

Cohort study of residents of a district with soil and groundwater industrial waste contamination

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Abstract

Introduction. A neighbourhood of the city of Ferrara (Italy) was built over an area polluted with chlorinated organic compounds. A residential cohort study was performed to assess the health profile of the population living in the polluted area.

Methods. The residential history of 3475 subjects who had lived in the East quadrant neighbourhood in the period 1994-2010 was constructed. Mortality for the period 1994-2010 and cancer incidence for the years 1994-2007 were studied. Standardised mortality ratios (SMR) for 2632 subjects and standardised incidence ratios (SIR) for 2578 subjects who had lived for at least 5 years in the area under study were calculated. Indicators were calculated for males and females combined, using the population of Ferrara as reference population.

Results: The health profile of the population of the East quadrant neighbourhood, defined using mortality indicators for major groups of causes, is essentially similar to that of the city of Ferrara. Increased mortality rates for lung cancer (SMR 131, 90% CI 94-178) and incidence rates for some cancer sites, including liver (SIR 135, 90% CI 67-243) were observed, albeit on the basis of few cases and with wide confidence intervals.

Discussion. The likelihood of observing significant increases in risk is reduced by the sizes of the cohorts and the short follow-up period, but some findings nonetheless suggest that, as a precautionary measure, the cohort study should be continued in parallel with measures for the reclamation of the site and that this study should take the form of epidemiological surveillance.

Key words

- cohort study
- mortality
- cancer incidence
- industrial waste

INTRODUCTION

The "East quadrant" area is a residential neighborhood of Ferrara in the Emilia-Romagna region of Italy. Between the 1940s and 1981 a brick kiln was active in the area and the quarrying of local clay for the kiln has left large, deep pits that are in contact with underground aquifers.

Parts of the disused pits are known to have been used between the 1950s and 1970s as dumps for urban waste and unquantifiable amounts of chlorinated pitches resulting from the chloromethane distillation process carried out in a plant operated by a local chemical complex are also present.

Studies conducted by the Ferrara municipal authorities revealed evidence of contamination with chlorinated organic compounds, some of them carcinogenic, that had

leaked into underground water tables and affected a wide surrounding area. Specifically, both the surface water tables and the first artesian aquifer are affected by the migration of plumes comprising mainly vinyl chloride [1].

Beginning in the 1950s, the area in proximity to that surrounding the kiln and relevant clay pits was gradually built over, a process of urbanization that continued in subsequent years (*Figure 1*). It is therefore possible that the residents have been exposed to harmful substances in their living environment, particularly on account of the passage of plumes, as mentioned above, beneath their homes.

Environmental monitoring programmes were developed in order to verify the possibility of both indoor and outdoor exposure: these envisaged the monitoring of 46 organic contaminants, including vinyl chloride [2]. A retrospective cohort study of the health of residents



Figure 1
Evolution over time of the urbanization of the "East quadrant" area. The location of a brick factory is shown in the picture of 1960.

was initiated in parallel with the monitoring programme applying a precautionary research approach [3]. In this case, the cohort study can provide a preliminary health profile of the potentially exposed population; at the same time, it constitutes the study base for a prospective epidemiological surveillance if regarded as appropriate. In this perspective, the findings of exposure assessment can contribute to defining the health outcomes of the epidemiological surveillance program [4].

There is only one case reported in the international literature of a site in which industrial waste was first abandoned and subsequently interred and where the health profile of the resident population was analysed through a residential cohort study [5, 6].

The present study aimed to describe the health profile of the population of the East quadrant through a retrospective cohort study, in order to assess the risk associated with local contamination.

METHODS

The area of the East quadrant neighborhood under study was defined on the basis of evidence of the presence in the groundwater of organohalogen compounds, particularly chlorinated ethenes and ethanes and vinyl chloride.

The resident population of the study area was identified by accessing electronic data relating to residents held in the municipal registry of Ferrara for the period 1994-2010. Mortality follow-up for the period 1994-2010 and cancer incidence follow-up for the period 1994-2007 were performed for all residents of the study area.

Follow-up of vital statistics was performed on the basis of data held in the death registry of the local health authority in Ferrara and, for subjects who had transferred to other municipalities in the Emilia-Romagna region, by searching through regional death registries. Deaths were identified by record linkage between cohort subjects and the mortality data bank, using dedicated software [7].

For cancer incidence, events were identified using record

linkage between cohort data and data relating to cancer incident cases of the Province of Ferrara Cancer Registry through the same software used for the mortality study.

The health profile of the resident population of the East quadrant was compiled using the method developed for the SENTIERI (Mortality study of residents in Italian polluted sites) study [8]. This involved the *a priori* selection of diseases on the basis of epidemiological evidence of the causal association between specific causes and residence in proximity to the following sources of pollution: chemical plants, petrochemical plants and refineries, landfills, incinerators. The latter source of contamination was included because the East quadrant area is close to an incinerator.

The contamination of the East quadrant contains a number of peculiar features that are not strictly ascribable to the scenarios usually associated with the above sources of contamination. Nonetheless, as historical data concerning exposure were lacking, it was decided to define the health profile on the basis of available evidence relating to the main sources of chemical pollution. The *a priori* causes of interest were: cancers of the stomach, colon, liver, lung and lymphatic system, non-Hodgkin lymphoma, diseases of the respiratory system, acute respiratory diseases (with a separate category for subjects under 14 years), asthma (with a separate category for subjects under 14 years), congenital malformations, perinatal morbidities.

"Primary liver" cancer as a cause of death was already included in the above criteria, but was also considered of interest on account of possible local exposure to vinyl chloride [9].

A period of 5 years of residence was considered as the minimum duration of "potential exposure" relevant to the studied health outcomes. Therefore, for data analysis, the cohort was limited to subjects who had resided in the study area for at least 5 years and only the events (*i.e.* death and cancer incidence) occurred after the 5th year of residence were accounted for.

The overall health status of the population of the East quadrant was defined using SMR (standardised mortality ratio) as the indicator for mortality and SIR (standardised incidence ratio) for cancer incidence. SMR and SIR were both calculated for males and females combined.

The control population chosen was that of the municipality of Ferrara. Reference rates for the control population were calculated separately by gender, age classes and five-year calendar periods. For the mortality study, the reference rates were based on local health authority databases, while for the cancer incidence study, reference rates were computed using data from the cancer registry of the province of Ferrara.

Statistical analysis was performed using "Stata" software [10].

RESULTS

The subjects who resided in the East quadrant area of Ferrara in the period 1994-2010 numbered 3475, of whom 2632 (1257 men and 1375 women) had resided there for a minimum of 5 years. Of these, 1229 men and 1349 women were studied for cancer incidence.

Table 1 shows the results of the mortality and cancer incidence analysis. The health profile of the East quadrant population, as defined by SMR and major groups of causes of death, is essentially better than that of the Ferrara district. Deaths due to cancers are similar to those found throughout the municipality as a whole.

With regard to causes of death defined as of *a priori* interest, cancers of the liver were comparable and just lit-

tle fewer than expected, the SMR for non-Hodgkin lymphomas was based on 4 observed cases compared with 3.4 expected, lung cancers were more numerous but not significantly higher than expected (SMR 131, 90% CI 94-178). The risk due to stomach cancers was based on 10 observed vs 7.6 expected cases. There were no deaths due to respiratory diseases in subjects less than 14 years, nor due to asthma either overall or in younger subjects, nor due to perinatal morbidities.

With regard to cancer incidence, the "all cancers" group shows slight and not statistically significant excess risk (SIR 109, CI 90% 97-124). Results regarding cancers of *a priori* interest were disparate and with confidence intervals including 100: cases for stomach, liver and lung cancers were in excess, while colorectal cancers and overall lymphohaematopoietic malignancies and non-Hodgkin lymphoma were fewer than expected.

DISCUSSION

With regard to mortality, lung cancers were the cause with the highest risk. These cancers belong to a group of multifactorial pathologies in which smoking is the greatest risk factor [11]. With regard to risks associated with environmental pollutants, there was no specific evidence of contamination of soil or water tables in the East quadrant area. However, the excess could be at least partly attributable to contamination of the air due to emissions from the brick kiln that operated nearby in the period between the end of the war and 1981; this

Table 1

Standardized mortality ratios (SMR) and standardized incidence ratios (SIR) for major groups of causes of death or cancer incidence, defined as of *a priori* interest in subjects resident in the East quadrant area of Ferrara (Italy) for at least 5 years between 1994 and 2010. Follow-up of vital statistics 1994-2010. Follow-up of cancer incidence 1994-2007. Males and females combined. Reference: mortality or cancer incidence rates of Ferrara municipality.

Cause	ICD IX	Observed deaths	Expected deaths	SMR x100	SMR CI 90%	ICD X	Observed cancers	Expected cancers	SIR x100	SIR CI 90%
All causes	0-999	293	361.6	81	73-89					
All cancers	140-239	119	121.3	98	84-114	C00-43,C45-96, All except C44	186	170	109	97-124
Stomach	151	10	7.6	132	72-224	C16	10	7.7	130	70-220
Colorectum	153-154	12	11.7	102	59-166	C18-21	25	27	93	64-129
Primary liver and cancer of intrahepatic biliary ducts	1550-1551	10	11.7	85	46-145	C22	8	5.9	135	67-243
Trachea, bronchi and lungs	162	30	22.9	131	94-178	C33-34	28	25.5	119	85-164
Malignant cancers of the lymphohaemato-poetic system	200-208	6	9.2	66	29-129	C81-C96	10	14.3	70	38-119
Non-Hodgkin lymphoma	200, 202	4	3.2	125	43-286	C82-85,C96	6	6.7	90	39-178
Cardiocirculatory diseases	390-459	115	137.7	83	71-98					
Respiratory tract diseases	460-519	10	20.1	50	27-84					
Acute respiratory diseases	460-466, 480-487	5	8.8	57	22-119					
Digestive tract diseases	520-579	12	15.9	75	43-122					
Genito-urinary tract diseases	580-629	<3	-	-	-					

old-style oil-fired plant probably emitted considerable quantities of dust into the immediate vicinity.

A comparison of the data for mortality and incidence by type of cancer shows only discrepancies in overall cancers and those of the liver and lungs, most likely due to the registration bias in lung and liver mortality data, as known from the literature [12]. Furthermore, when comparing observed mortality and the cancer incidence it should be borne in mind that the latter have an advantage on account that incidence rates are more informative than mortality rates, as incidence is not affected by factors that affect survival, such as the timeliness of diagnosis, appropriateness of therapy and access to centres of excellence for diagnosis and treatment.

As the cohort is of limited size and follow-up is limited to a maximum of 17 years for mortality and to 14 for incidence, the indicators are of low resolution power as a consequence risk estimates are mostly imprecise.

A recent WHO report on polluted sites underlined the importance of identifying the health profile of populations and prospective epidemiological surveillance as objectives for epidemiological research [13]. In this regard the information basis developed with a retrospective cohort study can become the point of departure for epidemiological surveillance to be implemented in parallel with measures for environmental reclamation.

CONCLUSIONS

The health profile of residents of the East quadrant area, as defined on the basis of cancer incidence and mortality due to causes *a priori* attributable to main sources of chemical exposure as proposed in the SENTIERI approach [8], showed no particularly relevant risk. Furthermore, the results of the environmental air monitoring campaign and the health risk assessment based thereon did not show any excess of risk attributable to exposure to the organic contaminants identified in the surface water tables [14]. However, considering a precautionary approach, the environmental monitoring should proceed together with the epidemiological surveillance. The latter should be developed periodically updating the residential cohort study and selecting the outcomes on the basis of results from exposure assessments.

Conflict of interest statement

The Authors declare no potential conflict of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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