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A Survey of Cancer and Childhood Leukemia in Al-Rafai District, Di Quar Governorate, Iraq, 2021-2024, with Measurements of Elements in Hair Samples of Affected Individuals and Family Interviews. Preliminary Results and Recommendations for Further Research

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Abstract

There is considerable anecdotal evidence in Southern Iraq about increases in cancer rates. To follow up on growing community concerns about high levels of cancer in Al-Rafai District of Di Quar Governorate, a survey of cancer in an *a priori* defined sample population of the district was carried out. The method was based on a previous questionnaire study of cancer and infant mortality in Fallujah, Iraq, in 2010 [Busby *et al.* 2010, Alaani *et al.* 2011]. The questionnaire survey of Al-Rafai district involved visiting 517 families. Results showed a significant excess cancer risk, including all malignancies in males [26 obs. Exp. 8.74; RR = 3.86; CI 2.78, 5.36; $p < 0.0000$], all malignancies in females [57 obs; 7.92 exp. RR = 6.25; CI 4.86, 8.02; $p < 0.0000$], childhood cancer 0 - 14 [7 Obs, Exp 0.13; RR = 52.6; CI 21.15, 131.0; $p < 0.0000$], breast cancer [24 Obs. Exp 2.6; RR 8.97; CI 5.18, 15.54; $p < 0.0000$], child leukemia 0 - 19 [6 Obs, Exp. 0.021; RR = 281; CI 114, 693; $p < 0.0000$], a similar excess to that found in Fallujah in 2010, and lymphoma 6 Obs. 0.5 Exp. RR 11.95; CI 3.65, 39.11; $p < 0.0000$. Of interest was the existence of a cohort birth year peak in the leukemia rate in young men 0 - 19y of 2003-2004, when the USA war created high levels of uranium contamination. A parallel ICPMS analysis of hair samples in 18 women with cancer showed unusually high levels of heavy metals, including uranium, and other indicators of serious background contamination. Some preliminary results of the survey, including interviews with 100 affected families, are also summarised. Recommendations for further action are made.

Keywords

Cancer, Leukemia, Heavy Metals, Depleted Uranium, Al Rafai, Di Qar Governorate, Fallujah

1. Introduction

Increases in cancer rates being registered in all countries that collect data are currently one of the main global health challenges. It has been known for at least 50 years that cancer is essentially a genetic disease expressed at the cellular level, and that the main cause of cancer is prior exposure to environmental agents that cause genetic damage, termed mutagens [1] [2]. Whilst cancer clearly has transgenerational genetic damage components, these arguably also (to a large extent) are caused by mutagenic exposures. In short, if there is an increase in cancer in a population that has enjoyed a stable cancer rate over time, it is reasonable to look for any earlier changes in environmental contamination that involve increases in mutagenic or cancer-causing materials. This is seldom done, and very few attempts to relate cancer increases to causes go further than blaming the victims for lifestyle behaviours, like smoking, obesity, alcohol, etc. There are time lags between exposures and clinical expression of cancer, generally depending on the level of exposure involved (owing to the replication rates of the tissues involved), but generally the lag period is between 10 and 20 years.

The Al-Rafai district of Di Quar governorate has seen anecdotal evidence, and indeed local hospital record evidence, of large increases in cancer in the last 10 years, leading to considerable community concern. The 2023 Iraq Cancer Registry report listed the all-cancer age-standardised rate in Di Quar province at the low end of the cancer risk league table in Iraq, with an age-standardised rate of 269 persons per 100,000 population per year [3].

The local community made a decision to carry out an epidemiological survey of cancer in a statistical sample of households in a specified region of the district, together with obtaining measurements of 50 chemical contaminant elements in hair samples from 18 women with cancer. Preliminary results are presented here.

2. Method

A questionnaire (in Arabic) was created, based on the Fallujah study questionnaire [4] [5]. It was decided that a background population of about 1000 individuals, based on visiting about 400 homes, would, on the basis of the survey of Fallujah, represent a statistically valid sample whilst minimizing work for the survey teams. The area to be included in the survey was drawn around a map of the district so as to include this number of homes. 517 houses in Al-Rafai district were visited by teams with the survey document. 100 households refused to answer the questionnaire, which left 417 responses. The population of the 417 households was 1370 individuals. All cancers which had occurred in the previous 10 years were recorded, with date of diagnosis, sex and age at diagnosis, type of cancer, and treating physician or hospital. The population at risk was obtained from the questionnaires as every person at the address.

The expected case numbers were calculated by multiplying the numbers of individuals registered by sex in the age groups 0 - 19, 20 - 30, and 30 - 65 by the mean rates for those age groups published for all Iraq for the cancer of interest in the 2023 National Cancer Registry report. This will have introduced some slight error since the resolution of the age-stratified cancer rates may have produced expected numbers which could be up to, but no greater than, 20%. The issue will be revisited in further analyses of the dataset.

Although the questionnaire asked for cancer cases for the previous 10 years, it was decided to restrict the analysis to the four years 2021 to 2024. This was, first, because the survey was carried out in 2025, and thus results for this year could not be accurately assigned to a whole year of data, and because of the loss of individuals in years prior to 2021 due to deaths. This is seen clearly in the small number of lung cancers reported relative to female breast cancer. The effect was clear in earlier survey epidemiology of this kind, e.g., the Fallujah study.

One hundred families were interviewed about further details of their lives following the cancer diagnosis. Smoking status was recorded for the individuals with cancer. Hair samples were collected from 40 individuals for element analysis using Inductively Coupled Plasma Mass Spectrometry (ICPMS), and samples were sent to Germany and the UK for analysis in separate labs. In the event, the samples from 18 men were too small to obtain statistically useful results. Eighteen samples from 16 women and 2 men gave useful results.

3. Results

3.1. Cancer

Results were constrained to the 4 years 2021-2024. They showed 110 cases in 4 years in a background survey population of 1370, a crude rate of 2007 cancers per 100,000 population per year. The population of Al Rafai in the 2024 Census is given in **Table 1**. Figures in italics are obtained by interpolation from the demographic graph in the 2024 Iraq Cancer Registry report. In **Table 2** is an outline of the approximate age breakdown of the survey population.

As in all such questionnaire studies, cancer numbers decrease for earlier years due to the bleeding of the population from deaths. This also occurred in the Fallujah study, and so the analysis focused on four years, 2021-2024. The failure to obtain responses from 100 households out of a total of 517 will have affected the Relative Risk results by a factor unlikely to be greater than 20% if it is assumed that the population that answered defined a normal statistical sample of the population surveyed. **Table 3** gives the numbers and relative risks for the main cancers found and statistical results based on standard Mantel-Haenszel methods [7].

Table 1. Census population of Al Rafai 2004 [6].

Age group	Males	Females
0 - 9	24,658	24,658
10 - 19	25,047	25,047
20 - 29	17,417	17,417
30 - 39	11,579	11,579
40 - 49	8561	8561
50 - 59	5833	5833
60 - 69	1513	3027
70 - 79	1042	2084
80+	-	1086

Table 2. Age breakdown of the population and all cancers reported in the survey population, all years of diagnosis. The table is restricted to individuals under age 65.

Age range	Male population	Male (cancers)	Female population	Female (cancers)
30 - 65	360	17	340	52
20 - 29	110	0	159	4
0 - 19	171	9	230	1

Table 3. Selected cancers in the survey population 2021-2024 and Relative Risks based on Iraq 2023 rates. Confidence intervals and p-values were calculated using Yates-corrected Chi-squared Mantel-Haenszel tables [7].

Site/type	O	E	RR	Statistics. 96% CI; p-value
All maligs M	26	8.74	3.86	2.78 < RR < 5.36; p < 0.0000
All maligs F	57	7.92	6.25	4.86 < RR < 8.02; p < 0.0000
Leukemia 0 - 19	6	0.021	281	114 < RR < 693; p < 0.0000
Leukemia all ages M + F	10	0.24	40.68	19.58 < RR < 84.5; p < 0.0000
Thyroid M + F	6	0.56	10.7	4.61 < RR < 24.7; p < 0.0000
F. breast	24	2.6	8.97	5.18 < RR < 15.54; p < 0.0000
*Lymphoma	6	0.50	11.95	3.65 < RR < 39.11
Childhood cancer 0 - 14	7	0.13	52.6	21.15 < RR < 131.0

*Rates for Non-Hodgkin Lymphoma were applied.

Table 4 focuses on leukemia in young men and all ages, since the excess risk was astonishingly high. A similarly high rate was found in the Fallujah study [Busby 2010]. Other cancer sites reported in the survey are listed in Table 5.

Table 4. Leukemia in the sample population. Confidence intervals and p-values were calculated using Yates-corrected Chi-squared Mantel-Haenszel tables.

Cancer type	Males	Females
Leukemia total	6	4
Ages at diagnosis	18, 12, 8, 19, 18, 11	26, 55, 60, 43
Year of birth	2004, 2012, 2013, 2004, 2003, 2010	1995, 1966, 1961, 1980
Expected (All ages)	0.577	0.29
Relative Risk (all ages)	10.26 (4.44 < RR < 23.69)	13.72 (4.84 < RR < 38.9)
p-value	<0.00000	<0.00000

Table 5. Other cancers reported in the survey.

Site	Male	Female
colorectal	6	3
pancreas	0	2
kidney	1	1
bladder	0	1
uterus	-	3
brain	0	1
lung	3	1
bone	1	0

Smoking

The number of smokers among those with cancer in the survey was reported as 6/26 for males and 0/57 for females.

3.2. Hair Sample Results

Forty-seven hair samples were collected and split into two portions. One was sent to Germany for ICPMS analysis. In this case, many of the samples had insufficient hair for a proper analysis and were set aside. The lab conducted a full 52-element test for the samples that it considered to have enough hair to provide statistically significant results. These were mainly hair from females, although two samples from males had enough hair and were tested.

In Tables 6-9, the elements that appear at more than three times the maximum normal background concentration are highlighted in pink. Those at twice the expected maximum background concentration are highlighted in yellow. Uranium was measured but is not included, since there was a wide range, with levels high in four individuals but low in others, such that the mean levels were not greater than twice the expected control value.

Table 6. Hair analysis results for elements in excess of the expected highest global average from uncontaminated areas.

Element	Expected	A10	A11	A12	A14	A17
Sex age		F 50	F 20	F 26	F 55	F 45
Fe	7.7 - 15	36.285	36.49	23.324	21.01	20.074
Mn	0.7 - 0.5	2.91	2.546	3.414	5.70	1.404
Ca	200 - 850	4177	6218.4	5970.97	3931.3	6428.5
Mg	20 - 115	597	550.9	814.6	498.3	231.35
Sr	0.11 - 4.28	29.09	33.7	34.723	23.732	13.037
Bi	<0.179	5.72	12.914	16.802	0.83	4.397
Al	<8	30.1	30.06	22.527	17.348	9.334
Ba	<2.65	-	6.108	-	-	-
Hg	<0.3	3.335	10.723	29.764	-	3.759
Ni	<0.85	3.026	-	1.24	-	1.31

Table 7. Hair analysis results for elements in excess of the expected highest global average from uncontaminated areas (continued).

Element	Expected	A18	A37	A39	A23
Sex age		F 51	F 82	F 43	F 33
Fe	7.7 - 15	-	59	-	51.832
Mn	0.7 - 0.5	1.042	10.3	2.498	3.737
Ca	200 - 850	1541	5169	3185	11,694
Mg	20 - 115	231.35	710	232	596
Sr	0.11 - 4.28	13.037	44	14.73	70.918
Bi	<0.179	0.475	1.002	-	-
Al	<8	9.334	45	15.35	44.678
Ba	<2.65	5.302	-	-	6.917
Hg	<0.3	-	-	-	8.403
Ni	<0.85	-	-	-	2.274

Table 8. Hair analysis results for elements in excess of the expected highest global average from uncontaminated areas (continued).

Element	Expected	A24	A27	A29	A32	A34
Sex age		F 52	F 58	F 58	F 49	F 20
Fe	7.7 - 15	21.4	21.33	11.68	15.97	11.395
Mn	0.7 - 0.5	14.32	1.54	1.4	1.14	1.972
Ca	200 - 850	9835	4008	2812	1849	1837
Mg	20 - 115	1039	420	239	209.32	191

Continued

Sr	0.11 - 4.28	55.54	15.04	20.18	14.708	12.62
Bi	<0.179	5.99	0.36	0.147	0.135	1.425
Al	<8	23.2	21.37	9.312	14.530	7.743
Ba	<2.65	9.21	2.29	2.797	2.149	1.674
Hg	<0.3	3.24	0.236	0.268	0.293	1.142
Ni	<0.85	3.19	2.63	1.146	0.175	0.715

Table 9. Hair analysis results for elements in excess of the expected highest global average from uncontaminated areas (continued).

Element	Expected	A35	A44	A47
Sex age		F 48	M 8	M 35
Fe	7.7 - 15	17.67	19.724	5.66
Mn	0.7 - 0.5	4.49	0.709	0.33
Ca	200 - 850	4420	391	32.6
Mg	20 - 115	473	42.5	29
Sr	0.11 - 4.28	24.45	2.009	3.02
Bi	<0.179	1.574	2.356	0.013
Al	<8	13.66	16.103	5.56
Ba	<2.65	3.763	0.441	0.788
Hg	<0.3	12.032	1.591	0.286
Ni	<0.85	0.730	0.185	0.208

3.3. Socioeconomic and Psychological Impact Derived from the Interviews

Field observations and structured interviews indicated that cancer exerts a profound and multidimensional burden on affected households in Al-Rafai District, extending beyond the medical condition itself to encompass severe socioeconomic disruption, psychological distress, and long-term social consequences. These effects were particularly pronounced among families living below the poverty line and in geographically remote areas with limited access to healthcare services.

Economic Impact

The financial consequences of cancer were consistently reported as catastrophic for many households.

High Treatment Costs: Families reported that direct medical expenses—including radiotherapy, chemotherapy, surgical procedures, medications, diagnostic tests, transportation to urban hospitals, and accommodation during treatment—frequently exceeded their entire monthly or annual income. In many cases, treatment costs were described as *unsustainable* without external assistance.

Loss of Income and Productivity. Patients undergoing treatment, as well as primary income earners who became caregivers, were often unable to maintain regular employment. This resulted in an immediate and sustained loss of household income, further destabilizing already vulnerable family economies.

Debt Accumulation and Asset Depletion. A large proportion of families reported resorting to borrowing money from relatives, neighbours, or informal lenders. Others were forced to sell essential assets, including livestock, agricultural equipment, or personal property in order to finance treatment. These coping strategies frequently led to long-term indebtedness and irreversible economic decline.

Geographical Inequality in Access to Healthcare. Residents of rural villages, marshland communities, and desert settlements frequently experienced long travel distances to specialized healthcare facilities and faced significant barriers in accessing specialized oncology services. Long travel distances, repeated hospital visits, and associated transportation costs created additional delays in diagnosis and treatment, often worsening clinical outcomes.

Psychological Impact. The psychological burden of cancer was described as severe and persistent, affecting both patients and their families.

Patient suffering: Patients commonly experienced intense psychological distress, including persistent anxiety, fear of disease progression, uncertainty about survival, and depressive symptoms. Many individuals expressed feelings of helplessness and loss of control over their lives, particularly following diagnosis.

Family Emotional Burden. Family members reported continuous emotional strain linked to witnessing the disease progression, managing financial pressures, and coping with repeated hospital journeys. The uncertainty surrounding treatment outcomes contributed to chronic stress and emotional exhaustion.

Impact on Children

Children living in affected households were indirectly but significantly impacted. They frequently experienced emotional insecurity, fear, and instability due to parental illness, reduced household income, and disruption of normal family functioning, including schooling and daily routines.

Social and Moral Consequences

Beyond the household level, the cumulative effects of illness and poverty produced broader social consequences within communities, including:

Declining morale and community well-being

Reduced capacity of families to cope with everyday challenges

Social withdrawal and isolation of affected households

Weak or absent formal support systems

Increasing strain on extended family networks and traditional social safety structures

In many cases, the illness was perceived not only as a medical condition but also as a destabilizing social event affecting entire family structures.

Cultural and Social Barriers to Reporting and Healthcare Utilization

Field observations indicated that cultural norms and social perceptions played a significant role in delaying diagnosis and limiting the reporting of cancer cases.

Stigma and Social Shame

Some families deliberately concealed cancer diagnoses due to fear of social judgment and stigma associated with chronic or fatal illness. Concerns regarding family reputation and the marriage prospects of relatives were frequently mentioned.

Limited Health Literacy

Low levels of education and insufficient public awareness contributed to poor recognition of early cancer symptoms, delayed healthcare-seeking behavior, and misunderstanding of disease mechanisms. In several cases, symptoms were initially attributed to non-medical or temporary causes.

Traditional Beliefs and Explanatory Models

Certain local cultural beliefs and folklore attributed cancer to supernatural causes, including witchcraft or spiritual influences. These beliefs, in some instances, influenced initial treatment choices and delayed engagement with formal medical services.

4. Discussion

This study represents a field-based, community-level epidemiological investigation conducted in Al-Rafai District, Dhi Qar Governorate. As with all cross-sectional household survey designs relying on retrospective reporting, the findings are subject to inherent methodological constraints, including recall bias, potential misclassification of diagnoses, survival bias, and the absence of independent clinical verification for all reported cases. The use of household-level enumeration as the sampling frame also introduces limitations related to population mobility and incomplete ascertainment of outcomes in deceased or migrated individuals.

Notwithstanding these limitations, the study design is consistent with established approaches used in conflict-affected and resource-limited settings where population-based cancer registries are incomplete or insufficiently granular. Similar methodologies have previously been applied in epidemiological investigations in Iraq and other post-conflict environments, where they have provided useful preliminary estimates of disease burden and spatial clustering patterns, particularly when triangulated with clinical and registry-based data where available [4].

A key feature of the present investigation is the integration of environmental exposure assessment through trace elemental analysis of biological matrices, specifically scalp hair samples analyzed via inductively coupled plasma mass spectrometry (ICP-MS). ICP-MS is a high-resolution, multi-element analytical technique widely accepted for environmental biomonitoring due to its low detection limits and capacity for simultaneous quantification of multiple trace metals. The use of internationally recognized laboratories further strengthens the analytical validity of the elemental data.

The epidemiological findings indicate a markedly elevated burden of malignancy within the surveyed population, with a disproportionate representation of childhood cancers (0 - 14 years), young population leukemia cases (0 - 19 years), and female breast cancer. The magnitude of the reported excess risks, if confirmed, would represent a substantial deviation from expected background incidence levels and suggests the possibility of non-random spatial and demographic clustering. The observed pattern of multiple cancer types within the same community further raises the hypothesis of a shared environmental exposure component rather than isolated sporadic disease occurrence.

The age-specific distribution of leukemia cases is of particular epidemiological interest. In contrast to the canonical age-incidence curve observed in most populations—characterized by a peak in early childhood (0 - 4 years) and a subsequent decline—the present data suggest an atypical distribution extending into late adolescence, with a peak around 18 years of age. Such a deviation from expected age-specific incidence patterns may indicate differences in exposure timing, latency dynamics, or sustained environmental exposure across developmental stages. However, alternative explanations, including reporting structure and survival-related ascertainment bias, cannot be excluded without independent registry linkage.

However, the observed temporal clustering of birth cohorts born immediately following the 2003 conflict period warrants cautious interpretation. While it may be hypothesized that early-life exposure to persistent environmental contaminants could contribute to later disease manifestation, including leukemogenesis, such inference remains ecological in nature and cannot establish causality. Nevertheless, the pattern is consistent with a hypothesis of long-latency environmental carcinogenesis, which has been documented in other exposure contexts involving persistent particulate contaminants.

It is well accepted that cancer is mostly an environmental disease initiated by exposure to carcinogenic agents [1] [2]. Thus, it is reasonable to ask what previous contamination events could have caused these significant excess rates. The results show particularly high levels of cancer in a population that can be shown objectively to have been contaminated with heavy metals, including Uranium. One hypothesis is that the results may be connected to exposures to radioactive particles of Uranium from the weapons use of Depleted Uranium DU. The spectrum includes cancers which are radiogenic: leukemia, thyroid cancer, non-Hodgkin lymphoma, and female breast cancer. Al-Rafai itself was not the site of any battles, but particulate uranium is an aerosol and travels very large distances, so it is possible that this may be one source of the effects seen. However, there are other possible sources of heavy metal contamination, including oilfield process water contaminating the groundwater.

The environmental component of the study identifies elevated concentrations of multiple heavy metals in hair samples from a subset of female cancer patients, including elements of toxicological relevance. While ICP-MS provides robust quantitative measurement, hair biomonitoring data should be interpreted as indicative of exposure rather than a definitive internal dose, due to the influence of exogenous contamination, cosmetic treatment, and individual metabolic differences. Nonetheless, the presence of remarkable heavy metal elevation across samples may suggest a shared exposure environment and justifies further environmental matrix sampling.

Potential sources of environmental contamination in the region are likely to be multifactorial. In addition to legacy contamination from military activity, industrial emissions, oil extraction and processing infrastructure, and contaminated groundwater systems, airborne particulate matter is associated with regional dust storm events. Disentangling these sources requires systematic environmental sampling of water, soil, air particulates, and locally produced foodstuffs, combined with geospatial exposure modelling.

A critical and policy-relevant observation is the apparent discrepancy between the findings of this survey and the national cancer registry data for Dhi Qar Governorate. The absence of comparably elevated incidence in official records may reflect limitations in cancer registration completeness, diagnostic access disparities, reporting lag, or regional under-ascertainment. This divergence highlights the importance of independent epidemiological surveillance in regions where health information systems may not fully capture disease burden.

Finally, qualitative data derived from household interviews provide important contextual insight into the broader determinants of health within the affected population. The documented socioeconomic deprivation, psychological distress, healthcare access barriers, and cultural stigma surrounding cancer diagnosis collectively represent significant modifiers of health-seeking behaviour and may contribute to delayed diagnosis and suboptimal treatment outcomes. These factors, while not direct etiological agents, are integral to understanding the observed disease burden and its societal impact.

5. Conclusion

In conclusion, the present study provides preliminary evidence of an elevated and demographically distinctive cancer burden in Al-Rafai District, alongside suggestive biomarker evidence of environmental exposure to toxic elements. However, given the observational and survey-based nature of the data, causal inference remains limited. Further investigation using population-based cancer registry linkage, longitudinal cohort designs, and comprehensive environmental sampling is essential to validate these findings and to clarify potential exposure-disease relationships within a robust inferential framework.

6. Recommendations

Based on the findings of this field-based epidemiological and environmental survey in Al-Rafai District, the following recommendations are proposed. These are intended to guide further scientific investigation, public health action, and environmental assessment, while acknowledging the observational nature and inherent limitations of the current study design.

6.1. Strengthening Cancer Surveillance and Registry Systems

There is a critical need to improve the completeness, accuracy, and regional resolution (granularity) of cancer registration in Dhi Qar Governorate. This includes:

- Enhancing case ascertainment mechanisms at hospital and primary healthcare levels
- Establishing active cancer surveillance systems in rural and underserved areas.
- Conducting independent validation studies comparing registry data with field-based observations
- Improving linkage between pathology laboratories, oncology units, and national registries

6.2. Comprehensive Environmental Investigation

Given the indication of elevated trace metal levels and the hypothesis of environmental exposure, a systematic environmental assessment is strongly recommended, including:

- Testing of drinking water sources (groundwater, wells, and municipal supply)
- Soil sampling in residential, agricultural, and floodplain areas
- Air quality monitoring for particulate matter and heavy metal content
- Analysis of locally produced food chains, including crop and livestock products
- Identification and mapping of potential contamination hotspots

6.3. Expanded Biomonitoring Studies

Further biological monitoring should be conducted to validate and expand upon the preliminary hair analysis findings.

- Larger population-based sampling, including controls from non-affected areas
- Use of multiple biological matrices (blood, urine, and hair)
- Standardization of sampling protocols to reduce contamination bias
- Inclusion of age- and sex-matched comparative groups

6.4. Analytical and Epidemiological Follow-Up Studies

To strengthen causal inference and improve methodological robustness, the following studies are recommended:

- Longitudinal cohort studies tracking incidence over time
- Case-control studies focusing on childhood leukemia and breast cancer
- Geospatial analysis of cancer clustering patterns
- Exposure reconstruction studies incorporating historical environmental data

6.5. Public Health Intervention and Risk Communication

Immediate public health measures should focus on reducing potential exposure risks and improving community awareness.

- Strengthening early diagnosis and referral pathways for cancer patients
- Implementing community-based health education programs

- Addressing misconceptions, stigma, and cultural barriers to healthcare access
- Providing psychosocial and financial support mechanisms for affected families

6.6. Policy and Environmental Governance

The findings highlight the importance of integrating environmental health considerations into regional planning and governance.

- Development of intersectoral collaboration among health, environment, water, and oil/gas authorities
- Regulatory assessment of industrial and extractive activities in the region
- Establishment of environmental risk assessment frameworks for contaminated areas
- Consideration of precautionary environmental remediation measures where necessary.

6.7. Independent Scientific Review

Given the discrepancy between survey findings and official registry data, it is recommended that:

- Independent national and international expert review panels evaluate the data.
- Replication studies are conducted by separate research groups.
- Open data sharing should be encouraged to facilitate external validation.
- Concluding Statement.
- These recommendations aim to provide a structured pathway for verifying the preliminary findings, clarifying potential environmental contributions, and addressing the broader public health implications in the region through coordinated scientific and policy actions.

Ethical Issues

The questionnaires were answered on the basis of complete confidentiality, and no personal information about the individuals or their addresses would be made public.

The Helsinki University guidelines on questionnaire studies were followed, the purpose of the study was made clear, and personal data was ensured to be safe and confidential.

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Author Contributions

CB designed the questionnaire in English, arranged for the ICPMS analysis to be carried out in Germany, analyzed the results, and helped write the report. RAF, KNA, DRA, DAA, HWS, AAH, and MHA advised and arranged the survey itself and the collection of the hair samples, translated the initial questionnaire into Arabic, and provided the results for the analysis. They also contributed to the writing of the paper.

Conflicts of Interest

No conflicts of interest are declared by any author.

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