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

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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 lymphohaematopoietic 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 with distance 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.**

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The area of Malagrotta, a south west suburb of Rome (region of Lazio) has been the object of concern because of several sources of environmental contamination potentially affecting the resident communities. A large waste disposal site (one of the largest in Europe), a waste incinerator, and a petrochemical refinery began operation at the beginning of the 1960s. The incinerator was closed in 1985 because of failure to comply with pollution control standards. As a result of public concern and media reports, the regional government of Lazio asked us to perform epidemiological studies on the workers employed in the industrial settings[1] and on the nearby population.

Several hazardous substances are routinely emitted from waste incinerators and petrochemical plants, including particulates, hydrogen chloride, chlorinated dibenzo-p-dioxins and dibenzofurans, polycyclic aromatic hydrocarbons (PAHs), chlorinated benzene, chlorinated phenols, and phthalates.[2] Epidemiological data on the long term effects on populations living in the vicinity of these industrial installations are limited.[3–6] A small area study was conducted to evaluate the incidence of laryngeal and lung cancer near incinerators in 10 different areas of Great Britain.[3] The study produced no evidence of an increased risk of cancer in populations living within a 10 km radius of the plants, and there was no evidence of decreasing risk with distance from the sites. An earlier study, conducted at Charnox Richard (Coppull, Lancashire, UK), however, had shown a significant decrease in risk for laryngeal cancer as a function of distance from the incinerator.[4] A geographical study to investigate cancer incidence and mortality in a population living in the vicinity of a petrochemical plant in south Wales[5] showed an excess of mortality from all cancers and from laryngeal cancer in the population living within a 7.5 km radius of the plant, but there was no evidence of decline in incidence or mortality with distance; the same study reported a significant decline in mortality from non-Hodgkin's lymphoma as distance from the plant increased.The results from studies conducted in the vicinity of waste disposal sites are controversial.[6–10]

The aim of this study was to investigate the mortality risk in the area of Malagrotta with small area techniques to evaluate the trend of the risk relative to distance from the plants. Specifically, we decided to analyse those causes of death which, in previous studies, were found to be in excess or for which there were existing hypotheses about a possible association with the existing sources of pollution[11]: all cancers,[5 12] laryngeal cancer,[3 4] lung cancer,[10 12] liver cancer,[12] kidney cancer, and lymphatic and haematopoietic cancers.[5]

Population and methods

The study area was defined by a circle of 10 km radius around the plants. The area lies in the western outskirts of Rome and includes some

densely populated districts, as well as extensive outlying districts with low population density.

An evaluation of the pollution level was conducted in 1992.[13–15] 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, dibenzofurans, 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 organic and inorganic compounds; the high concentrations of these compounds were also due to the heavy traffic of tank lorries in the area.

The source of data was the geographical information mortality system (GEOSIM)[16] 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-9 200–208), 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.[17 18] 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).

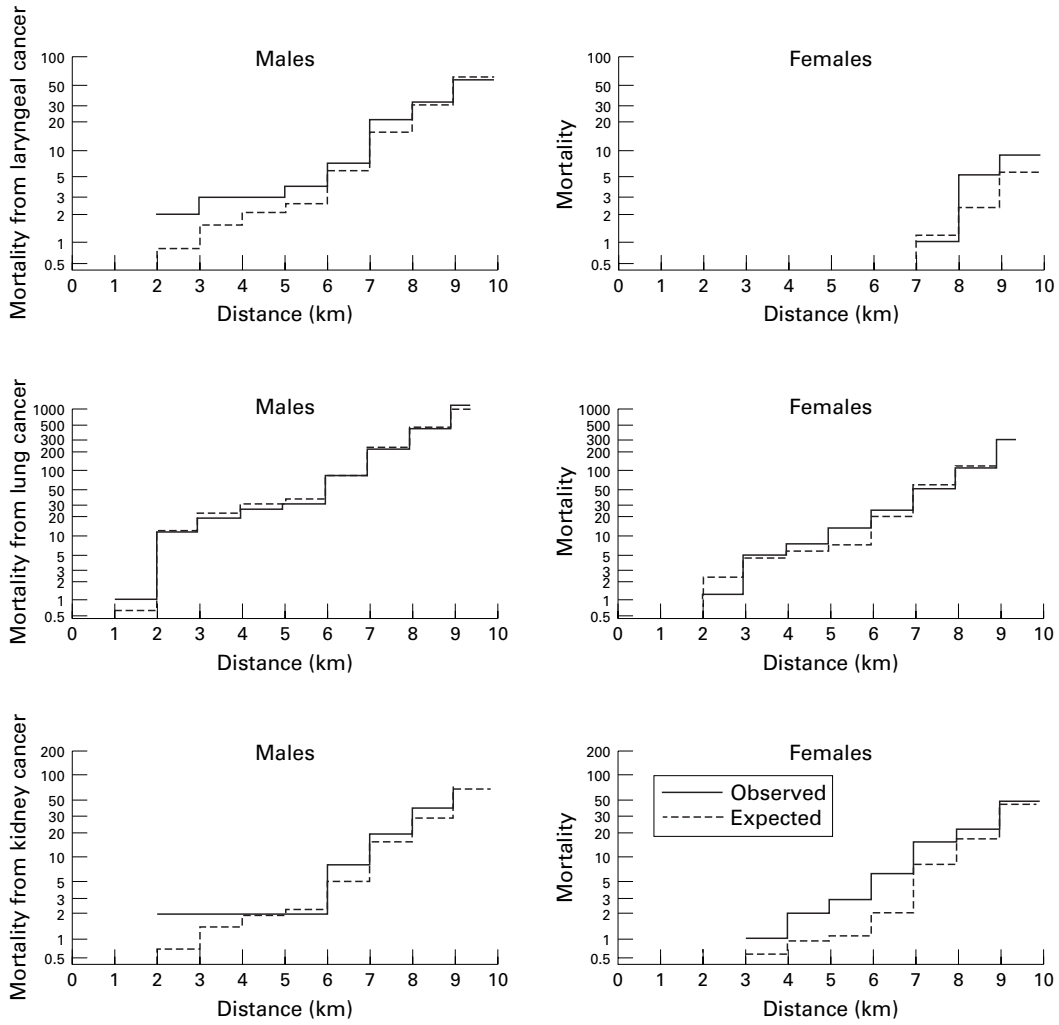
For the 3 km circle and the outer bands (between 3 and 8 km, and between 8 and 10 km), the numbers of cases observed (O), the numbers expected (E), and the standardised mortality ratios (SMRs) were calculated. The SMRs adjusted for the four socioeconomic levels were also computed. Two tailed 95% confidence 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

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

	0-3 km				*3-8 km*				*8-10 km*			
Causes of death	*O*	*SMR*	*SMR**	*95% CI**	*O*	*SMR*	*SMR**	*95% CI**	*O*	*SMR*	*SMR**	*95% CI**
Males:												
All causes	81	86	82	65–101	1759	95	92	88–96	6467	99	98	96–101
All cancers	30	92	88	60–126	590	94	91	84–99	2218	100	99	95–103
Liver cancer	0	0	0	—	26	70	69	45–101	129	97	95	80–113
Laryngeal cancer	2	293	236	27–800	19	146	133	80–206	34	74	72	50–100
Lung cancer	11	101	95	48–169	197	96	92	80–106	763	105	104	97–112
Kidney cancer	2	254	276	31–934	17	115	120	70–191	56	110	112	85–145
Lymphatic and haematopoietic cancer	3	122	120	24–337	42	91	89	64–120	150	94	95	80–111
Non-Hodgkin's lymphoma	2	262	251	29–851	12	85	83	43–143	50	102	102	76–135
Hodgkin's lymphoma	0	0	0	—	1	33	33	1–162	5	52	54	17–122
Multiple myeloma	0	0	0	—	4	60	64	17–158	23	95	99	63–148
Leukaemia	1	84	82	3–409	25	111	107	69–158	72	94	94	73–118
Females:												
All causes	56	91	90	68–117	1508	100	98	93–103	6083	102	102	100–105
All cancers	18	92	96	57–150	417	91	94	85–103	1730	101	103	98–108
Liver cancer	0	0	0	—	27	123	115	76–168	77	90	88	69–110
Laryngeal cancer	0	0	0	—	1	89	92	4–454	7	164	168	67–340
Lung cancer	1	49	55	2–271	40	83	90	64–122	189	105	108	93–124
Kidney cancer	0	0	0	—	15	207	198	111–325	31	113	111	76–158
Lymphatic and haematopoietic cancer	1	60	64	3–317	42	109	115	83–155	138	98	100	84–119
Non-Hodgkin's lymphoma	0	0	0	—	17	141	152	89–242	46	103	108	79–144
Hodgkin's lymphoma	0	0	0	—	1	48	50	2–250	7	100	101	40–204
Multiple myeloma	0	0	0	—	8	110	115	50–223	21	74	76	47–115
Leukaemia	1	132	137	5–679	16	95	98	56–158	64	105	106	82–135

* With adjustment for socioeconomic level.



Cumulative observed and expected cases as a function of distance from the plants for some causes of death.

for decline in risk at different distances from the plants. We used the test first described by Stone[19] and subsequently developed by Elliot *et al* (Stone's conditional test),[20] 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.

Table 1 (Continued)

0-10 km				*Stone's conditional test*	
O	*SMR*	*SMR**	*95% CI**	*p Value*	*p Value**
9307	98	97	95–99		
2838	98	97	94–101		
155	90	88	75–104	0.89	0.92
55	92	88	66–115	0.03	0.06
971	103	101	95–108	0.71	0.85
75	113	116	91–145	0.50	0.38
195	94	94	81–108	0.89	0.81
64	100	100	77–127	0.58	0.48
6	47	48	17–102		
27	87	91	60–131	0.66	0.75
98	98	97	79–118	0.65	0.76
7647	101	101	99–104		
2165	99	101	96–105		
104	96	93	76–113	0.38	0.62
8	147	151	65–293	0.33	0.44
230	100	104	91–118	0.33	0.36
46	132	129	94–172	0.15	0.27
181	100	103	89–119	0.27	0.27
63	110	116	90–149	0.16	0.18
8	87	88	38–172		
29	80	83	56–119	0.36	0.34
81	103	105	83–130	0.11	0.12

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 4985), there were no significant excesses for all causes or for all cancers. The mortality in men for laryngeal (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,[21] 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.[3 4]

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.[22]

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.[23 24]

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 analysed causes. We focused on the 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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