Small area study of mortality among people living near multiple sources of air pollution

P Michelozzi, D Fusco, F Forastiere, C Ancona, V Dell’Orco, C A Perucci

Abstract

Objective—In the area of Malagrotta, a suburb of Rome (Italy), a large waste disposal site, a waste incinerator plant, and an oil refinery plant became operational in the early 1960s and have represented three major sources of air pollution. To evaluate the potential health risk due to airborne contamination around these point sources, a small area analysis of mortality was conducted. Cancer of the liver, larynx, lung, kidney, lymphatic, and haematopoietic systems were evaluated.

Methods—Sex and age specific mortality (1987–93) and population denominators (1991) were available for the census tracts of the metropolitan area of Rome. Standardised mortality ratios (SMRs) were computed separately for males and females in bands of increasing distance from the plants, up to a radius of 10 km. Stone's test for the decline in risk with distance was performed with increments in radius of 1 km; SMRs were also computed after adjusting for a four level index of socioeconomic status.

Results—No overall excess or decline in risk with distance was found for liver, lung, and lymphohaeematopoietic cancers in either sex. For laryngeal cancer, an increased but not significant risk was found at 0–3 km and at 3–8 km. A significant decline in mortality from laryngeal cancer was found among men (p<0.03); the trend remained after adjusting for the socioeconomic index (p=0.06).

Conclusions—The study showed no association between proximity to the industrial sites and mortality for most of the several conditions considered. However, mortality from laryngeal cancer declined with distance from the sources of pollution. This result is interesting, as previous findings of an increased risk of laryngeal cancer near incinerators have been controversial.


Keywords: environmental epidemiology; waste disposal; small area analysis
densely populated districts, as well as extensive outlying districts with low population density.

An evaluation of the pollution level was conducted in 1992. Several potentially toxic substances produced by waste collection, transportation, treatment, and incineration were identified. In the waste disposal site, the main environmental contaminant was biogas, a complex chemical mixture composed mainly of methane and carbon dioxide. Measurements of the emission from the municipal incinerator plant showed the presence of nitrogen oxides (NO\(_x\)), carbon monoxide (CO), sulphur dioxide (SO\(_2\)), hydrogen chloride, chlorinated dibenzo-p-dioxins, dibenzo furans, and several metals (lead, chromium, vanadium, and mercury). Measurements carried out near the oil refinery plant showed high concentrations of SO\(_2\), NO\(_x\), suspended particulates, CO, and other substances produced by waste collection, transportation, treatment, and incineration.

The source of data was the geographical information mortality system (GEOSIM) in which the geographical unit used is the census tract (the smallest area for which population data are available). The Municipality of Rome (2 775 000 inhabitants according to the 1991 census of the National Statistics Office) is subdivided into 6108 census tracts, with an average of 480 inhabitants each. For each resident (geographically defined by the centroid of the census tract of residence), demographic data, and underlying cause of death, coded according to the ninth revision of the international classification of diseases (ICD-9), are available. Population data by sex and 5-year age group for each census tract were derived from the national census of 1991.

Mortality data for the years 1987–93 were analysed, and the following cancer sites were considered: all cancers (ICD-9 140–339), liver (ICD-9 155), larynx (ICD-9 161), lung (ICD-9 162), kidney (ICD-9 189), all lymphatic and haematopoietic cancers (ICD-9 160–208), non-Hodgkin's lymphoma (ICD-9 200,202), Hodgkin's lymphoma (ICD-9 201), multiple myeloma (ICD-9 203), and leukaemia (ICD-9 204–208).

To allow for possible confounding due to socioeconomic status, a deprivation score was calculated for each census tract from 1991 census data on education, occupation, unemployment, number of family members, overcrowding, and ownership of dwellings. To calculate the score for each census tract, we used the sum of the first three factors from a factor analysis with varimax mean (SD) rotation on all standardised variables of 0 (1); each census tract was assigned, on the basis of the quartile of distribution of the score, to one of four decreasing socioeconomic levels. A strong association has been found between such socioeconomic levels and mortality from cancer in Rome.18

**STATISTICAL METHODS**

The area taken up by the plants covers 2 km\(^2\). A central point of the plant area was identified, and starting from this point, two sets of circles were defined: three concentric circles with radii of 3, 8, and 10 km for descriptive purposes, and 10 concentric circles with a radius increasing from 1 to 10 km to define nine bands (each band including all the census tracts the centroids of which were within the defined distance). For the 3 km circle and the outer bands (between 8 and 10 km, and between 8 and 10 km), the numbers of cases observed (O), the numbers expected (E), and the standardised mortality ratios (SMRs) were calculated. The SMRs adjusted for the four socioeconomic levels were also computed. Two tailed 95% confidence intervals (95% CIs) were calculated, assuming a Poisson distribution of observed cases.

For the nine bands observed and expected numbers and SMRs (unadjusted and adjusted for socioeconomic level) were computed to test

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**The results for the areas within 0 and 10 km for 165 074 males and 176 315 females in Rome 1987–93**

<table>
<thead>
<tr>
<th>Causes of death</th>
<th>0–3 km</th>
<th>3–8 km</th>
<th>8–10 km</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All causes</td>
<td>81</td>
<td>86</td>
<td>82</td>
</tr>
<tr>
<td>All cancers</td>
<td>30</td>
<td>92</td>
<td>88</td>
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<tr>
<td>Liver cancer</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laryngeal cancer</td>
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<td>293</td>
<td>236</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>11</td>
<td>101</td>
<td>95</td>
</tr>
<tr>
<td>Kidney cancer</td>
<td>2</td>
<td>254</td>
<td>276</td>
</tr>
<tr>
<td>Lymphatic and haematopoietic cancer</td>
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<td>122</td>
<td>120</td>
</tr>
<tr>
<td>Non-Hodgkin's lymphoma</td>
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<td>251</td>
</tr>
<tr>
<td>Hodgkin's lymphoma</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Multiple myeloma</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>1</td>
<td>84</td>
<td>82</td>
</tr>
<tr>
<td><strong>Females:</strong></td>
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<td>All causes</td>
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</tr>
<tr>
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<tr>
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<tr>
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<tr>
<td>Non-Hodgkin's lymphoma</td>
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<td>0</td>
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</tr>
<tr>
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<td>101</td>
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</tr>
<tr>
<td>Leukaemia</td>
<td>1</td>
<td>132</td>
<td>137</td>
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</table>

* With adjustment for socioeconomic level.
for decline in risk at different distances from the plants. We used the test first described by Stone and subsequently developed by Elliot et al (Stone’s conditional test), in which a decrease in the risk of disease with an increase in distance from the source of pollution is tested against a null hypothesis of uniformly distributed risk (assuming that the observed number of cases in each band has a Poisson distribution). The test, which is trend specific, assumes as a null hypothesis an SMR which is constant in each circle and equal to the SMR of the entire area under examination. The significance level was determined with Monte Carlo simulations.

Results

The area within a 10 km radius included a population of 341,389 inhabitants (165,074 males and 176,315 females) living in 748 census tracts. The table shows the results for the areas within 0–3 km, 3–8 km, and 8–10 km, separately for males and females. For each cause of death, we have listed the number of observed deaths during the period, the SMR (both with and without adjustment for socioeconomic level), and the 95% CIs. Within a 3 km radius (population 49,853), there were no significant excesses for all causes or for all cancers. The mortality in men for laryngeal cancer (SMR 293) and kidney cancer (SMR 254), and for non-Hodgkin’s lymphoma (SMR 262) were higher than expected, although not significantly. The 3–8 km and 8–10 km bands had a population of 86,738 and 249,666, respectively. Analysis of the SMRs showed no signifi-
cant excesses among males; among females, there was a significantly higher mortality in the 3–8 km band for cancer of the kidney (SMR 207) even after adjustment for socioeconomic level.

The results of Stone’s conditional test, for the analysis of mortality risk as a function of distance from the plants, are shown in the last two columns of the table (with and without adjustment for socioeconomic level). Among males, the test was significant only for laryngeal cancer, with a decline in risk as a function of distance (p value=0.03). After adjustment for socioeconomic level the p value for the Stone’s conditional test was 0.06. Among females, no significant decline in risk was found.

The figure shows the graphs of the cumulative observed and expected cases as a function of distance from the plants for some causes of death. The excess of male laryngeal cancer was present up to a distance of 8 km: 21 cases were found in this area, as opposed to 13.7 expected cases (SMR 1.53; 95% CI 95 to 233), whereas within a 10 km radius the SMR was <100. Kidney cancer among women was higher than expected through the area.

Discussion

The high level of public concern about environmental contamination and its adverse effects on health tends to increase the demand for investigations of health risks among the exposed population. The present report was specifically motivated by a suspected risk of cancer. A recently developed method of small area analysis, applied in the United Kingdom, was used for this issue in Malagrotta. The results of the study are reassuring in that they show no excess in cancer for the population living in the area considered. However, some concern remains for cancer of the larynx. Although in the study area the mortality for this tumour was not significantly higher than expected, the risk seems to decrease as distance from the plants increases, leading us to hypothesise a possible effect associated with the emissions. This result is interesting because studies conducted on populations living in the vicinity of plants similar to those in our area have in the past produced conflicting results.

We did not find variations in risk of cancer of the lymphatic and haematopoietic system to be a function of distance. However, in different areas around refinery complexes in Great Britain, a significant decline in risk with distance from the source was found.

A significantly higher mortality for cancer of the kidney was found in women, although no decrease in risk with distance was shown; some studies have found an excess of mortality for this type of cancer in two cohorts of refinery workers.

The method used is a useful tool for evaluating the risk of disease in populations living around point sources of environmental pollution when studying low incidence diseases or small exposed populations. In the study area the SMRs for total cancers and for laryngeal cancer among males were 98 and 54 in the highest socioeconomic level and 102 and 128 in the lowest respectively. Our system also makes it possible to control for socioeconomic status, which can be an important confounder in studies of small areas, as zones near industrial plants are generally socioeconomically disadvantaged areas.

Among the limitations of the study, the ecological nature of the exposure, the inaccuracy of death certificates, and the possibility of significances due to multiple testing should be considered. Also, mortality data are a poor proxy for cancer incidence for diseases with long survival—such as cancer of the larynx.

In conclusion, our study did not show any increase in mortality in the resident population for any of the selected causes. We found a decrease in mortality risk for laryngeal cancer as a function of distance from the sources of emission; these results are based on a limited number of cases, and further studies will be necessary to clarify whether the presence of refineries or waste incinerators does represent a risk factor for this disease in resident populations.

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