Increased Incidence of Cancer and Asthma in Houses Built on a Former Dump Area

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Twelve blockhouses were built in Helsinki in the 1970s on a former dump area containing industrial and household waste. We investigated whether the exposure to landfill caused cancer or other chronic diseases in the inhabitants of these houses. From the Population Register, we identified 2,000 persons who had ever lived in houses built on the dump area and a similar reference cohort from similar houses elsewhere in Helsinki. We identified their cancer cases from the Cancer Registry, and the other chronic diseases eligible for free medication from the Finnish Social Insurance Institution. At the end of 1998, 88 cases of cancer had been diagnosed, whereas the expected number based on the incidence rates among all inhabitants of Helsinki was 76.1. The excess cases were entirely attributable to males and to follow-up ≥ 5 years after moving into the dump area [standardized incidence ratio (SIR) in this category, 1.61; 95% confidence interval (CI), 1.11–2.24], and they were distributed evenly over primary sites. The relative risk increased slightly with the number of years lived in the area. The relative risk of cancer between the dump area and reference houses was 1.50 (1.08–2.09), similar in both sexes. Of the other chronic diseases, the SIRs for asthma (1.63; CI, 1.27–2.07) and chronic pancreatitis (19.3; CI, 2.34–69.7) were significantly increased. The possibility of a causal association between dump exposure and incidence of cancer and asthma cannot be fully excluded. The Helsinki City Council decided to demolish the houses in the dump area, and most houses have already been destroyed. *Key words*: cancer, chronic diseases, cohort study, dump toxins, record linkage. *Environ Health Perspect* 109:1121–1125 (2001). [Online 22 October 2001]
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The Myllypuro blockhouse residential area was built in the 1970s in Helsinki, the capital city of Finland. The area had earlier been mostly forest, but 4.5 hectares had been used as a dump between 1954 and 1962. In 1975–1976, 12 blockhouses and a day care center were built on the former dump site. All these houses were rental properties owned by the City of Helsinki, except one private house. Over 2,000 inhabitants had been living in these houses.

Both household and industrial waste—e.g., from a gas manufacturing plant and a margarine factory—had been dumped in the area. Before the houses were built, the waste area was covered with only a layer of soil, which was one to several meters thick. In November 1998 a depression appeared in the yard of one of the blockhouses. When some soil was removed to find the cause of depression, waste with clear colors and a bad odor was discovered. The waste was subsequently identified as cyanides originating from the former gas manufacturing plant. This finding led to an extensive investigation of the area's soil, ground water, and indoor air samples. Clinical and epidemiologic studies were also performed to find possible adverse health effects among residents.

In this study, we aimed to assess the risk of cancer and chronic diseases among persons who lived in houses built on the dump area and to evaluate whether exposure to dump toxins could have increased these risks.

Materials and Methods

Cohort. We identified all persons who had been living in houses built on the landfill site (dump area) from the Population Register of Finland. From the same source we identified a comparison cohort of persons living in similar rented flats (reference houses) nearby but clearly outside the landfill site. We obtained full residential histories of these persons as well as data on possible emigration or death for every cohort member. Since 1 January 1967, all residents of Finland have a unique personal identification number that is used in all main registers in Finland.

Cancer. This cohort was followed up for cancer through the files of the population-based countrywide Finnish Cancer Registry, which has been operating since 1952, using the personal identification number as key. Follow-up for cancer started at the date of their move into the flat or on 1 January 1976, whichever was later, and ended at emigration, death, or on 31 December 1998, whichever occurred first. Eleven persons belonged to both subcohorts and were excluded from the analyses. We divided the cohort further according to the time elapsed since moving to the area. We calculated relative risks as a function of exposure time (categories < 2, 2–5, and 5+ years), with follow-up starting at the date when the person had been living the required time in the dump area.

We counted the numbers of observed cases and person-years at risk separately for three calendar periods (1976–1983, 1984–1990, and 1991–1998) by 5-year age groups. We calculated the expected numbers of cases for total cancer and for specific cancer types by multiplying the number of person-years in each age group by the corresponding average cancer incidence in Helsinki (0.5 million inhabitants) during the period of observation. As with the observed cases, we obtained the reference rates from the Finnish Cancer Registry. The specific cancer types selected *a priori* for analysis included cancer sites with known or suspected exceptional risk identified in earlier studies on similar exposures (*1–6*) as well as other common cancer types, to reflect the overall susceptibility to cancer among these persons. Because the residents were exposed to a mixture of numerous agents, no single target of potential risk could be named; even a systemic effect attributable to cancer at all sites was considered possible.

To calculate the standardized incidence ratio (SIR), we divided the observed number of cases by the expected number. The 95% confidence intervals (CI) for the SIR were based on the assumption that the number of observed cases followed a Poisson distribution.

Other chronic diseases. The incidence of chronic diseases among the inhabitants of dump area and reference houses was based on data from the registries of the Finnish Social Insurance Institution (FSII), which according to the Finnish legislation provides totally or partially free medicines to treat 44 chronic diseases. The physicians working in the public health system or in the private sector in Finland provide the FSII diagnoses of these diseases, and the coverage of information concerning these diseases is nearly complete. We obtained data for 1 January 1984 to 31 December 1998. We calculated the SIR in the same way we calculated it for cancer. The expected rates were based on

incidence rates for the entire population of Helsinki, calculated from the files of the FSII.

Exposure and environmental measurements. Because the houses in the dump area have municipal tap water, the area has no rivers or lakes, and no edible plants have been grown in the area, exposure occurs via dust, ambient air, and indoor air. Soil samples were studied from 66 points (*7*), interstitial soil gas samples from 9 points, and ground water samples from 15 points. The soil samples contained high concentrations of polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls, cyanides, and some heavy metals, exceeding the Finnish guidelines (*8*) more than 100-fold in several samples (Table 1). Polychlorinated dioxins or furans were not detected. In interstitial soil gas samples, the content of volatile organic compounds and hydrogen sulfide were 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 nonchlorinated aliphatic hydrocarbons and nonchlorinated monoaromatic hydrocarbons.

The indoor air pollutants were analyzed in samples from 38 apartments and the day care center. The samples were taken during winter, when the concentrations of pollutants originating from the soil are highest. Volatile organic compounds were analyzed in samples from all 38 apartments, hydrogen cyanide in 30, PAHs in 21, and vinyl chloride in 13 apartments. The concentrations were similar to those found earlier in normal (nonreference) blockhouse apartments in Helsinki (*9*).

Results

Cancer. There were 957 men and 1,057 women under follow-up in our study for cancer incidence in the dump area cohort. About 28% of the cohort members were children below 15 years at the beginning of the follow-up (Table 2). The mean length of follow-up was 13.4 years. Fifty percent of these persons had lived in the dump area for at least 5 years by the end of 1998. The number of persons belonging to the reference cohort and their typical residential histories were very similar to those in the dump area (Table 2).

During the follow-up period, 88 cases of cancer were diagnosed in the dump area cohort; the expected number was 73.1. Because it is generally not believed that any effect of dump toxins could be biologically plausible during the first years after moving into the landfill site, the five first years of follow-up (17 observed cases vs. 18.5 expected) are excluded from results described below. In

the sixth follow-up year or later there were 71 cancer cases, whereas the number expected in comparison with the whole population of Helsinki was 54.6 (Table 3). The excess was almost entirely attributable to males (SIR 1.61; 95% CI, 1.11–2.24). Males showed an excess of cancers of the pancreas (SIR 5.05; 95% CI, 1.38–12.9), and in skin (SIR for melanoma and nonmelanoma combined 4.03; 95% CI, 1.31–9.41), while there were no cases of these cancers among women.

The SIR of cancer (any site) increased with years lived in the dump area. Those who had lived in the dump area for less than two years had an overall cancer SIR of 1.03 (95% CI, 0.54–1.76), both males and females. For those who had lived in the area for 2–4.9 years the SIR was 1.15 (95% CI, 0.67–1.84), and for those with at least five years of residence it was 1.23 (95% CI, 0.91–1.62). From the site-specific excesses those of colorectal cancer and skin cancer were observed entirely among persons with at least five years of residence in the dump area, whereas the excess in pancreatic cancer was attributable to residential histories of less than two years.

There was one case of childhood cancer (age < 15 years), the expected rate being 0.7. The case was a pinealoma diagnosed at the age of 5 years.

Among persons having lived in the reference houses, 83 cases of cancer were diagnosed by the end of 1998; the expected number was 95.9 (Table 3). None of the cancer sites showed a SIR significantly different from 1.0, and the SIR decreased slightly by the increasing time since moving into the area.

The ratio of the SIR of the dump area cohort (SIR_D) and the SIR in the reference cohort (SIR_R) was in males 1.64 (1.00–2.68) and in females 1.41 (0.89–2.22); the combined ratio (1.50) was statistically significant (Table 3). None of the site-specific SIR_D/SIR_R ratios was statistically significantly different from 1.0; among cancer sites with more than five cases, the ratio was highest (3.14) for colorectal cancer.

Other chronic diseases. The average number of person-years in the follow-up for chronic diseases was 2.5 years shorter than in the follow-up for cancer because the incidence data were not available before 1984

Table 1. Concentrations of pollutants in the soil samples.

Pollutant	C_{max}	Cg	C_{max}/Cg	No. of analyses	No. of analyses exceeding guidelines
Polynuclear aromatic hydrocarbons					
Total (µg/m³)	3,300	20	170	54	22
Naphthalene (µg/m³)	1,700	1	1,700	54	16
Benzo[*a*]pyrene (µg/m³)	104	2	52	54	11
Volatile organic compounds (µg/m³)					
Chloroform (µg/m³)	5.6	1	5.5	37	1
Trichloroethane (µg/m³)	5.24	2	2.6	36	1
Tetrachloroethene (µg/m³)	4.09	0.5	8.2	36	1
Benzene (µg/m³)	2.5	0.5	5	36	3
Polychlorinated biphenyls (mg/m³)	27.7	0.05	550	3	2
Polychlorinated dioxins and furans (µg/m³)	NF	0.02	0	3	0
Cyanides (mg/m³)	210	10	21	61	5
Oils (mg/m³)	26,000	300	87	34	16
Zinc (mg/m³)	40,000	150	270	83	32
Lead (mg/m³)	25,400	60	420	83	26
Cadmium (mg/m³)	2	0.5	4	36	7
Mercury (mg/m³)	4.9	0.2	25	6	2
Copper (mg/m³)	5,300	100	53	83	25
Arsenic (mg/m³)	55	10	5.5	72	13

Abbreviations: Cg, guideline for residential area; C_{max}, maximum concentration; NF, not found.

Table 2. Number of persons living in the dump area and in the reference houses, and numbers of person-years at risk, by age.

Age	Dump area		Reference houses	
	No.[a]	Person-years	No.[a]	Person-years
Follow-up for cancer (1976–1998)				
Total	2,014	27,062	2,028	27,986
< 15 years	568	5,096	555	3,367
15–59 years	1,307	19,112	1,350	20,681
≥ 60 years	139	2,854	123	3,938
Follow-up for other chronic diseases (1984–1998)				
Total	1,968	21,503	1,996	20,802

[a]Age of persons defined at the beginning of follow-up.

(Table 2). The SIRs for chronic diseases with at least five observed cases is given in Table 4.

The incidence of asthma—which, due to a change in the coding practice of the FSII, is contaminated by about 5% of chronic obstructive pulmonary diseases since 1994—was significantly higher in the dump cohort than among all inhabitants in Helsinki (SIR 1.63; 95% CI, 1.27–2.07) or in the reference houses (Table 4). The relative risk of asthma did not vary by time after residents moved into dump site houses, nor with years lived in those houses. The incidence of rheumatic diseases was significantly lower than in the general population. Of the rarer diseases, there were two cases of chronic pancreatitis, compared to 0.1 expected (SIR 19.3; 95% CI, 2.34–69.7).

Discussion

Publications about possible health effects among the residents living near hazardous waste dumping plots are abundant. Most of these deal with cancer, congenital malformations, pregnancy complications, self-reported diseases, or subjective symptoms. Vrijheid (10) recently published an extensive literature review of studies about the effect of hazardous landfill sites on the occurrence of cancer, low birth weight, and congenital malformations. Evidence for causal effects of cancer has not been reliably demonstrated, although some studies have suggested an increased incidence of bladder, lung, stomach, or rectal cancer or leukemia (1–6). Evidence connecting exposures from landfill sites to incidence of pregnancy complications and congenital malformations is somewhat stronger (10). One study has suggested an increase of slight hepatic damages (11) and another of renal diseases (12).

Studies on health effects of dump areas can contain many potential biases, which complicate the interpretation of the results. The possible effect of exposure to chemicals from dumping plots is often minor compared to other etiologic factors. Still, information on confounders is usually deficient, so some of the observations attributed to dump chemicals may actually stem from residual confounding. The number of exposing chemicals is usually huge and not well identified, and the extent to which individuals are actually exposed is difficult to estimate. For studies concerning symptoms or self-reported diseases, recall bias, the possible exaggeration of symptoms among those exposed, and an often worried population may be prominent (10,13–16).

Some of the above-mentioned potential error sources may also exist in the present study. We adjusted the analyses for sex and age but not, for example, for smoking and consumption of alcohol. The only information about smoking among persons living on the landfill site we obtained from 336 adults in the context of voluntary medical investigations of the residents in 1999: 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 (17). It is likely that the participants of the voluntary examinations were selected toward health-conscious nonsmokers; thus, actual smoking in the dump area may not be lower than in Helsinki in general.

Table 3. Observed and expected numbers of cancer cases and SIRs with 95% CI among Finnish persons living in dump area and reference area, 1976–1998.

Primary site	Dump area				Reference houses				Dump/reference ratio	
	Obs	Exp	SIR_D	95% CI	Obs	Exp	SIR_R	95% CI	SIR_D/SIR_R	95% CI
All sites[a]	71	54.6	1.30	1.02–1.64	83	95.9	0.87	0.69–1.07	1.50	1.08–2.09
Males	34	21.2	1.61	1.11–2.24	38	38.8	0.98	0.69–1.34	1.64	1.00–2.68
Females	37	33.4	1.11	0.78–1.52	45	57.1	0.79	0.58–1.05	1.41	0.89–2.22
Gastrointestinal	15	11.0	1.37	0.77–2.25	18	20.1	0.90	0.53–1.41	1.52	0.72–3.20
Colorectum	7	4.6	1.52	0.61–3.13	4	8.3	0.48	0.13–1.23	3.14	0.80–14.6
Pancreas	4	1.9	2.11	0.58–5.41	5	3.5	1.45	0.47–3.38	1.46	0.29–6.79
Respiratory	9	6.7	1.34	0.61–2.54	15	12.9	1.16	0.65–1.91	1.15	0.44–2.82
Lung, bronchus	8	5.9	1.36	0.59–2.67	12	11.4	1.05	0.54–1.83	1.29	0.46–3.44
Breast	13	11.6	1.12	0.60–1.91	13	19.3	0.67	0.36–1.15	1.66	0.71–3.88
Female genitals	6	4.7	1.28	0.47–2.79	6	8.5	0.71	0.26–1.54	1.81	0.48–6.77
Male genitals	3	4.1	0.73	0.21–1.95	6	7.3	0.83	0.30–1.79	0.89	0.14–4.16
Urinary organs	5	3.4	1.46	0.47–3.39	8	6.2	1.30	0.56–2.56	1.12	0.29–3.89
Skin[a]	5	2.7	1.88	0.61–4.39	4	4.5	0.89	0.24–2.28	2.11	0.45–10.6
Brain/nervous system	4	2.6	1.55	0.42–3.97	3	4.2	0.71	0.15–2.08	2.17	0.37–14.8
Hematologic	5	3.6	1.38	0.44–3.21	6	6.1	0.98	0.36–2.14	1.40	0.34–5.52

Abbreviations: Exp, expected; Obs, observed; SIR_D, SIR for people living in dump area (excludes five first years); SIR_R, respective SIR in the reference area. Expected numbers are based on the sex- and age-specific incidence rates in Helsinki.
[a]Excludes basal cell carcinoma.

Table 4. Observed and expected numbers of noncancer chronic diseases[a] and SIRs with 95% CI among Finnish persons living in dump area and reference area, 1984–1998.

Primary disease	Dump area				Reference houses				Dump/reference ratio	
	Obs	Exp	SIR_D	95% CI	Obs	Exp	SIR_R	95% CI	SIR_D/SIR_R	95% CI
Diabetes	35	28.5	1.23	0.85–1.70	37	34.6	1.07	0.75–1.47	1.15	0.70–1.88
Hypothyreosis	15	18.9	0.79	0.44–1.30	25	23.0	1.09	0.70–1.60	0.73	0.36–1.44
Asthma[b]	67	41.0	1.63	1.27–2.07	41	4.9	0.91	0.66–1.23	1.79	1.20–2.71
Cardiovascular diseases[c]	155	158	0.98	0.83–1.14	188	213	0.88	0.76–1.01	1.11	0.89-1.38
Glaucoma	11	14.9	0.74	0.37–1.31	21	20.1	1.05	0.65–1.59	0.71	0.31–1.53
Rheumatic diseases	8	16.0	0.50	0.22–0.98	13	19.2	0.68	0.36–1.15	0.74	0.26–1.92
Chronic urinary tract infection	8	4.4	1.84	0.79–3.61	7	5.0	1.39	0.56–2.87	1.32	0.42–4.26
Mental and neurologic										
Parkinson	6	3.3	1.80	0.66–3.91	6	4.5	1.34	0.49–2.91	1.34	0.36–5.02
Epilepsy	10	14.5	0.69	0.33–1.27	11	14.8	0.74	0.37–1.32	0.93	0.36–2.42
Psychoses	23	25.8	0.89	0.56–1.33	27	28.8	0.94	0.62–1.36	0.95	0.52–1.72

Abbreviations: Exp, expected; Obs, observed; Expected numbers based on the sex and age specific incidence rates in Helsinki. All diseases with at least five cases in the dumpsite houses shown.
[a]From the reimbursement register of the Finnish Society Insurance Institution. [b]Since 1994 includes a small amount of other chronic obstructive bronchial diseases. [c]Cardiac failure, cardiac arrhythmias, coronary heart disease, and hypertension.

We measured exposure levels mainly from 1999, and there is almost no information about exposure histories of the persons who had been living in the area. Moreover, the ways the exposures metabolize from the soil to humans, and to what extent, are almost entirely unknown. It is believed that a "cocktail" of exposures might be considered carcinogenic, even if no single chemical agent can be pointed out; e.g., exposure to chemical mixtures may be considered more hazardous than to individual chemicals (*18*). Although no *a priori* confirmed cancer sites specific to the exposure mixture of this former dump could be pointed out, we considered a systemic effect possible. The observed excess for cancer at all sites combined in the dump area cohort fits with this hypothesis.

We believe that our study is not hampered by registration bias. The coverage of Population Register of Finland, the source of our cohort selection, is extremely high, and housing histories are mostly accurate, with some uncertainties in the dates of living periods mainly in the 1970s when the computerized register was created. The follow-up of cohort members for death and emigration is complete. Cancer registration in Finland is virtually complete (*19*) and the computerized record linkage procedure precise (*20*). The physician deciding whether a disease is entitled to reimbursable drugs must be a specialist, and the statement is checked by another specialist at the FSII. Still, we cannot exclude the possibility that the diagnosis may sometimes vary depending, e.g., on the preferences of the reporting physician, thus possibly causing slight incomparability between regions.

People living in the rented houses come predominantly from lower social classes with a high unemployment rate. With comparison to the average city population, a bias caused by general cancer-related lifestyle factors is likely. The overall cancer incidence among working-age Finnish men increases and among women decreases toward the lower social class, and there are large relative differences in site-specific cancer rates among social classes and among occupational categories (*21*). Therefore we selected another control population living in similar rented houses and probably coming from similar socioeconomic circumstances. There is about a 1.5-fold overall cancer incidence in persons living in the dump area compared with those in the reference houses, similarly in both sexes. The small number of cases did not allow proper site-specific comparison; the dump/reference area ratios of the SIRs were closest to statistical significance in colorectal cancer and breast cancer, both of which were not *a priori* targeted as likely dump toxin-related

cancer sites. Based on the quality of the chemicals found in the dump site and on the most probable means of exposure, via inhalation, increased relative risks were expected to be found in lung cancer (PAH), cancers in urinary organs, and hematologic cancers (*10,22*). However, we saw very little difference in these cancer sites between the dump and reference areas.

Typical of low social strata, the incidence among females in the reference houses was about 20% below the average of the general Helsinki population (*21*), whereas among males we saw a SIR of 1.0, rather than a SIR exceeding 1.0, which would have been typical for low social classes. Cancer incidence in Helsinki is 5–10% higher than in Finland in general. If we had compared the dump site cohort population with the average Finnish population—which would not be wrong given that many of the cohort members had recently moved to Helsinki from rural areas—the SIR among females in Myllypuro would have been 1.2 and among males 1.7. The latter rate is so high that it has rarely been seen for overall cancer incidence in any of the numerous cohorts analyzed by the Finnish Cancer Registry.

The strongest site-specific observation for cancer was the 5-fold risk of pancreatic cancer in males. Etiologic factors of pancreatic cancer—not necessarily unequivocally confirmed—include smoking and alcohol abuse (*23*). Populations in rented houses tend to include persons with social problems related to, for example, drinking. Accordingly, we saw a SIR of 2.0 for pancreatic cancer among males in the reference cohort consisting of persons with presumably similar backgrounds.

We saw in the dump area cohort a significant increase of chronic pancreatitis, which is caused most frequently by heavy alcohol consumption and has been linked with pancreatic cancer (*24,25*). Pancreatic cancer occurs with increased frequency among persons with long-standing diabetes (*26*), the risk of which was slightly increased in the dump area. Thus, the unusually high number of cases of pancreatic cancer might be explained by clustering of males with diabetes and pancreatitis-related behavior in those houses; the literature does not support a potential causal effect of environmental chemicals. The concentration of cases among males who lived only a short period in one flat also suggests that these diseases stem from lifestyle habits rather than the living environment.

The incidence of rheumatic diseases among persons living in the dump area was significantly lower than in the average population in Helsinki. Rheumatoid arthritis either is equally common among various socioeconomic classes, or low socioeconomic

classes should have increased rates (*27*). We have no explanation for our finding contradicting the *a priori* expectations.

The incidence of asthma increased significantly in the dump cohort. Environmental pollution does not belong to the known risk factors for asthma although asthmatic symptoms can be aggravated by pollution (*28*). The Myllypuro residents are not known to have been environmentally exposed to allergens for asthma, such as flours, molds, cotton dust, or metal fumes. We saw a significant 60% excess in the dump cohort in comparison with the average Helsinki population and 80% excess in comparison with the reference houses, but no increase in the relative risk with years lived in the dump area nor by time after moving to the area. We do not know to what extent dose–response or lag affect the risk of getting asthma, but these parameters are probably less important in asthma than in cancer etiology. Therefore, we consider it possible that part of the excess in asthma could be attributed to dump toxins.

The significantly higher cancer risk in persons living in the former dump area than in a reference cohort with likely similar lifestyle habits, a lag of several years after moving to the area before the excess started to appear, and a slight dose–response effect with years lived in the dump area suggest a causal relationship between dump toxins and cancer risk. The concentration of the cases in primary sites with no assumed association of this type of environmental exposures speaks against causality—but leaves the possibility of a systemic effect still open. Neither can we fully exclude the possibility that the excess risk of asthma may be associated with dump toxins.

Several plans were proposed about the destiny of the houses built on the former landfill site and about how to handle the dumped wastes. On the basis of legislation, public opinion, the inhabitants' concern, increased measured exposure levels, preliminary results suggesting a small excess of certain diseases, unpredictable future health hazards, and economic facts, the Helsinki City Council in June 1999 decided to demolish the houses (*29*). Helsinki City bought the privately owned apartments and arranged new flats for tenants of the city. Most houses had been destroyed by 2001. The wastes have been left in the ground, but tight isolation prevents exposure and leaching both horizontally and vertically. In the future, the area will become a park. The follow-up of health status of persons who lived in these houses will continue.

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