INSPQ
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DE SANTÉ PUBLIQUE
DU QUÉBEC

Evaluation of the Fichier hebdomadaire des décès for estimating heat wave impacts

EVALUATION

APRIL 2015

IMPACT EVALUATION REPORT

Québec

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ACKNOWLEDGEMENTS

The authors would like to thank the members of the Comité de surveillance de la Table nationale de concertation en santé environnementale (Monitoring committee of the National table on collaboration in environmental health) for their support and comments on the document. We would also like to thank Mr. Steve Toutant of the Environmental Health and Toxicology Branch for the geographical location of the deaths.

This document is available in its entirety in electronic format (PDF) on the Institut national de santé publique du Québec website at http://www.inspq.qc.ca.

Legal Deposit – 3e trimestre 2023
Bibliothèque et Archives nationales du Québec
ISBN: 978-2-550-89734-7 (FRENCH PDF)
ISBN: 978-2-550-94994-7 (PDF)

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LIST OF ACRONYMS

95% CI	95% confidence intervals
CERFO	Centre d'enseignement et de recherche en foresterie
CHSLD	Residential and long-term care centre
DA	Dissemination area
INSPQ	Institut national de santé publique du Québec
ISQ	Institut de la statistique du Québec
MSSS	Ministère de la Santé et des Services sociaux
RED	Registre des événements démographiques
RPHD	Regional public health department

HIGHLIGHTS

Background

Since the 2010 summer season, the Institut national de santé publique du Québec (INSPQ) has been producing an annual report on the impact of extreme heat waves on the health of the population, using the Fichier hebdomadaire des décès of the Institut de la statistique du Québec (ISQ). The main purpose of this study is to verify the validity of this data source. The study also aims to measure the impact of age, material deprivation, and the presence of urban heat islands on the frequency of deaths during extreme heat waves.

A useful monitoring tool

- The validity of data from the Fichier hebdomadaire des décès was assessed by comparing the impacts of the 2010 and 2011 heat waves with those obtained using the Registre des évènements démographiques (RED).
- The results indicate that the Fichier hebdomadaire des décès systematically underestimates the impacts of heat waves. To remedy this problem, it is suggested that more permissive statistical criteria should be applied in interpreting the results of the annual reports.
- The Fichier hebdomadaire des décès is a useful tool for monitoring the health impacts of heat waves, provided that the data are extracted at least four months after the end of the monitoring season. Unless this time frame is observed, the Fichier hebdomadaire des décès significantly underestimates the frequency of deaths.
- The production of annual heat wave impact monitoring reports should be continued. This monitoring allows public health departments to adjust preventive public health interventions.

Association with certain risk factors

- The effects of age, material deprivation, and urban heat islands on heat wave impacts were measured using data from the RED.
- In most socio-sanitary regions, the average age of those who died during heat waves was not statistically different from those who died during comparison periods.
- Analyses failed to demonstrate significant excess deaths during extreme heat waves in materially disadvantaged and very disadvantaged areas compared with other areas in the affected regions.
- The results also show that during heat waves, in a few socio-sanitary regions, the proportion of people residing in an urban heat island at the time of death is higher, compared to the comparison periods.
- Although these results are not conclusive, it is recommended that regional public health departments (RPHDs) continue to monitor the health impacts of heat by targeting the elderly, disadvantaged clienteles, as well as sectors with a significant concentration of urban heat islands.

SUMMARY

Since the 2010 summer season, the INSPQ has been producing an annual report on the impact of extreme heat waves on the health of the population, using the Fichier hebdomadaire des décès of the ISQ. No formal evaluation of the Fichier hebdomadaire des décès has been conducted to date.

The purpose of this study is to verify the validity of the Fichier hebdomadaire des décès used to produce these reports and to establish the relevance of using alternative data sources, such as the RED.

The additional information available in the RED provides a unique opportunity to estimate associations with selected risk factors, namely, age of heat wave decedents, material deprivation index, and residence in an urban heat island.

Methodology

The data used are deaths during extreme heat waves by health region during the 2010 and 2011 summer seasons. Death rates during heat waves are compared with death rates during comparison periods. Comparison periods are defined as days equivalent to days of extreme heat waves during previous years (3 or 5 years).

The analysis of associations with vulnerability factors uses only the RED data. For age, comparisons were made using frequency distributions and average age at death during heat waves and during comparison periods. For the material deprivation index, the ratio of the death rate observed during each heat wave to the death rate observed during the comparison period was calculated for deprived and highly deprived dissemination areas (DAs). This rate ratio was then compared to that obtained in the other DAs to measure whether the impact of the heat wave is greater for the most disadvantaged DAs compared to the rest of the region.

Finally, comparisons were made between the proportion of people who, at the time of death, resided in a heat island during the heat wave and that same proportion during the comparison periods.

Results

The results show differences of about 5% in the number of deaths during heat waves between the Fichier hebdomadaire des décès and the RED. The Fichier hebdomadaire des décès underestimates the number of deaths in the most recent years. Therefore, the underestimation is greater in the year covered by the annual monitoring report than in the comparison periods. Comparison of crude mortality rates between heat waves and comparison periods indicates that the Fichier hebdomadaire des décès does not identify all significant impacts observed with the RED.

In the RED, the age at death and the six-digit postal code of the place of residence at the time of death are available. These data made it possible, for the first time, to verify the effects of certain vulnerability factors with regard to the impacts of extreme heat on health.

The frequency distributions of deaths by age group during heat waves and comparison periods are very similar. However, in the Mauricie and Centre-du-Québec health region, the average age at death is higher during the heat wave than during the comparison periods.

The second vulnerability factor considered is the material deprivation index. Statistically, the impact of a heat wave on the death rate compared to the comparison period is not significantly greater in materially deprived and very deprived areas than in the rest of the region.

Finally, the results of the analyses of the proportions of deaths in heat islands indicate that in some health regions (Chaudière-Appalaches in 2010, Estrie and Lanaudière in July 2011) affected by a heat wave, the proportion of people who, at the time of death, resided in an urban heat island is higher than in the comparison period. However, in seven of the eight health regions where a significant impact of heat on deaths was documented (in 2010 or 2011), this same proportion was not statistically different compared to the comparison period.

Some of the results may be explained by methodological artifacts (material deprivation index) or inaccuracy in the geographic location of the person's residence at the time of death (based only on the six-digit postal code, with the patient's street address not available in the RED).

In conclusion, although it underestimates the impacts of heat waves, the Fichier hebdomadaire des décès of the ISQ is a useful source of data for the annual report on the health impacts of extreme heat waves. However, methodological changes should be considered when producing the annual monitoring reports

Given the climate change context, it is recommended that RPHDs continue to monitor the health impacts of heat. Their preventive interventions should continue to target groups of individuals who are vulnerable to the health impacts of heat, including the elderly, those who are materially disadvantaged, or who live in areas with a significant concentration of urban heat islands, although our results in these areas are not conclusive.

1 INTRODUCTION

Annual reports on the health impacts of extreme heat events at the provincial level use the Fichier hebdomadaire des décès of the ISQ as a data source (Lebel and Bustinza, 2011; Bustinza and Lebel, 2012; Lebel and Bustinza, 2013; Bustinza *et al.*, 2014).

While the Fichier hebdomadaire des décès is quickly available, the information it contains is not validated and is very fragmented (lack of geographic location other than the health region), lack of diagnosis, summary identification of age group). However, there are no other data sources that allow for analysis in a relatively short time frame of the impacts of heat waves on deaths.

This report provides useful data for RPHDs in planning prevention interventions. RPHD interventions target those most vulnerable to the health impacts of heat, i.e., the elderly, the mentally ill, the disadvantaged, and populations residing in an urban heat island. The validation of the Fichier hebdomadaire des décès used for the annual report on the impacts of extreme heat on the health of the population is therefore essential.

The RED could be an alternative data source. This is the official data source of the Ministère de la Santé et des Services sociaux (MSSS). Data from the RED (also known as the Fichier des décès) is complete and validated. However, due to the time required to complete the data validation process, there is a delay of approximately three years before the file is released. Thus, the 2010 RED was released in December 2013, and the 2011 RED was made available in July 2014.

In the context of climate change, it is likely that the frequency and intensity of heat waves will increase (Wu *et al.*, 2014). These temperature increases could exacerbate the impacts of heat waves on deaths. It can be hypothesized that the impacts may be greater within urban heat islands (Johnson and Wilson, 2009). Indeed, urban heat islands have higher temperatures than in surrounding rural areas, which can lead to significant health problems in certain population groups (Camilloni et Barros, 1997; Besancenot, 2002). The populations most vulnerable to the impacts of heat waves are mainly the most fragile groups of individuals (elderly, isolated, chronically ill), the disadvantaged, and individuals with mental or cognitive disorders (Vida, 2011; Tairou *et al.*, 2010; Lowe *et al.*, 2011).

The purpose of this study is to verify the validity of the ISQ Fichier hebdomadaire des décès used for the annual reports on extreme heat wave impacts. In addition, since the six-digit postal code is available in the RED, it will be possible, on an exploratory basis, to test whether the population health impacts of heat are greater in the most disadvantaged areas and in urban heat islands.

2 OBJECTIVES

The objectives of the study are:

- Compare the impact of extreme heat waves on deaths using data from the ISQ Fichier hebdomadaire des décès and the RED;
- Analyze the effect of age on deaths during extreme heat waves;
- Measure the impact of material deprivation on deaths during extreme heat waves;
- Measure the impact of urban heat islands on deaths during extreme heat waves.

3 METHODOLOGY

The study area is defined as the health regions in which an extreme heat wave was observed during the 2010 and 2011 summer seasons (May 1 to September 30).

3.1 Data sources

3.1.1 The Fichier hebdomadaire des décès

The ISQ Fichier hebdomadaire des décès was created in 2008 to track smog-related mortality. This mandate was entrusted to the INSPQ, which obtains an update of deaths for the last three years on a weekly basis. The INSPQ also uses this database to monitor the impacts of extreme heat waves on deaths. There are no diagnoses in the Fichier hebdomadaire des décès. The files are released on a weekly basis and changes may affect the frequency of deaths over the past three years. In order to simulate the use of the Fichier hebdomadaire des décès under conditions as close as possible to the realization of the annual monitoring report, we used the weekly files available in February of the following year. Thus, for the 2010 report, deaths are extracted from the February 21, 2011 file. For the 2011 report, deaths are extracted from the Fichier hebdomadaire des décès dated February 10, 2012.

3.1.2 The RED

The RED is an official database of the MSSS. It contains personal information on deaths among the Quebec population. Data is collected primarily through the death certificate (form SP-3). One of the purposes of the database is to monitor the health status of the population on an ongoing basis. Data were extracted from the Infocentre de santé publique du Québec data warehouse at the INSPQ. No selection criteria were applied and deaths from all causes were used.

3.1.3 Weather data

The weather data were obtained from Environment Canada and were extracted from the SUPREME (Système de surveillance et de prévention des impacts sanitaires des événements météorologiques extremes [System for monitoring and prevention of health impacts of extreme weather events]) database.

3.1.4 Population numbers

Demographic data by health region are from MSSS (Pelletier and Kammoun, 2010).

3.2 Fatality impact analysis

3.2.1 Impacts of extreme heat waves on deaths

An extreme heat wave is defined as a period when the three-day moving averages of minimum and maximum temperatures reach extreme heat thresholds (Appendix 1). To estimate health impacts, the period corresponding to the duration of the extreme heat wave plus the three consecutive days is used. Note that if several heat wave periods (on consecutive days) overlap, the heat waves should be combined into one period. The reference weather stations by health region are those used in 2014 (Appendix 1).

All-cause death rates during the 2010 and 2011 heat waves are compared, by health region, to death rates during the comparison period. A comparison period is defined as the same days of the week as the heat wave, during the previous five years. The comparison days must be the dates closest to the heat wave dates. The comparison period must not include a heat wave. In such a case, the year is removed from the comparison period.

3.2.2 The comparison between the Fichier hebdomadaire des décès and the RED

The hypothesis to be tested is that the impact of extreme heat waves on death rates, documented using the Fichier hebdomadaire des décès, is comparable to that documented with the RED. The ISQ Fichier hebdomadaire des décès has only been available since 2008. For this reason, the RED and the Fichier hebdomadaire des décès are compared using the years 2008 and 2009 for the 2010 heat wave, and 2008 to 2010 for the 2011 heat wave. As an exploratory measure, the impact of heat waves from the RED will also be estimated using five-year comparison periods.

The ISQ Fichier hebdomadaire des décès is preliminary and contains only a very rough identification of the age of the deceased (0-64 years, 65-74 years and 75 years and over). For this reason, crude rates will be used to compare the impact on deaths using either the RED or the Fichier hebdomadaire des décès.

3.2.3 Associations with certain risk factors

The presence of the six-digit postal code and age at death in the RED allows for additional analyses with selected risk factors. Therefore, it is possible to study the effect of age, as well as the associations with two risk factors: the material deprivation index and residence in an urban heat island at the time of death.

The deprivation index defined at the Quebec level was adapted so that it could be used to evaluate the effect of social inequalities on the use of front-line services at the local level. This regional version of the national index includes the same two dimensions, one material and the other social, but expresses the differences observed at the scale of the DAs. We retained only the material deprivation index. Thus, the disadvantaged areas correspond to the "disadvantaged" and "very disadvantaged" DAs (quintiles 4 and 5) of the regional version of the material deprivation index.

The term "urban heat island" refers to the observed temperature difference between urban environments and the surrounding rural areas. Observations have shown that temperatures in urban centres can be up to 12°C warmer than in the surrounding areas. More generally, the intensity of heat islands changes on a daily and seasonal basis depending on weather conditions (e.g., temperature, wind) and human activities (e.g., heat emitted by industries, motor vehicles) (http://www.monclimatmasante.qc.ca/vagues-de-chaleur.aspx). In Quebec, urban heat islands are established using satellite imagery, within DAs that have a population density ≥ 400 inhabitants/km^2. A two-kilometre wide buffer zone was added around these areas to avoid excluding some sectors of urban areas that would not have the required population density (e.g., some industrial zones). Mapping was conducted by INSPQ and the Centre d'enseignement et de recherche en foresterie (CERFO) in 2012. For more information on the methodology, the reader can consult this website: http://www.cerfo.qc.ca/index.php?id=159.

The RED includes the postal code (six digits) of the person's address at the time of death, as well as the 2006 DA identification. Unfortunately, it is not possible to know the place of death, nor the precise address of the residence. Thus, in the RED, the material deprivation index is determined by that of the DA in which the postal code of the person's residence at the time of death is located. Similarly, based on the postal code, it was determined whether the individual resided within an urban heat island classified as "hot" or "very hot" at the time of death.

From these data, the hypotheses to be tested are:

- The impact of a heat wave on the death rate, compared to the comparison period, is greater in materially disadvantaged and very disadvantaged areas than in the rest of the region;
- During a heat wave, the proportion of people who, at the time of death, resided in urban heat islands is greater than that obtained in the comparison period.

3.3 Statistical analysis

3.3.1 Crude rates

Crude mortality rates are calculated by health region and by heat wave. The formula for the crude rate is:

Equation 1 Calculation of a crude rate

$$\text{Crude rate} = \frac{\text{Total number of deaths}}{\text{Population X Number of days}} \text{ X 100 000}$$

The variance of the crude rate (Var(R_C)) (Equation 2) is calculated according to the method used at the Infocentre de santé publique (Institut national de santé publique du Québec in cooperation with the Groupe de travail des indicateurs du Plan commun de surveillance à l'Infocentre de santé publique, 2013):

Equation 2 Variance of a crude rate

$$Var(R_C) = \frac{d}{(PD)^2}$$

where: *d* is the number of deaths that occurred during the period; *PD* is the number of person-days at risk during the period.

3.3.2 Adjusted rates

For the analysis of RED data, the direct standardization method yields an age-adjusted death rate (R_A). The adjusted rate is obtained with the following equation:

Equation 3 Calculation of an adjusted rate

$$\boldsymbol{R_A = \sum_{i=1}^{k} w_i \, R_i}$$

where: w_i is the weight of age stratum i, sexes combined, of the reference population (Quebec 2011); R_i is the specific rate for age stratum i, 10-year age groups are used (0-9, 10-19,..., 80+); *k* is the number of age strata in the weight system.

The variance of the age-adjusted rate (Var(R_A)), which measures the precision of the age-adjusted rate, is calculated with the following formula:

Equation 4 Variance of an adjusted rate

$$Var(R_A) = \sum_{i=1}^{k} w_i^2 \frac{d_i}{(PD_i)^2}$$

where: w_i is the weight of age stratum i, sexes combined, of the reference population (Quebec 2011); d_i is the number of deaths that occurred during the period in age stratum i; *PD* is the number of person-days at risk during the period in age stratum i. *k* is the number of age strata in the weight system.

3.3.3 Comparison of two rates using confidence intervals

The following two methods are used to determine whether the crude or adjusted rates are different. The first method used is the most conservative and uses confidence intervals. The 95% confidence intervals (95% CI) are constructed using the respective variance equations presented earlier (Equation 2 and Equation 4).

Equation 5 Confidence intervals of a rate

$$Confidence\ intervals\ = e^{ln(T) \pm z_{\alpha/2} SE(ln(R))}$$

where: *SE* (ln*(R*)) is the standard error of the rate, estimated by :

$$SE\ (\ln(R)) = \frac{\sqrt{Var\ (R)}}{R}$$

Equation 2 or Equation 4 is used to calculate the variance of the crude or adjusted rate (Var(R)). When the confidence intervals do not overlap, it can be concluded that there is a statistically significant difference in the two rates at the 5% level. The 95% CIs are presented in the tables for illustrative purposes only. The comparison using rate ratio (next section) was selected in order to find out whether the two rates were statistically different.

3.3.4 Comparison of two rates using rate ratio

The second method to check for a statistically significant difference between two rates is to calculate the rate ratio (rate ratio = R_1 / R_2). The *z*-test of the difference in the natural logarithm of two rates is used to determine whether the difference is statistically significant (Equation 6).

Equation 6 Comparison of two rates

$$Z = \frac{ln(R_1) - ln(R_2)}{\sqrt{\left({}^{Var(R_1)}\!/_{R_1^2} + {}^{Var(R_2)}\!/_{R_2^2}\right)}}$$

where: ln(*R*) is the natural logarithm of the rate; *Var(R*) is the variance of the crude or adjusted rate depending on the comparison made.

Under the assumption that the two rates are equal *(*R_1 = R_2 or the rate ratio = 1), the *Z* statistic follows a standard normal distribution. When the sample values are inserted in the previous formula, the result is noted $Z_{observed}$ instead of *Z*. The *Z* value is associated with an α_{observed} value which is called the "*p*-value." The statistical significance level used is 5%. The same test is used for both crude and adjusted rates, as well as for comparing two rate ratios.

3.3.5 Analysis of age at death

The average age at death is calculated by health region during the extreme heat wave and during the comparison period of 2005 to 2009. The 95% CI is conventionally determined by the following formula:

Equation 7 95% confidence intervals for average age at death

$$CI\ 95\ \% =$$

$$average\ age\ \mp 1.96 * \sqrt{average\ age\ variance}$$

3.3.6 Analysis of the impact of material deprivation

The material deprivation index (section 3.2.3) is used to estimate the effect of socioeconomic factors on deaths during heat waves. The impact of the heat wave is first calculated as the following crude rates: (2010 / 2005-2009) and (2011 / 2006-2010), in disadvantaged and highly disadvantaged DAs (rate $ratio_1$ Table 1). The same was calculated for the other DAs (rate $ratio_2$ Table 1). The impact of material disadvantage is subsequently calculated as the ratio of these two rate ratios, which is: rate $ratio_1$ / rate $ratio_2$. The *z*-test is used to test whether this ratio is statistically significant.

Table 1 Calculation of rate ratios by material deprivation index

Death located in a DA with a material deprivation index	2010	2005-2009	Rate ratio 2010/2005-2009
Disadvantaged or very disadvantaged	Crude $ratio_1$	Crude $ratio_2$	Rate $ratio_1$=Crude $ratio_1$/Crude $ratio_2$
Other deprivation index	Crude $ratio_3$	Crude $ratio_4$	Rate $ratio_2$=Crude $ratio_3$/Crude $ratio_4$

3.3.7 Analysis of the impact of urban heat islands

As described in section 3.2.3, the delineation of urban heat islands is determined by analysis of satellite images in areas with a density of more than 400 inhabitants/km^2. Thus, heat island boundaries do not correspond to geostatistical and administrative boundaries. For this reason, it is not possible to estimate the population residing within urban heat islands using census data, so a comparison of crude or adjusted rates cannot be used. To measure the impact of heat waves on urban heat island deaths, the proportion of people who, at the time of death, resided in an urban heat island during heat waves and during comparison periods were determined by health region and heat wave. The proportions of deaths were compared using the GENMOD procedure of SAS software with binomial distribution and the logit link function.

4 RESULTS

4.1 Heat waves

The 2010 summer season was characterized by three extreme heat waves in May, July and August, respectively. The first heat wave was recorded from May 24 to 26 in the Nord-du-Québec and Abitibi-Témiscamingue health regions. The July heat wave affected nine health regions between July 4 and 9 (Table 2). Finally, another late heat wave was observed in five health regions between August 29 and September 2. In sum, twelve health regions were affected by an extreme heat wave in the summer of 2010. Four health regions were affected by two extreme heat waves (Abitibi-Témiscamingue [May and August], Outaouais [July and August], Nord-du-Québec [May and August] and Mauricie and Centre-du-Québec [July and August]).

It should be noted that during the 2010 heat waves, fewer than five deaths were recorded for the Nord-du-Québec health region (Table 2). For this reason, the rates are unstable, and it is impossible to compare rates in the comparison periods. The two heat waves of the Nord-du-Québec health region were removed from subsequent analyses.

During the summer of 2011, there was only one heat wave that affected four health regions, from July 19 to 26 in Outaouais and from July 20 to 26 in Estrie, Lanaudière and Montérégie (Table 2).

4.2 Comparison of heat wave impacts on deaths from the two data sources

The Fichier hebdomadaire des décès counts fewer deaths than the RED file (Table 2). The number of deaths during heat waves was underestimated by 4.6% in 2010 and 6.1% in 2011. For the 2010 heat waves, the Fichier hebdomadaire des décès included 63 fewer deaths than the RED. A good portion of the differences (27/63) are located in Montreal. The proportions of deaths vary from 0% (Abitibi-Témiscamingue) to 10.9% (2nd wave in Outaouais). For the 2011 heat waves, 21 fewer deaths (6.1%) were recorded in the Fichier hebdomadaire des décès compared to the RED. The proportions range from 4.6% to 10.2%.

For the comparison periods, the differences between the RED and the Fichier hebdomadaire des décès are on the order of 1% in 2008-2009 and 2% from 2008-2010. Because the time lag is greater for the comparison period, the number of deaths in the Fichier hebdomadaire des décès is much closer to that in the RED.

Table 2 Number of deaths during extreme heat waves and comparison periods, by data source

Socio-sanitary region	Date wave began	Duration (days)	Number of deaths			
			Heat waves of 2010		Comparison period 2008-2009	
			Fichier hebdomadaire des décès	RED	Fichier hebdomadaire des décès	RED
02 Saguenay–Lac-Saint-Jean	29-August	4	51	53	74	72
03 National Capital	05-July	5	112	115	201	202
04 Mauricie and Centre-du-Québec (1st wave)	05-July	5	120	125	190	193
04 Mauricie and Centre-du-Québec (2nd wave)	30-August	3	64	66	177	177
05 Estrie	05-July	5	52	54	86	83
06 Montreal	05-July	4	356	383	494	507
07 Outaouais (1st wave)	04-July	6	73	81	110	112
07 Outaouais (2nd wave)	30-August	4	41	46	74	80
08 Abitibi-Témiscamingue (1st wave)	24-May	3	16	16	31	30
08 Abitibi-Témiscamingue (2nd wave)	30-August	3	20	21	43	42
10 Nord-du-Québec (1st wave)	24-May	3	< 5	< 5	-*	< 5
10 Nord-du-Québec (2nd wave)	29-August	3	< 5	< 5	< 5	< 5
12 Chaudière-Appalaches	05-July	5	52	52	131	135
13 Laval	05-July	4	59	62	78	81
14 Lanaudière	05-July	5	76	77	112	114
16 Montérégie	06-July	3	198	204	245	246
Total			**1294**	**1357**	**2059**	**2080**
			Heat waves of 2011		**Comparison period 2008-2010**	
05 Estrie	20-July	4	51	55	123	124
07 Outaouais	19-July	5	53	59	145	148
14 Lanaudière	20-July	4	62	65	138	144
16 Montérégie	20-July	4	156	164	497	508
Total			**322**	**343**	**903**	**924**

* Data masked to ensure confidentiality.

Crude death rates by data source during heat waves are attached for comparison (Appendix 2, Appendix 3). Table 3 shows the ratios of the heat wave crude rates over the comparison periods. It can be seen that, for the year 2010, three of the heat waves identified as having a significant impact from RED data would not be detected using data from the Fichier hebdomadaire des décès. Thus, the heat waves in the Mauricie and Centre-du-Québec and Outaouais health regions in July 2010, as well as the August 2010 heat wave in the Saguenay–Lac-Saint-Jean health region, would not have had a significant impact on deaths if only the Fichier hebdomadaire des décès (Table 3) had been used. However, still for the month of July 2010, significant excess deaths were identified by both data sources in the Montreal, Montérégie, and Laval health regions (Table 3). Finally, during the heat wave of late August 2010, a deficit of deaths in the Mauricie and Centre-du-Québec region is significant using either data source.

Finally, in 2011 neither data source identified a significant impact of extreme heat waves on deaths (Table 3).

Table 3 Ratios of crude mortality rates during extreme heat waves and comparison periods, by data source

Socio-sanitary region	Fichier hebdomadaire des décès		RED	
	Rate ratio 2010/ 2008-2009	***P*-value of *z*-test**	**Rate ratio 2010/ 2008-2009**	***P*-value of *z*-test**
02 Saguenay–Lac-Saint-Jean	1.38	0.075	**1.48**	**0.031***
03 National Capital	1.10	0.408	1.13	0.308
04 Mauricie and Centre-du-Québec (1st wave)	1.25	0.052	**1.29**	**0.028***
04 Mauricie and Centre-du-Québec (2nd wave)	**0.72**	**0.023***	**0.74**	**0.037***
05 Estrie	1.20	0.304	1.29	0.146
06 Montreal	**1.43**	**< 0.0001***	**1.50**	**< 0.0001***
07 Outaouais (1st wave)	1.30	0.081	**1.42**	**0.017***
07 Outaouais (2nd wave)	1.09	0.671	1.13	0.518
08 Abitibi-Témiscamingue (1st wave)	1.03	0.919	1.07	0.836
08 Abitibi-Témiscamingue (2nd wave)	0.93	0.788	1.00	0.998
12 Chaudière-Appalaches	0.79	0.144	0.76	0.099
13 Laval	**1.48**	**0.023***	**1.50**	**0.017***
14 Lanaudière	1.32	0.062	1.31	0.064
16 Montérégie	**1.59**	**< 0.0001***	**1.63**	**< 0.0001***
	Rate ratio 2011/ 2008-2010	***P*-value of *z*-test**	**Rate ratio 2011/ 2008-2010**	***P*-value of *z*-test**
05 Estrie	1.23	0.217	1.31	0.092
07 Outaouais	1.07	0.680	1.17	0.320
14 Lanaudière	1.30	0.086	1.31	0.074
16 Montérégie	0.92	0.373	0.95	0.551

* Statistically significant difference (p-value < 0.05).

4.3 Associations with certain risk factors

Associations with age at death, material deprivation index, and urban heat island residence are analyzed using the RED, the 5-year comparison periods, and crude rate ratios. These analyses are for the five-year comparison periods.

Table 4 presents the impact of extreme heat waves established using RED data (crude rates) for five-year comparison periods.

For the 2010 heat waves, there are two differences from the 2008 and 2009 comparisons (Table 3). The rates of the second heat wave in the Mauricie and Centre-du-Québec region are not statistically different between the heat wave and the comparison period. In addition, death rates during the heat wave in the Lanaudière region are higher than during the comparison period.

For the 2011 summer season, death rates during the heat wave in the Estrie region are significantly higher than death rates during the comparison period.

Table 4 Crude mortality rates during extreme heat waves and five-year comparison periods, derived from the RED

Socio-sanitary region	Heat waves of 2010			Comparison period 2005-2009			*P*-value of *z*-test
	Number of deaths	Crude rates*	95% CI	Average number of deaths per wave	Crude rates*	95% CI	
02 Saguenay–Lac-Saint-Jean	**53**	**2.79**	**2.13-3.65**	**35.2**	**1.84**	**1.59-2.13**	**0.008†**
03 National Capital	115	2.09	1.74-2.51	107.4	1.99	1.83-2.17	0.646
04 Mauricie and Centre-du-Québec (1st wave)	**125**	**3.16**	**2.65-3.76**	**90.4**	**2.31**	**2.11-2.54**	**0.002†**
04 Mauricie and Centre-du-Québec (2nd wave)	66	2.22	1.75-2.83	70.8	2.42	2.18-2.68	0.534
05 Estrie	54	2.19	1.68-2.86	47.0	1.94	1.71-2.20	0.423
06 Montreal	**383**	**2.86**	**2.59-3.16**	**243.0**	**1.84**	**1.74-1.95**	**< 0.0001†**
07 Outaouais (1st wave)**	**81**	**2.49**	**2.00-3.09**	**55.5**	**1.76**	**1.54-2.00**	**0.008†**
07 Outaouais (2nd wave)	46	1.81	1.36-2.42	36.2	1.48	1.28-1.71	0.220
08 Abitibi-Témiscamingue (1st wave)	16	1.84	1.13-3.00	16.8	1.93	1.56-2.39	0.855
08 Abitibi-Témiscamingue (2nd wave)	21	2.41	1.57-3.70	15.4	1.77	1.42-2.21	0.209
12 Chaudière-Appalaches	52	1.60	1.22-2.10	59.0	1.85	1.65-2.07	0.343
13 Laval	**62**	**2.24**	**1.74-2.87**	**42.6**	**1.61**	**1.41-1.84**	**0.022†**
14 Lanaudière	**77**	**2.05**	**1.64-2.57**	**55.8**	**1.58**	**1.40-1.77**	**0.040†**
16 Montérégie	**204**	**2.35**	**2.05-2.70**	**141.4**	**1.69**	**1.57-1.82**	**< 0.0001†**
	Heat waves of 2011			**Comparison period 2006-2010**			***P*-value of *z*-test**
05 Estrie	**55**	**2.53**	**1.94-3.30**	**39.8**	**1.87**	**1.62-2.15**	**0.045†**
07 Outaouais***	59	2.01	1.56-2.60	50.8	1.79	1.56-2.05	0.423
14 Lanaudière	65	1.95	1.53-2.48	48.0	1.52	1.34-1.73	0.076
16 Montérégie	164	1.61	1.38-1.87	168.2	1.70	1.59-1.82	0.499

* Per 100,000 person-days.

** The year 2005 was excluded from the comparison period due to the presence of a heat wave.

*** The year 2006 was excluded from the comparison period due to the presence of a heat wave.

† Statistically significant difference (p-value < 0.05).

4.3.1 Age at death

Figures 1 and 2 show the frequency distributions of the number of deaths by age group during the 2010 and 2011 heat waves, as well as during the comparison periods. The frequency distributions of deaths during heat waves and during comparison periods are very similar. They are characterized by a higher frequency of death among people aged 75 years and older. In 2010, the average age of those who died was 75 during the heat wave and 74 during the comparison period. These averages are not significantly different, at the 5% level.

Figure 1 Frequency distribution of RED deaths, by age group and period of analysis, 2010

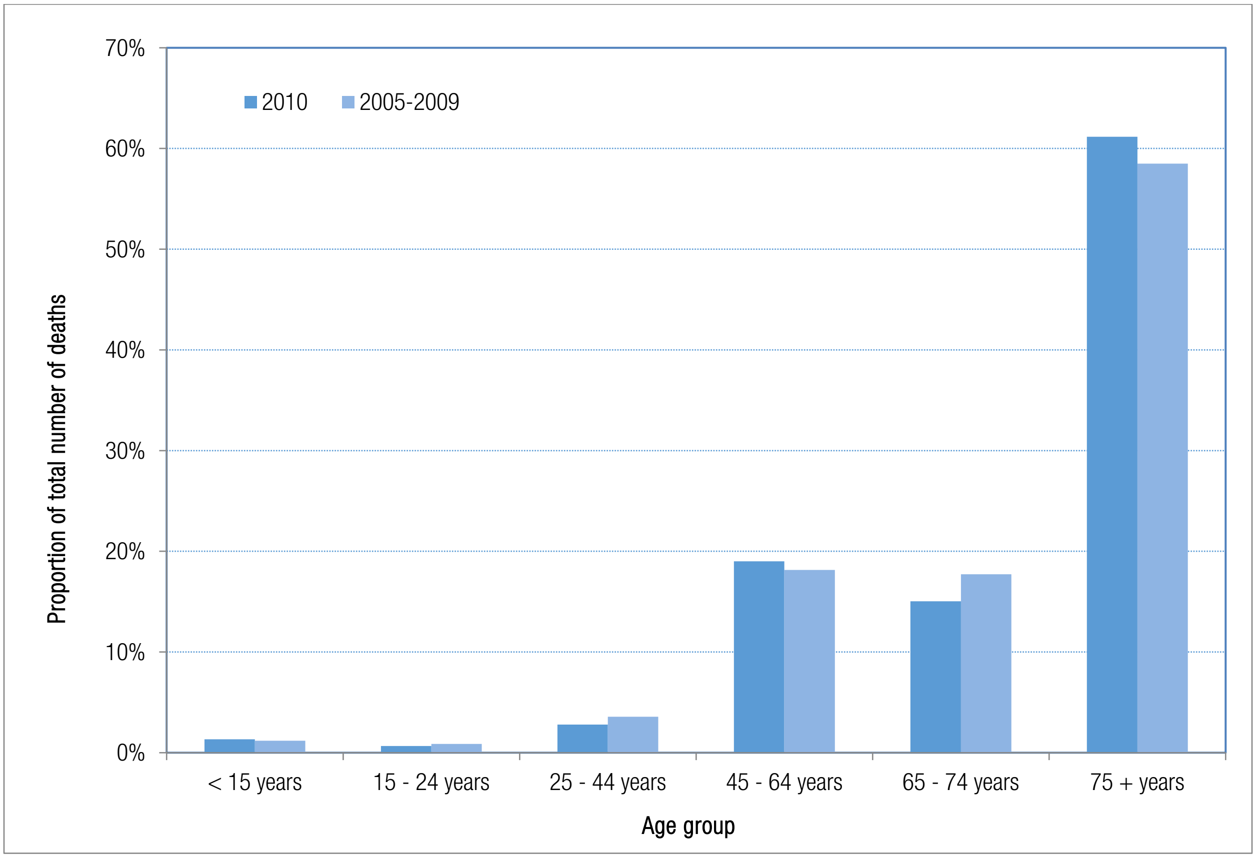
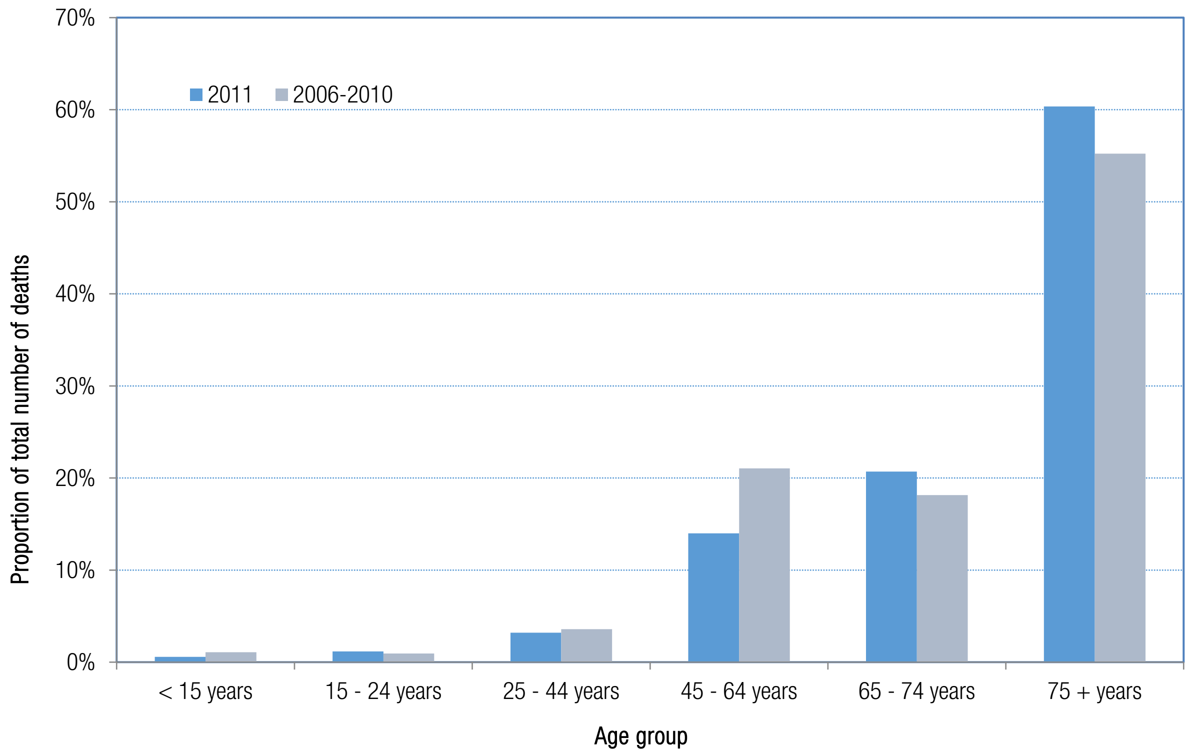


Figure 2 Frequency distribution of RED deaths, by age group and period of analysis, 2011



The average age by health region, by heat wave, as well as during the comparison period is presented in Table 5. Bolded lines indicate statistically significant differences, at the 5% level. Overall, the only statistically significant differences observed are in the Mauricie and Centre-du-Québec health regions (for both heat waves). Thus, the age of those who died in this region during the July 2010 heat wave is significantly higher than the age of those who died during the comparison period. The difference is about five years. No other statistically significant differences were observed by health region between the ages of those who died during the 2010 and 2011 extreme heat waves and during the comparison period.

Table 5 Average age of those who died during the 2010 and 2011 heat waves and comparison periods

Socio-sanitary region	Number of deaths	Comparison period	Average age (years)	95% CI
Heat waves of 2010				
02 Saguenay–Lac-Saint-Jean	53	2010	73.4	68.7-78.0
	176	2005-2009	75.3	72.9-77.7
03 National Capital	115	2010	75.5	72.1-78.9
	537	2005-2009	74.3	72.9-75.7
04 Mauricie and Centre-du-Québec (1st wave)*	**125**	**2010**	**78.2**	**75.6-80.9**
	452	**2005-2009**	**73.3**	**71.6-74.9**
04 Mauricie and Centre-du-Québec (2nd wave)*	**66**	**2010**	**78.7**	**75.6-81.8**
	354	**2005-2009**	**73.7**	**71.9-75.5**
05 Estrie	54	2010	76.0	71.6-80.5
	235	2005-2009	73.5	71.2-75.8
06 Montreal	383	2010	74.8	72.9-76.6
	1215	2005-2009	75.1	74.1-76.0
07 Outaouais (1st wave)	81	2010	72.1	68.6-75.6
	222	2005-2009	72.6	70.5-74.6
07 Outaouais (2nd wave)	46	2010	70.1	64.3-75.8
	181	2005-2009	70.4	67.9-73.0
08 Abitibi-Témiscamingue (1st wave)	16	2010	74.6	64.5-84.6
	84	2005-2009	74.4	71.0-77.7
08 Abitibi-Témiscamingue (2nd wave)	21	2010	66.9	59.0-74.7
	77	2005-2009	73.1	69.4-76.7
12 Chaudière-Appalaches	52	2010	77.5	73.3-81.7
	295	2005-2009	74.0	72.1-75.9
13 Laval	62	2010	73.9	69.4-78.4
	213	2005-2009	73.0	70.7-75.2
14 Lanaudière	77	2010	74.1	70.7-77.6
	279	2005-2009	70.8	68.8-72.9
16 Montérégie	204	2010	74.7	72.2-77.2
	707	2005-2009	72.8	71.4-74.1
Heat waves of 2011				
05 Estrie	55	2011	75.7	71.0-80.3
	199	2006-2010	76.2	73.9-78.5
07 Outaouais	59	2011	74.7	70.7-78.7
	203	2007-2010	71.2	68.9-73.6
14 Lanaudière	65	2011	73.0	69.4-76.7
	240	2006-2010	71.3	69.3-73.3
16 Montérégie	164	2011	76.1	73.8-78.4
	841	2006-2010	72.9	71.7-74.1

* Note: In the health regions shown in bold, the average age is statistically significantly different.

4.3.2 Material deprivation index

For the 2010 and 2011 heat waves, no statistically significant differences were observed between the crude rate ratio in the (materially) disadvantaged and highly disadvantaged DAs and the rate ratio obtained for the other DAs (Table 6).

Table 6 Ratio of crude mortality rate radio during extreme heat waves in disadvantaged and highly disadvantaged DAs to the rate ratio in other DAs

Socio-sanitary region	Disadvantaged and very disadvantaged DAs			Other DAs			Ratio of rate ratios	*P*-value of *z-test* of the ratio of rate ratios
	Number of deaths		Rate ratio 2010/ 2005-2009	Number of deaths		Rate ratio 2010/ 2005-2009		
	2010	2005-2009		2010	2005-2009			
02 Saguenay–Lac-Saint-Jean	21	80	1.31	28	79	1.77	0.74	0.362
03 National Capital	47	215	1.09	47	244	0.96	1.13	0.576
04 Mauricie and Centre-du-Québec (1st wave)	51	174	1.47	42	186	1.13	1.30	0.264
04 Mauricie and Centre-du-Québec (2nd wave)	24	130	0.92	20	140	0.71	1.29	0.432
05 Estrie	18	75	1.20	21	118	0.89	1.35	0.398
06 Montreal	117	382	1.53	159	542	1.47	1.04	0.756
07 Outaouais (1st wave)	29	93	1.25	38	101	1.50	0.83	0.511
07 Outaouais (2nd wave)	25	77	1.62	17	79	1.08	1.51	0.244
08 Abitibi-Témiscamingue (1st wave)	8	30	1.33	5	38	0.66	2.03	0.255
08 Abitibi-Témiscamingue (2nd wave)	11	26	2.12	7	38	0.92	2.30	0.128
12 Chaudière-Appalaches	20	118	0.85	22	139	0.79	1.07	0.837
13 Laval	25	81	1.54	24	98	1.22	1.26	0.474
14 Lanaudière	29	125	1.16	35	114	1.54	0.76	0.321
16 Montérégie	70	274	1.28	79	288	1.37	0.93	0.700
Socio-sanitary region	**Number of deaths**		**Rate ratio 2011/ 2006-2010**	**Number of deaths**		**Rate ratio 2011/ 2006-2010**	**Ratio of rate ratios**	***P*-value of *z-test* of the ratio of rate ratios**
	2011	**2006-2010**		**2011**	**2006-2010**			
05 Estrie	19	21	1.46	65	94	1.12	1.31	0.449
07 Outaouais	22	26	0.94	94	79	1.32	0.71	0.298
14 Lanaudière	28	25	1.40	100	98	1.28	1.10	0.764
16 Montérégie	59	73	0.98	300	379	0.96	1.02	0.913

4.3.3 Urban heat islands

The proportion of people who, at the time of death, resided in a heat island during the summer 2010 heat waves and the comparison periods are presented in Table 7. The only significant difference observed is in the Chaudière-Appalaches region. During the 2010 heat wave, the proportion of persons who, at the time of death, resided in an urban heat island in the Chaudière-Appalaches region was higher than during the comparison period.

During the extreme heat waves of the summer of 2011, this same proportion is significantly higher compared to the comparison periods in the Estrie and Lanaudière health regions (Table 7).

Table 7 Proportion of persons who, at the time of death, resided in an urban heat island during heat waves and comparison periods

Socio-sanitary region	Proportion of persons who, at the time of death, resided in a heat island (%)		*P*-value of the statistical test for comparison of proportions
	2010	Comparison period 2005-2009	
02 Saguenay–Lac-Saint-Jean	22.6	15.9	0.260
03 National Capital	31.3	26.8	0.329
04 Mauricie and Centre-du-Québec (1st wave)	36.0	31.0	0.287
04 Mauricie and Centre-du-Québec (2nd wave)	25.8	33.6	0.212
05 Estrie	37.0	26.4	0.120
06 Montreal	43.6	41.5	0.463
07 Outaouais (1st wave)	25.9	24.3	0.775
07 Outaouais (2nd wave)	8.7	19.9	0.085
08 Abitibi-Témiscamingue (1st wave)	12.5	8.3	0.596
08 Abitibi-Témiscamingue (2nd wave)	9.5	9.1	0.952
12 Chaudière-Appalaches	**34.6**	**21.4**	**0.040***
13 Laval	17.7	18.3	0.919
14 Lanaudière	14.3	12.9	0.751
16 Montérégie	19.6	19.7	0.987
	2011	**Comparison period 2006-2010**	***P*-value of the statistical test for comparison of proportions**
05 Estrie	**50.9**	**30.7**	**0.006***
07 Outaouais	32.2	21.7	0.098
14 Lanaudière	**24.6**	**11.3**	**0.007***
16 Montérégie	25.0	21.4	0.310

* Statistically significant difference (*p*-value < 0.05).

5 DISCUSSION

For the years 2010 and 2011, the number of deaths by health region differed on average by 5% between the Fichier hebdomadaire des décès and the RED. The Fichier hebdomadaire des décès has an almost systematic underestimation of heat wave deaths compared to the RED. The underestimation is smaller for the comparison periods. These differences are explained by the fact that the Fichier hebdomadaire des décès used, extracted in February 2011, is still preliminary. In addition, data from the Fichier hebdomadaire des décès were not validated. This difference is also acceptable, given the need to take stock of the summer season year after year.

Regarding the analysis of the impact of heat waves on deaths, for the year 2010, using the years 2008 and 2009 as a comparison period, the RED identifies excess deaths in six health regions. On the other hand, the Fichier hebdomadaire des décès identifies significant excesses only in three of these health regions (Montreal, Laval and Montérégie). However, these are excesses from the most intense (longest duration) heat waves, observed in three health regions that represent about 50% of the total population of the province. Thus, the use of the Fichier hebdomadaire des décès for the report on the 2010 summer season would not have identified significant excesses in the Saguenay–Lac-Saint-Jean, Mauricie and Centre-du-Québec, and Outaouais regions. Given the reduced statistical power, using only 2008 and 2009 as the comparison period, and the systematic underestimation of the Fichier hebdomadaire des décès, readers are advised to look closely at rate reports with borderline *p*-values (i.e., between 0.050 and 0.100).

Both databases also indicate a significant deficit of deaths during the heat wave of late August 2010 in the Mauricie and Centre-du-Québec health regions. This lower death rate during the extreme heat wave is difficult to explain. Needless to say, this result is not consistent with associations previously established in Quebec and elsewhere in the world during heat waves (Besancenot, 2002; Ledrans and Isnard, 2003; Carlson, 2007; Bustinza *et al*., 2013). Note that the number of deaths is low during this heat wave. Thus, it is possible that this incidental finding is related to the limited number of deaths during the two years available in the Fichier hebdomadaire des décès. To test this possibility, the impact on deaths was calculated using the 2005 to 2009 comparison period with the RED. The results presented in Table 4 show that this deficit is not significant when using crude rates for a five-year comparison period.

Thus, the ISQ Fichier hebdomadaire des décès is a useful tool for analyzing the impacts of heat waves on deaths. Based on the 2010 audits, this assertion is valid, provided that the extraction of data from the Fichier hebdomadaire des décès is done at least four months after the end of the monitoring season. Unless this time frame is observed, the Fichier hebdomadaire des décès is incomplete for the purpose of estimating the health impacts of extreme heat. In addition, because the Fichier hebdomadaire des décès underestimates the number of deaths per wave by health region, it is recommended that we be a little more liberal and pay particular attention to rate ratios that have *p*-values between 0.05 and 0.10.

In addition, it should be noted that there are methodological differences between this study and the previous 2010 extreme heat monitoring assessment. On the one hand, it is not possible to directly compare the results with the 2010 annual report, mainly because the heat wave and comparison periods are not defined in the same way. On the other hand, comparisons with the study published in 2013 (Bustinza *et al.*, 2013) are also limited because the death counts in that study combined provisional death files for the years 2008 and 2009 with RED files for earlier years. Another important methodological difference with the latter two publications concerns the determination of statistically significant rate differences. Thus, the comparison of deaths for the July wave, using the 95% CIs, leads to significant excesses in the Montreal and Montérégie health regions (Appendix 2 and Appendix 3). However, for the same heat wave, using the *p*-value of the crude rate ratios (*z*-test), significant excesses must be added in the Laval and Mauricie and Centre-du-Québec health regions (Table 3). Theoretically, the use of 95% CIs is more conservative than the *z*-test. This method (95% CI) had been used for simplicity when conducting heat wave health impact monitoring reports. The *z*-test is more conventional and better suited to the context of small numbers (of deaths). The latter identifies slightly more significant differences than the 95% CI method. For this reason, crude rate ratios (and the *z*-test) should be used in future monitoring reports on the health impacts of extreme heat waves.

There are some limitations associated with comparing the impacts of heat waves on deaths. A first limitation concerns the regional scale of analysis. The impacts of heat waves are mainly observed in urban areas (Johnson and Wilson, 2009). Using the entire territory of the health region, rather than restricting the analysis to urbanized areas only, is certainly likely to underestimate the impacts of heat on deaths. In addition, the effect of factors not considered (e.g., air pollution, heat wave intensity [duration and temperature], air conditioning) (Analitis *et al.*, 2014) could have a differential effect in urban and rural areas.

The definition of the five-year comparison period could potentially become problematic. Indeed, if heat waves occur on the same dates from one year to another, alternatives to the comparison period will eventually have to be found.

The estimated impacts depend on the definition of a heat wave. There is no uniform definition of a heat wave. Definitions are specific to each country and climate. The thresholds used in Quebec are based on a statistical analysis of the associations between temperature and all-cause mortality over a 24-year period (1981 to 2005) (Martel *et al.*, 2010). The thresholds established are intended to anticipate, based on weather forecasts, heat waves likely to result in 60% excess mortality. The thresholds should be reviewed in the near future considering the more recent death and weather data. The temperature criteria in effect in 2014 are used. They were applied (without weighting) to temperatures observed at reference weather stations by health region. Several other definitions of a heat wave exist (Lowe *et al.*, 2011) and could produce different results. On the other hand, the use of data from a single weather station per health region also imposes limitations, particularly with respect to the spatial representativeness of the weather station.

Risk and vulnerability factors

Age of the deceased

The frequency distribution of age at death during heat waves reveals that the majority (60%) of individuals who die during heat waves are aged 75 years and older. By health region, there is very little difference between the frequency distributions of deaths during heat waves and comparison periods. This situation is normal and similar to what has been observed elsewhere in the world (Carlson, 2007; Ledrans and Isnard, 2003).

In addition, comparisons are made with crude rates. It is possible, however, that the age structure between health regions affects the results. To test this hypothesis, comparisons by health region were made using adjusted rates from the RED data. The results are presented in Appendix 4. As can be seen from Table 4, for the 2010 heat waves, the excesses established with the standardized rates are not significant in the Saguenay–Lac-Saint-Jean, Laval and Lanaudière health regions. Similarly, for the 2011 heat wave, the significant excess in Estrie disappears when using standardized rates. Thus, the conclusions are different depending on whether crude or adjusted rates are used. It is also important to note that since the annual reports are produced with the Fichier hebdomadaire des décès and the age of individuals is not known accurately, direct standardization cannot be used. In addition, the reference periods are limited because the data from the Fichier hebdomadaire des décès have only been available since 2008.

The material deprivation index

With respect to the material deprivation index, the results do not indicate a higher impact in the most deprived areas compared to the other areas. This result seems surprising considering that the associations between disadvantage and health problems (including death) are widely known and documented (Doubeni *et al*., 2012). On the other hand, this association has also been demonstrated during heat waves elsewhere in the world (Greenberg *et al*., 1983; Carlson, 2007; Rey *et al*., 2009).

The results obtained with the material deprivation index should be viewed with caution. The deprivation index has two dimensions, one material and one social. For this study, only the material dimension was used. On the one hand, it should be noted that the material deprivation index is not based on individual information. It is compiled by principal component analysis using census data. It is then assigned to each death based on the six-digit postal code of the place of residence at the time of death. For a portion of the deaths (23%), it is not possible to calculate a deprivation index. This is particularly true, for example, of DAs that consist of a single residential and long-term care centre (CHSLD). Because Statistics Canada considers these facilities to be “collective households”, the census data is not released by DA, meaning that the deprivation index cannot be calculated (personal communication from Denis Hamel, July 2014). This is particularly critical in this study since deaths are primarily observed (approximately 60% of deaths) in persons over 75 years of age. In addition, the probability that they will reside in a CHSLD is very high at this advanced age. These findings typically constrain the analysis of associations between mortality and the deprivation index to premature mortality (i.e., before age 74). This cannot be applied in this study.

Thus, these results suggest that the material deprivation index (assigned to each death on the basis of DA) should not be used in the analysis of heat wave impacts on deaths.

Urban heat islands

The results of the urban heat island comparisons indicate that, during the 2010 heat wave, the proportion of deaths which, at the time of death, were located within an urban heat island, is higher than during the comparison periods in the Chaudière-Appalaches health region. In 2011, the proportion of deaths located in an urban heat island is higher than those of the comparison periods in Estrie and Lanaudière. Furthermore, in seven of the eight health regions where a significant impact of the heat wave on deaths was documented, no significant association with urban heat islands was observed.

A specific limitation of this analysis is that the population numbers must be considered stable between 2005 and 2010 (including populations residing in urban heat islands and those residing in other areas). However, it is impossible to verify this assertion.

These results are difficult to explain. In several studies, the presence of heat islands explains the high mortality in city centres during heat waves (Lowe *et al.*, 2011). This excess mortality is attributable to urban design, lack of vegetation, and density of materials, which reduces evapotranspiration (Johnson and Wilson, 2009). Another study documented a significant spatial association between deprivation and urban heat islands (Huang *et al*., 2011). It is possible that the proportion of persons who, at the time of death, resided in an urban heat island (or the proportion of the population residing there) may be too small to perform the analysis of heat island impact during the heat wave. It is also possible that this result is due to the fact that only the six-digit postal code of the place of residence at the time of death is available. It would surely be more appropriate to have the place of death, but this information is not available in the RED. Another limitation inherent in these data is that one must consider the place of residence as the place of exposure, which should be true in most cases in the elderly, but this assumption is impossible to verify.

6 CONCLUSION

In conclusion, the use of the Fichier hebdomadaire des décès to estimate the impacts of heat waves on deaths is appropriate, as long as there is a delay of at least four months between the end of the summer season and the extraction of the data, and *p*-values of rate ratios between 0.05 and 0.10 are also considered. The production of annual reports is useful for planning interventions to prevent the health impacts of heat.

There is very little significant difference in the age of those who died during the heat wave and the comparison period. The analysis of vulnerability factors indicates that the average age of the decedents is 75 years and that the vast majority of decedents are 75 years and older. On the other hand, the analyses performed do not confirm a significant statistical association between the material deprivation index and deaths during the heat wave. Finally, it was not possible to identify a significant association with the presence of heat islands.

Excess mortality during heat waves can be prevented. The prevention of this risk is one of the priorities of the World Health Organization (Lowe *et al.*, 2011). Measures to prevent exposure to heat are possible (Price *et al.*, 2013; White-Newsome *et al.*, 2014; Bittner *et al.*, 2014). Evaluation of the effectiveness of these preventive interventions in reducing deaths, however, remains difficult to measure and research is needed. It is recommended that RPHDs continue to monitor the health impacts of heat. RPHD preventive interventions should continue to target groups of individuals vulnerable to the health impacts of heat, including the elderly, the disadvantaged and those living in urban heat islands.

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ANNEX 1 REFERENCE WEATHER STATIONS AND EXTREME HEAT THRESHOLDS BY HEALTH REGION

Socio-sanitary region	Reference weather station	Extreme heat thresholds	
		Maximum temperature (°C)	Minimum temperature (°C)
01 Bas-Saint-Laurent	Amqui	31	16
02 Saguenay–Lac-Saint-Jean	Bagotville	31	16
03 National Capital	Jean Lesage Airport	31	16
04 Mauricie and Centre-du-Québec	Nicolet	31	18
05 Estrie	Lennoxville	31	18
06 Montreal	Dorval	33	20
07 Outaouais	Ottawa	31	18
08 Abitibi-Témiscamingue	Val d'Or	31	16
09 North Shore	Baie-Comeau	31	16
10 Nord-du-Québec	Matagami	31	16
11 Gaspésie–Îles-de-la-Madeleine	Gaspé	31	16
12 Chaudière-Appalaches	Beauceville	31	18
13 Laval	Dorval	33	20
14 Lanaudière	L'Assomption	33	20
15 Laurentians	Saint-Jovite	31	18
16 Montérégie	Saint-Hubert	33	20

ANNEX 2 CRUDE MORTALITY RATES DURING THE 2010 AND 2011 HEAT WAVES, BY DATA SOURCE

Socio-sanitary region	2010 - Fichier hebdomadaire des décès		2010 - RED	
	Crude rate*	95% CI	Crude rate*	95% CI
02 Saguenay–Lac-Saint-Jean	2.69	2.04-3.53	2.79	2.13-3.65
03 National Capital	2.04	1.69-2.45	2.09	1.74-2.51
04 Mauricie and Centre-du-Québec (1st wave)	3.03	2.53-3.63	3.16	2.65-3.76
04 Mauricie and Centre-du-Québec (2nd wave)	2.16	1.69-2.75	2.22	1.75-2.83
05 Estrie	2.11	1.61-2.77	2.19	1.68-2.86
06 Montreal	2.66	2.40-2.95	2.86	2.59-3.16
07 Outaouais (1st wave)	2.24	1.78-2.82	2.49	2.00-3.09
07 Outaouais (2nd wave)	1.62	1.19-2.20	1.81	1.36-2.42
08 Abitibi-Témiscamingue (1st wave)	1.84	1.13-3.00	1.84	1.13-3.00
08 Abitibi-Témiscamingue (2nd wave)	2.30	1.48-3.56	2.41	1.57-3.70
12 Chaudière-Appalaches	1.60	1.22-2.10	1.60	1.22-2.10
13 Laval	2.13	1.65-2.75	2.24	1.74-2.87
14 Lanaudière	2.03	1.62-2.54	2.05	1.64-2.57
16 Montérégie	2.29	1.99-2.63	2.35	2.05-2.70
	2011 - Fichier hebdomadaire des décès		2011 - RED	
05 Estrie	2.35	1.78-3.09	2.53	1.94-3.30
07 Outaouais	1.81	1.38-2.36	2.01	1.56-2.60
14 Lanaudière	1.86	1.45-2.38	1.95	1.53-2.48
16 Montérégie	1.53	1.31-1.79	1.61	1.38-1.87

* Per 100,000 person-days.

ANNEX 3 CRUDE MORTALITY RATES DURING THE COMPARISON PERIODS, BY DATA SOURCE

Socio-sanitary region	2008-2009 - Fichier hebdomadaire des décès		2008-2009 - RED	
	Crude rate*	95% CI	Crude rate*	95% CI
02 Saguenay–Lac-Saint-Jean	1.94	1.55-2.44	1.89	1.50-2.38
03 National Capital	1.85	1.61-2.12	1.86	1.62-2.13
04 Mauricie and Centre-du-Québec (1st wave)	2.42	2.10-2.79	2.46	2.13-2.83
04 Mauricie and Centre-du-Québec (2nd wave)	3.00	2.59-3.48	3.00	2.59-3.48
05 Estrie	1.76	1.42-2.17	1.70	1.37-2.11
06 Montreal	1.86	1.70-2.03	1.91	1.75-2.08
07 Outaouais (1st wave)	1.72	1.43-2.08	1.75	1.46-2.11
07 Outaouais (2nd wave)	1.49	1.19-1.87	1.61	1.29-2.00
08 Abitibi-Témiscamingue (1st wave)	1.78	1.25-2.53	1.72	1.21-2.47
08 Abitibi-Témiscamingue (2nd wave)	2.47	1.83-3.33	2.41	1.78-3.27
12 Chaudière-Appalaches	2.04	1.72-2.42	2.10	1.77-2.48
13 Laval	1.44	1.15-1.80	1.49	1.20-1.86
14 Lanaudière	1.54	1.28-1.85	1.56	1.30-1.88
16 Montérégie	1.44	1.27-1.63	1.44	1.27-1.64
	2008-2010 - Fichier hebdomadaire des décès		2008-2010 - RED	
05 Estrie	1.91	1.60-2.28	1.93	1.62-2.30
07 Outaouais	1.69	1.44-1.99	1.73	1.47-2.03
14 Lanaudière	1.43	1.21-1.69	1.49	1.27-1.76
16 Montérégie	1.66	1.52-1.81	1.69	1.55-1.85

* Per 100,000 person-days.

ANNEX 4 ADJUSTED RATES OF DEATH DURING EXTREME HEAT WAVES AND COMPARISON PERIODS 2005-2009 AND 2006-2010 FROM THE RED

Socio-sanitary region	Heat wave of 2010			Comparison period 2005-2009			*P*-value of *z-test*
	Number of deaths	Adjusted rates*	95% CI	Average number of deaths per wave	Adjusted rates*	95% CI	
02 Saguenay–Lac-Saint-Jean	53	2.63	2.01-3.45	35.2	1.97	1.70-2.28	0.063
03 National Capital	115	1.94	1.62-2.33	107.4	1.97	1.81-2.14	0.889
04 Mauricie and Centre-du-Québec (1st wave)	**125**	**2.73**	**2.29-3.26**	**90.4**	**2.16**	**1.97-2.37**	**0.021**†
04 Mauricie and Centre-du-Québec (2nd wave)	66	1.92	1.51-2.44	70.8	2.26	2.04-2.51	0.217
05 Estrie	54	2.09	1.60-2.72	47.0	1.96	1.72-2.22	0.673
06 Montreal	**383**	**2.81**	**2.54-3.11**	**243.0**	**1.86**	**1.76-1.97**	**< 0.0001**†
07 Outaouais (1st wave)**	**81**	**3.10**	**2.49-3.87**	**55.5**	**2.35**	**2.06-2.69**	**0.036**†
07 Outaouais (2nd wave)	46	2.29	1.71-3.06	36.2	1.98	1.71-2.30	0.391
08 Abitibi-Témiscamingue (1st wave)	16	1.99	1.22-3.26	16.8	2.29	1.85-2.84	0.611
08 Abitibi-Témiscamingue (2nd wave)	21	2.56	1.67-3.93	15.4	2.07	1.65-2.59	0.391
12 Chaudière-Appalaches	52	1.59	1.21-2.09	59.0	1.97	1.76-2.21	0.159
13 Laval	62	2.38	1.86-3.06	42.6	1.82	1.59-2.08	0.060
14 Lanaudière	77	2.51	2.00-3.14	55.8	2.02	1.79-2.27	0.097
16 Montérégie	**204**	**2.64**	**2.30-3.03**	**141.4**	**2.01**	**1.87-2.16**	**0.001**†
	Heat wave of 2011			**Comparison period 2006-2010**			***P*-value of *z-test***
05 Estrie	55	2.36	1.81-3.07	39.8	1.85	1.61-2.12	0.111
07 Outaouais***	59	2.52	1.95-3.26	50.8	2.30	2.00-2.65	0.548
14 Lanaudière	65	2.32	1.82-2.97	48.0	1.90	1.67-2.16	0.159
16 Montérégie	164	1.77	1.51-2.06	168.2	1.98	1.85-2.11	0.191

* Per 100,000 person-days.

** The year 2005 was excluded from the comparison period due to the presence of a heat wave.

*** The year 2006 was excluded from the comparison period due to the presence of a heat wave.

† Statistically significant difference (p-value < 0.05)

Publication N: 3349