Contaminant Exposure and Disease Prevalence in the Ramapough Lunaape Turtle Clan Community

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BACKGROUND

Members of the Ramapough Lunaape Turtle Clan Nation (RLTC) reside on a **500-acre Superfund site** in Ringwood, New Jersey (NJ), as the aftermath of the iron mining industry, and **over a decade of misgoverned waste dumping from the automotive industry**.

As of August 2023, on-site groundwater and soil sampling results from the U.S. Environmental Protection Agency (USEPA) still showed high levels of **human carcinogens or probable human carcinogens**, including **arsenic, benzene, and lead**.

Due to proximity of the residences to the Superfund site, it is hypothesized that **chronic exposure to toxic contaminants** that might have dispersed from the dumping site out to public spaces over time **could pose an imminent threat to community health**.

However, quantitative data on environmental exposure levels and health outcomes in the RLTC community are virtually non-existent.

PURPOSE

This study aims to create an interdisciplinary framework that combines monitoring of air, soil, and plants quality with survey research to:

1. Provide quantitative data on **exposure levels to heavy metals and benzene, and the associated potential health risk**, as well as a first look into **disease prevalence** in the RLTC community.
2. Examine the **potential association between living on/near a Superfund site, and disease pathogenesis.**

By shedding light on these two critical issues, findings of this study can inform remediation efforts, and advocate for **evidence-based support strategies that prioritize the well-being of the RLTC community**.

MAP

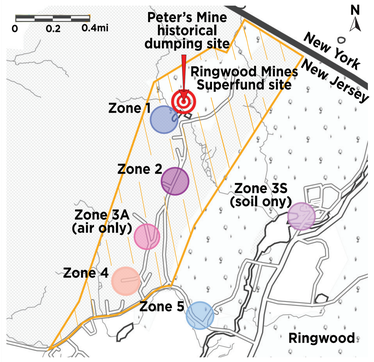


Figure 1. Map of environmental sampling locations in Ringwood, NJ
Air and soil/plant samples were taken inside all zones, except where noted.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Distance from dump site (m)	140	650	1350 (3A) 1500 (3S)	1650	1900
Plant species collected	Mugwort	Rough Bluegrass (3S)			Barberry

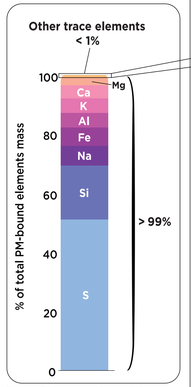


Figure 2. Average elemental composition of $PM_{2.5}$ across all sampling zones

RESULTS

(A)

	Air: PM-bound heavy metals (ng/m³)					Air: Total $PM_{2.5}$ (µg/m³)	Air: Benzene (µg/m³)
	Cadmium	Chromium	Lead	Manganese	Nickel		
Zone 1	ND	5.6	3.5	5.7	2.0	20.2	11.7
Zone 2	ND	ND	7.9	4.8	1.4	18.7	6.2
Zone 3A	*No data*						6.6
Zone 4	10.0	3.9	ND	5.3	2.1	22.9	4.4
Zone 5	ND	1.4	7.5	5.8	2.0	17.7	7.0
Average	2.5	1.8	5.1	5.3	1.9	19.9	7.2
Safety Standards	[1]1.04	[1]1.21 · 10^{-2} (Cr[VI])	[1]150	[1]5.21	[1]1.46	[2]35 (24-hour)	[1]0.36

(B)

	Soil (mg/kg)							Plant shoots (mg/kg)	
	Arsenic	Barium	Cadmium	Cobalt	Chromium	Lead	Nickel	Cadmium	Lead
Zone 1	17.5	27,540	2.2	40.5	99.2	510.9	92.4	3.1	7.3
Zone 2	6.8	*Saturated*	1.0	38.1	158.5	73.9	98.1	0.05	1.5
Zone 3S	16.3	26,029	0.94	35.3	123.5	466.8	139.8	0.2	1.9
Zone 4	4.3	17,784	0.82	35.5	112.8	69.1	76.5	1.1	0.83
Zone 5	11.3	*Saturated*	2.0	24.3	100.8	379.4	94.2	0.03	2.8
Average	10.7	22,284	1.46	34.7	119.6	281.5	95.8	*N/A*	
NJ Average[3]	8.3	56.0	0.29	4.3	18.6	93.8	10.5	*N/A*	
Safety Standards	[1]0.68	[1]1,530	[1]0.71	[2]2.34	[1]0.3 (Cr[VI])	[1]400	[1]145	[4]0.2	[4]0.3

Table 1. Concentrations of PM-bound heavy metals, total $PM_{2.5}$, benzene in air (A), and of heavy metals exceeding safety standards in soil and plants (B), in Ringwood, NJ
*Highlighted in **red** are air concentrations exceeding safety standards.*
[1] Screening Levels set by the USEPA
[2] National Ambient Air Quality Standards set by the USEPA
[3] NJ Department of Environmental Protection
[4] Permissible Food Limit set by the World Health Organization

(A)

	Air: PM-bound heavy metals					Air: Benzene
	Cadmium	Chromium	Lead	Manganese	Nickel	
	Hazard Index					
Children	0.24	1.7 · 10^{-2}	8.1 · 10^{-4}	0.10	0.13	0.23
Adults						
	Cancer Risk					
Children	1.6 · 10^{-6}	1.5 · 10^{-4}	3.4 · 10^{-6}	*N/A*	1.8 · 10^{-7}	2.0 · 10^{-5}
Adults						

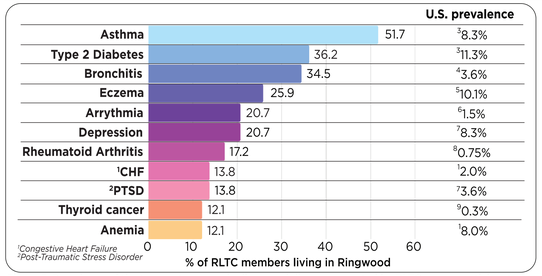
(B)

	Soil						
	Arsenic	Barium	Cadmium	Cobalt	Chromium	Lead	Nickel
	Hazard Index						
Children	0.31	1.5	0.20	1.5	0.51	1.0	6.6 · 10^{-2}
Adults	3.2 · 10^{-2}	0.17	2.1 · 10^{-3}	0.14	4.7 · 10^{-2}	9.7 · 10^{-2}	1.1 · 10^{-2}
	Cancer Risk						
Children	1.3 · 10^{-4}	*N/A*	6.9 · 10^{-5}	*N/A*	4.7 · 10^{-4}	3.4 · 10^{-6}	1.3 · 10^{-3}
Adults							

Table 2. Non-carcinogenic (hazard index) and carcinogenic risks from exposure to PM-bound heavy metals and benzene in air (A), and from exposure to heavy metals in soil (B), in Ringwood, NJ
*Highlighted in **red** are values that denote a significant risk (> 1 for non-carcinogenic; > 10^{-6} for carcinogenic)*

	Total Hazard Index	Total Cancer Risk
Children	5.9	5.9 · 10^{-4}
Adults	1.3	

Table 3. Total non-carcinogenic (hazard index) and carcinogenic risks from exposure to all air and soil contaminants
*Highlighted in **red** are values that denote a significant risk (> 1 for non-carcinogenic; > 10^{-6} for carcinogenic)*



[1]Congestive Heart Failure
[2]Post-Traumatic Stress Disorder

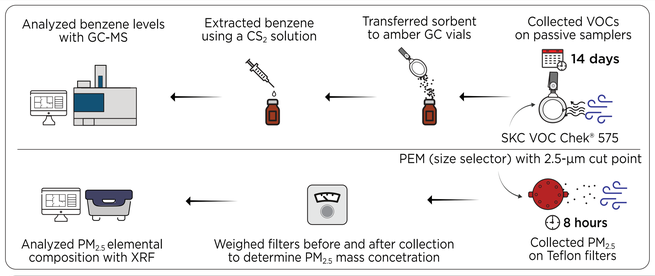
Figure 3. Prevalence of the ten most commonly diagnosed diseases reported by RLTC survey participants living in the Ringwood area (n = 56), relative to the U.S. national prevalence

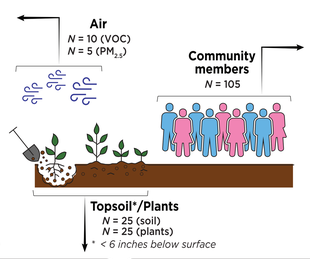
[3] Center for Disease Control and Prevention (US)
[4] American Lung Association
[5] National Eczema Association (US)
[6] Kornej et al. (2022)
[7] National Institute of Mental Health (US)
[8] Xu Y. and Wu Q. (2021)
[9] National Cancer Institute (US)

	Non-RLTC living outside of Ringwood	[1]Prevalence Ratio
Asthma	21.1%	2.76
Type 2 Diabetes	21.1%	1.93
Bronchitis	5.3%	7.50
Eczema	15.8%	1.88
Arrythmia	10.5%	4.13
Depression	5.3%	4.50
Rheumatoid Arthritis	5.3%	3.38
CHF	0.02%	5.71
PTSD	0.02%	6.47
Thyroid cancer	0.02%	5.71
Anemia	5.3%	2.63

Table 4. Prevalence of the most commonly diagnosed diseased reported by RLTC members in non-RLTC survey participants living outside of Ringwood (n = 19)
[1]The Prevalence Ratio is the ratio between the disease prevalence in the RTLC community living in Ringwood (numerator) vs. the non-RLTC community living outside of Ringwood (denominator).
*Highlighted in **red** are values that denote a significant association (> 1.0 for PR)*

METHODS



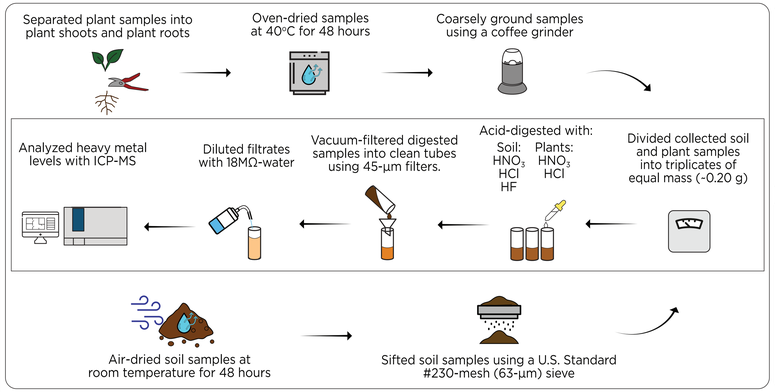


Community Health Survey
12 sections | On Paper or REDCap

Demographics	Health Assessment
Housing	Family Cancer History
Tobacco Use	Psychosocial
Food Intake	Life Events
Drink Intake	Family Resilience
Food Security	Historical Loss (*NA only*)

Select variables collected in surveys:
Place of Residence & Length of Stay
Age, Sex, Weight, Height
Education Level, Work Status, Income
Smoking Habits
Soda, Fast Food, Alcohol Consumption
Medical History (*diagnosed diseases*)
Stress Level (*Likert score*)

Glossary of acronyms used
ADD: Average Daily Dose
CR: Carcinogenic Risk
CS_2: Carbon Disulfide
GC: Gas Chromatography
HCl: Hydrochloric Acid
HF: Hydrofluoric Acid
HI: Hazard Index
HNO_3: Nitric Acid
ICP: Inductively-Coupled Plasma
MS: Mass Spectrometry
NA: Native American
PEM: Personal Environmental Monitor
PM: Particulate Matter
PR: Prevalence Ratio
RfD: Reference Dose
RLTC: Ramapough Lunaape Turtle Clan
SF: Cancer Slope Factor
XRF: X-Ray Fluroescence



Health Risk Calculations
Estimations of non-carcinogenic (HI) and carcinogenic (CR) risks associated with exposure to the heavy metals found in soil, and to benzene and PM-bound heavy metals in air, were calculated for children and adults.

For each contaminant j, in each exposure pathway i,

$$HI_j = \sum_i^3 \frac{ADD_{i,j}}{RfD_j} \quad | \quad CR_j = \sum_i^3 ADD_{i,j} \cdot SF_j$$

In the mixture of all n pollutants,

$$\textbf{Total HI} = \sum_j^n HI_j \quad | \quad \textbf{Total CR} = \sum_j^n CR_j$$

Health-Exposure Association Calculations
To determine a potential association between being a RLTC member living in Ringwood and disease prevalence, general 2x2 tables were created, and **unadjusted** prevalence ratios (PR) were calculated for the most commonly reported diseases in their survey responses.

	Outcome: Yes	Outcome: No	Total
RLTC members living in Ringwood	a	b	a + b
Non-RLTC living outside of Ringwood	c	d	c + d

$$PR = \frac{\left(\frac{a}{a+b}\right)}{\left(\frac{c}{c+d}\right)}$$

DISCUSSION / CONCLUSIONS

Elevated levels of toxic contaminants were found in the air, soil, and plant samples taken in and around the Ringwood Mines Superfund site, where many RLTC members reside.

Exposure to such levels of toxic contaminants can lead to an increased risk of experiencing both adverse non-carcinogenic and carcinogenic health effects, as evidenced by the Total HI and the Total CR.

The contaminants found in the area are linked to many of the diseases that were commonly diagnosed in the RLTC community:

- Heavy metals and asthma, eczema, CHF, and type 2 diabetes.
- Benzene and anemia.
- Arsenic, cadmium, and lead, which have endocrine-disrupting capabilities, and could affect the hormonal system, and promote malignancy (e.g. thyroid cancer).

Survey results underlined the fact that the well-being of the RLTC community members is under threat.

Environmental sampling results suggest that a potential risk factor to community health could be the contaminants present in the area.

However, further efforts are needed, and are currently under way to provide data to support this hypothesis:

- More survey responses to increase the power of the study.
- More environmental sampling to confirm the long-term presence of contaminants in the area.
- Additional testing for other compounds (e.g. PFAS, PCBs), and in other matrices (e.g. water) for a more holistic picture of exposure.
- Adjustment of epidemiological analyses for confounding variables (e.g. smoking, dietary intake, family history, other comorbidities).
- Monitoring of biomarkers of exposure, disease, and health risks to address variabilities between individuals.

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