Journal of Applied Sciences

ISSN 1812-5654

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 8 (8): 1453-1461, 2008
ISSN 1812-5654

Health Risk of *Escherichia coli* O157:H7 in Drinking Water and Meat and Meat Products and Vegetables to Diarrhoeic Confirmed and Non-Confirmed HIV/AIDS Patients

[1]B.O. Abong'o, [2]M.N.B. Momba and [3]N. Rodda
[1]Department of Biochemistry and Microbiology, School of Science and Technology,
University of Fort Hare, P/Bag X1314, Alice 5700, South Africa
[2]Department of Environmental, Water and Earth Sciences,
Arcadia Campus, Tshwane University of Technology (TUT), 175 Nelson Mandela Drive,
Arcadia, Pretoria 0002, South Africa
[3]School of Biological and Conservation Sciences, Howard College Campus,
University of Kwa-Zulu Natal, King George V Avenue, Glenwood, 4041 Durban, South Africa

Abstract: The current study explored the health risk of *E. coli* O157:H7 to diarrhoeic confirmed and non-confirmed HIV/AIDS patients due to their exposure to presumed ingestion of water, meat products and vegetables ostensibly contaminated with *E. coli* O157:H7. Strains of E. coli O157:H7 were isolated by enrichment culture and on Cefixime-Telurite Sorbitol MacConkey agar. Average counts of presumptive *E. coli* O157 were used for dose-response assessment. Probability of infection to confirmed and non-confirmed HIV/AIDS patients was 20 and 27% from meat and meat products, 21% and 15% from vegetables and 100% due to ingestion of 1500 mL person^{-1} day^{-1} of water. Drinking water had higher probability of transmitting *E. coli* O157:H7 infections than meat and meat products and vegetables. Probability of *E. coli* O157:H7 infections were high for confirmed HIV/AIDS patients than for non-confirmed patients. Water and foods consumed by HIV/AIDS patients should be safe of any microbial contaminants, these waters and foods should as well be investigated for other enteric pathogens to establish their safety.

Key words: Risk assessment, *Escherichia coli* O157:H7, water, meat and meat products, vegetables, HIV/AIDS, diarrhoea

INTRODUCTION

Risk assessment is a method used to organize and analyze scientific information to help estimate the probability and severity of an adverse effect because of a hazard. Applied to microbial water and food safety, the methodology can help to identify the stages in the operation, distribution, handling and consumption of foods and water that contribute to an increased risk of food and water-borne illnesses and help focus resources and efforts to most effectively reduce the risk of contracting such water and food-borne pathogens (Cassin *et al*., 1998). The probable reason why risk assessments related to pathogens, presents a key problem in most countries is due to lack of data on which to base estimates of disease burdens.

To specify a risk assessment with regard to disease causing pathogens, one need to identify the pathogen of concerns, the product it is associated with (water or food), a pathway, risk factors and the population at risk (Nauta *et al*., 2001).

For this study, the levels of *E. coli* O157:H7 in water, meat and meat products and vegetables consumed by the South African population residing in the Amathole district in the Eastern Cape Province, with a specific focus on diarrhoeic confirmed and non-confirmed HIV/AIDS patients, was investigated. *Escherichia coli* O157:H7 was chosen because of its association with water and foods, especially those of animal origin but also with vegetables (Vorster *et al*., 1994; Magwira *et al*., 2005; Josefa *et al*., 2005).

An important reason for conducting a risk assessment for pathogenic *E. coli* O157:H7 is its potential

Corresponding Author: M.N.B. Momba, Department of Environmental, Water and Earth Sciences, Arcadia Campus, Tshwane University of Technology (TUT), 175 Nelson Mandela Drive-Arcadia, Pretoria 0002, South Africa

impact on public health either directly or indirectly. There is a considerable evidence of persistent diarrhoea among adults and young children who are immunocompromised due to diseases such as HIV/AIDS (Ashton and Ramasha, 2002). However, the risk that *E. coli* O157:H7 poses to HIV/AIDS patients and its possible link to the diarrhoeic conditions in such patients have not been established. This was the foundation for the current study. In the study, we assessed the health risk that may result from the exposure of confirmed HIV/AIDS and non-confirmed HIV/AIDS patients with diarrhoea due to ingestion of water, meat and meat products and vegetables that in one way or another got contaminated with *E. coli* O157:H7.

Risk assessment consists of four main steps namely hazard identification, exposure assessment, dose-response assessment and risk characterization (Cassin *et al*., 1998). The knowledge in each step is combined to represent a cause-and-effect chain from the prevalence and population of a given microbial agent, in the present case *E. coli* O157:H7, to the probability and magnitude of health effects. In risk assessment, both the probability and impact of disease are considered. The quantities of daily intake of the water and or foods by the population are estimated based on a published data (Helena and Steyn, 2002).

Risk assessment model is therefore developed, which describes the pathogen population in the water and food product (Haas *et al*., 1999). The variability and uncertainty in the model are accommodated using probabilistic representations of the parameters (Potter, 1996). To generate a representative distribution of risk, the model is simulated with values selected from the probability distributions of the risk from the hazard (Thompson *et al*., 1992; Vose, 1996; Cassin *et al*., 1998). The direct output of the model is a distribution of health risk from ingesting water or eating a given food product by a particular group of population, in the present situation confirmed and non-confirmed HIV/AIDS patients with diarrhoea.

MATERIALS AND METHODS

Study population and samples: The exposure assessment in the present study was at the consumer level and the items that were considered for the risk assessment included water, meat and meat products and vegetables. The meat and meat products were biltong, cold meat, mincemeat and polony whereas the vegetable samples comprised of cabbage, carrot, cucumber, onions and spinach. Water samples were obtained from stand-pipes serving the informal settlements of Fort Beaufort, Alice, Dimbaza, Kwasaki, Mdantsane and Ngwenya.

The meat and meat products and vegetables were sampled from Fort Beaufort, Alice and Mdantsane between March 2005 and August 2006. The consumer demographics and health status was of confirmed HIV/AIDS and non-confirmed HIV/AIDS patients and were attending a referral hospital (Frere Hospital) East London for treatment. The term confirmed HIV/AIDS patients signifies the HIV/AIDS status of the patients were confirmed as positive by Frere Hospital HIV/AIDS clinic whereas non-confirmed are patients whose HIV/AIDS status were not known since they were not tested. However, both categories of patients had diarrhoea. The ages of the patients ranged between =10 and >50 years old.

Ethical approval: The University of Fort Hare Research Office (Govan Mbeki Research and Development Centre), the Provincial Department of Health (Bisho) and Regional Eastern Cape Ethical Review Committees granted ethical approval for the study.

Risk characterization: For the purposes of risk characterization, the hypothetical immunity of patients and extent of vulnerability of study cohorts to *E. coli* O157:H7 was based on a study in Japan which developed model parameters for the risk of illness associated with a confirmed *E. coli* O157:H7 outbreak in children and their teachers after consuming a lunch demonstrated to be contaminated by *E. coli* O157:H7 bacteria (Teunis *et al*., 2004). There are no published studies on risk analysis of *E. coli* O157:H7 in HIV-positive individuals. The only study that showed difference in risk of *E. coli* O157:H7 infection between such-groups of persons of differing susceptibility to *E. coli* O157:H7 infection was one in Japan (Teunis *et al*., 2004), which demonstrated that children were more susceptible to *E. coli* O157:H7 than their teachers. A beta-Poison model was used to calculate the probability of infection from a single exposure using the formula (Haas *et al*., 1999):

$$P_{inf} = 1 - (1 + d/\beta)^{-\alpha}$$

Where:

P_{inf} = Probability of infection

d = Infectious dose

β = Beta, model parameter

α = Alpha, model parameter

Dose d = CFU×g capita^{-1} day^{-1} or 1500 mL person^{-1} day^{-1}. water, assuming an average daily water intake of 1500 mL day^{-1}

CFU = Counts of presumptive *E. coli* O157 (cfu g^{-1} OR mL^{-1})

The presumptive *E. coli* O157:H7 counts determined for water, meat and meat products and vegetables from samples of these foodstuffs collected at several sites in the Eastern Cape were used to estimate the potential risk of *E. coli* O157:H7 infections to confirmed HIV/AIDS patients (modelled using parameters developed for children) and to non-confirmed HIV/AIDS patients (modelled using parameters developed for teachers). Presumed daily average quantities of water, meat and meat products and vegetables used for calculating exposure were adopted from a study on food consumptions in South Africa (Table 1) (Helena and Steyn, 2002).

The values used for β and α were adopted from the report by Teunis *et al.* (2004) mentioned above and were used to represent β and α values for confirmed HIV/AIDS patients with diarrhoea and non–confirmed HIV/AIDS patients also with diarrhoea. Based on the reasoning that children have a less well-developed immune system than adults, the β and α values for children (0.0844 and 1.442, respectively) were used for confirmed HIV/AIDS patients (compromised immune system) and the β and α values for teachers (0.0496 and 1.001, respectively) was used for non-confirmed HIV/AIDS patients (assumed to have normal immune function).

Using these model parameter, incorporating the average daily per capita quantities of water, vegetables, meat and meat products consumed (Helena and Steyn, 2002) and numbers of presumptive *E. coli* O157 (used to represent counts for presumptive *E. coli* O157:H7) actually cultured from these products sampled at various locations in the Eastern Cape, the following average individual risks due to a single exposure and prospective infections per 100 confirmed and non-confirmed HIV/AIDS patients with diarrhoea in a single outbreak were calculated.

Table 1: The average water, meat and meat products and vegetable intake in South Africa in mL person^{-1} day^{-1} or g capita^{-1} day^{-1} (Helena and Steyn, 2002)

Food/water	Quantity consumed	Population (%)	Comments
Water	1500.0	100.0	1500 mL person^{-1} day^{-1}
Cabbage	17.4	73.8	Cooked
Cucumber	2.5	12.8	Used raw tomato data as substitute
Onions	2.5	12.8	Used raw tomato data as substitute
Spinach	9.2	27.4	Cooked
Carrots	3.9	30.8	Cooked, flesh and skin
Biltong	4.6	46.0	beef sausage
Cold meat	4.4	34.6	Meat products and dishes
Mince	9.7	38.7	Beef stew
Polony	4.4	34.6	Meat products and dishes

RESULTS AND DISCUSSION

The risk of *E. coli* O157:H7 infection was found to be higher for confirmed HIV/AIDS patients than it was for the non-confirmed HIV/AIDS patients for water, meat and meat products and vegetables (Table 2-4). Nevertheless, the risk varied widely between and within samples of water, meat and meat products and vegetables for both confirmed and non-confirmed HIV/AIDS patients with diarrhoea.

Probability of *E. coli* O157:H7 infections from drinking water: The prospective risk of *E. coli* O157:H7 infection for both confirmed and non-confirmed HIV/AIDS patients was higher for water (Table 2) than for meat and vegetable samples. The average individual risk; to confirmed HIV/AIDS patients due to ingestion of 1500 mL person^{-1} day^{-1} of water ranged from 0.75 for Dimbaza water to 0.81 for Mdantsane water, with 95th percentile values of 0.8 for both. Average individual risk to non-confirmed HIV/AIDS patients was slightly lower for Dimbaza waters (0.57), but was higher for Mdantsane water (0.63) with 95th percentile values above 0.6 for both (Table 2, Fig. 1) respectively illustrate average individual probability of *E. coli* O157:H7 infection and 95th percentiles due to ingestion of 1500 mL person^{-1} day^{-1} of water in a single exposure for both confirmed and non-confirmed HIV/AIDS patients.

The probability of *E. coli* O157:H7 infections per 100 persons for both confirmed and non-confirmed HIV/AIDS population members drinking approximately 1500 mL person^{-1} day^{-1} of water from any of the distribution point was estimated at 1.00 (in other words, certainty of infection). This estimate is less likely to be reflective of true risk of infection than it is to be indicative of the high level of uncertainty associated with the assumptions made in this preliminary risk assessment exercise.

The exaggerated probability of *E. coli* O157:H7 infection due to intake of water could be attributable to

Table 2: Average individual risks of *E. coli* O157:H7 infection associated with consumption of 1500 mL person^{-1} day^{-1} of water from various distribution points

Water source	Average probability of infection (Pinf.)
Fort Beaufort	0.79 (0.61)
Alice	0.76 (0.58)
Dimbaza	0.75 (0.57)
Mdantsane	0.81 (0.63)
Ngwenya	0.77 (0.59)
Kwasaki	0.78 (0.59)

Unparenthesised numbers represents average risks of *E. coli* O157:H7 infections to confirmed HIV/AIDS patients, whereas numbers in parenthesis represents average risks to non-confirmed HIV/AIDS patients

Table 3: Average individual risks of *E. coli* O157:H7 infection and expected number of infections per 100 confirmed HIV/AIDS or non-confirmed HIV/AIDS patients associated with consumption of various meat and meat products

	HIV/AIDS	Av. probability of infection (Pinf.)			Exposed/100	Av. infected/100
Samples	Status	FB	AL	MD	Population	Population
Biltong	+ve	0.64 (29)	0.76 (35)	0.68 (31)	46	32
	–ve	0.46 (21)	0.57 (26)	0.50 (23)	46	23
Cold meat	+ve	0.67 (23)	0.67 (23)	0.69 (24)	35	23
	–ve	0.51 (18)	0.49 (17)	0.51 (18)	35	17
Mincemeat	+ve	0.76 (27)	0.78 (30)	0.71 (28)	39	28
	–ve	0.52 (20)	0.60 (23)	0.53 (21)	39	21
Polony	+ve	0.71 (25)	0.71 (25)	0.71 (25)	35	25
	–ve	0.52 (18)	0.53 (18)	0.50 (17)	35	17

Unparenthesised numbers (in average probability of infection) represent average individual risks of *E. coli* O157:H7 infections to confirmed HIV/AIDS or non-confirmed HIV/AIDS patients. Numbers in parenthesis represent expected infections per 100 persons in a single outbreak for each location and each meat and meat product. FB: Fort Beaufort, AL: Alice, MD: Mdantsane

Table 4: Average individual risks of *E. coli* O157:H7 infection and expected infections per 100 HIV-positive or HIV-negative patients associated with consumption of various vegetables

	HIV/AIDS	Av. probability of infection (Pinf.)			Exposed/100	Av. infected/100
Samples	Status	FB	AL	MD	Population	Population
Cabbage	+ve	0.68 (53)	0.71 (52)	0.66 (49)	78	51
	–ve	0.50 (39)	0.52 (38)	0.48 (35)	78	37
Carrot	+ve	0.66 (20)	0.61 (19)	0.62 (19)	31	19
	–ve	0.47 (14)	0.44 (14)	0.44 (14)	31	14
Cucumber	+ve	0.67 (9)	0.59 (8)	0.61 (8)	13	8
	–ve	0.49 (6)	0.41 (5)	0.43 (6)	13	6
Onion	+ve	0.66 (8)	0.59 (8)	0.58 (8)	13	8
	–ve	0.47 (6)	0.41 (5)	0.41 (5)	13	5
Spinach	+ve	0.68 (19)	0.65 (18)	0.62 (17)	27	18
	–ve	0.50 (14)	0.47 (13)	0.45 (12)	27	13

Unparenthesised numbers (in Source and Risk Estimate columns) represent average individual risks of *E. coli* O157:H7 infections to HIV-positive or HIV-negative patients. Numbers in parenthesis represent expected infections per 100 HIV-positive or HIV-negative patients in a single outbreak for each location and for a particular vegetable. FB: Fort Beaufort, AL: Alice, MD: Mdantsane

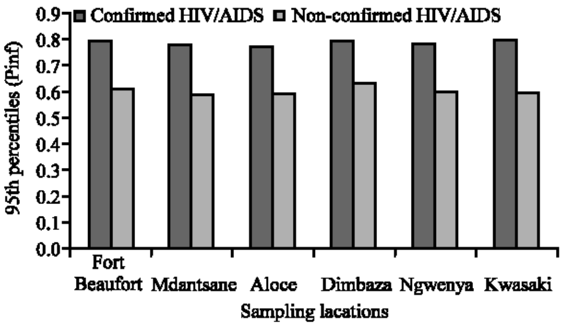

Fig. 1: 95th Percentiles (Pinf.) for *E. coli* O157:H7 infections due to ingestion of 1500 mL person^{-1} day^{-1} of water for confirmed and non-confirmed HIV/AIDS patients

the high-assumed daily intake of water (1500 mL person^{-1} day^{-1}) and high counts of presumptive *E. coli* O157:H7, which may include other strains of *E. coli* besides strain O157:H7.

Probability of *E. coli* O157:H7 infections from consumption of meat and meat products: The probability of *E. coli* O157:H7 infection associated with consumption of meat and meat products was also estimated for both patient categories (Table 2). The risk estimates for meat and meat products ranged from 0.64 to 0.78 for biltong from Fort Beaufort (consumption of 9.7 g capita^{-1} day^{-1}) and mincemeat from Alice (consumption of 4.6 g capita^{-1} day^{-1}), respectively, for the confirmed HIV/AIDS patient. The 95th percentile values were noted at 0.68 for biltong and 0.79 for mincemeat to this group of patients. Risk estimates for non-confirmed HIV/AIDS patients were lower, ranging from 0.46 for biltong from Fort Beaufort to 0.60 for mincemeat from Alice, respectively, with 95th percentile values of 0.5 for biltong from Fort Beaufort and 0.6 for mincemeat from Alice (Fig. 2), at a similar consumption rate.

When risks of *E. coli* O157:H7 infection were ranked by type of meat product, mincemeat was associated with the highest individual risk of infection in a single exposure followed closely by polony, biltong and lastly by cold meat. It was not surprising that mincemeat had the highest associated individual risk. Mincemeat has been reported to harbour high levels of *E. coli* O157:H7 because of the way the meat is ground, which serves to inoculates the whole batch of mincemeat during mincing (Flores and Stewart, 2004).

An astonishing observation was that biltong had the highest expected infection rate per population of 100 (an indication of population risk as opposed to individual

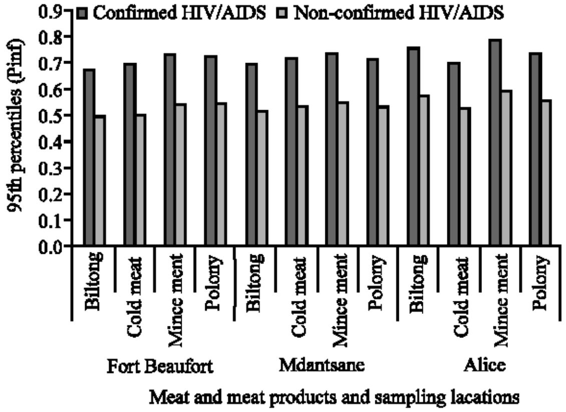

Fig. 2: 95th Percentiles (Pinf.) for *E. coli* O157:H7 infections due to consumption of meat and meat products for confirmed and non-confirmed HIV/AIDS patients

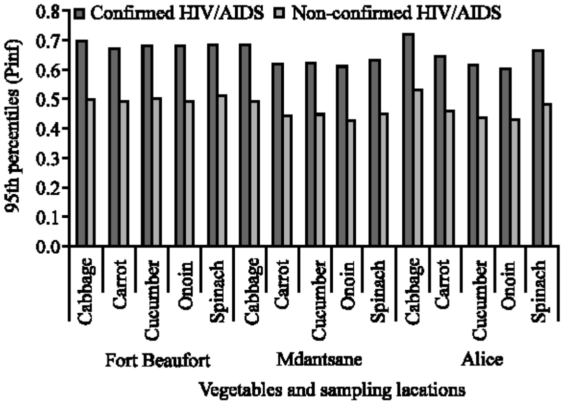

Fig. 3: 95th Percentiles (Pinf.) for *E. coli* O157:H7 infections due to consumption of vegetables for confirmed and non-confirmed HIV/AIDS patients

risk). Biltong was associated with population risk estimates of 32 and 23 per population of 100 among confirmed HIV/AIDS and non-confirmed HIV/AIDS patients, respectively. This observation could be at least partially the result of high consumption of biltong by South Africans (Helena and Steyn, 2002). Even though the quantities of biltong consumed per day (4.6 g capita^{-1} day^{-1}) by South Africans was found to be lower than that of mincemeat (9.7 g capita^{-1} day^{-1}), the number of people consuming biltong (46 persons per every 100 population) was higher than those consuming mincemeat (38 person per every 100 population) (Helena and Steyn, 2002).

The predicted consumption rate for cold meat and polony were similar and this is reflected in similar values for the associated individual risk of probability of *E. coli* O157:H7 infections and expected infections per 100 confirmed HIV/AIDS or non-confirmed HIV/AIDS patients. The average expected infections per 100 confirmed HIV/AIDS patients' consuming any of these meat products was predicted at 0.27 whereas average expected infection per 100 non-confirmed HIV/AIDS patients was estimated at 0.20.

Probability of *E. coli* O157:H7 infections from consumption of vegetables: Estimate of individual risk of *E. coli* O157:H7 infection because of consumption of vegetables ranged from 0.58 to 0.71 confirmed HIV/AIDS patients. The estimated 95th percentile values were at 0.6 for onions and 0.72 for the cabbages to confirmed HIV/AIDS patients (Fig. 3). This was observed for Mdantsane onions and Alice cabbage, for a single serving of 17.4 and 2.5 g capita^{-1} day^{-1}, respectively. Conversely, probability of *E. coli* O157:H7 infections to non-confirmed HIV/AIDS patients attributable to consumption of vegetables ranged between 0.41 and 0.52 on a single serving of the same quantities of cabbage and cucumber as above, respectively. The estimated 95th percentile values were at 0.4 for onions and 0.5 for the cabbages to non-confirmed HIV/AIDS patients. The average expected infections per 100 populations of confirmed HIV/AIDS patients' consuming these vegetables was estimated at 0.21. However, the average expected infections per 100 non-confirmed HIV/AIDS patients were considerably lower, at 0.15, which was almost the same as for that for confirmed HIV/AIDS patients.

The effect of variability on risk estimates of *E. coli* O157:H7 infections associated with consumption of water, meat and meat products and vegetables: The variability of the estimated risk represented graphically by the spread of the cumulative frequency distribution; was greatly influenced by the counts of presumptive *E. coli* O157. This is because the presumptive counts obtained for the water, meat and meat products and vegetables from the areas were used to derive the cumulative distribution frequency curves. Comparing the cumulative distribution frequency (data not shown), it was evidenced that the risk associated with drinking water showed the greatest variability, followed closely by meat and meat products and lastly by vegetables. Coincidentally, this order also corresponded to the extent of risk of *E. coli* O157:H7 infections associated with water, meat and meat products and vegetables to both confirmed and non–confirmed HIV/AIDS patients with diarrhoea. This could be due to high volumes of water consumed by South Africans as was also evidenced in other previous studies (Helena and Steyn, 2002; Steyn *et al*., 2004).

The variability of the estimated risk from drinking water were more spread than those for meat and meat products and vegetables for both confirmed and non-confirmed HIV/AIDS patients. The cumulative frequency distribution for water from Mdantsane was more spread with a higher 95th percentile value (0.8), for confirmed HIV/AIDS patients than for non-confirmed HIV/AIDS patients, (95th percentile value of 0.6), making it the source of drinking water with a greater variability, hence high individual risk of *E. coli* O157:H7 infections in a single exposure.

Conversely, water from Dimbaza showed a narrower spread. The 95th percentile value was noted at 0.78 to confirmed HIV/AIDS patients, implying that it had a lesser variability. However, this was still high compared to variability in estimated individual risk to non-confirmed HIV/AIDS patients drinking water from the same source (Dimbaza) with a 95th percentile value of 0.58. Therefore, a low individual risk of *E. coli* O157:H7 to non-confirmed HIV/AIDS than for confirmed HIV/AIDS patients due to drinking of water from Dimbaza was recorded.

The variability of the estimated risk from consumption of meat and meat products as shown by the cumulative frequency distribution were neither as spread as those for water nor as those for vegetables for both confirmed and non-confirmed HIV/AIDS patients (Table 3). As illustrated in Fig. 2, the cumulative frequency distribution for mincemeat from Alice was more spread with a higher 95th percentile value (0.78), for confirmed HIV/AIDS patients than for non-confirmed HIV/AIDS patients, (95th percentile value of 0.6), making it the meat and meat product with a greater variability, hence high risk of *E. coli* O157:H7 infections. Conversely, biltong showed a narrower spread. The 95th percentile value due to consumption of biltong was 0.68 to confirmed HIV/AIDS patients. This implied that biltong had a lesser variability and low risk of *E. coli* O157:H7 infection to confirmed HIV/AIDS patients, though this was still high compared to variability in estimated individual risk to non-confirmed HIV/AIDS patients consuming biltong (95th percentile value of 0.5). This low risk due to biltong could be due to inhibited growth of *E. coli* O157:H7 in biltong by preservatives.

The variability of the estimated risk from consumption of vegetables as shown by the cumulative frequency distribution were not as spread compared to those for water or meat and meat products to both confirmed and non-confirmed HIV/AIDS patients (Table 4). The cumulative frequency distribution for vegetables from Alice was more spread with a higher 95th percentile (0.6) value for confirmed HIV/AIDS patients than that for non-confirmed HIV/AIDS patients (95th percentile value of 0.5), making it the vegetable sample with a greater variability, hence high risk of *E. coli* O157:H7 infections. Conversely, onions from Mdantsane showed a narrow spread, even though it had a higher 95th percentile value (0.67), the variability was less spread and so a low individual risk of *E. coli* O157:H7 to confirmed HIV/AIDS patients was predicted. However, onions from Alice had a lesser variability with low percentile value (0.4) demonstrating a low risk of *E. coli* O157:H7 infection to non-confirmed HIV/AIDS patients

The effect of uncertainty on risk estimates of *E. coli* O157:H7 infections associated with consumption of water, meat and meat products and vegetables: One of the major sources of uncertainty in any risk model is the suitability of the model parameters. Model parameters must be chosen from published studies, which vary in exposure conditions from the data to which the model is applied. The type of model parameters chosen can introduce uncertainty in the applicability of the model outputs in the context of the specific exposure under investigation. Comparing the findings of the present investigation to that conducted by Teunis *et al.* (2004) in Japan on which the risk model used in the present study was based, the rate of infection in children in a confirmed *E. coli* O157:H7 outbreak (used to model risk to confirmed HIV/AIDS patients in the present study), was 0.25. This is only 2% lower than the overall risk of infection estimated for confirmed HIV/AIDS patients (0.27) in the present study. The infection rate to the teachers (used to model risk to non-confirmed HIV/AIDS patients in the current study) was 0.16. This attack rate is 4% lower than the estimated risk of infection to non-confirmed HIV/AIDS patients in the present study (0.20). It therefore suggests that; the model parameters developed by Teunis *et al.* (2004) for the *E. coli* O157:H7 outbreak among school-children and their teachers in Japan can reasonably be used to estimate risk of *E. coli* O157:H7 infection among confirmed and non-confirmed HIV/AIDS patients with diarrhoea due to consumption of meat and meat products. However, risk of *E. coli* O157:H7 infection to confirmed and non–confirmed HIV/AIDS patients in the present study is slightly overestimated relative to actual attack rates observed in the Japanese study. Since it is preferable to adopt a conservative approach when estimating risk, especially when the underlying data are subject to considerable uncertainty, the estimated risk values observed in the current study are acceptable.

The infection rates for confirmed and non-confirmed HIV/AIDS patients consuming vegetables were low (0.21 for confirmed and 0.15 for non-confirmed HIV/AIDS patients) than observed attack rates in the Japanese study

(0.21 for confirmed HIV/AIDS patients vs 0.25 for children in the Japanese study; 0.15 for non-confirmed HIV/AIDS patients *vs* 0.16 for teachers in the Japanese study). This suggests that the model parameters developed by Teunis *et al.* (2004) may not be suitable for the consumption of vegetables under South African conditions. However, there were various uncertainties associated with the choice for the vegetable consumption data (g capita^{-1} day^{-1} instead of g serving^{-1} as was the case in the Japanese study) used in the derivation of the risks of *E. coli* O157:H7 infections. The second source of uncertainty was the use of counts for presumptive *E. coli* O157 to represent counts for *E. coli* O157:H7. The study population was also selected based on the patients experiencing diarrhoea, rather than total exposed population. The estimated risks in the present study would have been lower if the risk of *E. coli* O157:H7 infection to confirmed and non-confirmed HIV/AIDS patients with diarrhoea was being compared to the risk of acquiring the bacteria by the general population who even though hypothetically could have been having diarrhoea but never reported to the clinics for treatment.

Overall confidence in risk estimates of *E. coli* O157:H7 infections associated with consumption of water, meat and meat products and vegetables presented in this study: The overall estimated distribution of *E. coli* O157:H7 in the water, meat and meat products and vegetables and its risk of infection to HIV/AIDS patients as predicted by the exposure model does not compare reasonably well with other published surveys. This is because currently there are no data on risk of *E. coli* O157:H7 infections from water, meat and meat products, or vegetables to HIV/AIDS patients in South Africa or anywhere in the world that is documented in literature.

Cassin *et al.* (1998) estimated variability of *E. coli* O157:H7 risk using a beta-binomial model to determine the probability of illness following ingestion of hamburgers contaminated with *E. coli* O157:H7. The population was assumed essentially uniform in terms of susceptibility to infections from these bacteria. The study of Cassin *et al.* (1998) is similar to the current study in terms of hazard characterization. Cassin *et al.* (1998) also used Monte Carlo simulation, as in the present study, although their study differed in terms of the exposed population and the assumed susceptibility of the population to the hazard (*E. coli* O157:H7). The patients in the present study comprised of persons with weakened immune system, which was presumed to be either due to diarrhoea or due to HIV/AIDS infections. However, Cassin *et al.* (1998) were able to establish that children aged 5 years and below in their study populations were more susceptible to *E. coli* O157:H7 infections by virtue of their under-developed immune systems.

In comparison, in the current study, risk of *E. coli* O157:H7 infection was modelled using data from a study, which fit a beta-Poisson model to actual infection data from an outbreak of *E. coli* O157:H7 in a school in Japan. Different values were derived for α and β model parameters for two sub-populations: children and teachers (Teunis *et al.*, 2004). This corresponds with the study of Cassin *et al.* (1998) in recognizing children as a sub-population with a relatively weaker immune system. This in a way supports the use of the model parameters for children to substitute for values for confirmed HIV/AIDS patients in the present study, since no values for HIV/AIDS patients were available.

All the samples (water, meat and meat products and vegetables) displayed a range of probability of propagating risk of *E. coli* O157:H7 infection resulting from a presumed ingestion of these bacteria. Cassin *et al.* (1998) made a similar observation when they modelled for the probability of *E. coli* O157:H7 infection resulting from a single hamburger meal. They argued that the probability of illness resulting from ingestion of *E. coli* O157:H7 described by individual simulation output was normally infinitesimal because of reduction in micro-organism load during cooking.

The USEPA limit for acceptable risk is no more than 1 in 10 000 excess infections per year, in the case of drinking water (United States Environmental Protection Agency, 1994), the estimated risks in the present study are exceedingly high, even for single exposures. This could be due to the uncertainties in the data attributable to high intake of water and the high presumptive *E. coli* O157:H7 counts that were used to derive the risks. The hypothetical analysis of possible risk of *E. coli* O157:H7 infection among both confirmed and non-confirmed HIV/AIDS patients with diarrhoea suggest that exposures of these populations under investigation were unacceptably high. Nevertheless, it should not be ignored that in the present study, all risks were modelled for the food products in their ready-to-eat forms that required no further cooking (boiling in the case of water). No adjustment such as washing or cooking was made for the reduction in *E. coli* O157:H7 levels for two reasons: (a) the study represented a theoretical exploration of possible impacts of *E. coli* O157:H7 contamination of food and drinking water, rather than trying to fit a risk model to actual outbreak data. Mostly, the conservative assumptions were used to represent worst-case scenario. (b) Since food preparation practices in the exposed population were not surveyed and were likely to include both cooked (boiled in the case of water) and uncooked forms of most of the products tested, using values for uncooked food products/unboiled water represented the most conservative approach in the current study. If reduction in *E. coli* O157:H7 during cooking had been taken into account, estimated individual risks and risks per 100 populations would have been lower.

The water and food consumption data could have also been over estimated, which may have resulted in higher risk estimation. A single exposure to *E. coli* O157:H7 in drinking water at a consumption rate of 1500 mL person^{-1} day^{-1} was found to have higher risk to both confirmed and non-confirmed HIV/AIDS patients than the risk associated with a single exposure from ingestion of meat and meat products and vegetables. This might be the result of the high-assumed daily intakes of water. It should also be noted that cross contamination, especially for meat and meat products and vegetables and even cross contamination of water from sampling bottles was not assessed and these may increase the uncertainty and consequently the variability of the risk estimates.

CONCLUSION

The precise relationship between the numbers of *E. coli* O157:H7 consumed and resulting adverse effects in HIV/AIDS patients is not well known. Generally, the probability of risk of *E. coli* O157:H7 infection was higher for confirmed HIV/AIDS patients than for the non-confirmed HIV/AIDS patients. Distribution of risk was prevalent across all the samples water, meat and meat products and vegetables. However, probability of infection due to water was higher than for meat and meat products and vegetables to both confirmed and non-confirmed HIV/AIDS patients.

This study comes to a conclusion that confirmed and non-confirmed HIV/AIDS patients have varied vulnerability to infections due to *E. coli* O157:H7, however, confirmed HIV/AIDS patients are at higher risk of developing *E. coli* O157:H7 induced diarrhoea than non-confirmed HIV/AIDS patients. The level of risk also varied with the type of food one consumes and that meat and meat products carried greater risk of infection than vegetables. Risk due to water ingestion also varied with source of water.

Future research is required to focus on handling of meat and meat products and farming practices in the growing of vegetables. The role of retail and house-hold handling of meat and meat products and vegetables and storage and handling of drinking water as possible risk factors for *E. coli* O157:H7 risks of infection to the public should be investigated.

ACKNOWLEDGMENTS

The authors wish to thank the National Research Foundation (NRF) of South Africa who sponsored this study. The dedicated work of Sr. A. Pagel (formerly of Frere Referral Hospital, East London) in the voluntary counselling of the patients and the collection of stool samples is also gratefully acknowledged.

REFERENCES

Ashton, P. and V. Ramasha, 2000. Water and HIV/AIDS: Some Strategic Considerations in Southern Africa. In: Hydropolitics in the Developing World, Turton, A.R. and R. Henwood (Eds.). A Southern African Perspective. African Water Issues Research Unit, Pretoria. South Africa, pp: 217-235.

Cassin, M.H., M.L. Anna, C.D.T. Ewen, R. William and R.M. Stephen, 1998. Quantitative risk assessment for *Escherichia coli* O157:H7 in ground beef hamburgers. Int. J. Food Microbiol., 41 (1): 21-44.

Flores, R.A. and T.E. Stewart, 2004. Empirical distribution models for *Escherichia coli* O157:H7 in ground beef produced by a mid-size commercial grinder. J. Food Sci., 69 (5): M121-M126.

Haas, C.N., J. Rose and C. Gerba, 1999. Quantitative Microbial Risk Assessment. John Wiley and Sons, New York.

Helena, J.N. and P. Steyn, 2002. Report on South African food consumption studies undertaken amongst different population groups (1983-2000): Average intakes of foods most commonly consumed. http://www.doh.gov.za/docs/reports/2002/. Accessed April 16, 2007.

Josefa, M.R., H.S. Phyllis, C. Collen, M.G. Patricia and L.S. David, 2005. Epidemiology of *Escherichia coli* O157:H7 outbreaks, United States, 1982- 2002. Emerg. Infect. Dis., 11 (4): 603-609.

Magwira, C.A., B.A. Gashe and E.K. Collison, 2005. Prevalence and antibiotic resistance profiles of *Escherichia coli* O157:H7 in beef products from retail outlets in Gaborone, Botswana. J. Food Prot., 68 (2): 403-406.

Nauta, M.J., E.G. Evers, K. Takumi and A.H. Havelaar, 2001. Risk assessment of Shiga-toxin producing *Escherichia coli* O157 in steak tartar in the Netherlands. RIVM Rapport 257851003. http://www.rivm.nl/bibliotheek/rapporten/ Accessed 05th April, 2007.

Potter, M.E., 1996. Risk assessment terms and definitions. J. Food Prot., pp: S6-S9 (Supplement).

Steyn, M., P. Jagals and B. Genthe, 2004. Assessment of microbial infection risk posed by ingestion of water during domestic water used and full-contact recreation in mid Southern African region. Water Sci. Technol., 50 (1): 301-308.

Teunis, P., T. Katsuhisa and S. Kunihiro, 2004. Dose response for infection by *Escherichia coli* O157:H7 from outbreak data. Risk Anal., 24 (2): 401-407.

Thompson, K.M., D.E. Burmaster and E.A.C. Crouch, 1992. Monte Carlo techniques for quantitative uncertainty analysis in public health risk assessments. Risk Anal., 12 (1): 53-63.

United States Environmental Protection Agency, 1994. National primary drinking water regulations: Enhanced surface water treatment requirements; proposed rule. Fed. Reg., 59 (38): 832-838.

Vorster, S.M., R.P. Greebe and G.L. Nortje, 1994. Incidence of *Staphylococcus aureus* and *Escherichia coli* in ground beef, broilers and processed meats in Pretoria, South Africa. J. Food Prot., 57: 305-310.

Vose, D., 1996. Quantitative Risk Analysis: A Guide to Monte Carlo Simulation Modeling. John Wiley and Sons, Inc., New York, USA.