Chronic Poverty and Childhood Asthma in the Maritimes Versus the Rest of Canada

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ABSTRACT

Objective: To examine the role of higher long-term poverty rates in the Maritimes as an explanation for higher rates of asthma among children 2-7 years of age.

Methods: Using longitudinal data from the National Longitudinal Survey of Children and Youth (NLSCY), logistic regressions examine associations between poverty duration and the probability of a child having been diagnosed with asthma, having a current asthma attack or experiencing wheezing in the past 12 months, controlling for other known determinants.

Results: NLSCY data indicate that 15.9% of Maritime children have been diagnosed with asthma, 8.7% have recently had an attack and 24.1% experienced wheezing, statistically higher levels than in the rest of Canada. Children in chronic poverty show rates that are over 30% higher than the Canadian averages. Although 19.9% of Maritime children have been chronically poor compared to 11.7% elsewhere, and although poverty is associated with a higher probability of asthma/wheezing, controlling for poverty status does not eliminate the regional difference in asthma rates. Including other controls with poverty status again does not fully explain the difference.

Conclusion: While these findings do not completely explain why asthma prevalence rates are higher for Maritime children, they do indicate important pathways from poverty to childhood asthma. For example, chronically poor children are more likely to have had low birthweights and are less likely to have been breastfed, both of which are correlates of asthma. Such information can be useful for policy-makers. Pollutants and other environmental factors associated with asthma not included in the study may help further explain regional differences.

MeSH terms: asthma; child; poverty; socio-economic factors

La traduction du résumé se trouve à la fin de l'article.

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In the year 2000, the federal, provincial and territorial governments in Canada passed the Early Childhood Development Agreement (ECDA), recognizing the importance of early childhood experiences on long-term development and overall well-being. An important aspect of the agreement focusses on the physical health of young children,¹ leading to critical questions on the determinants of health. Overwhelmingly, research suggests there is a link between socio-economic factors and health outcomes in children.²⁻⁵

Asthma is the most common chronic respiratory childhood condition in Canada, affecting everyday activities, leading to one quarter of school absenteeism,⁶ and potentially hindering development. It is particularly concerning that asthma prevalence rates for children have nearly doubled in Canada in less than a decade; similar trends are apparent in other western nations.⁷ This rise over a relatively short period has researchers looking beyond genetics alone. Studies⁸⁻¹¹ have suggested that asthma is the result of an interaction of genetic, environmental and socio-economic factors.

Earlier research^{12,13} has indicated a higher prevalence of childhood asthma in the Maritime provinces than elsewhere in Canada and higher rates of child poverty, both because children are more likely to be poor at any given point in time and because they are more likely to remain poor for long periods of time.¹⁴ Given clear evidence of a link between socio-economic status and child health,^{2,5} in this study, we assess the role of higher rates of long-term child poverty in the Maritimes as a potential explanation for higher rates of asthma among young children, controlling for other known risk factors. In our study and previous work,¹² the Maritime provinces (Nova Scotia, Prince Edward Island and New Brunswick) are grouped together because they have similar economic structures, similar exposure to sulphates¹² – a potentially important asthma determinant – and constitute a relevant grouping from the perspective of health policy since children in the three provinces fall under the jurisdiction of the IWK Health Centre for women and children.

METHODS

This study uses data from the fourth cycle (2000) of the Statistics Canada National

Longitudinal Survey of Children and Youth (NLSCY), a longitudinal survey designed to monitor the well-being of Canadian children from infancy, through adolescence and into adulthood. A sample of children aged 0-11 in 1994 was randomly selected using demographic information from the Labour Force Survey (LFS) to identify households with children; the survey is representative of children across the ten provinces (the LFS sampling frame is the basis for all nationally representative Statistics Canada household microdata surveys). Information used here is collected from parents (generally mothers) during face-to-face interviews in the home; parents are re-interviewed about their children every two years.

Although we examine health outcomes in 2000, data from earlier years are used, for example, to calculate 'longer-term' child poverty and whether the mother smoked during pregnancy and/or breastfed the child. Conforming to the ECDA focus on young children, we have selected a sample of children aged 2-7 in 2000 (those aged 0 to 1 were excluded given difficulties in diagnosing asthma in infants¹⁵). From a total of 16,341 two to seven year olds, 3,342 subjects were excluded because the biological mother was not present and hence we had no prenatal/breastfeeding histories; 1,779 were excluded due to missing information. After all exclusions, our sample consists of 11,077 subjects: 1,885 in the Maritimes and 9,192 in the rest of Canada.

Three outcome measures, all based on parental reports, are studied: 1) whether the child has ever been diagnosed with asthma; 2) whether he/she has had an asthma attack in the past 12 months (given a previous diagnosis); 3) whether the child has experienced wheezing in the chest in the past 12 months. Each measure has advantages. Since most control variables are current, having had an attack in the past 12 months is contemporaneous information. However, it seems important not to exclude children with a past diagnosis of asthma who may not have had a recent 'attack' only because their asthma is well managed. Finally, analyzing 'wheezing' avoids possible regional variations in physician practices^{12,16} or health care utilization.¹⁷

For each outcome measure, we report results from four logit regressions. In the first, to establish whether there are statisti-

TABLE I

Percentages and Means Dependent and Independent Variables, Children Aged 2-7

	Maritimes		Rest of Canada	
	All	Poor Twice	All	Poor Twice
Ever diagnosed asthma	15.9%	20.9%	13.3%	16.1%
Asthmatic attack in past 12 months (if diagnosed)	8.7%	11.4%	6.1%	8.9%
Wheezing in the chest past 12 months	24.1%	32.7%	20.3%	24.6%
Not poor 1998, 2000	66.3%	—	73.4%	—
Poor once	13.7%	—	14.9%	—
Poor twice	19.9%	—	11.7%	—
Age of child	4.5	4.3	4.5	4.4
Child is female	48.9%	50.7%	48.7%	48.8%
Mother was <20 at birth of child	3.8%	12.6%	2.5%	8.6%
Mother was 20-25 at birth of child	25.4%	40.8%	20.3%	37.6%
Mother was 26-35 at birth of child	61.7%	41.4%	64.4%	44.6%
Mother was ≥36 at birth of child	9.1%	5.1%	12.7%	9.3%
Single mother household	16.3%	50.0%	15.7%	53.9%
Child is the oldest in the household	45.9%	46.9%	43.2%	40.7%
Number of kids <17 in household	2.23	2.4	2.2	2.5
Residence is in a rural area	30.6%	31.8%	11.1%	15.6%
Child lives in a house	87.9%	71.4%	86.4%	68.4%
Mother has university degree	19.3%	1.9%	20.6%	3.9%
Child was in a daycare centre at age 0-1	3.1%	1.6%	4.1%	4.3%
Child was breastfed	68.0%	54.2%	79.0%	68.8%
Mother smoked during pregnancy	25.8%	49.1%	20.2%	35.9%
Child was low birthweight (<2500 grams)	4.7%	6.9%	6.9%	6.3%
Child was high birthweight (>4000 grams)	14.4%	10.1%	13.4%	12.0%
Either parent has diagnosed asthma	13.0%	18.8%	9.0%	10.9%
Number of subjects	1885	366	9192	1252

TABLE II

Diagnosed with Asthma by a Health Professional Ever, Ages 2-7 Years, Logit - Odds Ratios [95% confidence intervals in brackets]

	Model 1	Model 2	Model 3	Model 4
Maritimes vs. the rest of Canada	1.225*** [0.982-1.529]	1.197 [1.120-1.593]	1.275** [0.967-1.520]	1.213***
Household poor 1998 or 2000 vs. not poor in either year	—	1.337*** [0.997-1.792]	1.164 [0.845-1.604]	1.173 [0.847-1.624]
Household poor 1998 and 2000 vs. not poor in either year	—	1.377* [1.085-1.750]	1.159 [0.849-1.584]	1.152 [0.844-1.573]
Age of child	—	—	1.122* [1.064-1.182]	1.230* [1.071-1.192]
Female	—	—	0.539* [0.442-0.658]	0.519* [0.423-0.635]
Age of mother at birth of child <20 vs. 26-35	—	—	1.149 [0.724-1.823]	1.117 [0.701-1.782]
Age of mother at birth of child 20-25 vs. 26-35	—	—	1.081 [0.845-1.384]	1.037 [0.808-1.331]
Age of mother at birth of child >35 vs. 26-35	—	—	0.962 [0.688-1.345]	0.991 [0.705-1.393]
Single mother vs. couple household	—	—	1.221 [0.917-1.626]	1.214 [0.917-1.607]
Subject is the oldest child in household	—	—	0.848 [0.687-1.045]	0.854 [0.692-1.053]
No. of children in household	—	—	0.866** [0.771-0.973]	0.860** [0.764-0.969]
Residence in rural area vs. urban area	—	—	0.708* [0.563-0.889]	0.709* [0.564-0.891]
Child lives in house vs. apartment	—	—	0.992 [0.747-1.318]	0.998 [0.754-1.322]
Mother has a university degree	—	—	0.756** [0.580-0.985]	0.760** [0.580-0.996]
Child in daycare centre at age 0-1	—	—	1.389*** [0.948-2.035]	1.370 [0.935-2.007]
Child was breastfed	—	—	0.779** [0.622-0.977]	0.782** [0.623-0.982]
Mother smoked while pregnant	—	—	1.109 [0.881-1.395]	1.105 [0.876-1.393]
Birthweight <2500 g vs. birthweight 2500-4000 g	—	—	1.819* [1.212-2.728]	1.829* [1.208-2.769]
Birthweight >4000 g vs. birthweight 2500-4000 g	—	—	0.797 [0.588-1.079]	0.805 [0.593-1.092]
Either parent has diagnosed asthma	—	—	—	2.910* [2.327-3.641]

* significant at a 99% confidence level;

** significant at a 95% confidence level;

***significant at a 90% confidence level

TABLE III

Diagnosed with Asthma by a Health Professional and had an Asthma Attack in Past 12 Months, Ages 2-7 Years, Logit - Odds Ratios [95% confidence intervals in brackets]

	Model 1	Model 2	Model 3	Model 4
Maritimes vs. the rest of Canada	1.479** [1.087-2.011]	1.416** [1.041-1.926]	1.532* [1.120-2.096]	1.438** [1.045-1.978]
Household poor 1998 or 2000 vs. not poor in either year	—	1.228 [0.852-1.769]	1.133 [0.774-1.661]	1.146 [0.782-1.682]
Household poor 1998 and 2000 vs. not poor in either year	—	1.662* [1.190-2.322]	1.521** [1.012-2.864]	1.524** [1.015-2.289]
Age of child	—	—	1.058 [0.984-1.137]	1.067*** [0.991-1.148]
Female	—	—	0.495* [0.380-0.643]	0.468* [0.358-0.612]
Age of mother at birth of child <20 vs. 26-35	—	—	0.779 [0.363-1.674]	0.743 [0.348-1.587]
Age of mother at birth of child 20-25 vs. 26-35	—	—	1.018 [0.738-1.404]	0.954 [0.690-1.317]
Age of mother at birth of child >35 vs. 26-35	—	—	1.281 [0.823-1.995]	1.338 [0.853-2.098]
Single mother vs. couple household	—	—	1.250 [0.858-1.822]	1.236 [0.855-1.785]
Subject is the oldest child in household	—	—	0.814 [0.592-1.119]	0.819 [0.594-1.129]
No. of children in household	—	—	0.853** [0.726-1.003]	0.843** [0.716-0.991]
Residence in rural area vs. urban area	—	—	0.736*** [0.531-1.020]	0.736*** [0.531-1.109]
Child lives in house vs. apartment	—	—	0.968 [0.674-1.390]	0.978 [0.687-1.392]
Mother has a university degree	—	—	0.990 [0.698-1.404]	1.007 [0.705-1.436]
Child in daycare centre at age 0-1	—	—	1.120 [0.648-1.937]	1.094 [0.642-1.865]
Child was breastfed	—	—	0.827 [0.600-1.140]	0.831 [0.600-1.151]
Mother smoked while pregnant	—	—	1.195 [0.856-1.667]	1.181 [0.841-1.659]
Birthweight <2500 g vs. birthweight 2500-4000 g	—	—	2.360* [1.515-3.676]	2.410* [1.526-3.805]
Birthweight >4000 g vs. birthweight 2500-4000 g	—	—	0.956 [0.653-1.399]	0.973 [0.665-1.424]
Either parent has diagnosed asthma	—	—	—	3.663* [2.714-4.944]

* significant at a 99% confidence level; **significant at a 95% confidence level; ***significant at a 90% confidence level

cally different prevalence rates between the Maritime provinces and the rest of Canada, we simply regress each outcome measure on a variable indicating residence in the Maritimes in 2000.

To examine the hypothesis that duration of poverty plays a role in explaining higher prevalence of asthma in the Maritimes, we add to each logistic regression variables indicating: 1) that the child was poor in *either* 1998 or 2000 (i.e., *once* poor); and 2) that the child was poor in *both* 1998 and 2000 (i.e., *twice* poor) relative to a base case with no experiences of poverty over the period. Since the youngest children in our sample were two years old in 2000, two years is the longest history of poverty experience available for all children in our sample. Following accepted practice in the literature,^{18,19} a child is defined as 'poor' if household income is less than half of the Canadian median 'adjusted' income, where income is adjusted to account for differences in need by family size.

In the third model, we add control variables from the literature. These include: age and gender of the child,^{12,20,21} age of the mother at the child's birth,^{8,22} mother's education and marital status,^{12,22} number of siblings, indicators that the child is first-born,^{8,23} that residence is a house, that residence is rural,^{9,24,25} that the child attended daycare as an infant,²³ was breastfed,^{8,26} birthweight,^{22,27} maternal smoking during pregnancy.^{10,22,24,26}

Finally in model 4, we add an additional control indicating that either parent has been diagnosed with asthma.^{8,10,11} This is added separately as many similar factors affect both parent and child; thus including parental asthma will likely reduce the magnitude of other variables.

All statistical analyses were performed using STATA. Sampling weights are employed throughout, with robust standard errors to adjust for the stratified sample design and clustering for multiple children from the same household.

RESULTS

Table I indicates that in 2000, Maritime children were more likely to have ever experienced asthma, to have had a current asthma attack and/or to have experienced wheezing in the chest. Simple regressions confirm the statistical significance of these differences (see model 1, Tables II to IV).

In the Maritimes, more children experienced some poverty in *either* 1998 or 2000 or both, and it is particularly likely for a child in the Maritimes to have been chronically poor (see Table I). Moreover, children in poverty show higher prevalence rates for all three 'asthma' measures, with generally the highest rates for chronically poor children (see Figure 1). As model 2 for each outcome indicates (see Tables II to IV), controlling for number of poverty experiences in multivariate logistic regressions reduces the estimated magnitude of the Maritime difference for all outcomes.

In model 3, Tables II to IV, all controls except parental asthma are added. Girls are less likely to experience any of the outcomes, while older children are more likely to be diagnosed with asthma yet less likely to experience wheezing. Low-birthweight children are 1.8 times more likely to be diagnosed with asthma, 2.4 times as likely to have had a recent attack and 1.6 times more likely to have experienced wheezing. Having been breastfed or having a mother with a university degree is associated with a lower probability of being diagnosed with asthma, but there is no difference for current attacks or wheezing. Maternal smoking is insignificant throughout, nor is there generally any significant association with a child having attended a daycare centre before age two. Children in rural areas are about 0.7 times less likely to be diagnosed with asthma or to have had a recent attack, yet show no difference in parental-reported wheezing. Finally, children in single-mother households are nearly 1.5 times more likely to experience wheezing; there is no statistical association with the other outcomes.

With controls added, the direct effect of poverty disappears for diagnosed asthma and wheezing; chronically poor children remain 1.5 times more likely to have had a recent asthma attack than children experiencing no poverty. The estimated 'Maritime' differential is actually larger in model 3 than in model 1 for asthma diag-

nosis or current attacks; the differential is slightly smaller for wheezing.

In model 4, we add an indicator that either parent has been diagnosed with asthma, which shows a strong, positive association with the child having asthma. Including parental asthma reduces the magnitude of the Maritime coefficient, although a statistical difference remains for all outcomes. Results for other variables are qualitatively unchanged.

DISCUSSION

Our results confirm that Maritime children experience significantly more chronic poverty and, consistent with previous research,¹² a higher prevalence of asthma and wheezing than other Canadian children. The literature on asthma indicates a higher prevalence for contemporaneously poor children in both Canada and the US.^{28,29} Other work on links between socio-economic status (SES) and child health in general suggests that the strongest associations are for longer-term measures of SES, since health impacts may develop over time.^{30,31} From our results, it is clear that associations with asthma are larger for longer-term measures of child poverty.

However, when other control variables which are highly correlated with poverty status are added, the estimated size and significance of the direct channel from poverty to asthma diminishes. Instead, many of the poverty-associated controls are significant correlates of childhood asthma, suggesting that some of these variables are pathways through which poverty status can influence childhood asthma (e.g., breastfeeding; low birthweight, mother's education, lone-parent status). Moreover, to the extent that determinants often appear together in clusters (e.g., low birthweight, no breastfeeding, low education and poverty), associations with asthma may be cumulative.

As noted above, the coefficient on the Maritime variable is actually larger after all controls are added for both diagnosis and attacks. Consistent with previous studies,^{24,25,32,33} children living in rural areas have a lower probability of having asthma and there are more rural children in the Maritimes. Thus, once we control for rural status, the unexplained differential between the Maritimes and the rest of the

TABLE IV

Child Experiences Wheezing in the Chest in the Past 12 Months as Reported by the Parent, Ages 2-7 Years, Logit - Odds Ratios [95% confidence intervals in brackets]

	Model 1	Model 2	Model 3	Model 4
Maritimes vs. the rest of Canada [1.038-1.497]	1.247** [1.010]	1.214** [1.013-1.477]	1.223** [0.970-1.427]	1.176***
Household poor 1998 or 2000 vs. not poor in either year	—	1.256** [1.007-1.566]	1.041 [0.822-1.317]	1.045 [0.826-1.322]
Household poor 1998 and 2000 vs. not poor in either year	—	1.415* [1.134]	1.098 [0.844-1.430]	1.088 [0.839-1.410]
Age of child	—	—	0.959** [0.918-1.001]	0.962*** [0.921-1.005]
Female	—	—	0.716* [0.614-0.836]	0.697* [0.596-0.814]
Age of mother at birth of child <20 vs. 26-35	—	—	1.060 [0.728-1.545]	1.034 [0.709-1.508]
Age of mother at birth of child 20-25 vs. 26-35	—	—	1.162 [0.945-1.429]	1.124 [0.913-1.385]
Age of mother at birth of child >35 vs. 26-35	—	—	1.139 [0.869-1.494]	1.167 [0.887-1.535]
Single mother vs. couple household	—	—	1.453* [1.138-1.855]	1.455* [1.146-1.847]
Subject is the oldest child in household	—	—	0.953 [0.791-1.148]	0.964 [0.800-1.163]
No. of children in household	—	—	0.886** [0.798-0.985]	0.883** [0.795-0.981]
Residence in rural area vs. urban area	—	—	1.063 [0.887-1.273]	1.072 [0.894-1.286]
Child lives in house vs. apartment	—	—	0.989 [0.759-1.289]	0.995 [0.769-1.287]
Mother has a university degree	—	—	0.920 [0.753-1.125]	0.926 [0.755-1.134]
Child in daycare centre at age 0-1	—	—	1.165 [0.847-1.603]	1.151 [0.842-1.575]
Child was breastfed	—	—	0.990 [0.815-1.203]	0.993 [0.818-1.205]
Mother smoked while pregnant	—	—	1.149 [0.938-1.407]	1.152 [0.941-1.412]
Birthweight <2500 g vs. birthweight 2500-4000 g	—	—	1.582* [1.165-2.149]	1.575* [1.162-2.136]
Birthweight >4000 g vs. birthweight 2500-4000 g	—	—	0.896 [0.705-1.139]	0.909 [0.714-1.158]
Person most knowledgeable/ Spouse has asthma	—	—	—	2.537* [2.030-3.171]

* significant at a 99% confidence level; ** significant at a 95% confidence level; *** significant at a 90% confidence level

country increases. Interestingly, however, the rural variable is insignificant for wheezing. Since diagnosis involves a health care professional, variations in health care utilization between urban and rural areas³³ may influence differences in these asthma outcomes, whereas parent-observed wheezing shows no statistical difference.

Attendance at daycare and the presence of siblings has been shown in other research to reduce the probability of asthma later in life,^{23,34,35} possibly because early exposure to infections is protective. Consistent with this literature, our results indicate that additional siblings reduce the odds of asthma and wheezing. However, we find no link with attendance at daycare during infancy. One explanation for this difference could be that the other studies examine children over 5 years of age while we study children aged 2 to 7. Also, our daycare variable is a binary variable indicating attendance in the first two years of

life, while earlier studies examined the effects of daycare in the first six months or year of life.

Children in the Maritimes, especially the large number of chronically poor children, are particularly vulnerable to asthma. Thus, poverty alleviation remains a key long-term policy for reducing asthma in the region. In addition, our results suggest that chronic poverty status might be used to help identify children at particularly high risk for asthma for purposes of targeting policy. For example, physician and parental asthma education programs in low-income neighbourhoods could be very effective (e.g., encouraging healthy prenatal behaviour and breastfeeding).

Childhood asthma determinants unavailable in the NLSCY which might further help to explain regional differences in prevalence include conditions within the home such as dampness^{35,36} or indoor allergens such as pets and dust.^{10,28} These fac-

Figure 1. Asthma, current asthma, wheezing and poverty, Maritimes and the rest of Canada, children aged 2-7

tors may, again, be linked to socio-economic status.³⁷ Finally, the Maritime provinces have higher levels of humidity and particulate acid¹² pollution. Thus, weather and ambient environmental quality may also play a role.³⁸⁻⁴⁰

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RÉSUMÉ

Objectif : Examiner les liens possibles entre les taux élevés de pauvreté durable dans les Maritimes et les taux d'asthme élevés chez les enfants de deux à sept ans.

Méthode : À l'aide des données de l'Enquête longitudinale nationale sur les enfants et les jeunes, et après avoir apporté des ajustements pour tenir compte des effets d'autres déterminants connus, nous avons analysé par régression logistique le lien entre la durée de la pauvreté et la probabilité qu'un enfant ait reçu un diagnostic d'asthme, fasse actuellement des crises d'asthme ou ait éprouvé des symptômes de respiration sifflante au cours des 12 mois précédents.

Résultats : Selon les données de l'Enquête, 15,9 % des enfants des Maritimes avaient reçu un diagnostic d'asthme, 8,7 % avaient eu une crise d'asthme récemment, et 24,1 % avaient eu des symptômes de respiration sifflante. Ces niveaux étaient proportionnellement plus élevés que dans le reste du Canada. Les enfants vivant sous le seuil de pauvreté de façon chronique affichaient des taux de plus de 30 % supérieurs à la moyenne canadienne. Bien que 19,9 % des enfants des Maritimes aient vécu une pauvreté chronique (contre 11,7 % ailleurs au Canada), et bien que la pauvreté soit associée à une probabilité accrue d'asthme ou de respiration sifflante, l'écart régional dans les taux d'asthme ne disparaît pas, même après avoir apporté des ajustements pour tenir compte des effets de la pauvreté. L'ajout d'autres déterminants que la pauvreté n'explique pas non plus entièrement l'écart constaté.

Conclusion : Nos résultats n'expliquent pas entièrement la raison des taux supérieurs de prévalence de l'asthme chez les enfants des Maritimes, mais ils jettent un éclairage intéressant sur la progression de la pauvreté à l'asthme chez les enfants. Par exemple, les enfants qui vivent dans un état de pauvreté chronique sont plus susceptibles d'avoir eu un poids insuffisant à la naissance et moins susceptibles d'avoir été allaités, deux facteurs corrélés avec l'asthme. Ces renseignements peuvent être utiles aux décideurs. Les polluants et d'autres facteurs environnementaux associés à l'asthme dont la présente étude n'a pas tenu compte pourraient aussi expliquer une partie de l'écart régional.

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Book Review/Recension

Safe Drinking Water, Lessons from Recent Outbreaks in Affluent Nations

Steve E. Hrudey, Elizabeth J. Hrudey. London, England: IWA Publishing, 2004; 514 pp, US\$145

Steve and Elizabeth Hrudey are experts on the assessment and management of environmental health risks. They have assembled an excellent synopsis of drinking water outbreaks in wealthier countries.

The first three chapters of this book cover a variety of topics related to the supply of safe drinking water, including a review of the first-known drinking water outbreak reported by John Snow in London in 1854, a summary of waterborne microorganisms responsible for drinking water outbreaks, and a description of the source to tap concept to safe drinking water.

Chapter 4 is the core of the book, summarizing some 70 outbreak case studies from 14 countries spanning more than 30 years. Each case study details the drinking water system, the responsible microorganism (when known), and the circumstances leading to the outbreak. This information will be valuable to drinking water purveyors to help ensure that the same situations do not occur in their systems.

The next two chapters detail the recurring theme of the book, i.e., the necessity of "converting hindsight into foresight" to avoid future outbreaks. They describe many of the challenges facing the drinking water industry and the limitations encountered when responding to these challenges. The authors present some useful examples from jurisdictions around the world on the shift in the provision of drinking water from being reactive to a more preventive approach based on the concept of source to tap.

The final chapter emphasizes that the microbiological safety of drinking water should be the primary concern and that disinfection should never be compromised to reduce the formation of disinfection by-products. Although the book does not address chemical risks, it does recognize that under certain conditions some chemicals can pose a health risk and should be managed.

There are three take-home messages in this book. First, to avoid future outbreaks, we need to learn lessons from our past mistakes. Second, regardless of treatment technology in place, the skill of the individuals operating the technology is critical to the prevention of outbreaks. Operator training can be the difference between the successful management of a system and a serious outbreak. And third, the source to tap approach is the key to ensuring a continuous supply of safe drinking water.

The information presented in this book will benefit all those involved in the supply of safe drinking water, including plant operators, regulatory bodies, health officials, academics, consultants and many others. The authors have included an extensive list of references for those readers who are interested in exploring this topic further.

[Declaration of Interest: The reviewer provided data and comments to the authors on an early draft of this book.]

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