Human health risk assessment of air pollution in the regions of unsustainable heating sources. Case study – the tourist areas of southern Poland

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Introduction

Air quality, raises public concern owing to severe air pollution in many locations in Poland, especially on the areas offering great natural and landscape values for tourists. In Poland, household emissions, generated by cooking and heating stoves, boilers, and fireplaces, fired with coal or wood, are still high and uncontrollable [1,2]. On less affluent areas, poor quality fuel is often used and burning diverse municipal solid waste is quite common, additionally increasing hazardous emissions. Traffic emissions are placed at the second place after the communal and household sector [3] and the increasing number of vehicles in general causes the increase of so-called traffic-related air pollution [4,5].

The mountainous region around the Czorsztyn Reservoir (**Figure 1**) is one of the most attractive tourist areas in southern Poland and it offers opportunities for outdoor activities to both local residents and tourists, especially in the winter season. Air quality depends strongly there on traffic concentration and combustion of poor quality fuels for heating purposes [6].

The goal of the present study was to investigate the human health risk assessment (HHRA). We analysed health risk factor arising from inhalation exposure to ambient air contaminants in the popular tourist region of the Czorsztyn Reservoir in the Carpathians, for both residents and tourists, because tourist areas had been rarely investigated in Poland, under the national ambient-air quality monitoring network.

Materials and Methods

Study area. Air quality was investigated in twelve attractive tourist locations (**Figure 2**), in the surroundings of the Czorsztyn Reservoir during the winter season of 2017/2018 [7]:

1 – Maniowy, 2 – Łapsze Wyżne, 3 – Frydman, 4 – Klikuszowa, 5 – Jurgów, 6 – Huba, 7 – Ludźmierz, 8 – Kacwin, 9 – Dębno, 10 – Czorsztyn, 11 – Niedzica, 12 – Waksmund.

Air pollutant measurments. The concentrations of PM10, PM2.5, PM1, CO, O_3, and NO_2 were measured continuously between 18 December 2017 and 9 March 2018, using an Alphasense air sensor (station model: Sensor AirSense Extended; date of manufacture: 26 February 2017; zero-chamber calibration conducted on 7 March 2017; station software: SenseOS v.2.0).

QC/QA. Our air pollution content analyses involved real-time measurements within one second and average measurements, within three minutes. The results of the measurement were sent to and stored in the database in real time and the average hourly values of investigated pollutants were further used for health risk calculations. Sensor locations during measurements described the general city condition of air pollutants concentrations.

The accuracy of the performed measurements was checked by comparison with the measurement values achieved under the regional monitoring system of the Chief Inspectorate of Environmental Protection in Poland in the winter season [7].

Figure 1. Czorsztyn recreational area in southern Poland (R. Klimek).

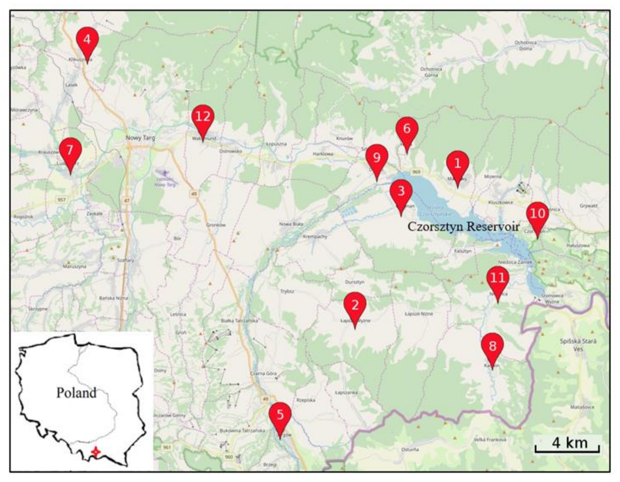

Figure 2. Air measurement sites in the villages surrounding the Czorsztyn Reservoir [7].

1 – Maniowy, 2 – Łapsze Wyżne, 3 – Frydman, 4 – Klikuszowa, 5 – Jurgów, 6 – Huba, 7 – Ludźmierz, 8 – Kacwin, 9 – Dębno, 10 – Czorsztyn, 11 – Niedzica, 12 – Waksmund

Human Health Risk Assessment

In our investigations, both resident and tourist exposure scenarios were analysed through the inhalation exposure pathway. Under each exposure scenario, the following subpopulations were considered: adults (>7 years), children (1-7 years), and infants (0-1 year).

Non-carcinogenic risk was calculated for NO_2, PM10, and PM2.5, because the reference values of those contaminants, i.e. the reference dose (RfD) for NO_2 and PM10 and the reference concentration (RfC) for PM2.5, were available in the toxicological databases [8-10].

Daily intake of pollutants: either exposure concentration (EC) or average daily dose (ADD) values were calculated according to Equations (1) [11] and (2) [12], respectively, depending on the available reference values:

$EC = (C \times ET \times EF \times ED)/AT$ (1) $ADD = (C \times IR \times ET \times EF \times ED)/(BW \times AT)$ (2),

Where: EC, exposure concentration (mg/m^3); ADD, average daily dose (mg/kg-day); C, contaminant concentration in air (the measured values were converted to mg/m^3); IR, inhalation rate (m^3/h); ET, exposure time (h/day); EF, exposure frequency (days/year); ED, exposure duration (years); BW, body weight (kg); AT, averaging time: ED, in years x 365 days/year x 24 hours/day, in hours.

Non-carcinogenic risk was calculated, using the hazard quotient (HQ) values, according to Equations (3) [11] and (4) [12], in respect of the available toxicological data:

$HQ = EC/RfC$ (3) $HQ = ADD/RfD$ (4),

Where HQ, hazard quotient (unitless); EC, exposure concentration (mg/m^3); ADD, average daily dose (mg/kg-day); RfC, reference concentration (mg/m^3); RfD, reference dose (mg/kg-day).

The target non-carcinogenic risk value was set at 1 [11], indicating lack of negative health effect on humans when risk values were <1.

Table 1. Total non-carcinogenic risk values on the study areas.

Tourist location	Location number	Resident scenario			Tourist scenario		
		Adult	Child	Infant	Adult	Child	Infant
Maniowy	1	7.74	7.87	7.87	1.32	1.34	1.34
Łapsze Wyżne	2	7.71	7.79	7.79	1.31	1.32	1.32
Frydman	3	5.59	5.66	5.66	0.95	0.96	0.96
Klikuszowa	4	4.08	4.16	4.15	0.69	0.71	0.71
Jurgów	5	6.44	6.53	6.52	1.09	1.11	1.11
Huba	6	11.29	11.43	11.42	1.92	1.94	1.94
Ludźmierz	7	8.84	8.92	8.92	1.50	1.52	1.51
Kacwin	8	12.83	12.93	12.93	2.18	2.20	2.20
Dębno	9	19.28	19.42	19.42	3.27	3.30	3.30
Czorsztyn	10	6.04	6.15	6.15	1.03	1.04	1.04
Niedzica	11	12.09	12.23	12.22	2.05	2.08	2.08
Waksmund	12	13.01	13.11	13.10	2.21	2.23	2.23
Mean		9.58	9.68	9.68	1.63	1.64	1.64

Results

It was revealed that the 24 h quality guideline recommended for $PM_{2.5}$, set at 25 µg/m^3 [1], was exceeded in eleven out of twelve investigated locations (except for No 4. Klikuszowa). The permissible 24 h PM_{10} content, set at 50 µg/m^3 [1,13], was exceeded in seven out of twelve locations. The mean contents of CO and $O_{3\ 8h}$ did not exceed the permissible contents of 10,000 µg/m^3 [13] and 120 µg/m^3 [13], respectively.

The total non-carcinogenic risk (sum of the HQ values) for $PM_{2.5}$, PM_{10}, and NO_2, significantly exceeded the target risk value of 1, under the resident scenario (**Table 1**). The highest total non-carcinogenic risk values exceeding the value of 10 were obtained for No. 9 Dębno, No. 12 Waksmund, No. 11 Niedzica, No. 8 Kacwin, and No. 6 Huba. Under the tourist exposure scenario, the total non-carcinogenic risk values did not exceed the target risk value of 1 in the cases of No. 3 Frydman and No. 4 Klikuszowa.

$PM_{2.5}$ was identified as a contaminant, with the strongest impact on the total risk value, approaching a 100% share (**Figure 3**).

In the individual cases of PM_{10} and NO_2, the calculated non-carcinogenic risk values indicated low to negligible risk, under both resident and tourist exposure scenarios.

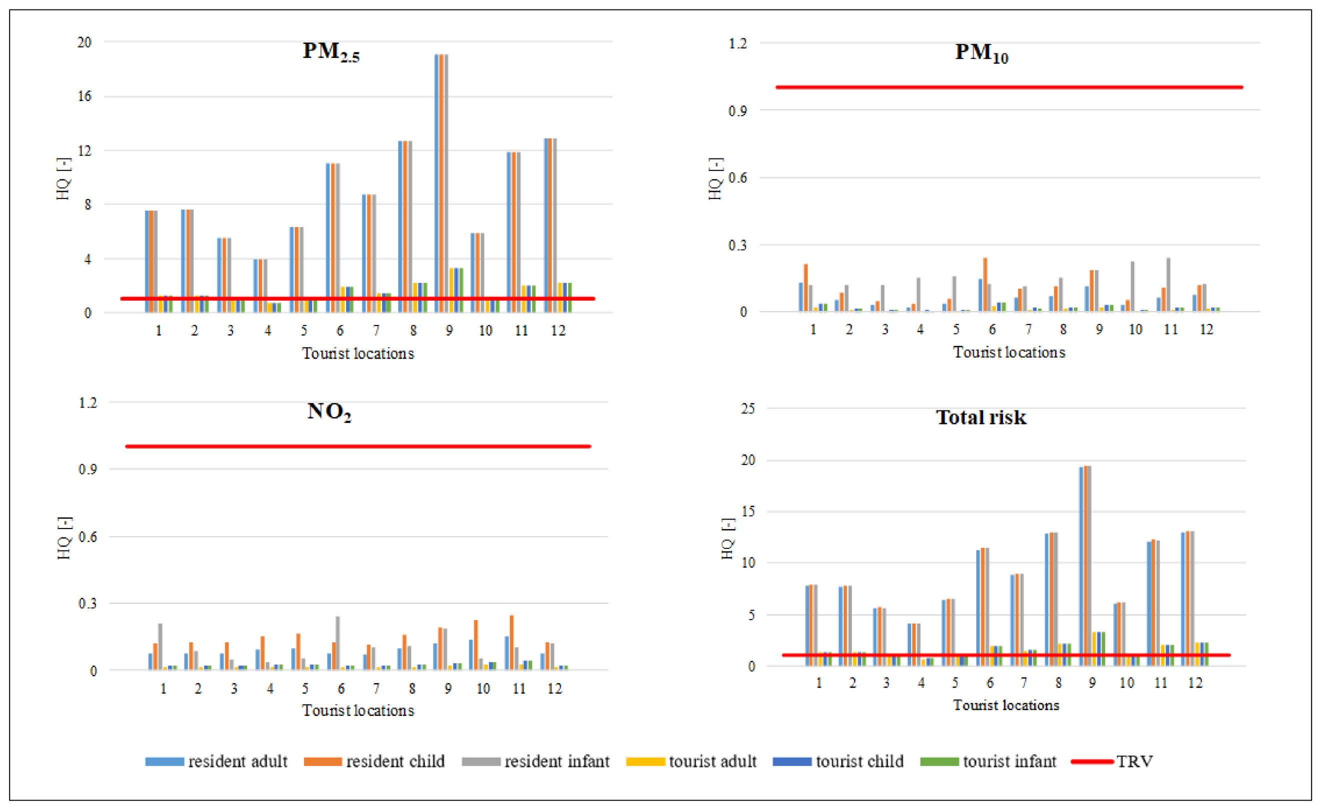

Figure 3. Non-carcinogenic risk values (HQ) for selected air pollutants on the study area (for location numbers, see Fig 2); TRV – target risk value.

Discussion

Our research revealed that air quality was poor or very poor [7] in the popular areas of the Czorsztyn Reservoir, while the risk values associated with air inhalation, estimated in the present study, were comparable to those identified in large cities, for instance Kraków [14,15]. The main cause of that situation was that the study areas involved small towns developed mainly with single-family houses. Individual means of transportations dominated there. Besides, the tourists travelled to those sites in their own vehicles, aggravating pollutant emissions. Furthermore, the main heating installations of the local houses were based on stoves burning poor quality fuels and even solid waste.

In our investigations, only non-carcinogenic risk was assessed. As to the pollutants that had been proved to be carcinogenic, no measured concentrations or reliable toxicological parameters were available to perform specific risk estimations. For that reason, our risk estimation results might be underestimated.

On the other hand, the pollutant contents exceeded permissible and recommended values in ambient air in the south of Poland during most of the months, in reference to the conservative risk assessment principle. Consequently, in our research, we made assumptions of the winter pollutant contents, in the inhalation exposure route.

Moreover, since the determination of the concentration ratio between outdoor and indoor air pollutant contents has not been clearly defined yet, our risk assessment calculations assumed a worst-case scenario according to the outdoor air pollutants concentrations. And that could have contributed to the calculated risk overestimation.

Nevertheless, the risk values obtained under the present project evidently revealed that poor air quality posed significant hazard to both residents and tourists.

Conclusions

Our studies determined health risk arising from the outdoor air inhalation pathway in the tourist regions, located in the surroundings of the Czorsztyn Reservoir.

Non-carcinogenic risk values were assessed for $PM_{2.5}$, PM_{10}, and NO_2, on the basis of the available toxicological data. Total risk figures significantly exceeded the target risk values under the residential exposure scenario for adults, children, and infants.

Under the tourist exposure scenario, the total risk value did not exceed the target risk value of 1, in the cases of two out of twelve analysed locations. $PM_{2.5}$ was determined to be the pollutant representing the highest share of the total risk value.

In summary, the current binding ban on poor-quality fuel burning and the campaign for the replacement of heating installations, under the regulations adopted in the Małopolska Region in 2017, can significantly improve air quality and lower health risk, as well as increase the attractiveness of holiday sites for potential tourists.

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References

1. *Air Quality in Europe—2020 Report*; EEA Report No 09/2020; Publications Office of the European Union: Luxembourg; European Environment Agency: København, Denmark, **2020**.
2. Jasek-Kamińska, A.; Zimnoch, M.; Wachniew, P.; Różański, K. Urban CO_2 budget: spatial; and seasonal variability of CO_2 emissions in Krakow, Poland. *Atmosphere* **2020**, *11*, 629, DOI: 10.3390/atmos11060629.
3. Chlebowska-Styś, A; Kobus, D.; Zathey, M.; Sówka, I. The impact of road transport on air quality in selected Polish cities. *Ecol* 413 *Chem Eng A* **2019**, *26 (1-2)*, 19–36.
4. Krzyżanowski, M.; Kuna-Dibbert, B.; Schneider, J. *Health effects of transport-related air pollution*. World Health Organization, 2005.
5. Matz, C.J.; Egyed, M.; Hocking, R.; Seenundun, S.; Charman, N.; Edmonds, N. Human health effects of traffic-related air pollution (TRAP): a scoping review protocol. *Systematic Reviews* **2019**, *8*, 223, 1–5.
6. Sówka, I.; Kobus, D.; Skotak, K.; Zathey, M.; Merenda, B.; Paciorek, M. Assessment of the health risk related to air pollution in 436 selected Polish health resorts. *J. Ecol. Eng.* **2019**, *20(10)*, 132–145.
7. Adamiec, E.; Dajda, J.; Gruszecka-Kosowska, A.; Helios-Rybicka, E.; Kisiel-Dorohinicki, M.; Klimek, R.; Pałka, D.; Wąs, J. Using 440 Medium-Cost Sensors to Estimate Air Quality in Remote Locations. Case Study of Niedzica, Southern Poland. *Atmosphere* **2019**, 441 *10*, 393.
8. Garbero, V.; Montaldo, A.; Lazovic, N.; Salizzoni, P.; Berrone, S.; Soulhac, L. The impact of the urban air pollution on the human health: a case study in Turin. In D. G. Styen & S. Trini Castelli (Eds.), Air Pollution Modelling and its Application XXI, 2012, 729–732. Dordrecht: Springer.
9. de Oliveira, B.F.A.; Ignotti, E.; Artaxo, P.; Saldiva, P.H.; Junger, W.L.; Hacon, S. Risk assessment of PM2.5 to child residents in Brazilian Amazon region with biofuel production. *Environ Health* **2012**, *11*, 64.
10. Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1) May 2020. US Environmental Protection Agency 2020, Washington DC, USA.
11. USEPA. Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual. Part A. Interim Report (Final); Technical Report No. PB-90-155581/XAB; US Environmental Protection Agency: Washington, DC, USA, 1989.
12. Office of Emergency and Remedial Response. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance.* US Environmental Protection Agency: Washington, DC, USA, 2009.
13. Regulation of the Minister of the Environment of 24 August 2012 concerning the levels of certain substances in the air. *J. Lows* **2012**, *1031*, 1–9.
14. Traczyk, P; Gruszecka-Kosowska, A. The Condition of Air Pollution in Kraków, Poland, in 2005–2020, with Health Risk Assessment. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6063; DOI: 10.3390/ijerph17176063.
15. Gruszecka-Kosowska, A. Assessment of the Kraków inhabitants' health risk caused by the exposure to inhalation of outdoor air contaminants. *Stoch. Env Res. Risk A.* **2018**, *32*, 485–499.