A follow-up of cancer incidence among former Finnish dump site residents: 1999–2011

Eero Pukkala

Finnish Cancer Registry, Institute for Statistical and Epidemiological Cancer Research, Helsinki, Finland and School of Health Sciences, University of Tampere, Tampere, Finland

Background: In an analysis of the years 1976–1998, a 50% excess in cancer incidence was observed among residents in twelve blockhouses in Helsinki, Finland on a former dump area containing industrial and household waste.
Objective: To assess cancer risk over a 13-year period 1999–2011 among residents formerly living in houses built on a dump area.
Methods: All 1879 persons who ever lived in the former dump area were identified and the number of cancer cases in this population was obtained from the Finnish Cancer Registry.
Results: After 5 years of residence at the dump site, the standardized incidence ratio of cancer (all sites combined) was 1.32 (95% CI: 0.94–1.79) in men and 0.53 (95% CI: 0.33–0.82) for women, in comparison with the general Helsinki population (1999–2011). No significant excess cancer risks were found.
Conclusions: Residing on a former dump area was not found to result in an increased risk of cancer.

Keywords: Cancer, Dump toxins, Finland

Introduction

In the late 1970s, 12 blockhouses and a daycare center were built on a former dump area actively used between 1954–1962 for industrial and household wastes in Helsinki, Finland. Before the houses were built, the area was covered with a layer of soil between one and several meters thick. In 1998, a depression with clear-colored waste and a bad smell was discovered and residents became worried about possible adverse health effects.

Soil samples studied during 1998–1999[1] revealed high concentrations of polynuclear aromatic hydrocarbons (maximum concentration: 3300 $\mu g/m^3$), polychlorinated biphenyls (maximum concentration: 27.7 mg/m^3), oils (maximum concentration: 26 000 mg/m^3), cyanide, and heavy metals (zinc, lead, copper). Volatile organic compounds (VOCs), hydrogen sulfide, and polynuclear aromatic hydrocarbons (PAHs) were high in interstitial soil gas samples, and iron was elevated in ground water samples. High VOC concentrations were not detected in indoor air samples collected in the winter from 38 apartments, when concentrations are the highest due to the freezing of the soil around, but not under, the houses.

By the end of 1998, 88 cancer cases were diagnosed in the residents of the former dump area houses, compared to the expected number of 76.1, based on the incidence rates among all inhabitants of Helsinki.[2] The excess cases were entirely attributable to males and to follow-up >5 years after moving into the former dump area [standardized incidence ratio (SIR) in this category: 1.6; 95% confidence interval (CI): 1.1–2.2] and they were distributed evenly over primary sites. The relative risk of cancer between the dump area and reference houses was 1.6 in men (95% CI: 1.0–2.7) and 1.4 in women (95% CI: 0.9–2.2).

For various health and economic reasons, in 1999, the Helsinki City Council decided to demolish the houses. The City bought the privately owned flats and arranged new flats for tenants. The houses were destroyed between 1999 and 2004. Most of the residents moved from the area before 2000.

For this study, the same cohort of people who lived in the former dump area houses were followed from 1999 to 2011. Following feedback from the first publication,[2] we created a larger reference cohort and made an attempt to classify the flats in the former dump area into categories based on assumed exposure level.

Methods

We used the Population Register of Finland to identify all persons that lived in houses built directly on top of the landfill site. We excluded 137 people living in flats that located outside, but near, the dump

Correspondence to: E. Pukkala, Finnish Cancer Registry, Institute for Statistical and Epidemiological Cancer Research, Pieni Roobertinkatu 9, FI-00130, Helsinki, Finland. Email: eero.pukkala@cancer.fi

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area. The exposed cohort was divided into (1) those who owned their flats and hypothesized to have a better of socio-economic position compared to non-owners (166 persons); (2) those who lived on the ground floor directly above the polluted soil, assumed to have the highest exposure (37 persons); and (3) those who lived in rented flats on upper floors (1976 persons).

A reference cohort (N=24 530) living in three nearby areas outside the former dump site was identified from the Population Register. The proportion of the reference population living in rented and privately owned flats and the ages of buildings were roughly similar to those in the dump area. The original reference cohort from the Kontula suburb used in the first analyses[2] was small ($n=\sim 2000$). Therefore, for this study, we extended the control group by more than 10-fold by adding reference houses from the suburbs of Itäkeskus and Tapulikaupunki. People who belonged to more than one sub-cohort were excluded from analyses. In addition to residential histories, the Population Register Center provided dates of emigration or death for everyone in the cohorts.

The cohorts were followed for cancer cases using the population-based countrywide Finnish Cancer Registry that provides a unique personal identity code for Finnish residents. Follow-up for cancer diagnosis started at the date of the move to a former dump area house or reference house, or on 1 January 1976, whichever was later, and ended at emigration, death, or on 31 December 2011, whichever occurred first.

We calculated the expected total and specific cancer cases by multiplying the number of person-years in each 5-year age group by the corresponding average cancer incidence in Helsinki (0.6 million inhabitants) during the period of observation. To calculate the SIR, we divided the observed number of cases by the expected number. The 95% CI for the SIR were based on the assumption that the number of observed cases followed a Poisson distribution.

Results were stratified based on time elapsed since moving to the former dump area or reference house. To observe the possible increase of cancer incidence with increasing duration of exposure, we also calculated SIRs according to the duration of residence, with follow-up starting at the date the person had been living in the area for the duration required.

Results

The total numbers of people in the exposed dump area and reference area cohorts were 1879 and 24 530, respectively (Table 1), of which 940 and 7008 (respectively) lived in the area for more than 5 years. The mean length of follow-up was 24.9 years in the exposed dump area and 22.1 years in the reference cohort. One hundred and seventy-two cases of cancer were observed in the residents of flats above the Myllypuro dumpsite study group and 1491 cases among residents in the reference houses (Table 1). The SIRs were 1.01 and 1.02, respectively.

The results from the analyses restricted to only cohort members who had been living in the same area for at least 5 years of residence were similar (Table 1). There were 520 persons living in the exposed flats for at least 10 years. They had 62 cancers diagnosed after 10 years of residence (SIR: 1.04; 95% CI: 0.80–1.33). The actual number of cancer cases diagnosed within 5 years of moving into the former dump area was 17 *versus* the expected 18.3 cases (SIR: 0.93; 95% CI: 0.54–1.49). The respective numbers for the reference houses were 155 and 152.14 (SIR: 1.02; 95% CI: 0.86–1.18). Since it is not biologically plausible that any effect of the dump toxins resulted within 5 years of moving into the exposed flats, we excluded the first 5 years of follow-up

Table 1 Observed (Obs) and expected (Exp) numbers of cancer cases and SIRs with 95% confidence intervals (CIs) among persons living in dump area and reference area, 1976–2011, classified according to the type of flat and duration of residence*

Area	Duration of residence									
	>0 years					≥5 years				
Type of flat	Persons	Obs	Exp	SIR	95% CI	Persons	Obs	Exp	SIR	95% CI
Myllypuro houses, dump site	1879	172	170.2	1.01	0.87–1.16	940	102	104.4	0.98	0.80–1.17
Ground floor rented	37	4	4.5	0.89	0.24–2.29	26	2	3.7	0.55	0.07–1.97
Upper floor rented	1676	154	141.9	1.09	0.92–1.26	805	87	82.1	1.06	0.85–1.30
Self-owned flat	166	14	23.9	**0.59**	**0.32–0.98**	109	13	18.7	0.70	0.37–1.19
Myllypuro houses, outside the dump site	137	19	11.1	**1.72**	**1.03–2.67**	69	15	7.1	**2.10**	**1.18–3.47**
Myllypuro houses, total	2016	191	181.3	1.05	0.91–1.21	1009	117	111.5	1.05	0.87–1.25
Reference houses	24 530	1492	1467.7	1.02	0.96–1.06		758	704.3	1.08	1.00–1.15
Kontula (original reference)	2043	217	234.6	0.92	0.81–1.05	1105	154	161.3	0.95	0.81–1.11
Itäkeskus/Tapulikaupunki (extended reference)	22 487	1275	1233.1	1.03	0.98–1.09	5903	604	543.0	**1.11**	**1.03–1.20**

Note: *The follow-up among residents begins immediately after moving into the area (left panel) or after having been living there for 5 years (right panel). The follow-up ends at death or on 31 December 2011, whichever was first.

from the site-specific results presented in Table 2. The overall cancer incidence in the dump area houses for the follow-up period 1976–1998 is reported in the earlier article[2] and was similar to the average incidence of cancer in Helsinki. However, the SIR for men was significantly increased. Of the approximately 20 excess cases among men in 1976–1998, nine were in the gastrointestinal tract (SIR: 1.65; 95% CI: 1.03–2.49) and eight in the lungs (SIR: 1.89; 95% CI; 1.10–3.02). There were no cancer types with significantly increased cancer incidence in 1976–1998 for women.

For the period 1999–2011, the SIRs were similar to 1976–1998 (Table 2). However, the overall cancer incidence for women who lived in former dump area houses was significantly decreased (SIR: 0.53; 95% CI: 0.33–0.82). In the exposed population, there were no cases of cancers in female genital organs (compared to the expected 4.1 cases, 95% CI: 0.00–0.91), and there were four fewer cases of breast cancer than expected.

The lung cancer incidence among people who lived in the former dump area houses was almost 60% higher than the average in Helsinki for both time periods. The combined SIR in the follow-up category 5 years since moving to the area (Table 2) was 1.59 (95% CI: 1.10–2.24). However, the lung cancer incidence was also increased in the reference houses, and the ratio of the SIRs of the exposed houses and reference houses was only 1.18 (95% CI: 0.78–1.73), which was not significantly different.

The incidence of cancer among the 137 persons who lived in flats in the Myllypuro houses located outside the former dump area and excluded from the exposed cohort was increased (SIR: 1.72; 95% CI: 1.03–2.67; Table 1). There was a significant excess of myeloma (two cases; SIR: 10.9; 95% CI: 2.03–60.7) and non-significant SIRs based on 1.5–1.8 excess cases also in lung cancer, skin melanoma, and brain cancer. The overall cancer risk increased further for people living in these flats for more than 5 years (15 cases; SIR: 2.10; 95% CI: 1.18–3.47). The inclusion of this population to the exposed cohort would increase the overall cancer SIR to 1.05 (Table 1).

Discussion

During the last three decades, several epidemiological studies were published concerning the association between the incidence of cancer and residence near

Table 2 Observed (Obs) and expected (Exp) numbers of cancer cases and SIRs with 95% confidence intervals (CIs) among persons who had lived at least 5 years in dump area and reference area*

Cancer site	Dump site area (1730 persons)								Reference area (23 776 persons)			
	1976–1998				1999–2011				1976–2011			
Sex	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI
All sites	155	151.96	1.02	0.87–1.18	60	67.78	0.89	0.68–1.13	1336	1315.54	1.02	0.96–1.07
Males	85	65.31	**1.30**	**1.04–1.60**	*40*	30.38	1.32	0.94–1.79	586	558.58	1.05	0.97–1.13
Females	70	86.65	0.81	0.63–1.02	20	37.40	**0.53**	**0.33–0.82**	750	756.96	0.99	0.92–1.06
Gastrointestinal organs	37	27.55	1.34	0.95–1.85	16	11.83	1.35	0.77–2.19	289	248.55	**1.16**	**1.03–1.30**
Stomach	4	3.84	1.04	0.28–2.66	1	1.24	0.81	0.02–4.49	40	31.02	1.29	0.92–1.75
Colon	9	7.73	1.16	0.53–2.20	5	3.43	1.46	0.47–3.39	64	62.28	1.03	0.79–1.31
Rectum	8	4.92	1.63	0.70–3.20	4	2.13	1.87	0.51–4.79	45	40.93	1.10	0.80–1.47
Liver	3	2.43	1.23	0.25–3.60	1	1.20	0.83	0.02–4.62	8	11.18	0.72	0.31–1.40
Gallbladder	2	1.09	1.84	0.22–6.63	1	0.37	2.68	0.07–14.9	12	8.07	1.49	0.77–2.59
Pancreas	8	5.26	1.52	0.66–2.99	3	2.33	1.29	0.27–3.76	49	40.53	1.21	0.89–1.59
Lung, bronchus	23	14.57	**1.58**	**1.00–2.36**	10	6.15	1.63	0.78–2.99	152	112.64	**1.35**	**1.14–1.57**
Breast	26	32.12	0.81	0.53–1.18	10	14.51	0.69	0.33–1.26	261	295.70	**0.88**	**0.78–0.99**
Female genital organs	9	10.51	0.86	0.39–1.62	…	4.05	**0.00**	**0.00–0.91**	42	39.57	1.06	0.77–1.43
Cervix uteri	2	1.42	1.15	0.14–4.16	…	0.43	0.00	0.00–8.64	24	14.70	**1.63**	**1.05–2.42**
Corpus uteri	2	4.80	0.42	0.05–1.50	…	1.94	0.00	0.00–1.90	41	37.57	1.09	0.78–1.48
Ovary	3	3.69	0.81	0.17–2.37	…	1.20	0.00	0.00–3.06	29	28.11	1.03	0.69–1.48
Prostate	13	17.61	0.74	0.39–1.26	6	9.14	0.66	0.24–1.42	123	140.45	0.88	0.73–1.03
Kidney	8	4.39	1.82	0.79–3.58	2	1.77	1.13	0.14–4.07	35	36.46	0.96	0.67–1.33
Urinary bladder	2	4.17	0.48	0.06–1.73	…	1.86	0.00	0.00–1.98	34	33.22	1.02	0.71–1.43
Skin melanoma	2	5.79	0.35	0.04–1.24	…	3.09	0.00	0.00–1.19	46	58.87	0.78	0.57–1.04
Skin, squamous cell carcinoma	3	3.48	0.86	0.18–2.52	1	1.91	0.52	0.01–2.91	33	27.53	1.20	0.83–1.68
Brain, nervous system	7	6.77	1.03	0.42–2.13	3	2.87	1.04	0.22–3.05	58	68.44	0.85	0.64–1.09
Thyroid gland	3	2.45	1.22	0.25–3.57	1	0.92	1.09	0.03–6.08	21	26.71	0.79	0.49–1.20
Non-Hodgkin lymphoma	5	5.86	0.85	0.28–1.99	2	2.61	0.77	0.09–2.77	68	52.38	**1.30**	**1.01–1.64**
Myeloma	2	1.62	1.23	0.15–4.45	1	0.70	1.43	0.04–7.98	13	12.81	1.02	0.54–1.73
Leukemia	1	2.84	0.35	0.01–1.96	1	1.15	0.87	0.02–4.85	23	25.07	0.92	0.58–1.37
Not included above:												
Skin, basal cell carcinoma	34	37.40	0.91	0.63–1.27	22	19.17	1.15	0.72–1.73	231	317.08	**0.73**	**0.64–0.82**

Note: *The follow-up begins 5 years after moving to the area and ends at death or on 31 December 2011 (whichever was first). For the dump site area, the follow-up is divided to the period 1976–1998 partly reported in earlier publication[2] and the update period 1999–2011.

former municipal or hazardous wastes dump sites. Some of these studies suggest that living near a dump site may increase the incidence of cancer[3–5] and others found no association.[6–11] This inconsistency has also been stated in three reviews about the health of populations living close to toxic waste sites from the 2000s.[12–14] It has been previously hypothesized that landfill exposures are associated with increased incidence of leukemia and cancers of the urinary tract, bladder, kidneys, liver, biliary ducts, brain, lungs, rectum, and stomach.

There are several factors that make studies of the association between dump exposure and cancer challenging. Knowledge about the significance of various chemicals and other exposures is insufficient and the quantification of past exposures often poor. Data for major potential confounders, such as smoking, were not available in this or previous studies.

However, we do have some information on exposure measured mainly in the late 1990s, indicating that environmental exposure levels were high. As previously reported,[1] soil samples contained high concentrations of PAHs, polychlorinated biphenyls, cyanides, and some heavy metals, exceeding the Finnish guidelines by more than 100-fold in several samples.[15] Polychlorinated dioxins or furans were not detected. In interstitial soil gas samples, the content of volatile organic compounds and hydrogen sulfide was high. In the ground water samples, pH values were high (6.5–7.7), as were electrical conductivity (31–260 mS/m), iron content (0.04–29 mg/l), and concentrations of PAHs (0.00064–0.052 mg/l). Some samples contained chlorinated and non-chlorinated aliphatic hydrocarbons and non-chlorinated monoaromatic hydrocarbons. These cross-sectional measurements do not necessarily correlate with long-time exposure histories of the persons who had been living in the area, and there is very little knowledge about the ways and to what extent the exposures metabolize from the soil to humans. In the previous publication on this exposed cohort,[2] we considered that the mixture of exposures might be carcinogenic and that a systemic cancer effect on the overall cancer incidence observed among the men might have been possible, although no significant excess risks could be confirmed for the *a priori* defined specific associations between the exposure agents and cancer types.

To our knowledge, our study is the first one investigating the risk of cancer among people living exactly on top of the former dump site and not in its surroundings as in earlier investigations. The *a priori* decision to exclude from the exposed cohort the 137 persons who lived in the flats marginally outside the exact former dump area may be questioned after having seen the result with seven to eight excess cases of cancer in this category. There are no data to demonstrate that exposure to the dump carcinogens would be lower in this group of persons.

The lack of individual level lifestyle factors could be partly overcome by creating a reference cohort of people living in a similar social environment to the exposed cohort and hence probably having similar diet, smoking habits, etc. Incidence of most cancers in the reference cohort was similar to the average of the entire population of Helsinki. However, the incidence of lung cancer and cervical cancer was significantly increased, typical for people in lower socioeconomic positions in Finland.[16] The lung cancer incidence among persons who lived in the former dump area houses was about 60% higher than the average in Helsinki, but less than 20% higher than in the reference houses, which is not a significant difference.

The reference cohort was selected based on their location in eastern Helsinki relatively near the landfill, living in flats built during the same time period as in the study group, and where the proportion of rented and owned flats was similar to that in the study area. The last criterion is important, because people living in rented flats are predominantly from lower social classes with a high rate of economically inactive persons, both of which are associated with cancer incidence rates differing from the average.[16,17] The only smoking information about people living on the dump site was obtained in 1999 from 336 adults in the context of voluntary medical investigations of residents: 55% of men and 35% of women were current or past smokers. The respective proportions in a random sample of the Helsinki population were 58% and 45%, according to the figures extracted from the unpublished database collected by the National Institute of Health for continuous follow-up of the health behavior among the Finnish population.[18] It is likely that the participants in the voluntary examinations were selected towards health conscious nonsmokers; thus, actual smoking in the former dump area may not have been lower than in Helsinki in general.

This study is based on high-quality data and therefore, not hampered by registration bias. The coverage of the Population Register of Finland, the source for our cohort selection, is extremely high and the follow-up for death and emigration is complete. Cancer registration in Finland is known to be more than 99% complete,[19] and the computerized record linkage procedure based on personal identity codes is precise.[20]

The overall cancer incidence among former residents of the dump area in the 2000s was lower than in the general population of Helsinki (and the reference population). The refined analysis of the cancer risk for the period 1976–1998 demonstrates smaller risk estimates than reported in the first paper.[2] The

modifications to this analysis (exclusion of residents living near, but not on, the dump site) resulted in a weaker observed association compared to the first paper. The finding of consistently elevated cancer incidence in men, but decreased incidence in women, who lived in the former dump area houses is puzzling. The main components of the excess in men were lung cancer and gastrointestinal cancer. It is possible that smoking may differ between the men and women living in the same households, but the gastrointestinal cancers are largely associated to dietary habits, which are likely similar in men and women living in the same families.[21]

Although exposure to harmful dump-borne agents disappeared in the early 2000s when the residents moved, the possible cancer-increasing effect of the past exposures should have been seen in the follow-up period 1999–2011, due to the long lag between exposure and a cancer diagnosis. Instead, the results from the extended follow-up found a decreased likelihood that exposures from the former dump area increased the risk of cancer in exposed residents.

Disclaimer Statements

Contributors The only author took care of study design, analyses, and writing.

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Conflicts of interest None.

Ethics approval No ethics approval is required for a register-based study in Finland.

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