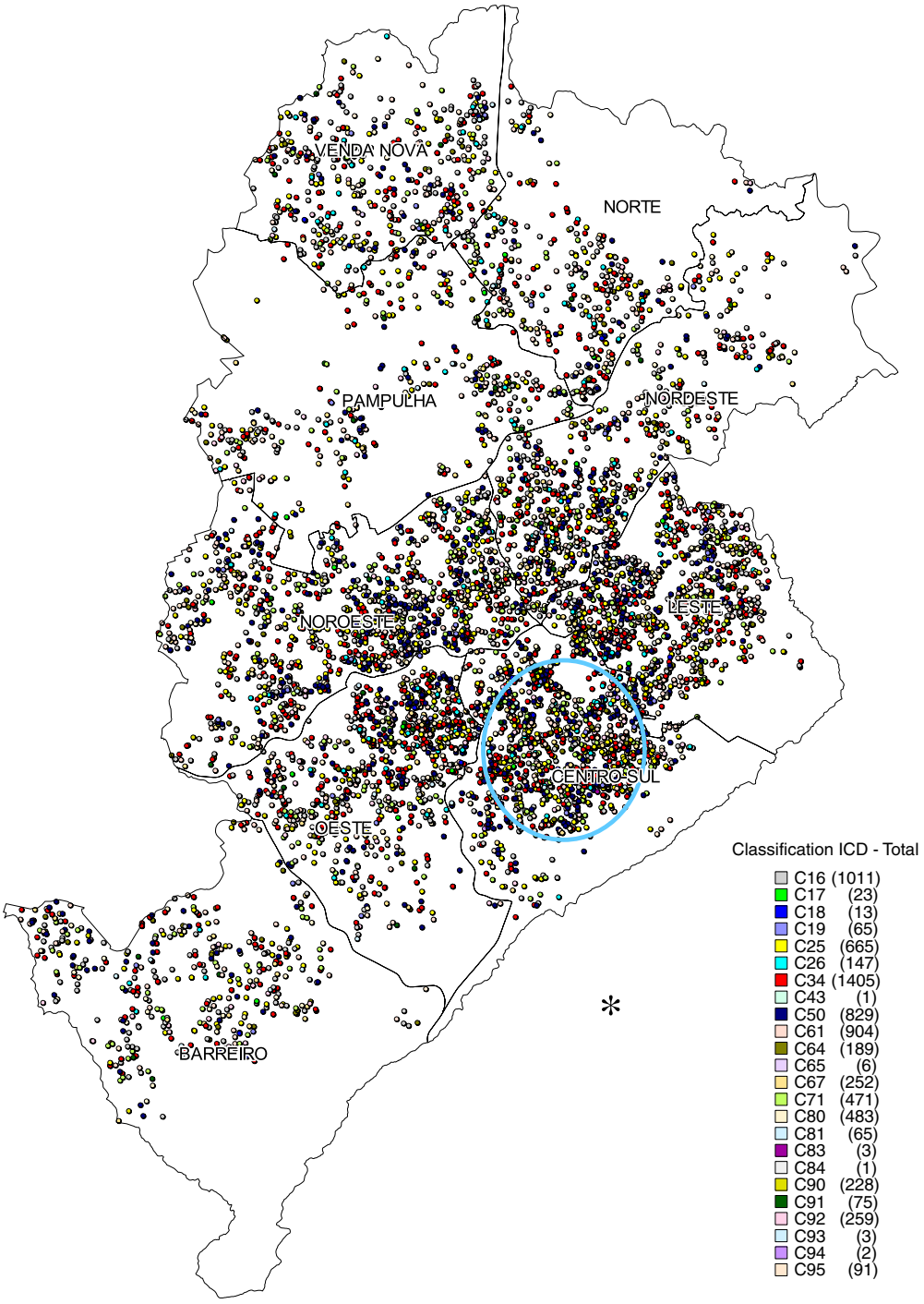


Fig. 7. Map of the total deaths by neoplasia in the Belo Horizonte municipality from 1996 to 2006, classified according to ICD. Total: 7191 deaths.

(C61), 12.57%; and malignant neoplasm of breast (C50), 11.53%. The largest absolute number of deaths was found in the Central-Southern region, followed by the Northwestern region. Also, the highest absolute numbers of lung cancer deaths (300 cases) and breast cancer deaths (210 cases) were found in Central-Southern SD (Table 2). The proportional mortality by gender can be seen in Figs. 13 and 14.

3.5. Estimates of the mortality rates by distance and time of exposure to BS

The mortality rates were estimated by correcting the population mortality by 10,000, according to the radius of distance from the BS within 1000 m. In the region within 100 m, the absolute number of deaths was 3569 (a percentage of 49.63%), and the mortality rate was 43.42 persons per 10,000 inhabitants. Compared to with the total population mortality rate, the relative risk in this area was 1.35. In the area up to 200 m there was a growth of 1408 deaths, a total of 4977 deaths, a mortality rate of 40.22 persons per 10,000 inhabitants and a relative risk of 1.25 (Table 5). In this way, the estimates of mortality by neoplasia were calculated inside radii up to 1000 m from the BSs. The relative risks presented a decreased dose–response gradient with residents' distance from the first licensed BSs.

Fig. 15 shows the mortality rate by neoplasia according to the distance from the BS in the Belo Horizonte municipality, during the studied period. The accumulated mortality rates by neoplasia,

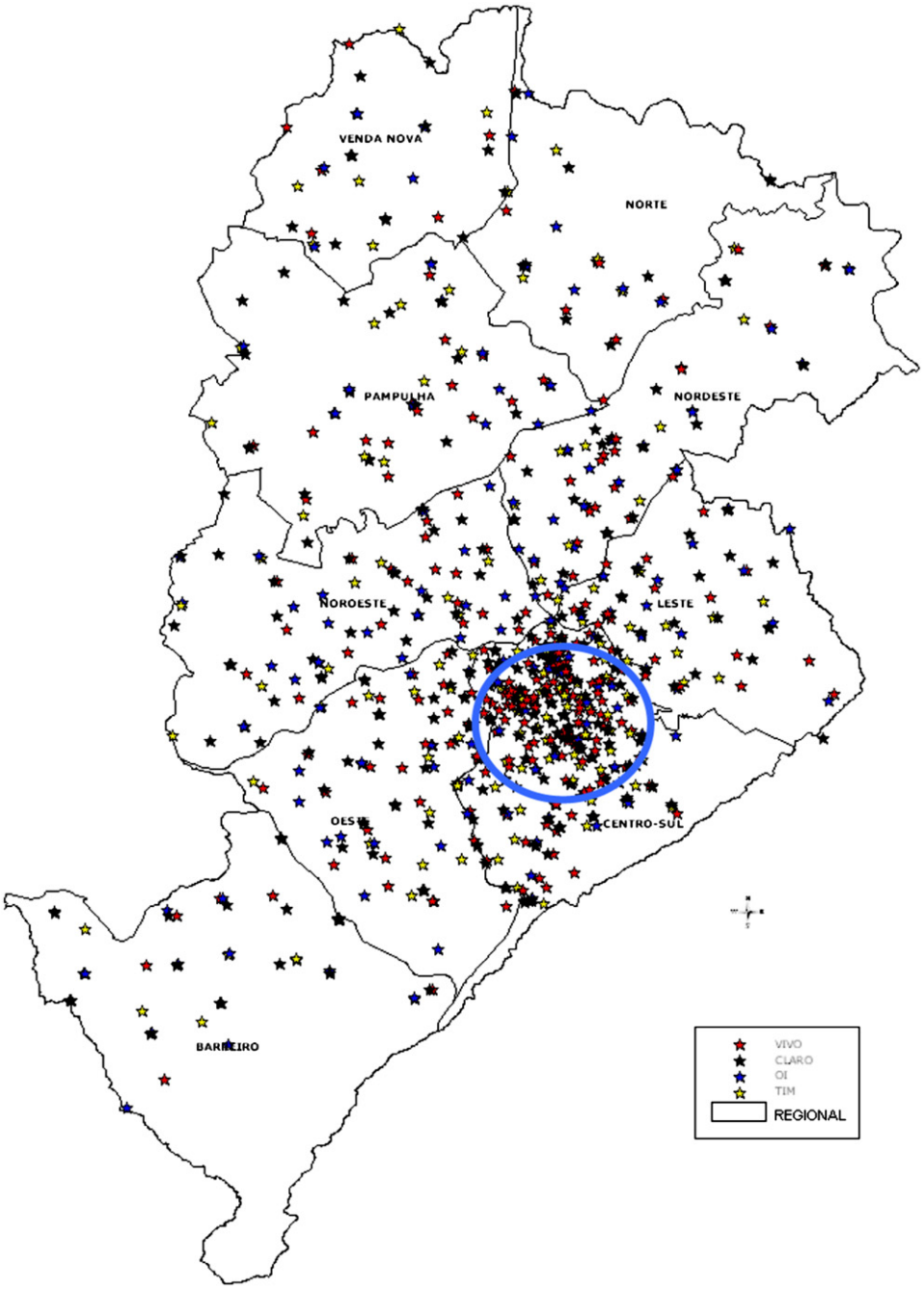


Fig. 8. Installed BSs in the Belo Horizonte municipality until 2006. Total amount = 856.

determined by dividing the total number of deaths during the period (n = 7191) by the total population living in the municipality (2,238,332), showed that there was a risk of dying of 32.12 per 10,000 inhabitants, as seen in Fig. 15. In this study, this figure represents the null hypothesis, i.e., the total number of deaths occurring in the period divided by the population, independent of the proximity to the BSs. Fig. 16 shows the distribution of the number of deaths by neoplasia versus duration of exposure since the date of operation of the first antenna in each analyzed CT.

3.6. Environmental monitoring of the electromagnetic field

The EMF results provided essential information for the assessment of risks to the health of the exposed persons in the community. A total of 400 points were measured in the Central-Southern region in 2008, where a major concentration of cellular telephony antennas was found. The mean intensity of the measured electric field was 7.32 V/m, varying from 0.4 to 12.4 V/m. It was common to find a stronger electric field at locations above the ground. The BS frequency bands ranged from approximately 800 MHz to 1800 MHz. In 2003, the power density varied from 0.898 μW/cm^2 to 3.066 μW/cm^2.

4. Discussion

Electric and EMFs interact with biological systems because they penetrate into organs and tissues, and the biological systems are ruled by delicate bioelectrochemical reactions that sustain the vital processes and receive the influence from those fields. As demonstrated in the literature

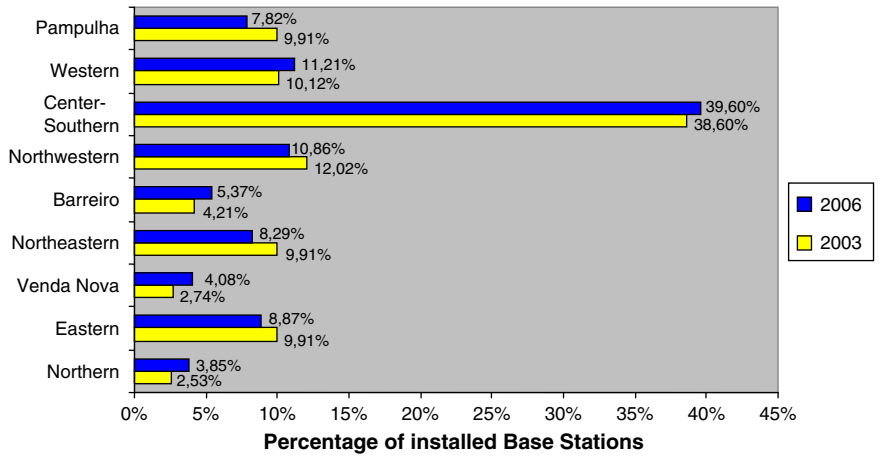


Fig. 9. BS percentage by Sanitary Districts in the Belo Horizonte municipality in 2003 and in 2006.

(Kundi and Hutter, 2009; Sage and Carpenter, 2009; Khurana, 2008; BIOINITIATIVE REPORT, 2007; Cherry, 2006; Cherry, 2007; Hardell and Sage, 2007), exposure to electromagnetic radiation of low intensities for long periods of time is a determinant for the aggravation and the emergence of diseases in humans. Studies point to observations of environmental carcinogens as an alert to the scientific community (Hardell et al., 2007). Bioeffects and adverse health effects occur at frequencies much lower than RF and extremely low frequencies (ELF), without any heating effect.

Khurana et al. (2010) identified by searching PubMed ten epidemiological studies that indicate the occurrence of neurobehavioral effects or cancer. In eight of those studies, the population lived within 500 m of a BS. However, all exposures were under the accepted international guidelines. Therefore, it is suggested that those guidelines may be inadequate in protecting the health of human populations. Additionally, more comprehensive epidemiological studies are necessary to evaluate long-term exposure to RF from mobile phones BSs to understand its health impact.

This research bases on the ecological study that uses geographical areas as units of pre-existing data to identify areas of risk. The data is already aggregated, and one does not know about the genetic characteristics, life habits, food choices and other factors of each individual. The ecological studies frequently begin the epidemiological process, and the discoveries are considered to be an alert.

In the Belo Horizonte municipality, the mortality rate was concentrated near the antennas and was not diffuse over the whole city. At a distance of up to 100 m, the absolute number of deaths was 3569, 49.63% of all deaths, the mortality rate was 43.42 persons per 10,000 and the relative risk was 1.35. When one does not consider the distances from the BSs for all the entire population of the Belo Horizonte municipality (2,238,332 inhabitants), the mortality rate was 32.12 per 10,000 inhabitants, which is the null hypothesis.

In this research, we found a mortality rate for the residents living within 500 m of the transmitter antennas of a BS greater than 34.76 per 10,000 inhabitants. This rate decreased for residents living farther from the BS, as shown in Fig. 15.

We concluded that the relative risk of death by neoplasia, according to the distance from a BS in the Belo Horizonte municipality, from 1996 to 2006, was greater within a radius of up to 500 m from the BSs (Table 5). In the town of Netanya, Israel, in 2004, the authors also found an increase of 4.15 times in the cancer incidence of the residents of a zone up to 350 m from the BS, compared to those who lived outside that area (Wolf and Wolf, 2004). A retrospective study in Naila, Germany, showed that the risk of new cancer cases was three times greater among the patients who had lived at a distance less than 400 m from a cellular telephone transmitter antenna during the last ten years (1994 and 2004), compared to those who lived at greater distances (Eger et al., 2004).

In addition, only the deaths of those who were exposed since the first license date of the BS were included in the study, even though there were antennas that were installed in the register date (before the licensing date).

Also, we observed that the Central-Southern SD possessed the greatest antenna concentration in the city and the most electromagnetic contamination. This region contained 38.60% of the installed antennas in 2003 and 39.60% in 2006. Again, through georeferencing, we observed a greater concentration of specific cases of death by neoplasia in the region. The accumulated incidence rate per 1000 residents was the largest in Central-Southern SD, reaching 5.83; this rate was the lowest (2.05) in Barreiro region.

In the Central-Southern SD, there are no factories; it is a strictly residential area, with some services and commerce. No power lines, highways, airports or railroads exist in the area. However, many private vehicles come and go in the region, and its inhabitants possess higher social status and affluence. It contains many wooded streets and gardens. The Central-Southern SD has other aggravating exposures, including noise, gases, fumes, aerodispersoids, and hydrocarbonates, each of which also damage human health. Despite the presence of diverse and aggressive potential agents that may have influenced the quality of life and the health of the dwellers living in the area, the mortality rates remained concentrated near the antennas, with a dose–response gradient, and were not diffuse all over the city.

Age and sex did not appear to be a confounder in this study. In Belo Horizonte municipality, like all of Brazil, the population suffers from a demographic transition characterized by the aging of the population, and this is a possible confounder for all chronic degenerative diseases. Looking at the profile of the proportional mortality by age and gender throughout the 10 years studied, there is no specific trend for either men or women, and the highest percentage started at age 40 and increased to age 60. Irrespective of the year, the proportional mortality by gender and age remained stable during the period, suggesting there is no relevant change in the proportion of deaths by cancer when age is taken into consideration.

According to the ICNIRP guidelines, the human levels to the public at large (ICNIRP, 1998), for the frequency (f) band ranged from 400 to 2000 MHz, the electric field intensity E ($V.m^{-1}$) equals 1.375 $f^{½}$ V/m, which equals 1.375 $\sqrt{f}$ V/m.

These values are according to the reference level patterns for the public at large when compared with the current Brazilian federal law which establishes the following limits: for a 900 MHz field intensity an electric field of 41.25 V/m and a power density of 451.34 μW/cm^2, for a 1800 MHz field intensity an electric field of 58.33 V/m and a power density of 902.49 μW/cm^2. These human exposure limits are exclusively based on thermal effects.

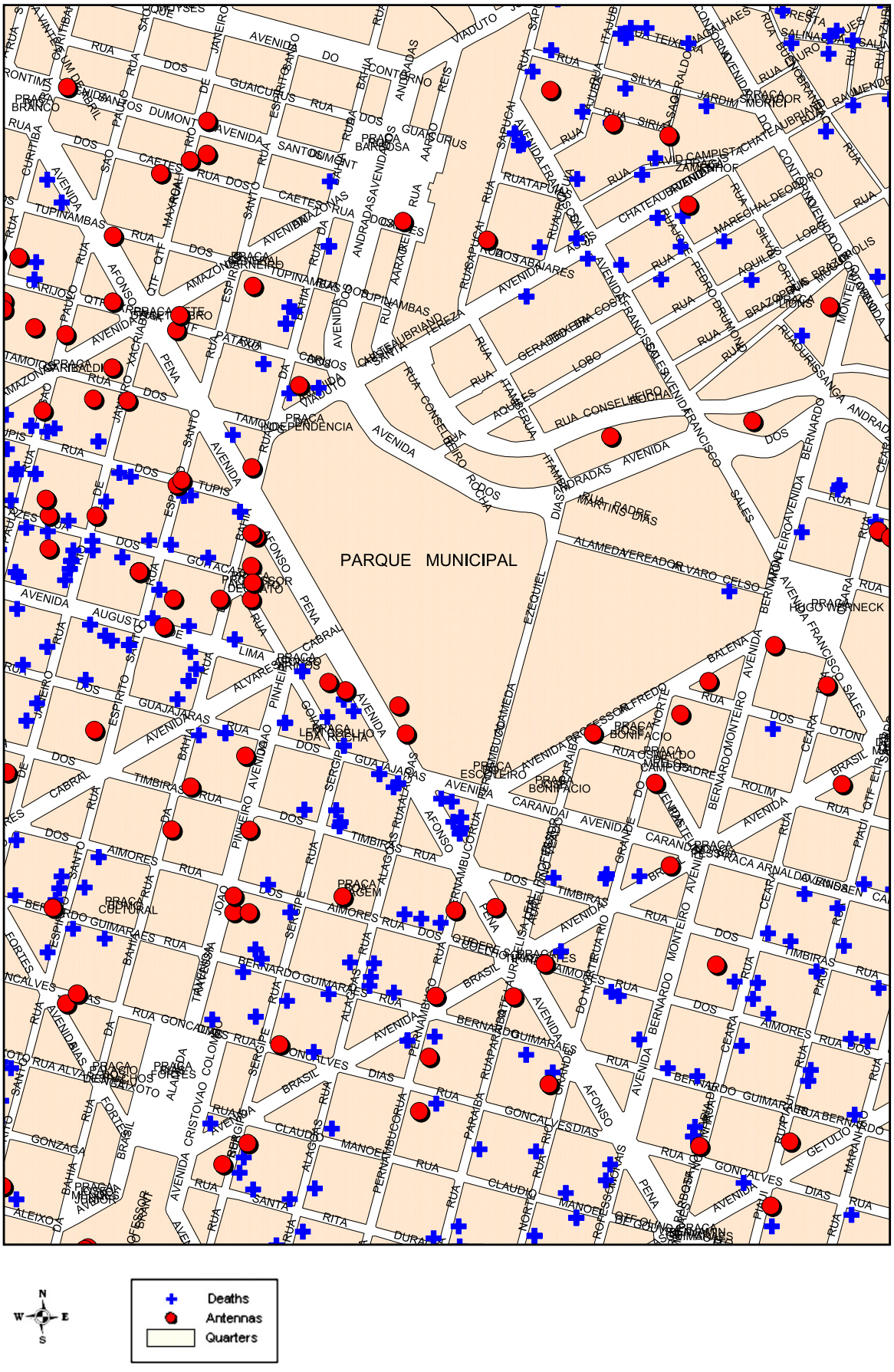


Fig. 10. Sample of geocoded deaths and BS locations in downtown Belo Horizonte City located in Central-Southern region.

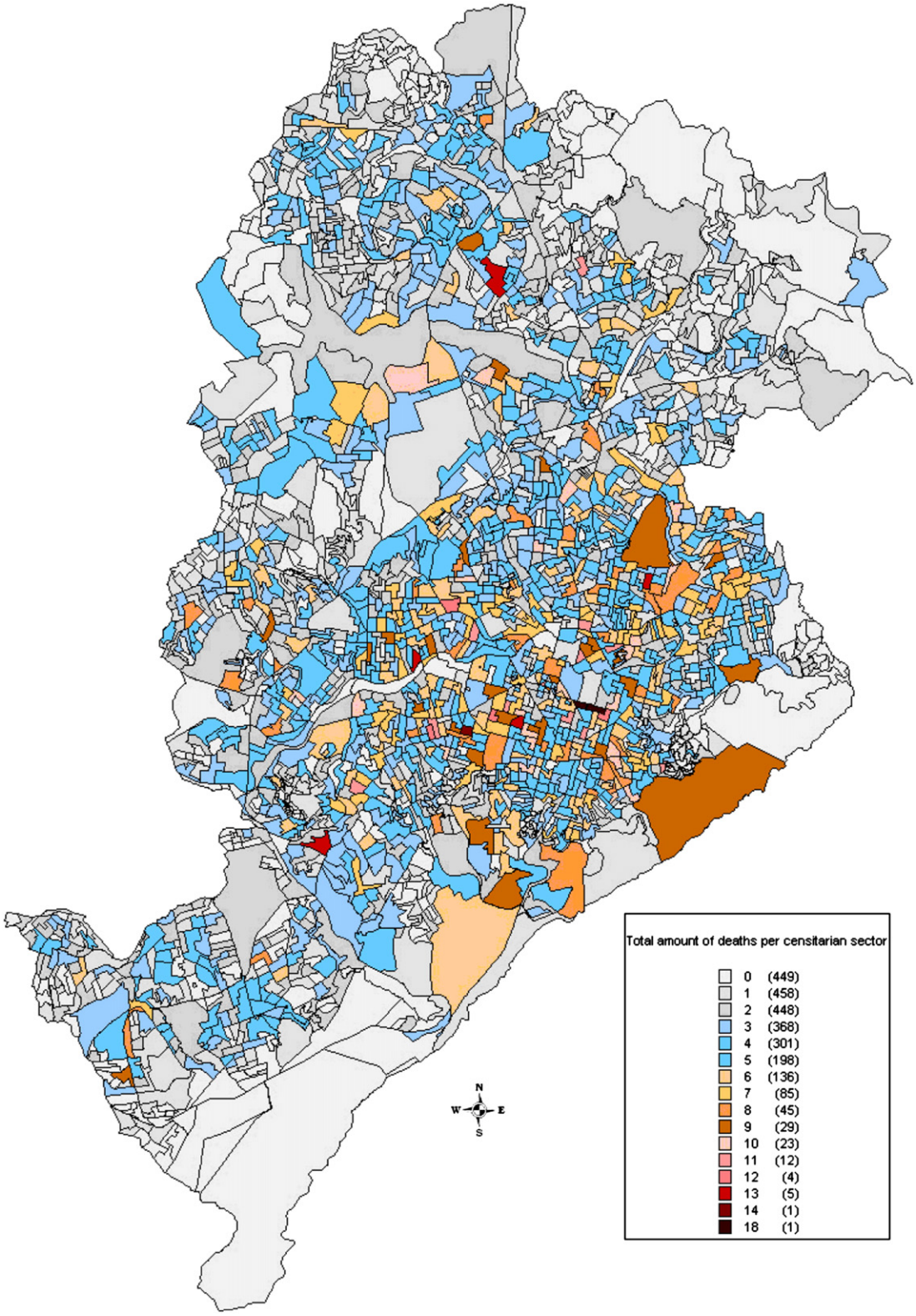


Fig. 11. Map of 7191 cancer deaths geocoded by CT.

In 2003, the largest electric field found during environmental monitoring of the BSs was 3.4 V/m and the greatest power density was 3.06 μW/cm^2. In 2008, the largest electric field found during environmental monitoring of the BSs was 12.4 V/m, and the greatest power density was 40.78 μW/cm^2 near the cellular antennas in the 890 to 1800 MHz frequency band. These values were much larger than those reported in the Netanya study (approximately 0.53 μW/cm^2). The smallest values found in the measurements were a field intensity of 0.4 V/m and a power density of 0.04 μW/cm^2.

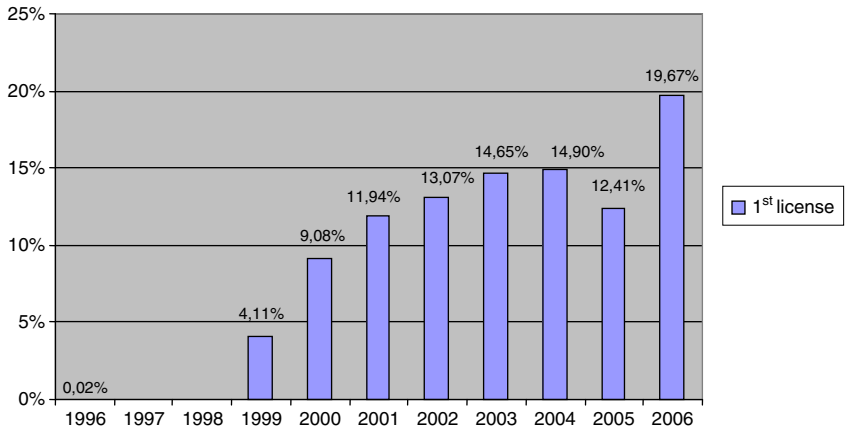


Fig. 12. Percentage of neoplasia deaths per year in the Belo Horizonte municipality, from 1996 to 2006, using the first license date.

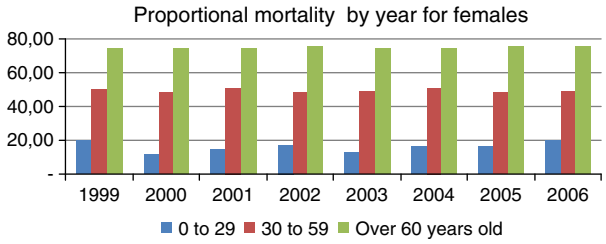


Fig. 13. Proportional mortality by year for females.

The major advantage of this ecological study is that it is the first epidemiological approach to determine the existence of a possible association between a determined exposure and a health outcome using the group characteristics.

The principal limitations of the present study concern the study design and the use of secondary data. By design, the group results could not be extrapolated to each person in the population. Although the data were well standardized and collected from official personnel in the City Health Department, they are subject to misclassification due to lack of information and errors in the entering of data and diagnosis. Finally, neither the life habits nor the genetic factors of the residents could be taken into account.

Despite these limitations, the present study has brought important contributions to the issue, the most important of which is the existence of a cluster of deaths by neoplasia associated with BS clusters. Although the direction of this relationship could not be specified, this work has demonstrated the existence of such clusters. Until more extensive studies are conducted, we urge the adoption of the Precautionary Principle and a revision of national policies toward stronger restrictions of the human limits associated with this technology. The adoption of EMF and radiation levels similar to the more restrictive exposure limits of many other countries and towns would be one important public health provision. On this matter, we refer to the Porto Alegre Resolution.

The Precautionary Principle states that when there are signs of possible adverse effects to health or to the environment, although uncertain, the risks of inaction can be greater than the risks of acting, especially in relation to the control of human exposures to non-ionizing radiation. The Precautionary Principle reverses the burden of proof from those who suspect a risk on those who take the actions and affirm that only when new scientific discoveries will be recognized as the unique criterion to establish or to change guidelines. The principle asserts that precaution be maintained until new proven researches be done.

From May 18th to 19th, 2009. in Porto Alegre City, Rio Grande do Sul State, Brazil, occurred The International NIR (Non-Ionizing Radiation) and Health Workshop ("Seminário Internacional sobre RNI, a Saúde e o Ambiente"), sponsored by the Federal University of Rio Grande do Sul. The purpose of the workshop was to present lectures as a basis to initiate discussions among Brazilian and foreign scientists and public health authorities on the potential biological and health consequences and the setting of exposure limits of non-ionizing electromagnetic fields/radiation (NIR).

The workshop also was under the sponsorship of the Brazilian Ministry of Health, as well as some other governmental and non-

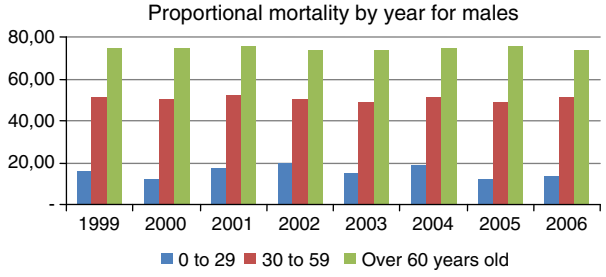


Fig. 14. Proportional mortality by year for males.

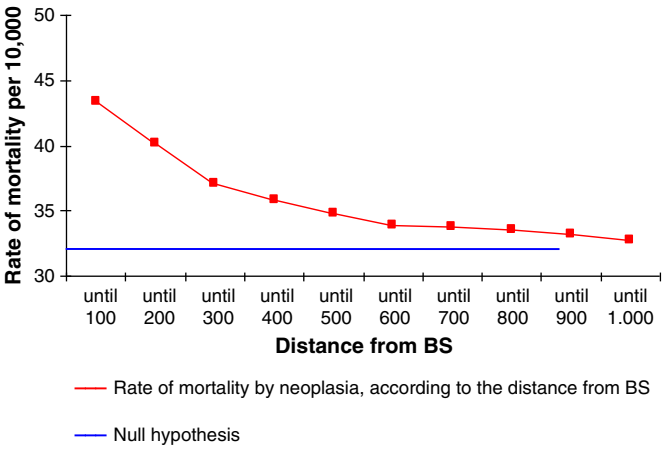


Fig. 15. Rate of mortality by neoplasia, according to the distance from the BS in Belo Horizonte municipality, from 1996 to 2006, and the null hypothesis.

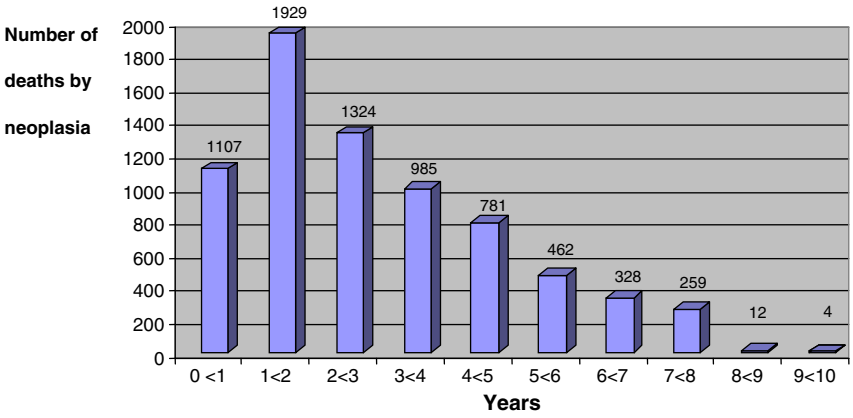


Fig. 16. Distribution of the number of deaths by neoplasia versus duration of exposure since the date that the first antenna in each analyzed CT came into operation.

governmental organizations. International researchers from several countries delivered talks on selected subjects.

Researchers, public health authorities, as well as authorities from the legislative, executive and judiciary governmental bodies from Brazil and other South American countries were also present.

Site: www.ufrgs.br/ppgee/rni.htm

After the event, the Porto Alegre Resolution was approved by the scientists from many countries and participants who have understood that the health protection, the well-being and the environment require the immediate adoption of the Precautionary Principle and some precautionary practices.

Site: http://www.icems.eu/docs/resolutions/Porto_Alegre_Resolution.pdf

5. Conclusion

This research showed the existence of a spatial correlation between cases of death by neoplasia and the locations of the BSs, in the Belo Horizonte municipality from 1996 to 2006.

The mortality rates and the relative risk were higher for the residents inside a radius of 500 m from the BS, compared to the average mortality rate of the entire city, and a decreased dose–response gradient was observed for residents who lived farther away from the BS. The major antenna concentration was located in the Central-Southern SD of the city, which also had the largest accumulated incidence (5.83/1000 inhabitants).

The measured values of the EMF, determined in 2008 and 2003, were substantially below the values allowed by the Brazilian federal law nr. 11934, May 5, 2009. Nevertheless, the values encountered in this study surpassed the limits of human exposure adopted by many other countries and cities in the world, including Italy (10 μW/cm^2); China (6.6 μW/cm^2); Switzerland (4.2 μW/cm^2); Paris, France (1 μW/cm^2); Salzburg, Austria (0.1 μW/cm^2); and Porto Alegre, Brazil (4.2 μW/cm^2).

New epidemiological studies must explore this issue with more timely and appropriate methodology to provide evidence that may confirm the relationship between risk and hazard at an individual level. Meanwhile, we strongly suggest the adoption of the Precautionary Principle until the limits of human exposure, as established in Brazilian Federal Law, can be re-evaluated.

Supplementary materials related to this article can be found online at doi:10.1016/j.scitotenv.2011.05.051.

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