Environmental Stressors and Older Adult Morbidity: Initial Findings from University Medical Centre Maribor as Part of a Slovenian - Turkish Bilateral Study

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Environmental stressors such as air pollution and weather variability are increasingly recognized as important determinants of health in older adults, yet evidence on their short-term effects in Central Europe remains limited. This study examines associations between meteorological conditions, air pollution, and cardiovascular and respiratory morbidity among adults aged 65 years and older presenting to emergency departments in Slovenia. A retrospective observational analysis of emergency department visits in 2024 (N = 4,870) was conducted, linking ICD-10 diagnoses with daily meteorological and air pollution data (NO_2, $PM_{2.5}$, PM_{10}, benzene) and analyzed using multivariable regression models adjusted for age, sex, and season. Cardiovascular disease prevalence was primarily age-driven, whereas respiratory morbidity showed clear seasonal patterns and significant associations with NO_2, particularly during the cold season, with higher temperature and humidity showing protective effects. These findings suggest that short-term environmental stressors disproportionately affect respiratory health in older adults and support future cross-country comparative analyses.

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1   Introduction

Population ageing, combined with increasing exposure to environmental stressors, poses a growing public health challenge. Older adults are particularly vulnerable to adverse health effects of air pollution and extreme weather conditions due to physiological ageing, multimorbidity, and reduced adaptive capacity(World Health Organisation, 2024). Cardiovascular and respiratory diseases remain leading causes of morbidity and healthcare utilization in this population(Tran et al., 2023; Xu et al., 2019).

Short-term exposure to air pollutants such as nitrogen dioxide (NO_2) and particulate matter has been linked to acute respiratory exacerbations and cardiovascular events(Meng et al., 2021). However, findings vary across regions, and evidence from Central and Southeastern Europe remains limited. Slovenia and Turkiye share similar demographic ageing trends but differ in climatic conditions and pollution profiles, providing an opportunity for comparative research.

This study represents the Slovenian analytical component of a broader bilateral Slovenian–Turkish project investigating environmental determinants of older adult morbidity. This conference paper aims to present initial and extended findings from Slovenia, focusing on associations between meteorological conditions, air pollution, and cardiovascular and respiratory disease burden among older adults presenting to emergency departments.

2   Materials and Methods

2.1   Study Design and Population

A retrospective observational study was conducted using anonymized emergency department records from the University Medical Centre Maribor, Slovenia. The study population included all adults aged 65 years and older who presented to the emergency department during 2024 (N = 4,870). The demographic characteristics and disease profiles of the study population are summarized in Table 1.

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2.2   Health Outcomes

Diagnoses were classified using ICD-10 codes and grouped into:

- Cardiovascular diseases (I-codes),
- Respiratory diseases (J-codes),
- Disease-specific outcomes (e.g., heart failure, atrial fibrillation, pneumonia, COPD, asthma),
- Multimorbidity, defined as the presence of two or more diagnosed conditions.

2.3   Environmental Exposures

Daily environmental data were obtained from the Slovenian Environment Agency and included:

- Mean daily temperature (°C),
- Relative humidity (%),
- Air pollutants: NO_2, $PM_{2.5}$, PM_{10}, and benzene (μg/m³).

Environmental variables were matched temporally with emergency department visits.

2.4   Statistical Analysis

Statistical analyses were performed using the trial version of IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). Descriptive statistics summarized demographic characteristics, disease prevalence, and exposure distributions. Spearman correlation analyses were used to assess relationships among environmental variables and inform model specifications.

Associations between environmental exposures and health outcomes were examined using:

–   Binary logistic regression for disease presence,
–   Robust Poisson regression for aggregated outcomes and multimorbidity burden.

All models were adjusted for age, sex, and season (cold vs. warm). Sensitivity analyses included alternative exposure metrics and seasonal stratification. Statistical significance was set at $p < 0.05$.

3　Results

3.1　Population Characteristic

Table 1: Demographic characteristics and disease profiles of older adults presenting to emergency departments, overall and by sex

Variable	Total (N=4,870)	Female (n=2,441)	Male (n=2,429)
Age, years	Median(Q1–Q3; min–max):79 (72–84; 65–103)	Median(Q1–Q3):	Median(Q1–Q3; min–max):79 (72–84; 65–103)
WHO age classification			
65–74 years	1,684 (34.6%)	669 (39.7%)	1,015 (60.3%)
75–84 years	2,003 (41.1%)	1,016 (50.7%)	987 (49.3%)
≥85 years	1,183 (24.3%)	756 (63.9%)	427 (36.1%)
Any cardiovascular disease			
Yes	4,458 (91.5%)	2,248 (92.1%)	2,210 (91.0%)
No	412 (8.5%)	193 (7.9%)	219 (9.0%)
Any respiratory disease			
Yes	2,486 (51.0%)	1,215 (49.8%)	1,271 (52.3%)
No	2,384 (49.0%)	1,226 (50.2%)	1,158 (47.7%)
Multimorbidity (≥2 diseases)			
Yes	3,648 (74.9%)	1,793 (73.5%)	1,855 (76.4%)
No	1,222 (25.1%)	648 (26.5%)	574 (23.6%)
No. of diag. diseases per individual	Median (Q1–Q3; min-max): 3 (2–5; 1–11)	Median (Q1–Q3; min–max): 3 (2–5; 1–10)	Median (Q1–Q3; min–max): 3 (2–4; 1–11)

Continuous variables are presented as median (Q1–Q3; min–max) due to non-normal distributions. Categorical variables are presented as n (%). Multimorbidity was defined as the presence of two or more diagnosed diseases. Cardiovascular and respiratory diseases indicate the presence of at least one ICD-10 diagnosis within the respective disease group. No missing data was observed for variables included in this table.

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Table 2: The annual and seasonal distribution of meteorological conditions and air pollution levels corresponding to emergency department visits among older adults

Variable	Annual Median (Q1-Q3)	Annual Min-Max	Winter Median (Q1-Q3)	Winter Min-Max	Spring Median (Q1-Q3)	Spring Min-Max	Summer Median (Q1-Q3)	Summer Min-Max	Autumn Median (Q1-Q3)	Autumn Min-Max
Temperature (ºC)	12.3 (7.2–19.5)	−3.1-28.1	5.1 (2.2–8.2)	−3.1-12.6	13.9 (9.5–17.1)	3.0-21.3	46165 (22.0–25.6)	14.6-28.1	12.2 (7.3–16.6)	1.3-25.5
Relative humidity (%)	68.0 (60.8–78.1)	40.8-93.7	69.6 (60.1–79.3)	41.0-91.7	62.6 (55.7–71.0)	40.8-92.1	63.8 (59.6–70.7)	50.5-92.0	77.8 (67.5–85.7)	47.2-93.7
NO$_2$ (µg/m³)	24.5 (19.1–30.2)	5.9–64.6	33.3 (26.0–43.6)	13.1–64.6	24.8 (20.2–28.5)	5.9–46.0	19.5 (14.1–22.1)	10.2–30.4	24.3 (18.7–27.7)	7.1–50.9
PM$_{2.5}$ (µg/m³)	10.4 (6.9–17.3)	0.9–52.7	18.1 (10.8–24.8)	2.1–52.7	8.3 (5.7–12.4)	2.0–41.3	8.8 (6.6–12.1)	2.9–28.4	12.6 (6.2–21.2)	0.9–47.0
PM$_{10}$ (µg/m³)	17.5 (11.9–28.1)	2.6–131.2	27.1 (16.7–36.4)	5.4–77.3	15.4 (10.2–23.0)	4.5–131.2	14.6 (11.8–18.5)	6.0–67.4	20.6 (10.7–31.8)	2.6–56.2
Benzene (µg/m³)	0.68 (0.38–1.39)	0.0–4.4	1.60 (1.09–2.23)	0.4–4.1	0.51 (0.39–0.86)	0.1–1.8	0.17 (0.12–0.36)	0.0–2.8	0.93 (0.63–1.50)	0.3–4.4

Environmental variables were summarized at the daily level. Overall values are presented as median (Q1–Q3; minimum–maximum), while seasonal values are presented as median (Q1–Q3). Seasons were defined as winter (December–February), spring (March–May), summer (June–August), and autumn (September–November). No missing data was observed for environmental variables.

Table 1 provides an overview of the demographic characteristics and disease profiles of the study population. The median age of the study population was 79 years, with a balanced sex distribution. Cardiovascular disease was present in 91.5% of individuals, respiratory disease in 51.0%, and multimorbidity in 74.9%.

3.2   Environmental Conditions

Marked seasonal variability was observed (Table 2). Air pollutant concentrations, particularly NO_2 and particulate matter, were higher during the cold season, while temperatures were lowest in winter and highest in summer.

3.3   Cardiovascular Outcomes

Age was the dominant determinant of cardiovascular disease prevalence (Table 3). Each additional year of age was associated with a significant increase in cardiovascular disease burden. Short-term variations in air pollution and meteorological conditions showed no consistent independent associations with aggregated cardiovascular outcomes.

Table 3: Adjusted associations between environmental exposures and cardiovascular disease among older adults

Variable			
Environmental exposures	Adjusted OR	95% CI (Lower–Upper)	p-value
Mean Daily $PM_{2.5}$ (µg/m³)	0.998	0.992 – 1.005	0.599
Mean Daily PM_{10} (µg/m³)	0.997	0.990 – 1.005	0.470
Mean Daily NO_2 (µg/m³)	0.995	0.983 – 1.008	0.490
Mean Daily Benzene (µg/m³)	1030	0.880 – 1.210	0.720
Covariates			
Age (per 1-year increase)	**1072**	**1.057 – 1.088**	**<0.001**
Sex (female vs male)	0.960	0.781 – 1.181	0.701
Season – Spring vs Winter	1042	0.780 – 1.393	0.779
Season – Summer vs Winter	0.998	0.745 – 1.335	0.987
Season – Autumn vs Winter	1085	0.802 – 1.468	0.597

Binary logistic regression models were used. All models were adjusted for age (continuous), sex, and season (winter as the reference category). Odds ratios (ORs) represent the change in odds of having any cardiovascular disease per unit increase in the corresponding variable. N = 4,870.

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3.4 Respiratory Outcomes

Respiratory disease prevalence demonstrated strong seasonal patterns (Table 4). Higher NO_2 concentrations were associated with increased respiratory disease prevalence, particularly during the cold season. Warmer temperatures and higher humidity were inversely associated with several respiratory outcomes, including respiratory failure and pneumonia.

Table 4: Adjusted associations between environmental exposures, age, and respiratory diseases among older adults

Variable			
Environmental exposures	**Adjusted OR**	**95% CI (Lower–Upper)**	**p-value**
Mean Daily $PM_{2.5}$ (µg/m³)	0.998	0.992 – 1.005	0.599
Mean Daily PM_{10} (µg/m³)	0.997	0.990 – 1.005	0.470
Mean Daily NO_2 (µg/m³)	0.995	0.983 – 1.008	0.490
Mean Daily Benzene (µg/m³)	1030	0.880 – 1.210	0.720
Covariates			
Age (per 1-year increase)	1007	1.000 – 1.014	0.060
Sex (female vs male)	**0.882**	**0.786 – 0.989**	**0.032**
Season – Spring vs Winter	**1486**	**1.264 – 1.747**	**<0.001**
Season – Summer vs Winter	1040	0.885 – 1.223	0.632
Season – Autumn vs Winter	0.893	0.758 – 1.053	0.178

Binary logistic regression models were used to examine the associations between environmental exposures and the presence of any respiratory disease among older adults. All models were adjusted for age (continuous), sex, and season (winter as the reference category). Each environmental exposure was entered separately using a single-pollutant approach. Odds ratios (ORs) and 95% confidence intervals (CI) represent the change in odds of having any respiratory disease per unit increase in the corresponding variable. N = 4,870.

3.5 Multimorbidity

Multimorbidity burden increased steadily with age and was higher during spring compared with winter (Table 5). Overall, multimorbidity showed limited sensitivity to short-term air pollution exposure, although modest associations with NO_2 were observed during the cold season.

Table 5: Associations Between Environmental Exposures and Multimorbidity Burden

Variable	Adjusted IRR	95% CI (Lower–Upper)	p-value
Mean Daily $PM_{2.5}$ (µg/m³)	0.999	0.997 – 1.001	0.379
Mean Daily PM_{10} (µg/m³)	0.999	0.998 – 1.001	0.262
Mean Daily NO_2 (µg/m³)	1000	0.998 – 1.002	0.914
Mean Daily Benzene (µg/m³)	0.990	0.965 – 1.016	0.459
Age (per 1-year increase)	**1008**	**1.006 – 1.010**	**<0.001**
Sex (female vs male)	**0.945**	**0.913 – 0.977**	**0.001**
Season – Spring vs Winter	**1108**	**1.057 – 1.168**	**<0.001**
Season – Summer vs Winter	1041	0.992 – 1.095	0.106
Season – Autumn vs Winter	0.980	0.926 – 1.029	0.370

Incidence Rate Ratios (IRRs) were obtained from Poisson regression models with a log link function. Each environmental exposure was examined in a separate model to avoid multicollinearity. Pearson chi-square/df values (~0.9) indicated no overdispersion in any model.

4   Discussion

This study provides comprehensive evidence on environmental determinants of older adult morbidity in Slovenia using real-world emergency department data. The findings highlight a clear contrast between cardiovascular and respiratory outcomes. While cardiovascular disease prevalence appears primarily driven by age and chronic disease accumulation, respiratory morbidity shows greater sensitivity to short-term environmental stressors(Lai et al., 2025; Liu et al., 2022; Ning et al., 2025).

The observed association between NO_2 and respiratory outcomes aligns with the role of traffic-related pollution in triggering acute respiratory conditions(Meng et al., 2021). Seasonal effects further emphasize the importance of cold-season exposure profiles(Ning et al., 2025). The limited association between air pollution and cardiovascular outcomes may reflect the chronic nature of cardiovascular disease and the use of prevalence-based analyses.

Strengths of this study include the large sample size, detailed diagnostic classification, and robust analytical strategy. Limitations include the single-center design, lack of individual exposure assessment, and inability to infer causality. Moreover, the present study applied conventional regression-based statistical methods, which was appropriate given the predefined exposure variables, and clearly

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defined clinical outcomes. As the Slovenian–Turkish project expands to include larger datasets, AI-based techniques could help capture complex interactions among environmental variables and improve predictive risk stratification.

5   Conclusion

Among older adults presenting to emergency departments in Slovenia, short-term environmental stressors—particularly traffic-related air pollution and cold-season conditions—are more strongly associated with respiratory than cardiovascular morbidity. Age remains the primary driver of cardiovascular disease and multimorbidity burden. These findings provide a solid evidence base for the planned Slovenian–Turkish comparative analyses and support the integration of environmental considerations into public health strategies for ageing populations.

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