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ORIGINAL ARTICLE

Mortality analysis by neighbourhood in a city with high levels of industrial air pollution

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Abstract
Objectives Taranto, a city in south-eastern Italy, suffers serious environmental pollution from industrial sources. A previous cohort analysis found mortality excesses among neighbourhoods closest to industrial areas. Aim of this study was to investigate whether mortality also increased in other neighbourhoods compared to Apulia region.
Methods Standardized mortality ratios were computed. Number of deaths and of person-years at risk by neighbourhood came from the previous cohort study for 1998–2008 period. Reference population was Apulia region excluding Taranto province. A meta-analysis was conducted across less close neighbourhoods computing summary SMR estimates and evaluating heterogeneity.
Results For the entire city higher mortality values are confirmed for all causes, all malignant neoplasms and several specific sites, neurological, cardiac, respiratory and digestive diseases. High mortality values are not confined to neighbourhoods closest to industrial areas for lung cancer, cardiac, respiratory and digestive diseases, in both sexes, and among women for all malignant neoplasms and pancreatic cancer.
Conclusions Increased mortality risks can also be observed in Taranto neighbourhoods not directly adjacent to industrial areas. Spatial trend, impact of socio-economic factors and duration of residence should be further explored.

Keywords Cohort mortality analysis · High risk area · Industrial air pollution · Taranto

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Introduction

In 2012, the city of Taranto leaped to the headlines of the Italian and European media as one of the most polluted cities in Italy and Europe. Taranto is located in south-eastern Italy in the Apulia region and has a peculiar geo-spatial conformation (Fig. 1), with a population of about 200,000 inhabitants living in an area created by natural harbors: the inner "small sea", including two lagoons, and the external "large sea" a bay enclosed by two small islands.

In the 1990s the area was formally decreed by the Italian Ministry of Environment to be as an "area at high risk of environmental crisis", and later included among the 14 sites in the national interest requiring remediation, due to the massive presence since the early 1960s of industrial sites with environmentally impacting activities, including

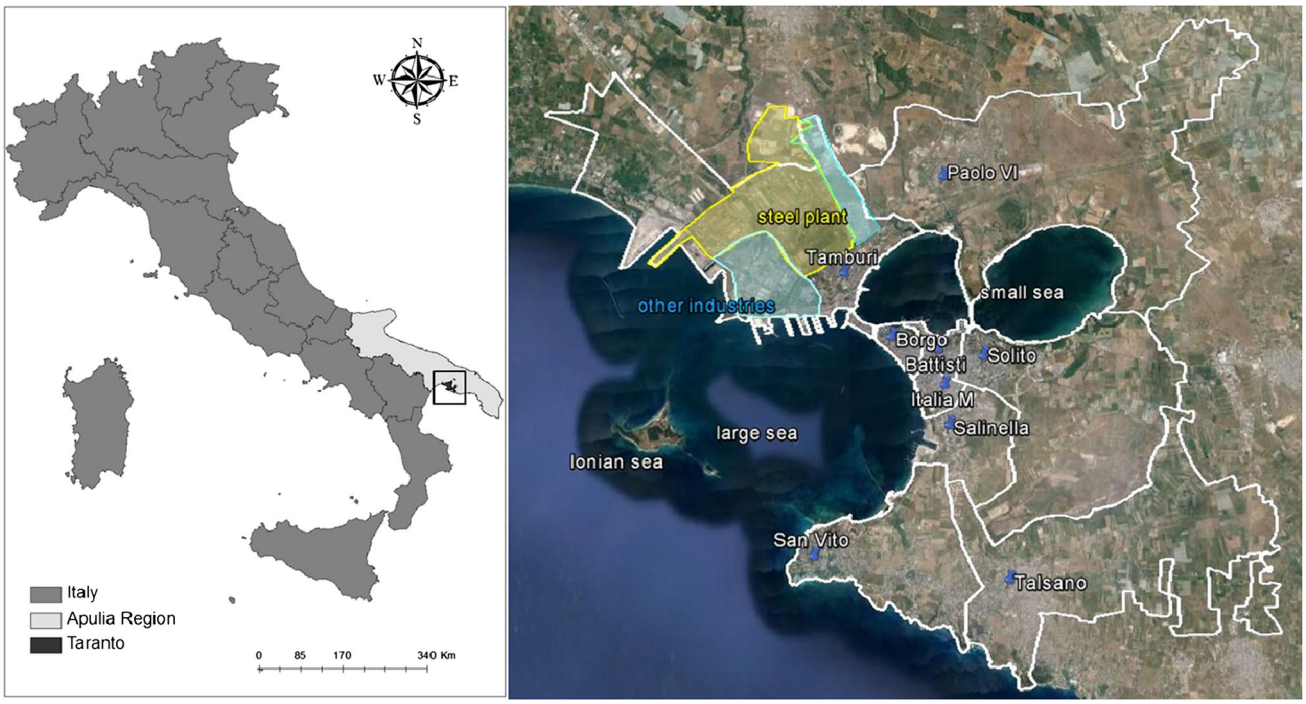

Fig. 1 Taranto city, Italy: neighbourhoods and main plants in the industrial area

steel production (one of the largest plants in Europe), mineral deposits, oil refining, cement production, fuel storage, power production, waste material management, mining industry, military plants and the harbor.

Further environmentally impacting activities are more deeply integrated in the urban area and are related to the presence of a large cargo port supporting industrial and commercial activities. Emissions data were first reported for 2005, when the inventory of emissions was carried out by the Apulia Regional Protection Agency (ARPA 2005).

In the late 1960s the Paolo VI borough, on the northern side of the "small sea", was built mainly as a residential area of the steel plant's workers. The factory itself occupies an area twice that of the inner city area, with open-air mineral deposits contiguous to a residential neighbourhood called Tamburi. The 2004 report of the European Pollutant Emission Register, showing that 8.8 % of European dioxin emissions in the atmosphere were produced by this steel factory, (EPER 2004), had wide echoes in the population and since then protest has grown. Because of the enormous amount of other pollutant emissions as well (see Table 518 of Perizia Chimica della Procura di Taranto 2012), today, the problem has become a national issue since it is the largest steel company in Europe.

Since the late 1980s several epidemiological studies have shown high mortality risks in Taranto, for all causes, all cancers and in particular for lung, pleura, bladder, lympho-hematopoietic system and, respiratory disease and pneumonia (WHO-OMS 1997; Martuzzi et al. 2002; Mitis et al. 2005; Vigotti et al. 2007; Graziano et al. 2009; Martinelli et al. 2009).The National Institute of Health (ISS) conducted a study called SENTIERI analysing mortality risks among populations living near the "sites of national interest for environmental remediation" (SIN). The first analyses explored the period 1995–2002, and the more recent ones the years 2003–2009. Regional population was used as reference for indirect standardization (Pirastu et al. 2011; Comba et al. 2012).

In both periods a highly compromised situation was described regarding the health of residents in Taranto and Statte, a small surrounding municipality. Number of deaths in 2003–2009, adjusted for a socioeconomic indicator, significantly exceeded the expected in both sexes for mortality due to all causes, cancers, lung cancer, pleural mesothelioma, non-Hodgkin's lymphoma, cardiovascular disease and specifically hypertensive and ischemic heart disease, all respiratory and acute and chronic respiratory diseases, digestive diseases and cirrhosis, and among women traumatic pathologies (Comba et al. 2012).

All these studies, like those on acute health effects of air pollution (Berti et al. 2009; Martuzzi et al. 2006; Biggeri et al. 2002), identified industrial emissions as the main source of air pollution in Taranto.

In 2011 the Court of Taranto requested a survey to evaluate emissions from the steel plants and an epidemiological study to investigate on the health status of the

resident population (Perizia Chimica della Procura di Taranto 2012; Perizia Epidemiologica 2012). Results led the Taranto Court to order the seizure of many sectors of the steel plant.

The epidemiological study used current data on mortality and hospitalization and includes two studies, broken down by neighbourhood, a case crossover analysis on the acute effects of air pollution and a cohort study on the chronic ones.

In the latter study the cohort of residents from 1998, the first year of the local computerized vital status register, was followed-up until 2010. Demographic data were linked to registers of cause of death for the years 1998–2008, and of hospital admissions from 1998 to 2010.

Mortality and hospitalization risks were calculated by districts and socioeconomic position using Cox models. Recently published results (Mataloni et al. 2012), showed greater effects on the health of population residing in neighbourhoods closest to the industrial area (Paolo VI, Tamburi and Borgo), which are the most polluted, according to a dispersion model (Gariazzo et al. 2007). People living in these areas showed higher levels of mortality: major risks were observed for all malignant neoplasms, cancer of pancreas and lung, cardiac diseases (mainly ischemic), respiratory diseases (mainly acute), and digestive system diseases. Mortality risks were especially higher among residents of the Paolo VI neighbourhood. Mortality risks for all causes, cancers, and cardiovascular and respiratory diseases were found to be higher in lower socioeconomic groups.

Recently short-term health effects of air pollutants in terms of mortality and hospital admissions were confirmed (Scarinzi et al. 2013; Alessandrini et al. 2013) and the impact on mortality estimated (Baccini et al. 2013).

In summary, previous ecological studies have reported mortality excesses in Taranto compared to the external territory of Apulia region, while the cohort study of residents since 1998 found that inside the city mortality risks are higher in proximity of the industrial area.

The aim of this study was to investigate whether mortality excesses in Taranto, found in the previous cohort analyses, are confined to industrial neighbourhoods or whether increased mortality can also be observed in other neighbourhoods of Taranto.

Methods

Person-years at risk and number of deaths by residence neighbourhoods at the beginning of the follow-up are derived from the epidemiological study (Mataloni et al. 2012) requested by the court. In that study 321,356 people were enrolled in the cohort and individual follow-up for assessment of vital status at 31/12/2008 was performed using municipality data. The cohort was enrolled by linkages to different individual registries provided by the municipality: registry of address changes, emigration and vital status. Residential addresses at the beginning of the follow-up were geocoded through ARCGIS software. Causes of death were codified following the ICD.9 (International classification of diseases, version 9) by the Local Health Unit mortality register that is part of the Regional Mortality Register (RENCAM).

For the present study we used total number of deaths by cause and number of person-years at risk according to sex and neighbourhood by 5-year age classes for the whole period 1998–2008 and for three different calendar periods: 1998–2000, 2001–2004, and 2005–2008.

Mortality data for the Apulia region also came from RENCAM and refer to period 2000–2006. For each Apulia province the population data in the same years were provided by National Institute of Statistics (ISTAT: http://demo.istat.it/). Reference population was Apulia region excluding Taranto Province. Reference rates, computed for periods 2000, 2001–2004 and 2005–2006, and person the years at risk were utilized for calculating the expected number of deaths in each Taranto neighbourhood.

Causes of death are the same as in the paper by Mataloni et al. (2012), and are reported in Table S1 of supplemental material. Standardized mortality ratio (SMR%), and 95 % Confidence Limits, for each neighbourhood and for the whole city, have been computed for years 1998–2008 summing up the expected number for each period. SMR% are presented for the whole city and for neighbourhood nearest to industrial area, while for the six less close neighbourhoods, a meta-analysis was performed to calculate summary estimates for causes of death with at least three observed cases. Heterogeneity between neighbourhood was assessed using I^2 statistic and statistical significance of heterogeneity was analysed with the Q statistic. Analysis were conducted using STATA10 (2007) software.

Results

Cohort population

The resident populations in each neighbourhood at the beginning of follow-up are reported in Table 1 by sex and age distribution. Paolo VI and San Vito districts have fewer inhabitants, with a sex ratio over 1.0 and like Tamburi and Talsano a younger average age, while in Borgo, Battisti and Italia Montegranaro elderly people prevail.

Table 1 Population cohort, by neighbourhood, sex and age class distribution, Taranto, Italy. 1998–2008

Neighbourhoods	Males			Females			Males + females	
	0–34 %	65+ %	Total no.	0–34 %	65+ %	Total no.	Total no.	(%)
Tamburi	53.0	12.7	11,818	47.9	18.7	12,382	24,300	(10.8)
Borgo	46.1	16.6	13,281	37.9	26.1	15,327	28,708	(12.8)
Paolo VI	57.5	6.7	8,312	55.1	7.5	8,061	16,474	(7.3)
Battisti	45.3	17.4	13,935	40.0	24.2	15,426	29,462	(13.1)
Italia M	44.5	16.3	15,479	39.5	21.1	17,413	32,993	(14.7)
Solito	47.4	11.7	13,114	44.1	14.1	13,952	27,167	(12.1)
Salinella	48.7	10.1	11,237	45.1	13.3	11,764	23,100	(10.3)
San Vito	51.2	7.8	8,697	50.0	9.1	8,613	17,410	(7.8)
Talsano	53.0	8.2	12,742	51.4	10.5	12,863	25,705	(11.4)
All city	49.0	12.5	108,616	44.6	17.3	115,803	224,519	(100)

Mortality

Results in Fig. 2; Table 2, commented on below, were selected based on meta-analysis across less-exposed areas, choosing diseases with summary risk estimates significantly higher than the reference value. In Table 2 meta-analytic summary risk estimates for random effects have been reported, as they are more conservative and have wider confidence intervals, although homogeneity tests across the six districts were not significant, except for digestive diseases in males.

In supplemental material all results by each neighbourhood and for the whole city are reported from Table S2 to Table S6, while all summary estimates for fixed and random effects, statistics Q test for heterogeneity and p values are reported in Table S7. Mortality due to all causes in the whole city is about 4 % in excess with respect to the rest of region. Citizens living in Tamburi (the closest area to the steel factory) have more than 15 % risk of dying from all causes; the risk is lower but still greater than expected among residents in Borgo (10 %) but in Paolo VI area risk of dying is over 30 % among men and women. In the rest of the city total mortality levels do not differ from reference values.

Among cardiovascular diseases, mortality due to all cardiac diseases is high among men and women living in the entire city and shows the highest values among residents near the industrial area; moreover, risks are significantly higher than expected also in the rest of other districts: everywhere among men, and in almost all districts among women (Table S3–S4). In both sexes, and the whole city, mortality due to all respiratory pathologies and Chronic Obstructive Pulmonary Disease (COPD) is over 25 and 45 %. In both sexes and pathologies, mortality values are particularly high in Paolo VI, but also in Tamburi, Borgo and in the rest of districts.

Risks of death due to respiratory infections show different patterns: in both sexes values are significantly high in the whole city but only in Borgo district and in the rest of the city.

Mortality due to digestive system diseases is higher than in Apulia region in the whole city and in almost all districts among men and women. Male mortality shows significant heterogeneity across the six neighbourhoods. Mortality from neurological diseases was significantly increased in Taranto as whole, but among men only in Tamburi, while among women it was close to significantly increased in Tamburi and Paolo VI. In both sexes summary risk estimates across the rest of the city are in excess (especially in Battisti, Salinella and Italia Montegranaro as reported in Table S3–S4).

Mortality from all malignant neoplasms shows a 9 % excess in the whole city in both sexes. Conversely the mortality pattern differs by gender. Among men higher risks were found in Paolo VI (45 %), Tamburi (25 %), Borgo (10 %) and in the rest of city (+5 %) (especially in Salinella district as reported in Table S5).

Female mortality excesses are found only in Paolo VI (+35 %) and in the rest of neighbourhoods (+10 %): (in Battisti, Salinella and San Vito as reported in Table S6) Male lung cancer mortality is high in the whole city (+25 %) and everywhere except in San Vito (Table S5); the highest values are found in Paolo VI (+100 %) and Tamburi (+43 %). Similarly SMR% by pleural mesothelioma is over 500 % in males wherever resident. Female lung cancer mortality also exceeds the reference values in the city as a whole (+22 %), in Paolo district VI (+94 %) and across other districts (+22 %), mainly Italia-Montegranaro (Table S6).

In the city pancreatic cancer mortality is high only among women (+33 %) but excesses are significant only for residents in Borgo and in other neighbourhoods (mainly in Battisti and San Vito: as reported in Table S6).

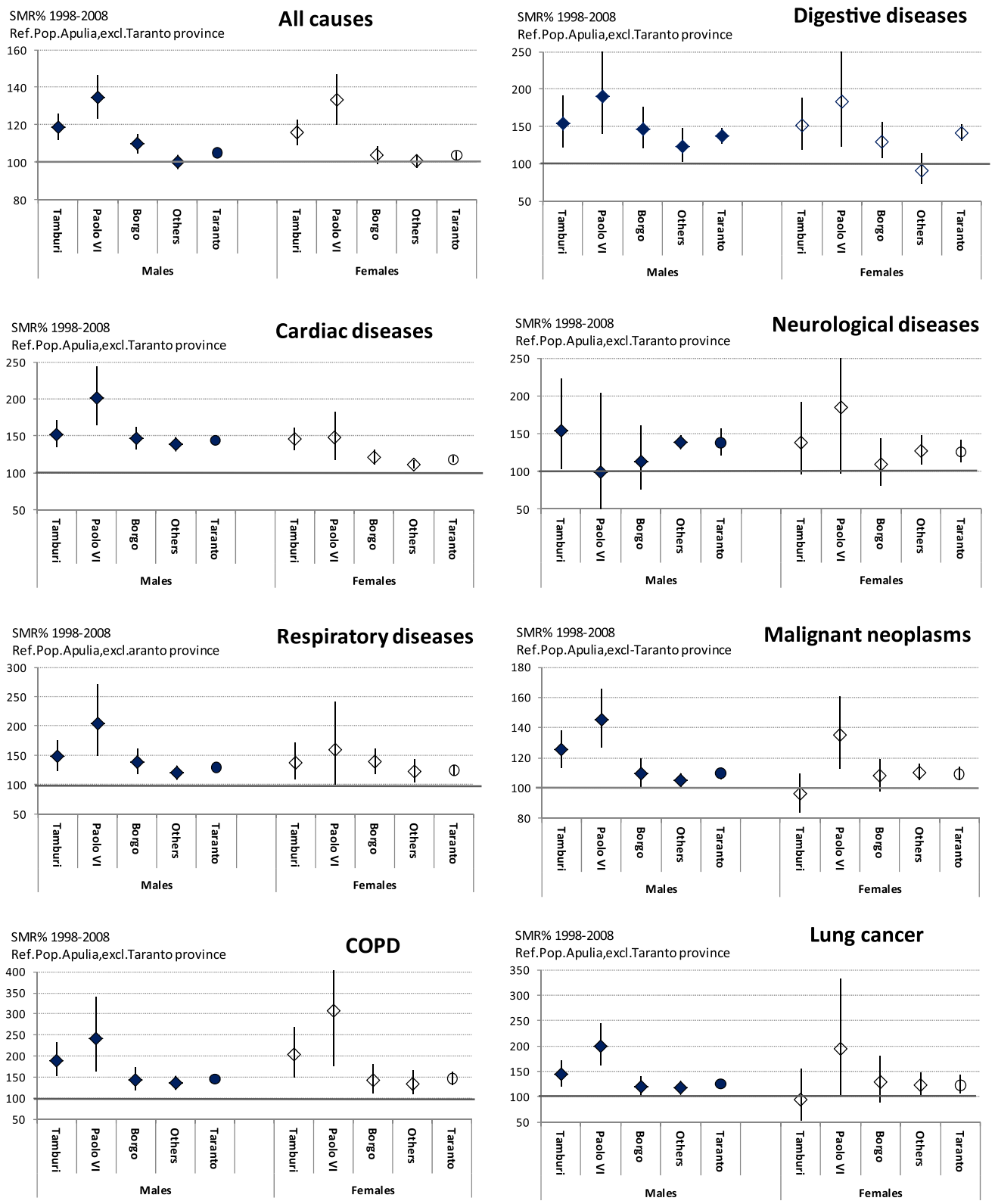

Fig. 2 SMR% for selected causes of death by sex and neighbourhood, Taranto, Italy; Ref. Pop. Apulia excluding Taranto province, 1998–2008

Table 2 The SMR% and 95 % CL by selected causes and sex, Taranto city, Italy, 1998–2008. Ref. Pop. Apulia region excluding Taranto Province

Cause of deaths	Sex	Taranto city		Neighbourhoods									
				Tamburi		Paolo VI		Borgo		Others[$]			
		SMR%	95 % CI	SMR%	95 % CI	SMR%	95 % CI	SMR%	95 % CI	SMR%	95 % CI	Heterogeneity test	
												Q	*p* value
All causes	M	105.2	103.1–107.3	118.8	112.2–125.6	134.5	123.5–146.2	109.9	104.7–115.3	100.1	97.7–102.6	4.76	0.446
Cardiac diseases	M	143.8	137.8–150.0	152.2	134.2–171.8	201.7	165.2–244.0	146.3	132.1–161.6	139.1	131.4–147.2	5.705	0.336
Respiratory diseases	M	129.7	121.6–138.2	148.2	123.0–176.9	204.3	150.6–270.8	139.0	119.2–161.0	121.0	111.5–131.4	2.998	0.700
COPD	M	146.1	135.0–158.0	189.2	152.7–231.7	241.3	165.0–340.6	144.3	118.6–174.0	136.2	121.2–152.9	6.247	0.283
Respiratory infections	M	121.5	106.1–138.6	95.6	58.4–147.7	186.3	93.0–333.3	153.1	113.6–201.8	116.9	98.3–139.0	4.374	0.497
Digestive diseases	M	136.9	126.8–147.5	154.2	122.4–191.6	189.6	139.3–252.1	146.2	120.2–176.0	122.9	102.7–147.1	16.06	0.007
Neurological diseases	M	138.0	120.8–157.0	154.1	102.4–222.7	99.0	39.8–204.0	112.5	75.9–160.7	145.0	123.6–170.1	1.978	0.852
Malignant neoplasms	M	109.8	106.1–113.5	125.5	113.5–138.5	145.1	126.7–165.5	109.8	100.5–119.8	105.0	100.7–109.5	4.07	0.539
Lung cancer	M	125.2	117.9–132.8	143.7	119.8–170.9	200.0	161.6–244.8	119.1	100.8–139.7	118.4	109.9–127.5	2.51	0.775
Pleura mesothelioma	M	597.9	491.9–720.1	653.7	337.7–1142	584.7	214.4–1272	604.3	345.6–981.2	6 17.6	470.4–810.8	6.23	0.285
Pancreatic cancer	M	100.0	83.3–119.2	152.4	91.8–238.0	177.3	91.6–309.7	72.8	38.8–124.5	93.6	74.1–118.1	1.78	0.878
All causes	F	103.8	101.8–105.9	115.9	109.5–122.6	133.3	120.4–147.1	103.8	99.3–108.3	100.7	97.2–104.4	9.20	0.101
Cardiac diseases	F	117.9	113.5–122.4	145.7	131.2–161.3	147.8	117.9–183.0	120.8	111.5–130.7	111.0	105.7–116.6	3.63	0.603
Respiratory diseases	F	124.3	115.1–134.1	137.2	109.2–170.4	159.5	100.0–241.5	139.2	118.9–161.9	116.2	105.0–128.5	4.12	0.532
COPD	F	147.4	131.6–164.5	203.9	150.8–269.5	307.5	175.9–499.4	142.9	111.2–180.9	134.1	108.6–165.8	8.75	0.120
Respiratory infections	F	121.7	107.3–137.5	89.7	55.6–137.2	76.0	20.7–194.4	145.0	113.0–183.1	122.3	104.1–143.6	2.71	0.745
Digestive diseases	F	141.2	130.6–152.4	151.4	119.5–189.2	183.2	122.7–263.1	129.4	107.1–154.9	141.8	128.7–156.3	4.984	0.418
Neurological diseases	F	126.0	111.8–141.4	138.1	96.2–192.1	184.7	98.3–315.8	109.3	81.2–144.2	127.1	109.5–147.5	1.48	0.916
Malignant neoplasms	F	109.4	105.1–113.9	96.4	84.3–109.8	135.2	112.6–160.9	108.3	98.4–119.0	110.3	105.1–115.9	4.79	0.442
Lung cancer	F	122.8	105.8–141.7	94.1	52.7–155.1	194.3	103.4–332.3	128.9	89.2–180.1	122.8	102.0–147.9	2.77	0.735
Pancreatic cancer	F	132.9	113.3–155.0	136.1	80.7–215.2	124.1	45.5–270.1	146.9	101.1–206.2	132.6	107.9–163.0	5.18	0.395
Trauma and poisoning	F	166.9	150.1–185.2	275.5	212.2–351.9	99.1	45.4–188.1	241.4	196.0–294.2	134.0	115.3–155.6	3.73	0.589

[$] SMR% and 95 % CI: meta-analytic results estimates for random effects

Finally women have higher risk of dying for traumatic causes either if they live in Tamburi and Paolo VI neighbourhoods or in the other ones.

Discussion

Results of this study for the whole city of Taranto are in line with those of previous ecological studies in both sexes: mortality rates are higher than the regional ones for all causes, malignant neoplasms and for respiratory and digestive diseases.

Results by neighbourhood confirm those already observed in the previous analyses (Mataloni et al. 2012) conducted using as internal reference population the city of Taranto and two small municipalities close to industrial plants, that are included in the Taranto area at high risk of environmental crisis as defined by the Italian Ministry of Environment in 1990. In that study highest risks have been observed in neighbourhoods closest to this area and that among these the Paolo VI shows the highest mortality values in both genders for nearly all pathologies. The latter was an unexpected result because the Tamburi district had always been considered the most at risk. Paolo VI neighbourhood was built in the 1960s to house steel plant workers but citizens from other districts, especially Tamburi and Borgo, would also have moved there over time. Population living in Paolo VI is still quite young (55–57 % under 34 years of age) and belong to low social class, like in Tamburi.

Socio-economic factors may affect mortality risk across districts but it was not possible adjust the estimates by this variable. However, Mataloni et al. (2012) described the spatial distribution inside the city of a deprivation index developed by Caranci et al. (2010) and based on 2001 national census variables on socioeconomic domains of education, unemployment, dwelling ownership and overcrowding. Over 65 % of residents in Paolo VI and Tamburi belong to the lowest level of the index, while in the farther district of San Vito 62 % of the residents are at the highest level (see Mataloni et al. 2012). This could partially explain the high mortality values among men due to occupational exposure and low socio-economic class but does not explain the high values among women.

A recent paper on the spatial variability of air pollutants in Taranto (Mangia et al. 2013) revealed that, depending on meteorological conditions, emission sources differently affect various areas of the city; the influence of the industrial site may be primarily identified with the SO_2 data series exhibiting higher mean values and positive correlations with wind speed when the monitoring station is downwind from the industrial site. Particularly the monitoring station located in Paolo VI recorded the highest SO_2 mean concentration values, which are one and a half times those found at the closest station to industrial site, in the Tamburi neighbourhood. These findings indicate that, due to meteorological conditions, Paolo VI suffers more air pollution than other neighbourhoods, and may justify the high mortality values found among women living in this area.

Moreover our results shows that mortality excesses are not confined to those areas.

These include mortality from respiratory pathologies (lung cancer, all respiratory diseases COPD and respiratory infections) and from digestive, neurological and cardiac diseases in both genders, and among women from all malignant neoplasms and pancreatic cancer.

In Taranto mortality due to respiratory disease a clear upward time trend is shown: it was below regional levels in the early 1970s (Vigotti et al. 2007) while now it is 24–30 % over the expected values. Occupational exposure and smoking habits may play a role in the onset of respiratory pathologies, also in women. Female unemployment is as high as anywhere else in the South and women are certainly not employed in the hazardous work of heavy industry. The 2003 the percentage of employed women 15–64 years of age was quite similar between Taranto Province (25.4 %) and the Apulia region (26.5 %) and it was much lower than in Italy (42.7 %) (Marini 2004).

Regarding females smoking habits data are available only at the national, regional and sub-regional level, but not for individual cities. The National Multipurpose Survey (ISTAT 2010a, b) reports that the percentage of smokers of Apulia (22.2 %) does not differ much from the national one (22.8 %). At the sub-regional level (ISTAT 2007) in the vast areas including Brindisi and Taranto provinces, smoking habit, in 2005, was not significantly different from that in the Apulia region. Percentage of female smokers in Brindisi and Taranto provinces was 10.4 % (95 % CI: 8.4–12.5) while the regional estimate was 10.0 % (95 % CI: 9.1–11.0). Among men, estimated smoking was 30.5 % (95 % CI: 26.9–34.1) and the regional one was 28.4 % (95 % CI: 26.7–30.0). In, absence of a more detailed breakdowns, data on smoking habits do not allow exclusion or confirmation of an increase in smokers in study areas, especially among women.

Occupational exposure and smoking habits are certainly important in male mortality from lung and pleura cancer and from COPD, which surpass the expected values all over the city. Since the beginning of the last century, Taranto, the most industrialized city in southern Italy, has an important military port with an arsenal that in the past employed many thousands of workers.

With respect to pleural mesothelioma, the Report of the National Registry of Mesothelioma (ReNaM) (De Zotti et al. 2010) cites as a peculiarity in the Apulia region a high

proportion of cases attributed to a non-professional exposure to asbestos; moreover, in a previous report, for the period 1988–1996, over 75 % (9 cases in 12) of female cases resident in Taranto were among housewives (Musti et al. 1997).

Mortality from digestive diseases should be deeper investigated; mortality from liver cirrhosis is common in the southern regions, especially among women as previous geographical studies have shown (Cislaghi 2005). Also among women mortality from all malignant neoplasms deserves further study through the cancer registry active in the past few years.

In our analyses we could not take into account the distribution of economic indicators that could certainly affect these trends in some of the districts. The map of socio-economic indicators reported in Mataloni et al. (2012), at census level, shows that some districts have a heterogeneous distribution of this indicator. Standardization by this index using the Apulia region may change results in some neighbourhoods, but it would not change the general pattern of a high level of mortality. Moreover, it would have been appropriate to take into account the duration of residence. However, as Mataloni et al. (2012) reports, about 81–85 % of cohort subjects did not change residence during the follow-up; it would be interesting to separate persons resident for longer periods in the same neighbourhood from those moving after shorter periods.

In conclusion, our results confirm that the levels of mortality in Taranto city are higher than in the rest of the Apulia region, and that these high values, especially for respiratory pathologies, are not always confined to the areas closest to industrial plants. The next step will be to investigate a spatial trend associated with levels of air pollutants estimated by a dispersion model, the impact of socio-economic factors and, possibly, the duration of residence.

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