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ORIGINAL ARTICLE

Residents complaining of health effects in a community exposed to complex pollution: potential exposure and health status compared with a reference group

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Abstract

Aim The aim of this study was to evaluate the range and frequency of health complaints reported by residents potentially exposed to complex environmental pollution. Secondly, the aim was to provide individuals who suspected pollution-related health effects with the opportunity to have their concerns assessed by specialists in environmental medicine.This article describes the characteristics of residents reporting health complaints attributed to the pollution compared with a reference group of residents, who did not suspect that the pollution affected their health.

Subjects and methods An invitation was sent to all 10,460 adult residents in the town and surrounding areas, followed by a question on whether they suspected their health problems were related to the pollution. Among the 3,679 (35%) respondents, 270 individuals reported health problems they attributed to the pollution (cases) and agreed to participate. The final study population consisted of 203 cases and 202 age- and sex-matched referents drawn from respondents who did not suspect pollution-related health issues. Participants underwent a comprehensive interview regarding health status, concerns, and living conditions with emphasis on potential exposures, followed by a clinical examination.

Results Compared to referents, cases reported significantly lower self-rated health and a higher prevalence of chronic diseases, particularly neurological and respiratory conditions. However, no differences were observed between cases and referents in duration of residence in the town, residential area, type of housing, or occupational exposure. The registrered health status was not correlated to concerns about the subject's own and family's health.

Conclusion Individuals reporting pollution-related health concerns exhibited substantially higher burden of morbidity than referents, despite no differences were observed in assessed indicators of present or historical exposure.

Keywords Community pollution · Generation pollution · Case-referent study · Health complaints · Exposure

Background

In Grindsted, a town in Jutland, Denmark, extensive industrial pollution has been known for many years In order to elucidate the potential health impact on local inhabitants, a program was established.

As a part of this program, actual or former residents, who suspected their symptoms or diseases were related to pollution, were invited to a consultation with a physician specialized in environmental medicine. The purpose was dual, on one hand to give the resident a possibility to explain their symptoms and cncerns to a qualified person, on the other hand to reveal the type of complaints and their possible relation to the possible personal exposure.

The present publication is based on the results of this initiative, termed the "resident survey", and provides a characterization of individuals reporting pollution-related health problems through comparison with a reference group.

Grindsted is a town of approximately 15,000 inhabitants located in a largely rural region. The largest industrial factory, Grindstedværket, was established in 1924 and historically produced various chemicals including pharmaceuticals and vitamins. In the past 30 years, the company has focused exclusively on food ingredients. Pollution primarily originated from waste disposal on-site or in adjacent areas, or with wastewater initially discharged into a river flowing through the town. Although emissions ceased in the 1970 s,

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pollutants have leached into the groundwater beneath the town, emerging near the river (Frederiksen et al. 2019). In 2020, the factory ground of Grindstedværket was identified by Danish Regions as one of the ten largest soil pollutions in Denmark and classified as an intergenerational (legacy) pollution.

Detailed analyses have identified 1,200 chemical substances in the pollution plume, 57% of which pose environmental risks, including degradation products (notably vinyl chloride) of chlorinated solvents pharmaceuticals, and heavy metals—mercury being a significant concern due to substantial deposition (Region Souther Denmark 2009) While public drinking water sources are located outside contaminated zones, private wells have been commonly utilized in certain areas mainly for irrigation. In some areas these wells were found to be contaminated and their use was subsequently banned in 2021.

Although known since 1944, the pollution was predominantly regarded as an environmental issue until 2017–2018, when suspicion of adverse health effects, including a possible cluster of Amyotrophic Lateral Sclerosis (ALS), arose. A 2020 register-based study compared the incidence of diseases in Grindsted to 12 similar towns and found no overall increased disease incidence. (Wodschow et al. 2020) The study further indicated that the population of Grindsted exhibited lower overall mortality and higher fertility rates compared to the reference towns. Among the various diseases and analyses considered, the incidence rates of prostate and thyroid cancer were elevated, whereas the incidence of other cancer types was reduced. Regarding ALS, the overall incidence during the period 1971–2017 was comparable to that of the reference population, with 22 cases observed and an incidence rate ratio (IRR) of 1.02 (95% confidence interval: 0.64–1.53). However, public concern was focused on a sub-analysis revealing a localized cluster within one area of Grindsted where 5 cases were identified, corresponding to an IRR of 2.51 (95% CI: 1.04–6.08).

In response to ongoing public concern, the council and the Region of Southern Denmark initiated further investigations, comprising the present resident survey. In parallel, an update on the registerbased study was initiated together with a human health risk assessment of the consistuents of the pollution.

Aims

The aim of this paper is to systematically evaluate the character and frequency of health complaints reported by residents living in a town with a complex environmental pollution. Which are the health problems of persons with these complaints and how can the complaints be related to past or present exposure?

Materials and methods

The study was conducted using a case-referent design, where the study base constituted a personal invitation to all adult residents in the town to participate. The case group consisted of responders who reported symptoms or illnesses they believed to be related to environmental pollution. The referent group comprised randomly selected Grindsted residents, who consented to participate in the study and did not suspect having symptoms or health conditions relating to the pollution.

Subjects

Invitations were sent to residents aged 18 years or older, who according to the the Danisk Health Data Authorities were living in Grindsted or within a 5 km from the border of the city as per February 1, 2023 using unique personal identification numbers (Schmidt et al. 2014). Invitations were sent digitally or by mail. Non-responders received a reminder after three weeks. Participants completed a short online questionnaire indicating whether they suspected pollution-related symptoms and willingness to participate. Non-respondents who failed to reply despite a reminder were excluded from the study. Former Grindsted residents who wished to participate were able to enroll in the study through an official website.

Cases were defined as individuals who answered "Yes" to the question: *"Do you suspect that your symptoms are due to the pollution in Grindsted?"* and subsequently confirmed their willingness to participate in a medical consultation. Participants had the opportunity to describe their symptoms and diagnoses in an open-text field.

Referents were selected from among respondents who answered "No" to the question regarding pollution-related symptoms but indicated willingness to participate as part of a reference group. For each case, one referent was randomly selected, matched by sex and five-year age group.

Clinical examinations

Both cases and referents underwent standardized clinical consultations at the Department of Occupational and Environmental Medicine, Grindsted Hospital. Three specialists conducted the consultations, each specialist examined both cases and referents. Cases were examined from 21 February to 7 July 2023, whereas referents were examined from 20 August through 7 December 2023.

The medical consultation comprised a structured interview supported by a comprehensive electronic

questionnaire, followed by a standardized physical examination with a particular focus on neurological signs.

The interview included detailed questions regarding present and previous symptoms, medical conditions, and medication use. In addition, cases were specifically to reportany current symptoms or illnesses they perceived related to pollution exposure. Fertility history was also assessed, including information on both the physical and mental health of each child.

Potential exposure to environmental contamination was evaluated for all participants. This assessment included information on past and present housing: residential address, duration of residence, type of housing, and the use of water from private wells or boreholes. Furthermore, potential exposure through contact with polluted rivers and lakes in the Grindsted area was considered, as was occupational exposures—particularly employment at Grindstedværket.

Participants concerns about the risks associated with living in Grindsted were collected as free-text responses.

The clinical examination included an evaluation of general and nutritional status, auscultation of the heart and lungs, measurement of blood pressure, and a neurological assessment covering muscle strength, sensory function, posture, gait and reflexes.

At the end of the individual consultation, participants received personalized feedback on the findings of the examination. If a condition required medical attention, the paticipant was referred to their general practitioner or to the relevant hospital department for further diagnostic evaluation and treatment.

Data analysis

Symptoms and diagnoses reported by participants were independently coded by two doctors (SBD and JB) using the International Classification of Primary Care, Second Edition (ICPC-2). The text reports of concerns were categorized in four thematic groups: 1. Concerns about disease risk for themselves or their family members. 2. Issues related to the occupational environment, particularly in connection with current or historical pollution. 3. General concerns regarding Grindsted's future, environmental quality, and public reputation. 4. Worries unrelated to residence in Grindsted.

Background variables included: Born in Grindsted (yes/no), total years of residence in the city, duration of employment at Grindstedværket; current occupational status, and highest level of educational attainment.

Residential addresses – both current and former—were categorized into four geographical zones based on the likelihood of environmental contamination, consistent with the classification used in a previous registry-based study (Wodschow et al. 2020). The number of years participants had lived in residences using water from private wells or boreholes was also recorded and scored.

Differences between cases and referents were analyzed using the Chi-squared test for categorical variables and Student's t-test for continuous variables. Additionally binary variables were tested using unconditional logistic regression, while subjective health was analyzed using negative binomial regression. All statistical tests were two-sided, and p-values < 0.05 were considered statistically significant. To ensure participant anonymity, data in tables and figures were only reported when the number of individuals in a cell was three or more. All statistical analyses were performed using Stata®, version 18 (StataCorp, College Station, TX, USA).

Results

A total of 10,439 residents were invited to participate, of whom 3,679 (35%) responded. In addition, 39 former residents of Grindsted independently contacted the study team to report suspected symptoms or illnesses related to local environmental pollution.

In total, 313 individuals (3%) reported that they believed their symptoms or diseases were attributable to pollution in Grindsted. Of these, 270 (86%) expressed interest in undergoing a medical consultation. Ultimately, 203 individuals completed the consultation and were included in the final case group, of whom 18 were former residents of Grindsted (6 males and 12 females).

In the reference group, 1,653 current residents volunteered for participation. From this pool, 202 individuals were selected to be sex- and age-matched to the case group and subsequently underwent the same medical consultation.

Table 1 presents the background characteristics of the 203 cases and 202 referents. A higher proportion of cases reported lifelong recidence in Grindsted, although the total duration of residence in the town did not differ significantly between the groups. There was no significant differences in alcohol consumption and smoking habits. A smaller proportion of cases were currently employed compared to referents. However, educational attainment was similar across groups, with 48% in both groups having completed skilled education. Compared with referents, cases more frequently reported previous occupational exposure to smoke and other pollutants, and a higher proportion had been employed at Grindstedværket.

Diseases and symptoms reported in response to the invitation

Among the 203 cases, 191 individuals reported between 0 and 11 symptoms or diseases at the time of responding to the invitation (mean: 1.77). Figure 1 depicts the

Table 1 Data for cases and referents.

		Cases n = 203	Referents n = 202
	Females	105 (51,7%)	105 (51,9%)
	Males	98 (48,3%)	97 (48,1%)
Age	Years (range)	59.6 (19–89)	60.0 (20–89)
Residents in Grindsted	Lifelong residents	**53 (25%)**	**38 (19%)**
	Residents for part of their life	**115 (57%)**	**145 (72%)**
	Moved away from Grindsted[a)]	**25 (12%)**	**14 (7%)**
	Unknown	1 (0%)	4 (2%)
Current residential area	Rural district (low contamination)	**22(12%)**	**45(22%)**
	Center and suburban parts (moderate contamination)	**105 (57%)**	**93 (46%)**
	Eastern part (contamination uncertain)	26 (14%)	31(15%)
	Along the stream (highest contamination)	32(17%)	33(16%)
Duration of residence in Grindsted	Mean, range (years)	41.1 (2,5–88)	38.2 (1,5–78)
Number of residential addresses in Grindsted	Mean, range	**3.7 (1–10)**	**2.9 (1–10)**
Duration of residence at each address	Mean (range)	26.1 (1–79)	27.2(1–75)
Current or past use of private well (number of residences)	No use	443 (58,8%)	378 (64,2%)
	Irrigation	32 (4,2%)	49 (8,3%)
	Irrigating vegetables	75 (10,0%)	53 (9,0%)
	Other use	57 (7,6%)	42 (7,1%)
	No information onwater use	147 (19,5%)	67 (11,4%)
Years of residence in a house using a private well		14.2 (0–78)	13.2 (0–75)
Alcohol consumption (drinks per week)	Mean (range)	3.8 (0–25)	4.2 (0–21)
Employment status	Employed	**67 (34%)**	**99 (49%)**
	In education	2 (1%)	5 (2%)
	On sick leave	8 (4%)	5 (2%)
	Temporarily unemployed	5 (2%)	2 (1%)
	Permanently out of work	**97 (49%)**	**82 (41%)**
	Other	**17 (9%)**	**8 (4%)**
Reported exposure to gases, vapours, dust or smoke (current or former workplace)	Yes	**96 (48%)**	**72 (35%)**
Employment at Grindstedværket	Yes	**45 (22%)**	**29 (14%)**
Number of years employed at Grindstedværket	Mean (range)	**9.8 (< 1–42)**	**6.4 (< 1–38)**
Highest level of education	Primary/elementary school	19 (10%)	20 (10%)
	Secondary education	4 (2%)	9 (4%)
	Vocational education	96 (48%)	97 (48%)
	Bachelor's degree	33 (16%)	29 (14%)
	Master's degree	11 (6%)	10 (5%)
	Other education	39 (19%)	37 (18%)

Bold text denounces a significant difference between cases and referents ($p < 0.05$)

[a)] Including those moved from Grindsted to the rural districts within the area of investigation.

distribution of reported conditions by diagnostic category. Neurological and respiratory disorders were the most frequently reported categories. Eight individuals reported a diagnosis of parkinsonism and another eight reported multiple sclerosis. The most frequent neurological symptoms included headache, sensory disturbances, involuntary movements, and memory impairment. The reported respiratory condition was asthma, with six cases, while common respiratory symptoms included dyspnea and cough.

Of the 43 cases who reported a cancer diagnosis, breast cancer was the most reported (8 cases), followed by colorectal cancer (6 cases) and hematologic or lymphatic malignanacies (5 cases). (see supplementary figure S1).

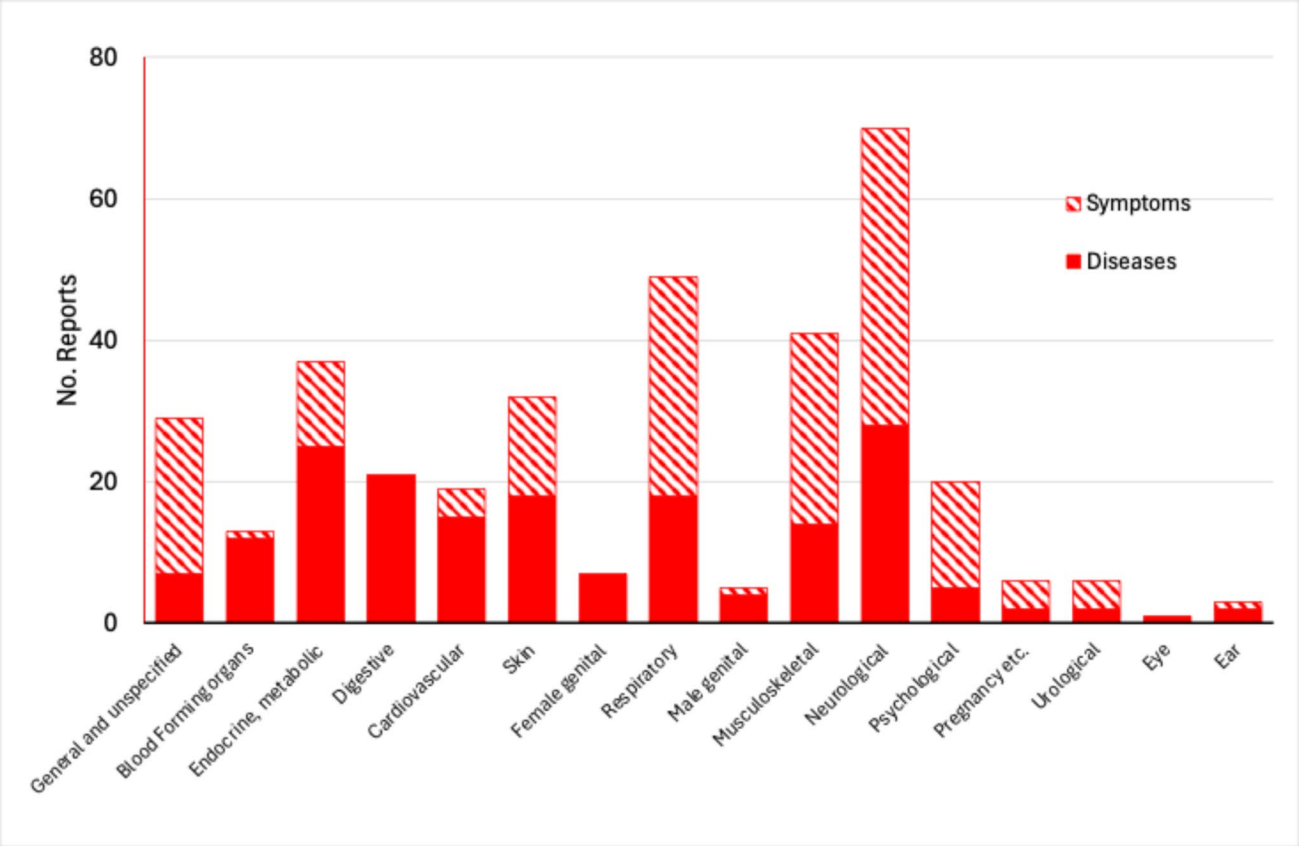

Fig. 1 Health complaints reported by the cases by the invitation, catagorized in main grups according to ICPC-2

The clinical examination of cases and referents

Compared to the referents, cases reported significantly poorer self-perceived health. Specifically, 58% of cases rated their health reported as poor or very poor, in contrast to only 12% of referents. In contrast, only 8% of cases reported their health as very good or excellent, compared to 44% of referents (See supplementary Table S1).

Figure 2 illustrates the number of recorded diseases and symptoms across diagnostic categories for both cases and referents. Supplemental Table S2 presents the distribution of the most frequently reported conditions or symptoms within each disease group.

The greatest differences between cases and referents were observed for neurological diseases and symptoms. Multiple sclerosis and parkinsonism were reported exclusively among cases. Additionnally, migraines and peripheral nervous system disorders were more frequent in the case group whereas headaches occurred with similar frequency in cases and referents.

Cases reported a higher prevalence of psychological disorders and symptoms, primarily including depression, sleep disturbances, memory impairment, and dizziness. The category of hyperkinetic disorders among cases encompassed diagnoses, such as ADHD and autism spectrum disorders.

Cardiovascular diseases were common in both cases and referents, with no significant differences overall. Hypertension was the most prevalent cardiovascular condition, followed by arrhythmias. However, cases exhibited a higher frequency of stroke and other cardiac diseases compared to referents. Cases also demonstrated a higher prevalence of chronic obstructive pulmonary disease (COPD) and various respiratory symptoms, whereas the occurrence of asthma and hay fever was similar between the two groups. Musculoskeletal disorders and symptoms were highly prevalent in both cases and referents. Additionally, cases reported an increased frequency of urinary and female genital conditions, encompassing a range of diagnoses. In contrast, referents showed a higher incidence of ocular conditions such as cataract and glaucoma.

A current or previous cancer diagnosis was reported by 57 cases and 33 referents ($p < 0.001$, for details see Supplementary Table S2). The most commonly reported cancers included skin cancer equally distributed between melanoma and non-melanoma skin cancers – followed by colorectal,

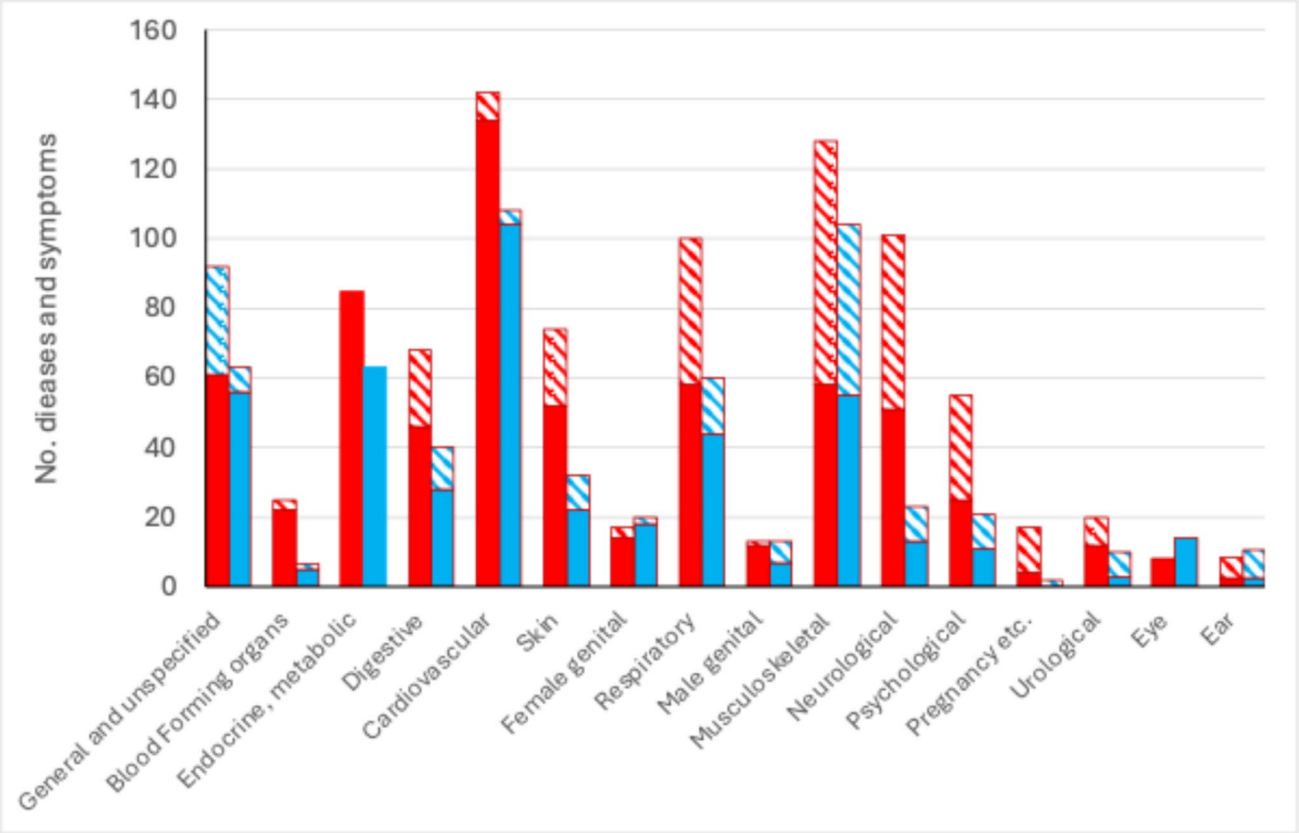

Fig. 2 Number of diseases and symptoms in cases (red) and referents (blue) split in main ICPC-2 groups. The solid bars show diseases and striped bars symptoms

breast, and prostate cancers. Reports of hematologic malignancies, including blood cancers and lymphomas, comprised different subtypes in both groups.

Both cases and referents indicated that their reported symptoms were chronic with a mean duration of 14.1 years. Approximately 75% of these symptoms were ongoing at the time of the study, and about half of the symptoms, as well as nearly all diagnosed diseases, had been evaluated or treated within the healthcare system. Cases reported use of a higher number of different medications (mean 5.1; range 0–18) compared to referents (mean 2.8; range 0–13).

Fertility and children

Among the cases, 166 individuals (82%) had a total of 396 children (mean per case 2.0 children per parent, age range 0 to 60 years), whereas 191 referents (95%) had 440 children (mean 2.2 children per parent). In the case group, 63% of pregnancies occurred while residing in Grindsted, compared to 70% among referents (see Table 2). Physical health problems were reported in 40% of children, and mental health problems in 20%, ranging from mild conditions to severe, lifelong disabilities.

Cases reported a higher prevalence of mental health issues in their children compared to referents. However, no significant differences were observed in the prevalence of physical or psychological problems based on whether the pregnancy occurred during residence in Grindsted.

Clinical signs

Pulmonary auscultation revealed a higher frequency of abnormal findings among cases, primarily wheezing and other signs consistent with COPD or asthma (see supplementary Figure S3). In contrast, cardiac auscultation did not show any significant differences between cases and referents. Neurological examination indicated a higher prevalence of coordination difficulties among cases. However, no significant differences were observed between the two groups in other neurological assessments, including muscle strength, reflexes, sensory function, or gait.

External factors

Table 1 presents the distribution of participants' current residences across the defined contamination zones. A higher

Table 2 Frequency of children with physical and psychological health problems in cases and referents according to maternal residence in Grindsted during pregnancy

	Cases		Referents		Cases and referents combined		Cases	Referents
Maternal residence in Grindsted during pregnancy	Yes (n = 250)	No (n = 146)	Yes (n = 307)	No (n = 133)	Yes (n = 557)	No (n = 277)	(n = 396)	(n = 440)
Sex of offspring (male/female/not reported)	128/111/11	70/73/3	162/140/5	61/72/0	290/251/16	131/145/3	198/184/14	223/212/5
Birthyear (mean, earliest/latest)	1990 1960–2022	1986 1956–2022	1991 1955–2023	1988 1962–2021	1990 1955–2023	1987 1956–2022	1988 1956–2022	1990 1955–2023
Physical problems	105 (42%)	68 (47%)	120 (39%)	44 (33%)	225 (40%)	112 (40%)	173 (44%)	164 (37%)
Psychological problems	44 (18%)	34 (23%)	40 (13%)	27 (20%)	**84 (15%)**	**61 (22%)**	**78 (20%)**	**67 (15%)**

Bold indicates statistically significant differences between groups ($p < 0.05$)

Table 3 Odds Ratios and 95% conficnece intervals for the relationship between reported health problems (rows) and concern for personal or family health as well as case status (across)

	Concern about personal or family health	Case vs. referent
Self-rated health[a)]	1.05 (0.92—1.18)	**1.31 (1.18—1.18)**
Neuropsychological	0.99 (0.54—1.80)	**2.76 (1.51—5.02)**
Cancer	1.26 (0.70—2.26)	1.53 (0.87—2.69)
Cardiovascular	0.64 (0.40—1.04)	**1.70 (1.09—2.64)**
Airways	0.68 (0.41—1.14)	**1.85 (1.16—2.95)**
Musculoskeletal	1.35 (0.84—2.18)	1.35 (0.87—2.11)
Other diseases	1.65 (0.88—3.11)	**2.70 (1.55—4.71)**

Logistic regression analyses included case status, sex, and residential area. **Bold** values indicate statistical significance

[a)] Self-rated health was analyzed using negative binomial regression and the reported figures are coefficients per unit increase

proportion of cases resided in the central part of Grindsted, whereas fewer cases lived in rural areas compared with referents.

Despite these differences in geographic distribution, no consistent pattern was observed in the prevalence of diseases or symptoms across the residential zones. Furthermore, no association was found between health outcomes and the number of years participants had lived in dwellings supplied by private wells or boreholes. Although more cases than referents had been employed at Grindstedværket there was no correlation between reported diseases and employment.

Diseases and symptoms vs. concerns

Table 3 presents the relationship between participants' expressed health concerns and reported health conditions across the different groups.

Cases reported both a higher level of concern and a greater number of health problems as well as an impaired self -reported health compared with referents. However, controlling for case status no significant correlation was observed between concerns about personal or family health and the presence of specific symptoms or diseases. No association was observed between concerns about the other items (the environment in general, the occupational environment at Grindstedværket, or concerns unrelated to the pollution) and reported health conditions or symptoms. (See supplementary Table S3, a-d).

Discussion

Using a personal invitation to participate we demontrated a clear willingness among residents to participate in research addressing the potential health effects of a complex environmental pollution,

Approximately 3% of the adult population in Grindsted reported current health problems they suspected were linked to local pollution. Compared with a reference group, these cases were characterized by markedly poorer self-reported health and a high prevalence of chronic neuropsychological and general health problems.

However, cases did not differ significantly from referents when assessing exposure by the use of indirect indicators, such as residential area, duration of residence in potentially contaminated zones, and use of groundwater from private wells.

A major strength of this study is the relatively high response rate: more than one-third of the nearly 10,500 invited adults responded, including a substantial proportion who did not report pollution-related health concerns. This suggests broad community engagement and enhances the generalizability of the findings. The reference group is considered representative of the general adult population in Grindsted and the surrounding area, as participants were drawn from the same population and under the same

conditions as the case group, with a similarly high participation rate.

A limitation of the study is the non-specific case definition, which was intentionally broad in order to capture a wide range of potentially relevant health concerns—from mild symptoms and subjective complaints to serious diagnosed conditions. This approach was necessary given the complex and long-term environmental contamination in Grindsted, involving numerous substances with varying toxicological properties. Due to the absence of clear toxicological hypotheses and the uncertainty regarding routes and timing of exposure only indirect or proxy indicators of exposure could be used.

Another limitation concerns the inclusion of 18 former residents (9% of cases) who self-referred following the public discussion of the issue. These individuals may represent a highly selected subgroup, as their participation required both awareness of the invitation and willingness to travel for the consultation. However, they were retained in the analyses as they constituted a small proportion of the case group and they did not differ meaningfully from current residents in terms of reported health outcomes. A sensitivity analysis excluding the former residents confirmed that their inclusion did not alter the overall findings.

Perhaps the most striking finding is the substantially poorer self-reported health among cases, compared with the referents, who rated their health more positively than the national average (Health 2023). Individuals reporting neurological diseases—and to a lesser extent respiratory conditions—were particularly likely to associate their health issues with environmental pollution (Clougherty and Ocampo 2023). This perception may be influenced by longstanding public discourse on local environmental hazards, including specific concerns related to ALS, as well as broader awareness of the risks associated with pollution, which have been discussed publicly for decades. Despite these perceptions, individual reports of disease showed only weak correlations with expressed concerns about personal or environmental health.

Fertility and health of the offspring—particularly neurobehavioral development—are well-established indicators of susceptibility to environmental pollution exposure (Payne-Sturges et al. 2023; Rocabois et al. 2024). In our study, cases reported having slightly fewer children than referents; however, no differences were observed based on whether the pregnancy occurred during residence in Grindsted. Interestingly, the modest excess of psychological problems reported in the children of cases was primarily seen in those not born when their mother lived in Grindsted.

Our findings on fertility are consistent with results from the register-based studies, which also found no evidence of increased health problems among children conceived and born in Grindsted over a period spanning more than 60 years (Kjærulff et al. 2024; Wodschow et al. 2020).

The environmental pollution in Grindsted is well-documented through extensive measurements conducted over several decades (Sanderson and Fauser 2024). A defining feature of the area is the widespread historical use of near-surface groundwater from private wells. Several of these wells have been found to be contaminated, resulting in recent regulatory prohibitions on their use (Sanderson and Fauser 2024). However, the extent to which this contamination has translated into actual human exposure remains uncertain, as no model of individual-level exposure is currently available. The proxy indicators of exposure—such as area of residential location within Grindsted, housing type, and historical use of private wells—did not demonstrate any evidence of dose–response relationships with the reported health outcomes. Other potential sources of pollution, primarily industrial sites emitting air contaminants, may exist; however, no specific active production facility could be identified as a probable contributor to current environmental health risks. Additionally, the higher proportion of employement at Grindstedværket and the lower overall employment rate among cases were not associated with an increased reporting of health problems.

In parallel to our study the register-based study was updated, monitoring the population through 2021 (Kjærulff et al. 2024). There was no evidence of specific excess health burden in Grindsted relative to comparable towns. The modestly elevated incidence of ALS in a specific area was also observed in this update, consistent with the previous report,(Wodschow et al. 2020) although no additional cases were identified. In the clinical examinations we looked specifically for discrete signs of neurological diseases, but found no no sign of undiagnosed conditions, even in area of concern about ALS.

In discussions of health concerns related to pollution it is often challenging to disentangle to which extend a heightened awareness leads to health effects by increased reporting of symptoms (Ammons et al. 2022; Bergstra et al. 2018; Dory et al. 2017; Pasetto et al. 2024). Our cases reported both more concern and more health problems than the referents. However, we did not observe any significant association between the individually expressed concerns and the reporting of diseases or symptoms. The wording of the inquiry, which primarily targeted paticipants concerned about their health problems, may have obscured the potential mediating effect of individual concerns on disease, but the lack of correlation between concern and health status is still remarkable.

The present survey design, which included clinical consultations, demanded considerably more resources than most other types of investigations. Nevertheless, the objective of providing residents with the opportunity to present

their health concerns directly to a specialist was successfully achieved. Although the clinicians were unable to establish a definitive link between pollution exposure and the reported health problems, participants generally expressed satisfaction with the consultation process. Furthermore, the study's main findings, when presented at a public meeting, were generally well received by an audience that included residents, local politicians, and representatives from both the municipal and regional authorities.

Conclusion

This study demonstrated that direct engagement with township residents achieved a high response rate from both individuals concerned about pollution-related health problems and from the large population without such concerns. Compared with the reference population participants reporting suspected health effects exhibited significantly poorer self-reported health, particularly regarding neurological and respiratory conditions,. However, no differences were observed between cases and referents in terms of current or past exposure indicators and we found no correlation between the reported concerns about health and the reporting of diseases. These findings align with results from two register-based studies. As a tool for investigating the health burden associated with widespread environmental pollution, this type of study is valuable for identifying both symptoms and community concerns. Key prerequisites include the involvement of consultation staff with expertise in environmental medicine, ensuring community acceptance of the study's conduct, and presenting the results publicly in a transparent manner.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10389-026-02770-8.

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Authors contribution JB has been primary investigator, conducted the planning, application, conducted a part of the clinical examinations, data collection and analysis. He has written the initial draft of this publication.

SBD has participated in the planning, conducted a part of the clinical examinations, participated in data analysis and contributed to the publication.

EKP has participated in the planning, mainly constructing the databases and schemes used in the project, participated in data analysis and contributed to the publication.

KOG has participated in the planning; he has had a major role in data analysis and contributed to the publication.

JR has participated in the planning, contributed to data analysis and contributed to the publication.

LRS has participated in the planning as responsible for the project in relation to the Region, participated in data analysis, and contributed to the publication.

All authors have contributed to the final manuscript and approved the submission.

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Data availability Data is stored at OPEN and the project is registered in their project catalogue (OPEN_1689, https://open.rsyd.dk/projekter/projektliste/). Custom code or anonymized data can be obtained by contacting OPEN@rsyd.dk, which will facilitate potential collaboration with the authors.

Declarations

Ethical approval As the study involved no interventions or invasive procedures, the Research Ethics Committee for the Region of Southern Denmark determined that formal ethical approval was not required.

Data was recorded in REDCap and subsequently processed in OPEN Analyse (OPEN—Open Patient data Explorative Network, Odense, Denmark) following the Region of Southern Denmark's general data processing permit (Rec. no. 22/35493).
An advisory board was established to support the study comprising two resident representatives, a general practitioner from Grindsted, and professional staff from the Billund Municipality and the Region of Southern Denmark.

Consent to participate Participation in the study was entirely voluntary and all participants provided informed consent for scientific use of their data. Only data collected through responses to the invitations or during the medical consultations were used.

Consent for publication All participants provided informed consent for the scientific use of their data.

Conflicts of interests None of the authors have any financial or personal conflict of interest.

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References

Ammons S, Aja H, Ghazarian AA, Lai GY, Ellison GL (2022) Perception of worry of harm from air pollution: results from the Health

Information National Trends Survey (HINTS). BMC Public Health 22(1):1254. https://doi.org/10.1186/s12889-022-13450-z
Bergstra AD, Brunekreef B, Burdorf A (2018) The mediating role of risk perception in the association between industry-related air pollution and health. PLoS One 13(5):e0196783. https://doi.org/10.1371/journal.pone.0196783
Clougherty JE, Ocampo P (2023) Perception matters: perceived vs. objective air quality measures and asthma diagnosis among urban adults. Int J Environ Res Public Health. https://doi.org/10.3390/ijerph20176648
Dory G, Qiu Z, Qiu CM, Fu MR, Ryan CE (2017) A phenomenological understanding of residents' emotional distress of living in an environmental justice community. Int J Qual Stud Health Well-Being 12(1):1269450. https://doi.org/10.1080/17482631.2016.1269450
Frederiksen M, Broholm M, Bjerg P (2019) Evaluation of the pollution of soil and ground water on the factory area of Grindstedværket and the influence on downstream ground water. Danish Technical University. Dpt. of Water and Environmental Technology, Lyngby, Denmark
Health NIoP (2023) Danes' Health. Results from the Danish National Health Profile. In: The National Board of Health. https://dansk ernessundhed.dk/#:~:text=Velkommen%20til%20Den%20Nationale%20Sundhedsprofil%20for%202010%2C%202013%2C,og%202023%20i%20unders%C3%B8gelserne%20%22Hvordan%20har%20du%20det%3F%22. 2023
Kjærulff T et al (2024) Disease incidence among citizens of Grindsted. An update National Institute of Public Health. University of Southern Denmark, Copenhagen. https://www.sdu.dk/da/sif/rapporter/2020/sygdomsforekomst+blandt+borgere+i+grindsted
Pasetto R et al (2024) Promotion of environmental public health and environmental justice in communities affected by large and long lasting industrial contamination: methods applied and lessons learned from the case study of Porto Torres (Italy). Front Public Health 12:1408127. https://doi.org/10.3389/fpubh.2024.1408127
Payne-Sturges DC et al (2023) Disparities in toxic chemical exposures and associated neurodevelopmental outcomes: a scoping review and systematic evidence map of the epidemiological literature. Environ Health Perspect 131(9):96001. https://doi.org/10.1289/ehp11750
Region Souther Denmark N (2009) Statement on the use of chemicals on Grindstedværket and the potential threat to the environment
Rocabois A et al (2024) Chemical exposome and children health: identification of dose-response relationships from meta-analyses and epidemiological studies. Environ Res 262(1):119811. https://doi.org/10.1016/j.envres.2024.119811
Sanderson H, Fauser P (2024) Human risk analysis of the Grindsted contaminations DCE-report. vol 609. Danish Centre For Environment And Energy. Aarhus University Roskilde
Schmidt M, Pedersen L, Sorensen HT (2014) The danish civil registration system as a tool in epidemiology. Eur J Epidemiol 29(8):541–549. https://doi.org/10.1007/s10654-014-9930-3
Wodschow K et al (2020) Disease incidence among citizens of Grindsted. A register-based study National Institute of Public Health. University of Southern Denmark, Copenhagen. https://www.sdu.dk/da/sif/rapporter/2024/sygdomsforekomst_blandt_borgere_i_grindsted_opdateret

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