Environmental Pollution 207 (2015) 88–96

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Investigating social inequalities in exposure to drinking water contaminants in rural areas

Ianis Delpla [a, *], Tarik Benmarhnia [b], Alexandre Lebel [a, c], Patrick Levallois [d, e], Manuel J. Rodriguez [a]

[a] École supérieure d'aménagement du territoire et de développement régional (ESAD), Université Laval, 1624 Pavillon Savard, Québec, QC, G1K-7P4, Canada
[b] Institute for Health and Social Policy, McGill University, Meredith Charles House, 1130 Pine Avenue West, Montreal, QC, H3A 1A3, Canada
[c] Evaluation Platform on Obesity Prevention, Quebec Heart and Lung Institute, Québec, QC, G1K-7P4, Canada
[d] Direction de la santé environnementale et de la toxicologie, Institut National de Santé Publique du Québec, Québec, QC, G1V 5B3, Canada
[e] Axe santé des populations et pratiques optimales en santé, Centre de recherche du Centre hospitalier universitaire (CHU) de Québec, Québec, QC, G1V 2M2, Canada

ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form 18 August 2015
Accepted 24 August 2015
Available online 11 September 2015

Keywords:
Chemical drinking water quality
Environmental justice
Rural areas

ABSTRACT

Few studies have assessed social inequalities in exposure to drinking water contaminants. This study explores this issue in 593 rural municipalities of Québec, Canada. Quartiles of an ecological composite deprivation index were used as a proxy of socioeconomic status. Total trihalomethanes (TTHMs) and lead were chosen as proxies of chemical drinking water quality. The results show that the majority of deprived rural municipalities apply no treatment to their water (26%) or use a basic treatment (51%), whereas a relative majority of the wealthiest municipalities (40%) use advanced treatment. The proportion of municipalities having important lead (>5 μg/L) levels is highest in most deprived municipalities. Moreover, most deprived municipalities have a higher risk of high tap lead levels (RR = 1.33; 95% CI: 1.30, 1.36). Conversely, most deprived municipalities have a lower risk of high TTHMs levels (RR = 0.78; 95%CI: 0.69, 0.86). These findings suggest an environmental inequality in drinking water contaminants distribution in rural municipalities.

1. Introduction

An increasing number of studies suggest that people living in a community with lower socioeconomic status tend to be exposed more frequently to higher levels of environmental pollution (Briggs et al., 2008; Laurian, 2008; Mitchell and Dorling, 2003; Sexton et al., 1993) and, consequently, to disproportionate environmental health risks (Sexton et al., 1993). In addition, these populations may also show a greater susceptibility to health effects (Evans and Kantrowitz, 2002; O'Neill et al., 2003) and a lower capacity of resilience (Emelianoff, 2008). As an example, there is increasing evidence of greater exposure to air pollutants in deprived urban communities in Canada (Buzzelli and Jerrett, 2007; Crouse et al., 2009) and elsewhere (Perlin et al., 2001), and of greater susceptibility to health risks (Bell et al., 2014).

Yet, very few studies have explored social inequities in terms of exposure to drinking water contaminants. However, some of these studies have suggested that populations living in deprived socioeconomic areas could be more exposed to unsafe drinking water. For example, in New Zealand, Hales et al. (2003) revealed that people living in deprived areas are exposed to the greatest health risks (calculated on the basis of source, treatment plant and distribution network scoring) from community water supplies. In their study, the authors report that the odds ratio of water supplies being at higher risk varies between 1.7 and 2.7 for most deprived rural areas compared to the most privileged ones.

Other studies have focused on specific drinking water contaminants such as disinfection by-products (DBPs), arsenic and nitrates. Several studies with contrasted results have been conducted for DBPs, using varied deprivation definitions. In a study conducted across England, Briggs et al. (2008) found positive associations between levels of trihalomethanes (THMs) in drinking water and community income, and negative correlations between THM levels and community educational attainment and employment. Conversely, Evans et al. (2013) and Vrijheid et al. (2010) found no significant relationships between individuals or community deprivation and THM concentrations in drinking water in two separate studies conducted in several rural and urban areas of the

* Corresponding author.
E-mail address: Ianis.Delpla@crad.ulaval.ca (I. Delpla).

http://dx.doi.org/10.1016/j.envpol.2015.08.046
0269-7491/

United States (Massachusetts) and Spain, respectively. Furthermore, studies conducted on DBPs have also revealed that highly educated people are less exposed to these drinking water contaminants through ingestion due to a higher consumption of bottled water (Castaño-Vinyals et al., 2011; Forssén et al., 2009). However, although these studies have explored inequities in exposure to THMs, none have been directed towards regulation compliance challenges.

Lead service lines are more common in older districts, also frequently characterized by low income (VanDerslice, 2011). Consequently, potential disparities in lead exposure through tap water could also be present (Bushnik et al., 2010; VanDerslice, 2011). However, according to VanDerslice (2011) and to our knowledge, no study has examined this issue to date.

These chemicals contaminants (lead and DBPs) could potentially produce serious health outcome even at low concentrations. Consequently, they are strictly regulated in Canada (Health Canada, 2014). Epidemiological studies have reported positive associations between DBP exposure and adverse effects such as cancers (bladder and colon) and reproductive outcomes (stillbirth, small for gestational age and growth retardation) (Levallois et al., 2012; Richardson et al., 2007; Toledano et al., 2005; Villanueva et al., 2003). Lead exposure is associated with diverse adverse health effects on neurologic and cognitive development and with changes in the renal, hematopoietic and immune systems (Hu et al., 2010). Moreover, it is also recognized that there is no safe level of exposure to this contaminant (Oulhote et al., 2011).

Drinking water source contamination and contaminant exposure issues are of great concern in rural areas due to strong pressures from anthropogenic activities. Intensive agricultural activities and livestock production can lead to high levels of contaminants (i.e., pesticides) in water sources (Dubrovsky et al., 2010). Additionally, levels of contamination also show significant seasonal fluctuations due to climate and agricultural practices (Dubrovsky et al., 2010). Consequently, in Canada and elsewhere, rural water often needs more advanced treatment than urban water (Peterson and Torchia, 2008). However, rural water treatment plants are often isolated and/or lack financial, technical and management support, thereby leading to poorer drinking water quality at the consumer tap. These issues are even more critical for the smallest utilities, those serving only a few hundred people (MDDEP, 2012a). As a result, some differences in potential health risks associated with water supplies have been reported between urban and rural areas (Hales et al., 2003). To our knowledge, no study has focused on rural areas in North America or elsewhere. Thus, there is a need to conduct a study on these areas.

In this study, we explore potential social inequalities in drinking water contaminant levels in rural areas in the province of Québec, Canada. Two main objectives were set for this study: i) evaluate differences in water treatment according to municipal deprivation levels, ii) assess whether rural municipalities with lower socioeconomic status are exposed to higher levels of drinking water contaminants, namely TTHMs and lead and, assess how these disparities are likely to be modified with distribution network size and season.

2. Data and methods

2.1. Area under study and administrative study scale

The project was conducted in municipal distribution networks located in rural municipalities in the province of Québec, Canada. Rural areas are defined as areas outside the commuting zone of larger urban centres, i.e., outside Census Metropolitan Areas and Census Agglomerations, with populations of less than 10,000 using the definition of “rural areas and small towns” proposed by Statistics Canada (du Plessis et al., 2001). Based on this restriction, census subdivisions (CS) (a geostatistic unit used by Statistics Canada to designate municipalities as specified by the provincial law), were used. Finally, the study included “unclassified municipalities” (not defined as rural or urban), located in remote areas of Québec (*Côte Nord* and *Nord du Québec*) and with populations of less than 10,000. All selected municipalities were labelled as “rural” in this document.

The unit of analysis retained for the study is the municipal distribution network. Distribution networks were nested within municipalities. This geographical scale is relevant for studying drinking water distribution networks in rural areas of Québec because their size is relatively small and they are generally within municipalities' boundaries.

2.2. Water quality data

The period of this study covers 2004 to 2008 in order to coincide with the deprivation data (see next section “Measure of deprivation”). The chemical water quality parameters included in this study were selected as indicators of potential environmental inequality in exposure based on their relevance to health risk assessment. Thus, DBPs (represented by total trihalomethanes-TTHMs), and lead were selected as indicators of drinking water chemical contamination.

Water quality data were provided by the regulatory monitoring program set by the Québec Ministry of Environment (MDDEP, 2010). According to the Québec regulation on drinking water production (MDDEP, 2012b), drinking water parameters are sampled quarterly (seasonally) for TTHMs and annually for lead. Samples for lead were almost exclusively taken during summer (97% of samples taken between July and September). This study used an extended database on chemical drinking water quality constructed from all existing municipal distribution networks providing water to more than 20 residents in Québec (Cool et al., 2014). This database also contains complete information on sources, water treatment types and distribution networks (number of people supplied, interconnections, etc.).

For the purpose of this study, three types of water treatment were considered: i) no treatment, ii) chlorination only and iii) advanced treatment (defined as a combination of primary treatment such as filtration and/or coagulation, and disinfection). “Chlorination only” was considered here as it is a simple and inexpensive means of disinfection frequently used by small municipalities to ensure the safety of their distributed waters. Additionally, information on the presence of a softening step in drinking water treatment was considered because soft waters may favour lead lines corrosion and increase lead concentrations in tap water (Craun and McCabe, 1975; Sharrett and Feinleb, 1975).

2.3. Measure of deprivation

As a proxy for the municipalities' socioeconomic status, we used an ecological composite deprivation index developed for Canada (Pampalon et al., 2009, 2010) from census data obtained by Statistics Canada (Statistics Canada, 2006). This index is based on the Townsend proposal to distinguish material and social deprivation (Townsend, 1987). The index includes six socioeconomic indicators gathered into a material well-being dimension (proportion of people with a high school diploma, employment ratio and average income) and a social condition dimension (proportion of individuals living alone, separated, divorced or widowed, and proportion of single-parent families). In this study, only the material dimension of deprivation was considered, as it lumps together