)		17	16	5	13	21
Norovirus ^a (x 100,000 inhabitants)		27 ^c	25 ^c	11 ^c	19 ^c	27 ^c
Acquired listeriosis ^b (Total reported cases)		71	113	94	82	94
	Fatal	4	16	18	11	12
Perinatal Listeriosis ^b (Total reported cases)		7	4	2 ^d	12	8
	Fatal	2	0	0	4	2
STEC O157 ^b (Total reported cases)		59	35	36	55	71
	Hospitalized	23 ^e	13	13	22	17
Hepatitis A virus ^b (Total reported cases)		188 ^g	166	50	78	93
	Hospitalized	57 ⁱ	135 ^j	12 ^k	23 ^l	30
Hepatitis E virus ^a (x 100,000 inhabitants)		2	2	2	1	1

Notes: a) Incidences per 100,000 inhabitants are presented in italics and the presented numbers are rounded: ≥ 10 to two significant figures (e.g. 12.5 = 12) and < 10 to 1 significant figure (e.g. 0.89=0.9); b) reported cases; c) estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance data and therefore not directly comparable to numbers from before 2012; d) one twin; e) known for 58/59 cases; f) ~ 275 cases are (in)directly linked to an international outbreak in men having sex with men (MSM); g) 65 cases are (in)directly linked to an international outbreak of MSM h) known for 368/374 cases; i) known for 187/188 cases; j) known for 159/166 cases; k) known for 47/50 cases; l) known for 76/78 cases.

2.2 Number of incident cases

Ten of the selected pathogens (i.e. *Campylobacter spp.*; STEC O157; *Salmonella spp.*; all three toxin-producing bacteria; norovirus; rotavirus; *Cryptosporidium spp.*; *Giardia spp.*) cause mainly acute gastroenteritis. The other four pathogens (i.e. *Listeria monocytogenes*; *Toxoplasma gondii*; hepatitis A virus; hepatitis E virus) cause also other diseases (e.g. meningitis, sepsis, hepatitis). The estimated number of incident cases of (acute) gastroenteritis by pathogen in 2022 is presented in Table 4. The estimated number of incident cases of diseases by non-gastrointestinal pathogens in 2022 is presented in Table 5. The number of incident cases by the 14 pathogens for the years 2018-2022 is presented in Figure 1 and in Table A.2 in Annex I.

The estimated total number of cases due to the 14 food-related pathogens with 1,599,000 cases in 2022 was higher than in 2021

(1,287,000 cases) and in 2020 (963,000 cases). The total number of estimated cases was even higher than the number of cases estimated in 2019 (1,570,000) the year preceding the Covid-19 pandemic.

Table 4 Mean estimated number of incident cases and 95% uncertainty interval (between brackets) of gastroenteritis by pathogen in the Netherlands, 2022.

Pathogen	Number of incident cases[#]			Fatal cases[#]
	General population (x 1,000)	GP visit (x 1,000)	Hospitalised (x 1,000)	
All causes	4,900	230	23	NA [#]
	(4,100-5,800)	(71-540)	-	
Bacteria – infectious				
<i>Campylobacter spp.</i>	57	14	1	38
	(7-160)	(7-26)	(0.41-2)	(25-53)
<i>STEC O157</i>	2	0	0.02	4
	(0.21-9)	(0-0)	(0.02-0.02)	(2-7)
<i>Salmonella spp.</i>	23	3	1	20
	(2-70)	(2-6)	(0.52-2)	(18-23)
Bacteria – toxin producing				
<i>Bacillus cereus</i>	53	7	0.22	0
	(18-130)	(2-21)	(0.07-0.53)	(0-0)
<i>Clostridium perfringens</i>	170	32	0.31	5
	(57-380)	(7-85)	(0.11-0.65)	(0.1-19)
<i>Staphylococcus aureus</i>	290	41	1	7
	(130-560)	(12-100)	(0.65-3)	(0.16-29)
Viruses				
<i>Norovirus</i>	620	14	2	70
	(420-900)	(8-23)	(1-3)	(29-130)
<i>Rotavirus</i>	270	16	6	48
	(130-490)	(10-25)	(4-8)	(15-110)
Protozoa				
<i>Cryptosporidium spp.</i>	48	3	0.41	3
	(15-120)	(1-5)	(0.16-0.83)	(0.06-13)
<i>Giardia spp.</i>	55	5	0.3	2
	(27-110)	(3-9)	(0.03-0.93)	(0.04-6)

[#]Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 5 Mean estimated number of incident cases and 95% uncertainty interval (between brackets) of non-gastrointestinal pathogen in the Netherlands, 2022.

Pathogen	Number of incident cases mean (95% CI)		Fatal cases mean (95% CI)	
<i>Listeria monocytogenes</i>				
<i>Perinatal</i>	8		2	
<i>Acquired</i>	94		12	
<i>Hepatitis A virus</i> [#]	460	(290-730)	1	(0.87-2)
<i>Hepatitis E virus</i> [#]	760	(450-1200)	9	(3-19)
<i>Toxoplasma gondii</i> [#]				
<i>Congenital</i>	370	(190-650)	13	(8-21)
<i>Acquired</i> ^{**}	430	(200-740)	0	

*No uncertainty because *Listeria* cases were acquired through surveillance. The reported number of cases of listeriosis includes only cases with systemic symptoms. Mild cases of listeriosis are not monitored and the number is thus unknown. ; ** chorioretinitis only.
[#]The presented numbers are rounded: ≥10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

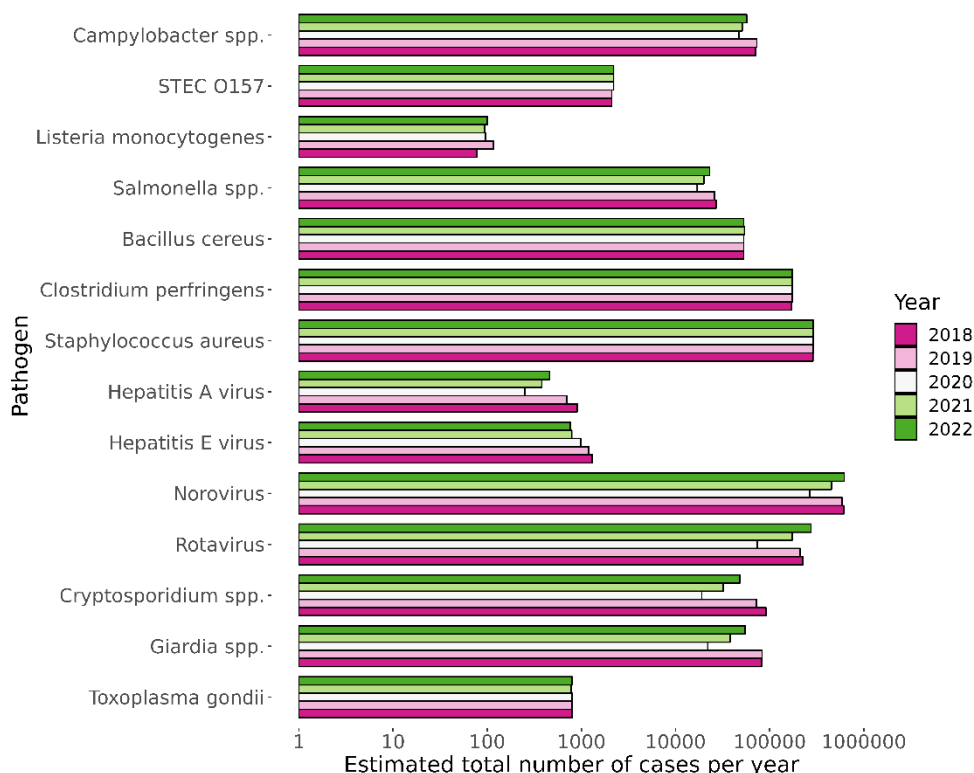


Figure 1 Comparison of mean estimated number of incident cases of food-related pathogens, 2018-2022.

The total number of estimated fatal cases due to foodborne disease in 2022 was higher than in 2021 and in 2020 (230 fatal cases in 2022 compared to 200 fatal cases in 2021 and to 163 fatal cases in 2020), but was slightly lower than in 2019 (245 fatal cases) (see Table A.3 in Annex).

2.3 Disease burden by pathogen

Table 6 presents the estimated burden of disease by pathogen for the total Dutch population in 2022, expressed as DALY per 100,000 inhabitants and DALY per case, both undiscounted and discounted with 1.5% rate.

The total disease burden of the 14 pathogens in 2022 is estimated at 10.000 DALYs and is higher than in 2020 and in 2021 but slightly lower than in the years preceding the pandemic (Table A.4 in Annex). For example, compared with 2021, an increase in disease burden was found for *Campylobacter* spp. (+200 DALYs), *Salmonella* spp. (+60 DALYs), norovirus (+600 DALYs), rotavirus (+580 DALYs), hepatitis A virus (+8 DALYs) *Cryptosporidium* spp. (+28 DALYs) and *Giardia* spp. (+50 DALYs).

In Figure 2, the contributions to total DALYs of the years lived with disability (YLD) associated with acute infections are shown per pathogen, as well as YLD associated with sequelae and years of life lost (YLL) due to premature mortality. YLD associated with acute infections contributed with 14% to the total disease burden; YLD associated with sequelae/residuals contributed 35% and YLL 51% of the total disease burden. The distribution between the different categories varied between pathogens (see Figure 2 for details).

Table 6. Mean total DALY per year, DALY per 100,000 inhabitants and DALY per case of illness in the Netherlands, 2022.

Pathogen	DALY/year		DALY per 100,000/year		DALY per case	
	0%	1.5%	0%	1.5%	0%	1.5%
<i>Discount rate</i>	0%	1.5%	0%	1.5%	0%	1.5%
Bacteria – infectious						
<i>Campylobacter spp.</i>	2500	2300	15	13	0.04	0.04
<i>STEC O157</i>	150	120	0.87	0.68	0.07	0.05
<i>Salmonella spp.</i>	960	850	6	5	0.04	0.04
<i>L. monocytogenes (perinatal)</i>	230	130	1	0.75	29	16
<i>L. monocytogenes (acquired)</i>	100	98	0.59	0.56	1	1
<i>L. monocytogenes (total)</i>	330	230	2	1	3	2
Bacteria – toxin producing						
<i>Bacillus cereus</i>	32	32	0.19	0.19	0.001	0.001
<i>Clostridium perfringens</i>	200	190	1	1	0.001	0.001
<i>Staphylococcus aureus</i>	220	210	1	1	0.001	0.001
Viruses						
<i>Norovirus</i>	2000	1800	11	10	0.003	0.003
<i>Rotavirus</i>	1500	1300	8	7	0.005	0.005
<i>Hepatitis A virus</i>	50	40	0.29	0.23	0.11	0.09
<i>Hepatitis E virus</i>	300	240	2	1	0.39	0.31
Protozoa						
<i>Cryptosporidium spp.</i>	84	80	0.48	0.46	0.002	0.002
<i>Giardia spp.</i>	150	140	0.84	0.83	0.003	0.003
<i>Toxoplasma gondii (congenital)</i>	1700	990	10	6	5	3
<i>Toxoplasma gondii (acquired)</i>	290	210	2	1	0.66	0.49
<i>Toxoplasma gondii (total)</i>	2000	1200	12	7	3	1

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

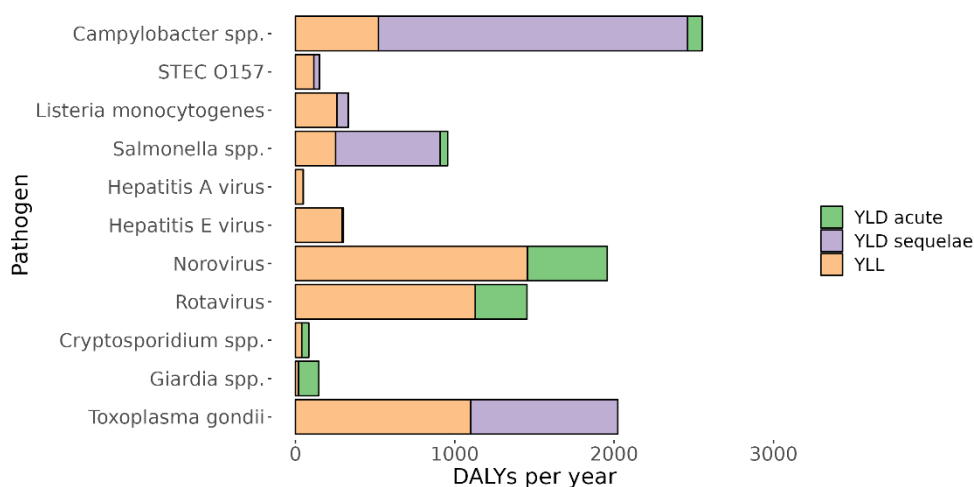


Figure 2 Mean DALY per year of food-related pathogens in 2022, split up into YLD associated with acute infections; YLD associated with sequelae and YLL.

The mean disease burden by the 14 pathogens for the years 2018-2022 is presented in Figure 3 and in Table A.4 in Annex.

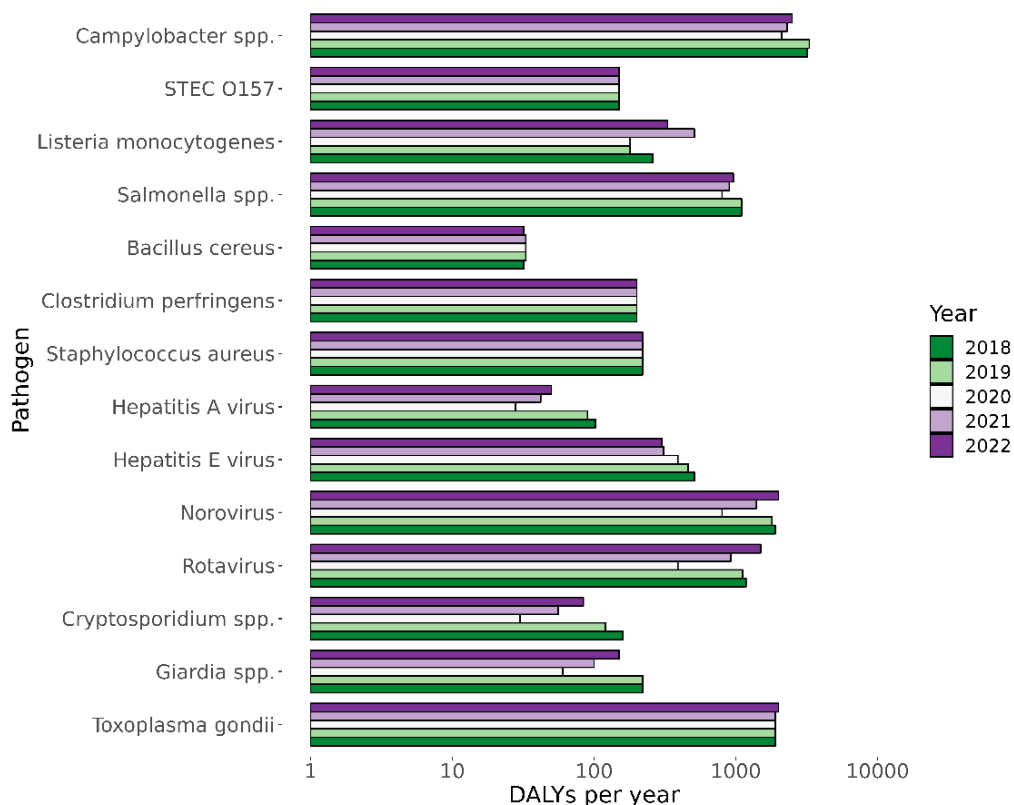


Figure 3 Comparison of disease burden (undiscounted DALYs) of food-related pathogens in 2018-2022.

2.4 Cost-of-illness by pathogen

The total CoI in 2021 (478 M€; discounted at 4%) was higher than in 2021 (397 M€; discounted at 4%) and in 2020 (317 M€; discounted at 4%), but still lower than the years preceding the COVID-19 pandemic

(Table 7, Figures 4-5, and Annex Table A.5). The four pathogens causing the largest CoI were norovirus (128 M€), rotavirus (91 M€), *Staphylococcus aureus* toxin (72 M€) and *Campylobacter* (57 M€). The lowest contribution to the CoI was by hepatitis A virus (0.9 M€). The largest changes in CoI compared to 2021 were for norovirus (+33 M€ and rotavirus +29 M€). The average cost per case was largest for perinatal *Listeria monocytogenes* infections (258,000 €/case).

Table 7 Estimated mean total costs of illness (COI), mean COI per 100,000 inhabitants and mean COI per case of illness in the Netherlands, 2022.

Pathogen	COI/year (M€)*		COI per 100,000 (k€)*		COI per case (€)*	
	0%	4%	0%	4%	0%	4%
Discount rate						
	0%	4%	0%	4%	0%	4%
Bacteria – infectious						
<i>Campylobacter spp.</i>	62	57	350	330	1,100	1,000
<i>STEC O157</i>	13	7	74	38	5,900	3,000
<i>Salmonella spp.</i>	22	21	130	120	960	900
<i>L. monocytogenes (perinatal)</i>	6	2	34	12	735,000	258,000
<i>L. monocytogenes (acquired)</i>	3	3	18	17	32,000	31,000
<i>L. monocytogenes (total)</i>	9	5	51	28	88,000	48,000
Bacteria – toxin producing						
<i>Bacillus cereus</i>	13	13	75	75	250	250
<i>Clostridium perfringens</i>	35	35	200	200	200	200
<i>Staphylococcus aureus</i>	72	72	410	410	250	250
Viruses						
Norovirus	130	130	730	730	210	210
Rotavirus	91	91	520	520	330	330
Hepatitis A virus	0.8	0.8	5	5	1,900	1,900
Hepatitis E virus	4	4	23	23	5,400	5,400
Protozoa						
<i>Cryptosporidium spp.</i>	14	14	83	83	300	300
<i>Giardia spp.</i>	13	13	73	73	230	230
<i>Toxoplasma gondii (congenital)</i>	55	17	310	100	148,000	47,000
<i>Toxoplasma gondii (acquired)</i>	1	1	8	8	3200	3200
<i>Toxoplasma gondii (total)</i>	56	19	320	110	70,000	23,000

Used abbreviations: million € (M€); 1000 € (k€). * Total COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million = 0.002). COI per 100,000 and COI per case are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000 or 123 k€); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300 or 1.3 k€). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

In Figure 4, the mean CoI per year was split up in healthcare costs, patient/family costs and costs in other sectors. The latest were mostly productivity losses of patients and caregivers being absent from work. Healthcare costs accounted for 21% of the total costs for the 14 pathogens, patient/family costs for 2% and costs in other sectors accounted for 77%. The distribution between the different cost categories varied between pathogens.

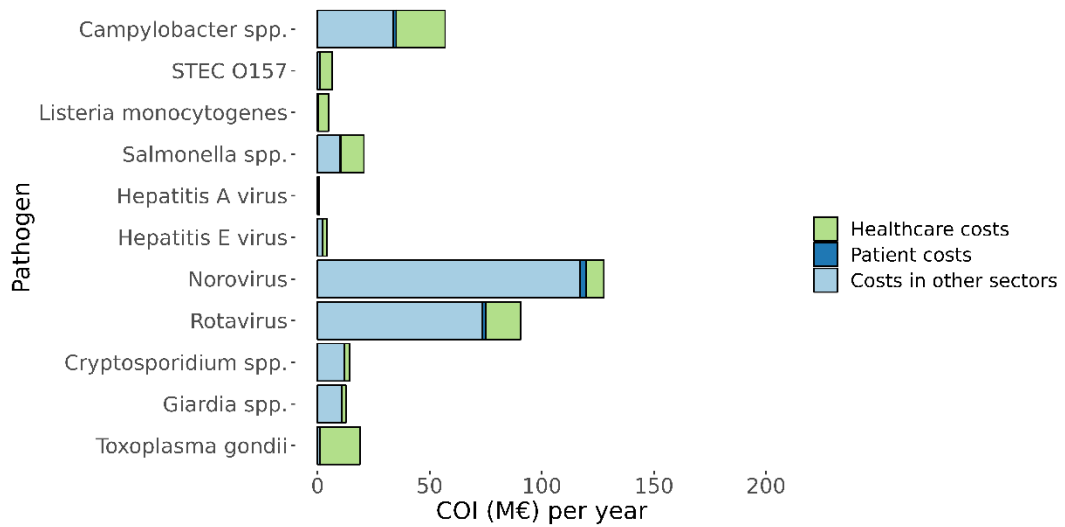


Figure 4 Mean cost-of-illness (discounted) per year of food-related pathogens in 2022, split up into healthcare costs, patient costs and costs in other sectors.

The mean CoI estimates per pathogen for the years 2018-2022 is presented in Figure 5 and in Table A.5 in Annex.

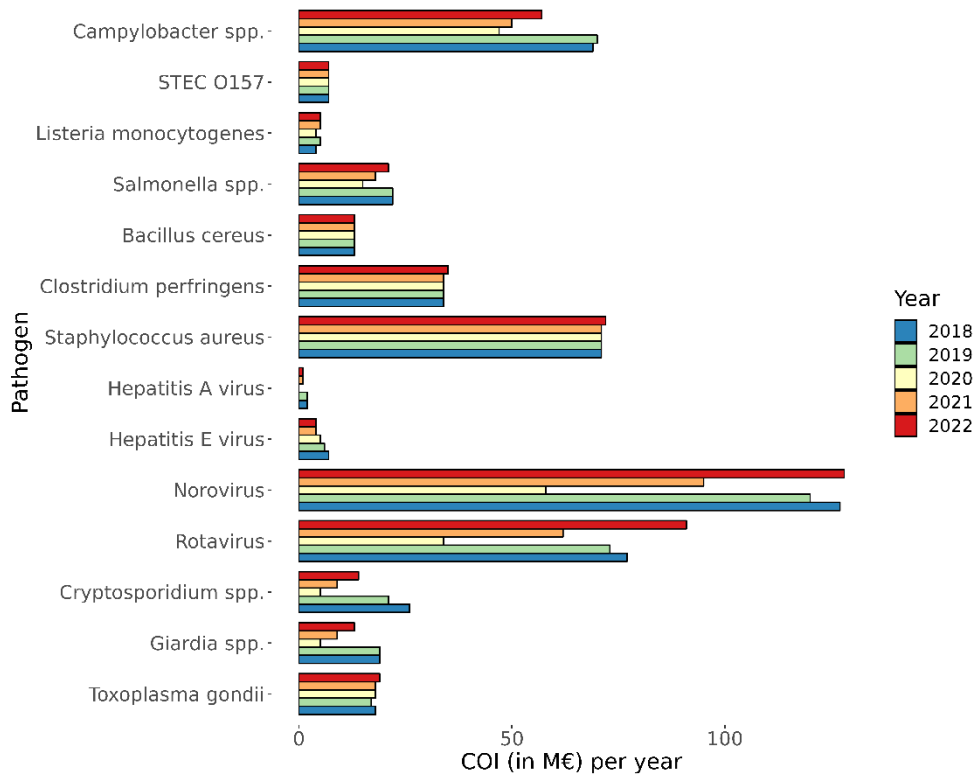


Figure 5 Comparison of cost-of-illness (M€, discounted at 4% and expressed in 2022 euros) of food-related pathogens in 2018-2022.

Attribution

The attribution results for the DALYs and CoI in 2022 are presented in Table 8 for the main pathways and in Table 9 for the different food groups. More details can be found in the Tables A.6–A.13 of the Annex. Foodborne disease burden accounted for 43% of the total burden (i.e. 4,300 DALYs of the total burden of 10,000 DALYs per year), and 42% of the total CoI (i.e. 201 M€ of the 478 M€). About 56% of the foodborne burden was associated with meat (i.e. poultry, pork, beef & lamb). These foods were also estimated to cause 42% of all food-related fatal cases, indicating that the pathogens associated with these foods are considered to cause more severe infections than pathogens associated with other foods. The attributions are estimated using the proportions from the expert elicitation of Havelaar et al. [8]. For four pathogens (i.e. *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp. and STEC O157), however, we did not use the estimates from the aforementioned expert elicitation, but we used the average attributable fractions estimated by a novel Bayesian statistical model that integrates the attribution estimates from the expert elicitation with attribution estimates based on empirical data from microbial subtyping and case-control studies [9].

The attribution results for incidence, number of fatal cases, DALYs and CoI estimates of foodborne diseases for the years 2018-2022 are presented in Tables 10-13. The foodborne disease burden increased by 100 DALYs from 4,200 DALYs in 2021 to 4,300 DALYs in 2022. The CoI increased by 12M€ from 189 M€ in 2021 to 201 M€ in 2022.

Table 8 Attribution of the mean estimated number of incident cases, fatalities, disease burden and cost-of-illness of foodborne disease^a to the major transmission pathways in the Netherlands, 2022.

Main pathway	Food	Environment	Human	Animal	Travel	Total
<i>Number of incident cases (per year)^b</i>	654,000	187,000	553,000	71,000	135,000	1,599,000
<i>Number of fatal cases (per year)^b</i>	81	35	73	14	30	230
<i>Disease burden (DALY, undiscounted)^b</i>	4,300	1,900	2,300	660	1,300	10,000
<i>Disease burden (DALY, discounted (1.5%))^b</i>	3,500	1,400	2,000	560	1,100	8,600
<i>Cost of illness (M€, undiscounted)^c</i>	231	78	142	28	53	531
<i>Cost of illness (M€, discounted (4%))^c</i>	201	63	140	25	49	478

a) Due to the 14 pathogens included in this study.

b) Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

c) Costs are expressed in million € (M€).

Table 9 Attribution of the mean incidence, fatalities, disease burden and cost-of-illness of foodborne disease^a to food group in the Netherlands, 2022.

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish & shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
Number of incident cases (per year)^b	111,000	44,000	52,000	19,000	52,000	54,000	38,000	15,000	40,000	121,000	107,000	654,000
Number of fatal cases (per year)^b	11	9	14	3	7	7	8	2	3	4	13	81
Disease burden (DALY, undiscounted)^b	740	810	880	130	270	290	310	76	110	200	500	4,300
Disease burden (DALY, discounted (1.5%))^b	580	550	760	110	210	250	240	67	97	170	430	3,500
Cost of illness (M€, undiscounted)^c	40	29	29	6	18	17	15	5	11	31	30	231
Cost of illness (M€, discounted (4%))^c	33	18	26	6	16	15	12	4	10	30	29	201

a) Due to the 14 pathogens included in this study

b) Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $< 100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and < 10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

c) Costs are expressed in million € (M€)

Table 10 Attribution of mean incidence to food in the Netherlands for 2018-2022, total and by pathogen.

Pathogen	Incidence/year				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	40,000	41,000	28,000	30,000	32,000
<i>STEC O157</i>	780	770	850	870	800
<i>Salmonella spp.</i>	12,000	12,000	8,700	10,000	11,000
<i>Listeria monocytogenes</i>	61	92	77	76	82
<i>Bacillus cereus</i>	47,000	48,000	48,000	48,000	47,000
<i>Clostridium perfringens</i>	155,000	157,000	157,000	157,000	157,000
<i>Staphylococcus aureus</i>	251,000	252,000	252,000	252,000	253,000
<i>Norovirus</i>	103,000	98,000	44,000	76,000	103,000
<i>Rotavirus</i>	29,000	27,000	10,000	22,000	36,000
<i>Hepatitis A virus</i>	69	75	62	89	52
<i>Hepatitis E virus</i>	180	160	140	110	100
<i>Cryptosporidium spp.</i>	10,900	8,600	2,200	3,900	5,800
<i>Giardia spp.</i>	11,000	11,000	2,800	4,900	7,200
<i>Toxoplasma gondii</i>	430	430	430	430	450
Total	660,000	655,000	553,000	606,000	654,000

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 11 Attribution of mean number of fatal cases to food in the Netherlands for 2018-2022, total and by pathogen.

Pathogen	Number of fatal cases/year				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	26	30	21	22	22
<i>STEC O157</i>	1	1	2	2	1
<i>Salmonella spp.</i>	12	11	12	15	9
<i>Listeria monocytogenes</i>	5	13	15	12	11
<i>Bacillus cereus</i>	0	0	0	0	0
<i>Clostridium perfringens</i>	4	4	4	4	4
<i>Staphylococcus aureus</i>	6	6	6	6	6
<i>Norovirus</i>	11	11	5	9	12
<i>Rotavirus</i>	5	5	2	4	6
<i>Hepatitis A virus</i>	0.2	0.3	0.2	0.3	0.2
<i>Hepatitis E virus</i>	2	2	2	1	1
<i>Cryptosporidium spp.</i>	1	1	0	0.2	0.4
<i>Giardia spp.</i>	0.3	0.3	0.1	0.1	0.2
<i>Toxoplasma gondii</i>	7	7	7	7	7
Total	81	90	76	82	81

Table 12 Attribution of mean disease burden (DALY per year, undiscounted) to food in the Netherlands for 2018-2022, total and by pathogen.

Pathogen	DALY (undiscounted)/year				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	1,800	1,800	1,300	1,400	1,400
<i>STEC O157</i>	56	56	59	61	56
<i>Salmonella spp.</i>	520	510	400	470	440
<i>Listeria monocytogenes</i>	210	140	140	410	270
<i>Bacillus cereus</i>	29	29	29	29	29
<i>Clostridium perfringens</i>	180	180	180	180	180
<i>Staphylococcus aureus</i>	190	190	190	190	190
<i>Norovirus</i>	320	310	140	240	330
<i>Rotavirus</i>	150	150	50	120	190
<i>Hepatitis A virus</i>	8	8	6	10	6
<i>Hepatitis E virus</i>	71	63	54	43	41
<i>Cryptosporidium spp.</i>	19	15	4	7	10
<i>Giardia spp.</i>	28	29	7	13	19
<i>Toxoplasma gondii</i>	1,100	1,000	1,100	1,100	1,100
Total	4,600	4,600	3,600	4,200	4,300

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table 13 Attribution of mean COI (M€/year discounted at 4%) to food in the Netherlands for 2018-2022, total and by pathogen

Pathogen	COI per year (4%)/year (Million €, expressed in 2022 euros)				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	39	39	28	30	32
<i>STEC O157</i>	4	4	4	4	2
<i>Salmonella spp.</i>	12	12	9	11	10
<i>Listeria monocytogenes</i>	2	3	2	3	4
<i>Bacillus cereus</i>	12	12	12	12	12
<i>Clostridium perfringens</i>	31	31	31	31	31
<i>Staphylococcus aureus</i>	62	62	62	62	63
<i>Norovirus</i>	22	20	10	16	21
<i>Rotavirus</i>	10	9	4	8	12
<i>Hepatitis A virus</i>	0.2	0.2	0.0	0.6	0.1
<i>Hepatitis E virus</i>	1.0	0.8	0.7	0.6	0.6
<i>Cryptosporidium spp.</i>	3	3	1	1	2
<i>Giardia spp.</i>	2	2	1	1	2
<i>Toxoplasma gondii</i>	10	10	10	10	11
Total	210	208	174	189	201

Total COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

3 Overall conclusions

This report provides a public health perspective on the burden of 14 food-related pathogens in the Netherlands. The ranking of the foodborne pathogens when using burden of disease metrics is different compared to the ranking based on disease incidence. In 2022, we observed an increase in the number of incident cases for some of the 14 food-related pathogens, especially for norovirus, rotavirus, hepatitis A and *Campylobacter* spp. compared to the year 2020 and 2021.

The total BoD of the 14 food-related pathogens in 2022 (10,000 DALYs) was higher than in 2021 (9,100 DALYs, +10%) and 2020 (7,300 DALYs, +37%), but still lower than pre-COVID-19 pandemic year 2019 (11,000 DALYs, -9%). The fraction of the burden attributable to foodborne transmission in 2022 also increased compared to 2021 (from 4,200 DALYs to 4,300 DALYs; +2%) and in 2020 (3,600 DALYs, +16%), but was also lower than in 2019 (4,600 DALYs, -6%), albeit proportionally less than the overall BoD. Overall, we observed an increase in the burden of disease compared to the year 2020 and 2021 for *Campylobacter* spp., *Salmonella* spp., norovirus and rotavirus. In 2022, the disease burden for *Campylobacter* spp. and *Salmonella* spp. were almost back at pre-COVID-19 levels. For norovirus and rotavirus, however, the disease burden in 2022 was even higher than the years preceding the COVID-19 pandemic. *Listeria* was associated with a much lower disease burden in 2022 compared with 2021, but it was higher than the years before 2021.

The total CoI of the 14 food-related pathogens in 2022 was estimated at 478 million euros, which was higher than in 2021 (397 million euros, +20%) and 2020 (317 million euros, +51%). The highest costs were accounted for by norovirus. The costs resulting from infections contracted through food in 2022 (201 million euros) were higher than in 2021 (189 million euros, +6%) and 2020 (173 million euros, +16%). The total COI of *Campylobacter* spp. and *Salmonella* spp. in 2022 were much higher than in 2020 and in 2021 and were slowly increasing towards the levels of pre-COVID-19. The total COI of norovirus and rotavirus were much higher than in 2020 and 2021 and were at the same level or even higher than in the pre-pandemic years.

Overall, the disease burden and associated costs caused by the 14 food-related pathogens in the Netherlands increased in 2022 as compared to the pandemic years 2021 and 2020, but it was still lower than in 2019, the last year before the COVID-19 pandemic. This indicates that the burden caused by these pathogens is almost back to the pre-COVID-19 levels.

4 References

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Annex Detailed results

Table A.1 Trends in incidence per 100,000 inhabitants and reported cases, respectively, of food-related pathogens, 1999-2022.

Year	Ca ^a	Sa ^a	Cryp ^a	RV ^a	NV ^a	aLm ^b	aLm fatal ^b	pLm ^b	pLm fatal ^b	O157 ^b	O157 hosp ^b	HAV ^b	HAV hosp ^b	HEV ^a
1999	39	21		19	14					32				
2000	42	20		16	13					43				
2001	44	20		18	11					41				
2002	41	15		17	12					49				
2003	33	21		18	13					57				
2004	40	16		15	13					37				
2005	44	13		21	16	85	15	6		53				
2006	40	16		26	17	59	17	5	1	40		258	39	
2007	41	12		20	15	60	12	6	1	83		168	27	
2008	39	16		27	18	51	6	1	1	45		183	35	
2009	44	12		31	18	76	4	3	1	57	21	176	29	
2010	50	14		35	23	73	13	4	1	51	21	262	52	0.8
2011	51	12		24	21	79	4	9	1	65	18 ^d	125	25	0.9
2012	49	21		20	26 ^c	71	8	6	0	85	31 ^e	121	28	1
2013	48	9	6	23	26 ^c	76	7	3	0	90	36 ^f	109	30	0.9
2014	48	9	6	9	25 ^c	92	9	4	2	79	31 ^g	105	23	2
2015	43	9	10	20	27 ^c	69	15	3	1	76	27 ^h	80	23	3
2016	38	11	12	10	33 ^c	89	8	7	4	64	21 ⁱ	81	22	3
2017	33	9	8	16	23 ^c	112	10	3	2	58	23	374 ^k	90 ^m	2
2018	35	9	10	17	27 ^c	71	4	7	2	59	23 ^j	188 ^l	57 ⁿ	2
2019	35	9	8	16	25 ^c	113	16	4	0	35	13	166	135 ^o	2
2020	23	5	2	5	11 ^c	94	18	2	0	36	13	50	12 ^p	2
2021	24	6	4	13	19 ^c	82	11	12	4	55	22	78	23 ^q	1
2022	27	7	6	21	27^c	94	12	8	2	71	17	93	30^r	1

Used abbreviations: Ca: *Campylobacter* spp.; Sa: *Salmonella* spp.; Cryp: *Cryptosporidium* spp.; RV: rotavirus; NV: norovirus; aLm: acquired listeriosis; pLm: perinatal listeriosis; O157: STEC o157; HAV: hepatitis A virus; hosp: hospitalized; HEV: hepatitis E virus.

Notes: a).per 100,000 inhabitants whereby presented numbers are rounded: ≥ 10 to two significant numbers (e.g. 12.5 = 12) and < 10 to 1 significant number (e.g. 0.89=0.9); b) reported cases; c) estimated norovirus-associated hospitalized cases derived from RIVM laboratory surveillance data and therefore not directly comparable to numbers from before 2012; d) known for 57/65 cases; e) known for 77/85 cases; f) known for 84/90 cases; g) known for 71/79 cases; h) known for 68/76 cases; i) known for 60/64 cases; j) known for 58 out of 59 cases; k) ~ 275 cases are (in)directly linked to an international outbreak in men-having sex with men (MSM); l) 65 cases are (in)directly linked to an international outbreak of MSM m) known for 368/374 cases; n) known for 187/188 cases; o) known for 159/166 cases; p) known for 47/50 cases; q) known for 76/78 cases; r) known for 86/93 cases.

Table A.2 Mean number of incident cases by pathogen in the Netherlands, 2018-2022.

Pathogen	Estimated mean number of incident cases/year				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	71,000	73,000	47,000	51,000	57,000
STEC O157	2,100	2,100	2,200	2,200	2,200
<i>Salmonella spp.</i>	27,000	26,000	17,000	20,000	23,000
<i>Listeria monocytogenes</i>	78	120	96	94	100
<i>B. cereus</i> toxin	53,000	53,000	53,000	54,000	53,000
<i>C. perfringens</i> toxin	171,000	173,000	174,000	174,000	174,000
<i>S. aureus</i> toxin	288,000	289,000	289,000	289,000	290,000
Norovirus	615,000	585,000	265,000	453,000	619,000
Rotavirus	224,000	211,000	74,000	173,000	275,000
Hepatitis A virus	900	700	200	380	460
Hepatitis E virus	1,300	1,200	1,000	790	760
<i>Cryptosporidium spp.</i>	91,000	72,000	19,000	32,000	48,000
<i>Giardia spp.</i>	82,000	83,000	22,000	38,000	55,000
<i>Toxoplasma gondii</i>	770	760	770	780	800
Total	1,630,000	1,570,000	963,000	1,287,000	1,599,000

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figures (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.3 Mean number of fatal cases by pathogen in the Netherlands, 2018-2022.

Pathogen	Estimated mean number of fatal cases/year				
	2018	2019	2020	2021	2022
<i>Campylobacter spp.</i>	47	53	36	37	38
STEC O157	4	4	4	4	4
<i>Salmonella spp.</i>	25	24	23	28	20
<i>Listeria monocytogenes</i>	6	16	19	15	14
<i>B. cereus</i> toxin	0	0	0	0	0
<i>C. perfringens</i> toxin	5	5	5	5	5
<i>S. aureus</i> toxin	7	7	7	7	7
Norovirus	69	66	30	52	70
Rotavirus	38	36	12	31	48
Hepatitis A virus	3	3	1	1	1
Hepatitis E virus	15	13	13	9	9
<i>Cryptosporidium spp.</i>	6	4	1	2	3
<i>Giardia spp.</i>	2	2	1	1	2
<i>Toxoplasma gondii</i>	12	12	12	12	13
Total	238	245	163	200	230

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.4. Mean estimated disease burden (undiscounted DALY/year) in the Netherlands for the years 2018-2022, total and by pathogen.

Pathogen	Mean estimated disease burden (undiscounted DALY/year)				
	2018	2019	2020	2021	2022
<i>Campylobacter</i> spp.	3,200	3,300	2,100	2,300	2,500
STEC O157	150	150	150	150	150
<i>Salmonella</i> spp.	1,100	1,100	800	900	960
<i>Listeria monocytogenes</i>	260	180	180	510	330
<i>B. cereus</i> toxin	32	33	33	33	32
<i>C. perfringens</i> toxin	200	200	200	200	200
<i>S. aureus</i> toxin	220	220	220	220	220
Norovirus	1,900	1,800	800	1,400	2,000
Rotavirus	1,200	1,100	390	920	1,500
Hepatitis A virus	100	90	28	42	50
Hepatitis E virus	510	460	390	310	300
<i>Cryptosporidium</i> spp.	160	120	30	56	84
<i>Giardia</i> spp.	220	220	60	100	150
<i>Toxoplasma gondii</i>	1,900	1,900	1,900	1,900	2,000
Total	11,000	11,000	7,300	9,100	10,000

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figures (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help). There is one exception, *Listeria monocytogenes* which are acquired through surveillance.

Table A.5 Mean discounted COI (4%) in million euros in the Netherlands for 2018-2022, total and by pathogen.

Pathogen	COI per year (4%)/year (Million €, expressed in 2022 euros)				
	2018	2019	2020	2021	2022
<i>Campylobacter</i> spp.	69	70	47	50	57
STEC O157	7	7	7	7	7
<i>Salmonella</i> spp.	22	22	15	18	21
<i>Listeria monocytogenes</i>	4	5	4	5	5
<i>B. cereus</i> toxin	13	13	13	13	13
<i>C. perfringens</i> toxin	34	34	34	34	35
<i>S. aureus</i> toxin	71	71	71	71	72
Norovirus	127	120	58	95	128
Rotavirus	77	73	34	62	91
Hepatitis A virus	2	2	0.5	0.7	0.9
Hepatitis E virus	7	6	5	4	4
<i>Cryptosporidium</i> spp.	26	21	5	9	14
<i>Giardia</i> spp.	19	19	5	9	13
<i>Toxoplasma gondii</i>	18	17	18	18	19
Total	495	480	317	397	478

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.6 Attribution of mean estimated number of incident cases by pathogen to main pathways in the Netherlands, 2022.

Main pathway	Food	Environment	Human	Animal	Travel	Total
<i>Campylobacter</i> spp.	32,000	8,600	1,700	6,300	8,600	57,000
STEC O157	800	320	210	400	440	2,200
<i>Salmonella</i> spp.	11,000	1,200	2,600	1,800	6,900	23,000
<i>Listeria monocytogenes</i>	82	5	4	4	7	100
<i>B. cereus</i> toxin	47,000	580	640	580	3,900	53,000
<i>C. perfringens</i> toxin	157,000	3,800	3,700	3,700	5,600	174,000
<i>S. aureus</i> toxin	253,000	10,000	9,300	6,400	11,000	290,000
Norovirus	103,000	88,000	343,000	31,000	54,000	619,000
Rotavirus	36,000	47,000	160,000	8,200	24,000	275,000
Hepatitis A virus	52	51	83	0	270	460
Hepatitis E virus	100	190	58	82	330	760
<i>Cryptosporidium</i> spp.	5,800	13,000	13,000	6,500	9,500	48,000
<i>Giardia</i> spp.	7,200	13,000	19,000	5,900	9,800	55,000
<i>Toxoplasma gondii</i>	450	290	7	20	37	800
Total	654,000	187,000	553,000	71,000	135,000	1,599,000

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.7 Attribution of mean estimated number of fatal cases to main pathways in the Netherlands, 2022.

Main pathway	Food	Environment	Human	Animal	Travel	Total
<i>Campylobacter</i> spp.	21	6	1	4	6	38
STEC O157	1	0.6	0.4	0.7	0.8	4
<i>Salmonella</i> spp.	9	1	2	2	6	20
<i>Listeria monocytogenes</i>	11	0.7	0.6	0.6	1	14
<i>B. cereus</i> toxin	0	0	0	0	0	0
<i>C. perfringens</i> toxin	4	0.1	0.1	0.1	0.1	5
<i>S. aureus</i> toxin	6	0.3	0.2	0.2	0.3	7
Norovirus	12	10	39	3	6	70
Rotavirus	6	8	28	1	4	48
Hepatitis A virus	0.2	0.2	0.3	0	0.9	1
Hepatitis E virus	1	2	0.7	0.9	4	9
<i>Cryptosporidium</i> spp.	0.4	0.8	0.8	0.4	0.6	3
<i>Giardia</i> spp.	0.2	0.4	0.5	0.2	0.3	2
<i>Toxoplasma gondii</i>	7	5	0.1	0.3	0.6	13
Total	81	35	73	14	30	230

Presented numbers are rounded: ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.8 Attribution of mean disease burden (DALY per year, undiscounted) to main pathways in the Netherlands, 2022.

Main pathway	Food	Environment	Human	Animal	Travel	Total
<i>Campylobacter</i> spp.	1,400	380	76	280	380	2,500
STEC O157	56	23	14	28	31	150
<i>Salmonella</i> spp.	440	49	110	73	290	960
<i>Listeria monocytogenes</i>	270	17	13	13	23	330
<i>B. cereus</i> toxin	29	0.4	0.4	0.4	2	32
<i>C. perfringens</i> toxin	180	4	4	4	6	200
<i>S. aureus</i> toxin	190	8	7	5	8	220
Norovirus	330	280	1,100	98	170	2,000
Rotavirus	190	250	850	44	130	1,500
Hepatitis A virus	6	6	9	0	30	50
Hepatitis E virus	41	74	23	32	130	300
<i>Cryptosporidium</i> spp.	10	23	23	11	16	84
<i>Giardia</i> spp.	19	35	51	16	26	150
<i>Toxoplasma gondii</i>	1,100	730	18	51	93	2,000
Total	4,300	1,900	2,300	660	1,300	10,000

Presented numbers are rounded: ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and < 10 to 1 significant figure (e.g. 0.0023 = 0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.9 Attribution of mean cost-of-illness (M€ per year, discounted at 4%) to main pathways in the Netherlands, 2022

Main pathway	Food	Environment	Human	Animal	Travel	Total
<i>Campylobacter</i> spp.	32	9	2	6	9	57
STEC O157	2	1	0.6	1	1	7
<i>Salmonella</i> spp.	10	1	2	2	6	21
<i>Listeria monocytogenes</i>	4	0.2	0.2	0.2	0.3	5
<i>B. cereus</i> toxin	12	0.1	0.2	0.1	1	13
<i>C. perfringens</i> toxin	31	0.8	0.7	0.7	1	35
<i>S. aureus</i> toxin	63	3.0	2	2	3	72
Norovirus	21	18	71	6	11	128
Rotavirus	12	15	53	3	8	91
Hepatitis A virus	0.1	0.1	0.2	0	0.5	0.9
Hepatitis E virus	0.6	1	0.3	0.4	2	4
<i>Cryptosporidium</i> spp.	2	4	4	2	3	14
<i>Giardia</i> spp.	2	3	4	1	2	13
<i>Toxoplasma gondii</i>	11	7	0.2	0.5	0.9	19
Total	201	63	140	25	49	478

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million = 0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.10 Attribution of mean incidence by pathogen to food groups in the Netherlands, 2022.

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish & shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
<i>Campylobacter</i> spp.	6,200	990	16,000	740	1,300	2,200	990	580	580	580	2,200	32,000
STEC O157	520	74	18	14	28	18	28	21	18	21	41	800
<i>Salmonella</i> spp.	790	2,300	1,400	1,600	740	440	630	330	440	620	1,300	11,000
<i>Listeria monocytogenes</i>	5	5	9	2	23	5	23	2	3	3	2	82
<i>B. cereus</i> toxin	3,400	1,700	760	1,700	2,700	950	950	800	8,000	25,000	1,100	47,000
<i>C. perfringens</i> toxin	75,000	13,000	11,000	4,400	6,400	10,000	11,000	3,900	4,100	12,000	5,700	157,000
<i>S. aureus</i> toxin	19,000	20,000	20,000	8,300	37,000	15,000	5,100	4,600	19,000	75,000	30,000	253,000
Norovirus	3,300	3,200	3,000	2,000	2,100	16,000	7,500	3,200	5,400	5,200	53,000	103,000
Rotavirus	0	1,000	0	0	610	6,900	8,500	1,600	2,700	1,600	13,000	36,000
Hepatitis A virus	0	0	0	0	0	7	7	2	2	2	33	52
Hepatitis E virus	0	77	0	0	0	5	8	4	0	0	11	100
<i>Cryptosporidium</i> spp.	1,500	250	170	160	530	1,300	1,200	170	0	170	350	5,800
<i>Giardia</i> spp.	1,400	350	220	0	550	930	2,400	230	0	240	880	7,200
<i>Toxoplasma gondii</i>	100	230	22	0	21	17	26	0	0	10	26	450
Total	111,000	44,000	52,000	19,000	52,000	54,000	38,000	15,000	40,000	121,000	107,000	654,000

Presented numbers are rounded: $\geq 100,000$ to three significant figures (e.g. 123,256 = 123,000); between $<100,000$ and ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and <10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.11 Attribution of mean number of fatal cases by pathogen to food groups in the Netherlands, 2022.

Food groups	Beef & lamb	Pork	Poultry	Eggs	Dairy	Fish & shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
<i>Campylobacter</i> spp.	4	0.7	10	0.5	0.9	1	0.7	0.4	0.4	0.4	1	22
STEC O157	1	0.1	0.03	0.03	0.05	0.03	0.05	0.04	0.03	0.04	0.07	1
<i>Salmonella</i> spp.	0.7	2	1	1	0.6	0.4	0.6	0.3	0.4	0.5	1	9
<i>Listeria monocytogenes</i>	0.7	0.6	1	0.3	3	0.7	3	0.2	0.4	0.4	0.3	11
<i>B. cereus</i> toxin	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. perfringens</i> toxin	2	0.3	0.3	0.1	0.2	0.3	0.3	0.1	0.1	0.3	0.1	4
<i>S. aureus</i> toxin	0.5	0.5	0.5	0.2	0.9	0.4	0.1	0.1	0.5	2	0.7	6
Norovirus	0.4	0.4	0.3	0.2	0.2	2	0.8	0.4	0.6	0.6	6	12
Rotavirus	0	0.2	0	0	0.1	1	1	0.3	0.5	0.3	2	6
Hepatitis A virus	0	0	0	0	0	0.02	0.02	0.007	0.007	0.005	0.1	0.2
Hepatitis E virus	0	0.9	0	0	0	0.06	0.09	0.04	0	0	0.1	1
<i>Cryptosporidium</i> spp.	0.09	0.02	0.01	0.01	0.03	0.08	0.07	0.01	0	0.01	0.02	0.4
<i>Giardia</i> spp.	0.04	0.01	0.006	0	0.02	0.03	0.07	0.006	0	0.007	0.02	0.2
<i>Toxoplasma gondii</i>	2	4	0.3	0	0.3	0.3	0.4	0	0	0.2	0.4	7
Total	11	9	14	3	7	7	8	2	3	4	13	81

Presented numbers are rounded: ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and < 10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.12 Attribution of mean disease burden (DALY per year, undiscounted) by pathogen to food groups in the Netherlands, 2022

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish & shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
<i>Campylobacter</i> spp.	280	44	700	33	59	99	44	26	26	26	99	1400
STEC O157	36	5	1	1	2	1	2	1	1	1	3	56
<i>Salmonella</i> spp.	33	97	59	69	31	18	26	14	18	26	55	440
<i>Listeria monocytogenes</i>	16	15	30	7	76	16	76	6	8	8	8	270
<i>B. cereus</i> toxin	2	1	0.5	1	2	0.6	0.6	0.5	5	15	0.7	29
<i>C. perfringens</i> toxin	86	15	13	5	7	12	12	5	5	14	6	180
<i>S. aureus</i> toxin	14	15	15	6	28	11	4	3	14	57	23	190
Norovirus	10	10	9	6	7	51	24	10	17	16	170	330
Rotavirus	0	5	0	0	3	37	45	8	14	9	68	190
Hepatitis A virus	0	0	0	0	0	0.7	0.7	0.2	0.2	0.2	4	6
Hepatitis E virus	0	30	0	0	0	2	3	1	0	0	4	41
<i>Cryptosporidium</i> spp.	3	0.4	0.3	0.3	0.9	2	2	0.3	0	0.3	0.6	10
<i>Giardia</i> spp.	4	0.9	0.6	0	1	2	6	0.6	0	0.6	2	19
<i>Toxoplasma gondii</i>	260	570	54	0	52	42	66	0	0	26	65	1100
Total	740	810	880	130	270	290	310	76	110	200	500	4300

Presented numbers are rounded: ≥ 10 to two significant figures (e.g. 1,325 = 1,300) and < 10 to 1 significant figure (e.g. 0.0023=0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

Table A.13 Attribution of mean cost-of-illness (M€ per year, discounted at 4%) by pathogen to food groups in the Netherlands, 2022.

Food groups	Beef & Lamb	Pork	Poultry	Eggs	Dairy	Fish& shellfish	Produce	Beverages	Grains	Other foods	Humans & animals	Total
<i>Campylobacter</i> spp.	6	1	16	0.7	1	2	1	0.6	0.6	0.6	2	32
STEC O157	2	0.2	0.06	0.04	0.08	0.06	0.08	0.06	0.05	0.06	0.1	2
<i>Salmonella</i> spp.	0.7	2	1	1	0.7	0.4	0.6	0.3	0.4	0.6	1	10
<i>Listeria monocytogenes</i>	0.2	0.2	0.4	0.1	1	0.2	1	0.09	0.1	0.1	0.1	4
<i>B. cereus</i> toxin	0.8	0.4	0.2	0.4	0.6	0.2	0.2	0.2	2	6	0.3	12
<i>C. perfringens</i> toxin	15	3	2	0.9	1	2	2	0.8	0.8	2	1	31
<i>S. aureus</i> toxin	5	5	5	2	9	4	1	1	5	19	7	63
Norovirus	0.7	0.7	0.6	0.4	0.4	3	2	0.7	1	1	11	21
Rotavirus	0	0.3	0	0	0.2	2	3	0.5	0.9	0.5	4	12
Hepatitis A virus	0	0	0	0	0	0.01	0.01	0	0	0	0.06	0.1
Hepatitis E virus	0	0.4	0	0	0	0.03	0.04	0.02	0	0	0.06	0.6
<i>Cryptosporidium</i> spp.	0.4	0.08	0.05	0.05	0.2	0.4	0.4	0.05	0	0.05	0.1	2
<i>Giardia</i> spp.	0.3	0.08	0.05	0	0.1	0.2	0.5	0.05	0	0.05	0.2	2
<i>Toxoplasma gondii</i>	2	5	0.5	0	0.5	0.4	0.6	0	0	0.2	0.6	11
Total	33	18	26	6	16	15	12	4	10	30	29	201

COI per year are presented in million € (M€) and if less than 1 million rounded to 1 significant figure (e.g. 0.0023 million =0.002). The presented numbers are estimates that rely on annual surveillance data being corrected for: i) coverage (where applicable); ii) underdiagnosis and underreporting; and iii) under-ascertainment (i.e. being sick without requiring medical help).

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