Biological determinants and perceived risks among Macedonian citizens against real environmental burden

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Abstract

Environmental concerns are among the most pressing issues in the modern era. While levels of exposure to chemicals and pollution may vary across time and place, the general public is still becoming increasingly concerned with air and water pollution caused by power generation, chemical runoff, transportation, and industrial facilities. Citizen's risk perceptions concerning environmental exposures reflect the public's awareness of certain environmental issues. These perceptions are triggered by different factors including biological determinants. With this study, we sought 1) to assess the general public's perceptions of risk from a set of environmental exposures compared with national evaluation and monitoring data published by national relevant environmental institution; and 2) to obtain data about biological determinants in risk perception. Methods. A modified multipurpose questionnaire was sent to the participants in an electronic form by e-mail and was published on social networks and municipalities' web sites. The responses to the questionnaire were given anonymously and voluntarily. The results of perceived risk were analyzed using descriptive statistical methods and inferential statistics with bivariate correlation, Pearson Chi-square test and independent samples T-test. Additionally, we compare results with Annual Report for Quality of

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Environment for 2020-2022 of the Republic of North Macedonia, published on webpage of Ministry of Environment, as secondary data source. Results. During the observation period, 220 people responded to the survey, with female respondents being predominant (70%). Analysis showed that there was no statistically significant difference between genders regarding risk perception. According to Likert scale, with 95% CI, among anthropogenic sources, respondents stated they were extremely worried about air pollution and very worried or worried about noise, waste and dangerous industry which is in accordance with real data for environmental pollution for stated period. The age of citizens is statistically significant related to the judgement of the environmental conditions in the living area of resident population. Conclusion. Biological factors like age and gender challenge the perceived risks related to specific environmental exposures among the general population. In brief, we found that the general public assigned risk scores which is in line with the officially public environmental data. For air pollution the public perceived extreme anxiety than the assessed specific parameters in air by experts.

Keywords: ecological risks, biological factors, environmental parameters

Introduction

Environmental concerns are among the most pressing issues in the modern era. While levels of exposure to chemicals and pollution may vary across time and place, the general public is still becoming increasingly concerned with air and water pollution caused by power generation, chemical runoff, transportation, and industrial facilities. Citizen's risk perceptions concerning environmental exposures reflect the public's awareness of certain environmental issues. As an example, understanding public risk perception of air pollution provides valuable insights for authorities and policymakers to develop risk management strategies for public health, disaster risk reduction, and climate change adaptation. Air pollution is a major threat to the environment and human health, causing 6.67 million deaths worldwide in 2019, ranking it as the fourth leading cause of death.**[1]** Besides air pollution, certain environmental problems that are influential today generally include the greenhouse effect or global warming, the depletion of ozone layer, hazardous materials and wastes, the degradation of water resources and wetlands, the destruction of forests, urbanization, and population growth. Environmental problems that arise as human intervention in nature increases have brought about risks that threaten the life on earth. In this regard, risk can be considered a social structure of modern society.

Risk perception can be defined as an evaluation of a hazard and the judgment of its consequences to the environment or health, made by an individual, a group of people, or society based on both hazard features and personal beliefs.**[2]** It emerged as a research field and became highly relevant for policymakers in the late 1960s, mainly fostered by public opposition to technology.**[3]** Society seemed to accept risks to the extent that they were associated with benefits and were termed as "voluntary". This is related to a sense of "controllability" where less risk is perceived in situations that are under personal control, which is not particularly the case for many environmental exposures.**[4]** People's perceptions of risk often differ from risk assessment's objective determination of risk. Such differences are not easily

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eliminated by the pursuit of risk communication programs targeted at the general public.**[5]** of whether it is a real risk or not, consequences occur because people act based upon their personal perception of risk, not to the risk itself.**[6]** Thus, the social response to a perceived hazard may be amplified (or minimized) beyond what is expected by experts, institutions, or the media. This suggests that risk cannot be effectively studied, discussed, or managed, in isolation from the social context of engaged stakeholders and their appraisals.**[7]** The most widely used and described paradigm in risk perception research is the psychometric paradigm. In this model, it is assumed that risk is subjectively defined by the individual and may be influenced by several psychological, social and institutional factors.**[8]** As opposed to psychological approaches, sociological perspectives focus on social interactions in the context of risks. In these approaches, undesirable events conception, the perception of uncertainty and even reality are assumed as socially constructed.**[6]**

Unlike the point of view of science and technology, the perception of risks by non-experts is not objective. Risk perception refers to the evaluation and adoption of sensory perceptions or information about risks and hazards in an individual's mind. Experts usually equate a risk with the expected average loss (damage) per unit of time. However, non-experts perceive risks as a complex, multidimensional phenomenon that has a decisive impact on the perceived risk size in case of risky situations and in which even the subjective expectation of loss (damage) plays a secondary role. The factors of risk perception for non-experts include the following: the identification of risk sources and the causes of risk (natural or anthropogenic), the possibility of dominance and personal control, the familiarity with risk sources, the willingness to take risks, the likelihood of a risk source causing a disaster, the objective distribution effect of benefit and risk, the reversibility of risk results, personal experiences with technology and nature, and exposure.**[9]**

The literature suggests that there are differences in perception of environmental risks based on several key characteristics, which fall into three categories: biological characteristics, location and health. Together these variables could potentially affect perception of environmental risk. Women consistently express higher concerns about risk than do men.**[10]** Age has also frequently been associated with risk perception, although results are mixed across studies. In particular, older people have expressed higher or lower levels of concern than their younger counterparts depending on the exposures being analysed.**[11]**

With this study, we sought 1) to assess the general public's perceptions of risk from a set of environmental exposures compared with national evaluation and monitoring data published by national relevant environmental institution in North Macedonia; and 2) to obtain data about biological determinants in risk perception. The general aim of the study is to obtain relevant data for role of biological determinants in perceived risks among Macedonian citizens against real environmental burden.

Material and Methods

Environmental data

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The data of air pollution, waste and noise were collected form Annual Report for Quality of Environment for 2020-2022 of the Republic of North Macedonia, published on webpage of Ministry of Environment.[12,13] The air quality data were obtained by National automatic monitoring system, which contains 21 permanent and 1 mobile monitoring station in different measurement points in North Macedonia. The results for general polluting substances (SOx and NOx), heavy metals (Pb, Cd and Hg) and persistent organic pollutants (POPs) in air are presented as total annual concentrations compared to base year. The result for PM10 and PM2,5 is presented as number of daily means exceeding concentrations compared to recommended annual means. The results for hazard waste are presented as amount of annual treated waste in tons. The intensity of noise in environment is measured by two indicators: Ld (daily) and Ln (night).

Survey

A multipurpose modified questionnaire was sent to the participants in an electronic form by e-mail and was published on social networks and municipalities' web sites. All the participants were citizens of North Macedonia. The survey was conducted in the period of December 2021-January 2022. The responses to the questionnaire were given anonymously and voluntarily. To achieve the aim of the survey, the modified multipurpose questionnaire for multipurpose investigation of the population living near high-risk CS,[14] was developed. The questionnaire was composed of four sections, which aimed to investigate: a) the characteristics of individuals; b) risk perception; c) availability of ecological information; and d) home conditions and healthy status. The form of the questionnaire was structured to obtain answers to the questions with a purpose to present variables. The questionnaire contains closed questions, for which respondents should answer the questions according to Likert scale,[15] grading with scores from 1 to 4, where score 1 indicates "extremely exposed/ most probably" and score 4 indicates "not at all/ impossible". A large set of the questionnaire included items related to biological data, sociodemographic information, and state of health (sex, age, place of birth, level of education, self-perceived health status). Some of this information was used in the analyses of risk perception.

Statistical analysis

The results of perceived risk were analyzed using descriptive statistical methods and inferential statistics with bivariate correlation, Pearson Chi-square test and independent samples T-test.

A p-value less than 0.05 was considered statistically significant, 95% confidence interval (CI) was calculated.

Additionally, we have compared results with Annual Report for Quality of Environment for 2020-2022 of the Republic of North Macedonia, published on webpage of Ministry of Environment, as secondary data source.

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Results

Environmental monitoring data

In this section we present the results for pollution of air, noise, and waste for the period 2020-2022, based on the data from the national monitoring system in North Macedonia.

The results for annual monitoring of general polluting substances (SOx and NOx), heavy metals (Pb, Cd and Hg) and persistent organic pollutants (POPs) in air, are given in table 1. As shown on the table, we noticed reduction in all emissions in 2021, compared to base year for SOx and NOx[1], for heavy metals[2] and for POPs[3]. According to the data given in Annual Report for Quality of Environment for 2020-2022 of the Republic of North Macedonia,[12] for 2021 and 2022, the particulate matters (PM10, and PM2,5) are still the most critical air pollutants. For PM10, the number of daily mean exceeding concentrations compared to recommended annual mean (40 μg/m^3 for PM10) is around 3-4 times higher than permitted exceeding (30 days). The annual average concentration of PM2,5 for 2022 measured in Skopje (measurement point Lisiche) is 35, 20 μg/m^3 and is higher than the recommended annual mean of 25 μg/m^3.

Table 1: Results for emissions in air of general polluting substances, heavy metals, and POPs for 2021 compared with base year.

Protocol for polluting substances	Upper limits – highest for 2010 [Gg]	Emissions for 2021 [Gg]	Difference of upper limits – highest and emissions for 2021 [Gg]	Difference of upper limits – highest and emissions for 2021 [%]
SOx	110	88.63	21.37	-19.43
NOx	39	21.37	17.63	-45.21
Protocol for heavy metals	Emissions for 1990 [Mg]	Emissions for 2021 [Mg]	Difference 2021-1990	Reduction compared to 1990 [%]
Pb	232.48	2.64	229.90	-98.87

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[1] National upper limits – highest for 2010 base year are given in the rulebook for amount of upper limits – highest (Official Gazzette of Republic of Macedonia no. 2/2010, 156/2011, 111/2014)

[2] National upper limits – highest for 1990 base year are given in Protocol for heavy metals, 2010. Available on: Republic of Macedonia (moepp.gov.mk)

[3] National upper limits – highest for 1990 base year are given in Protocol for POPs, 2010. Available on: Republic of Macedonia (moepp.gov.mk)

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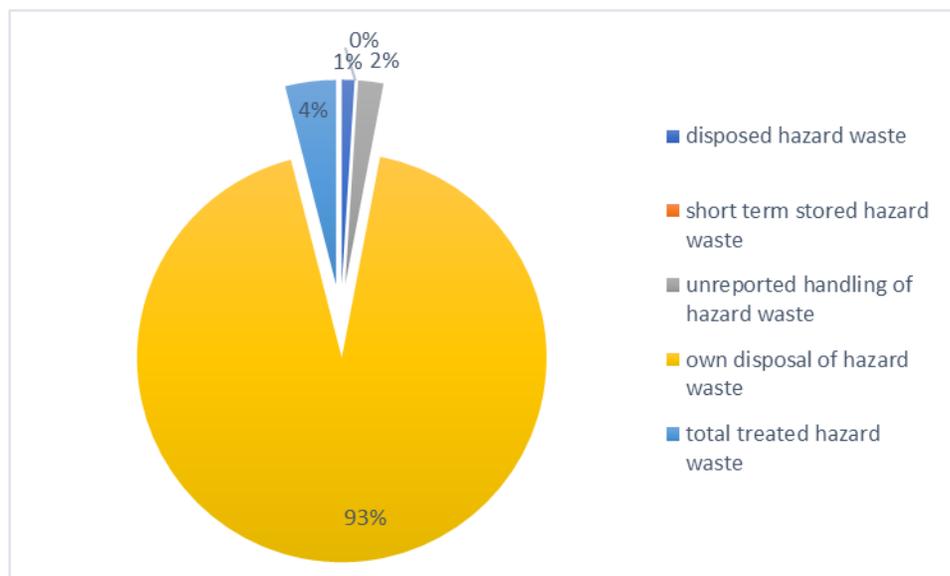9

Cd	1.61	0.23	1.38	-85.87
Hg	0.67	0.21	0.46	-69.10
Protocols for POPs	Emissions for 1990	Emissions for 2021	Difference 2021-1990	Difference 2021-1990 [%]
PAHs [Mg]	7.20	4.18	3.02	-42.00
HCB [kg]	44.29	0.16	44.12	-99.63

Source: The table is created by author according to the data given in Annual Report for Quality of Environment for 2020-2022 of the Republic of North Macedonia, MOEPP. Available on www.moepp.gov.mk

The Figure 1 presents reported results for annual treatment of industrial hazard waste in 2021 in North Macedonia. Of a total of 434.794 tons hazard waste, only 4 % (18.877 tons) is treated waste, 93 % (404.099 tons) is treated by companies themselves. There is still 2 % (7.966 tons) of hazard waste with unspecified treatment.

The results for noise intensity in Skopje region has shown that in all measurement points (14 in total), the value of Ld exceeds the WHO recommended daily upper limit of 53 dB (A) from 4,00 to 16,00 dB (A) and the night values Ln exceeded WHO recommended daily night limit of 45 dB (A) from 2,00 to 11,00 dB (A).

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Figure 1: Treatment with industrial waste in 2021

Results from risk perception survey

Of a total of 220 respondents, more than a half, about 70% (n=154) were female and the other 30% (n=66) were male respondents who voluntarily answered the questions. The average age of respondents was 40 years, where the youngest was 23 years old and the oldest 70 years. As regards the education, most respondents had a high-school diploma. Most respondents have living place in Skopje.

Analysis of the questions and received answers for risk perception (Figure 2) showed that residents, from anthropogenic sources (given in scale from 1 "extremely exposed" to 4 "not at all") perceived air pollution as the highest risk with extreme exposure level (*m=1.47*), followed by water pollution (*m=2.58*) and noise (*m=2.51*) which were perceived as great to moderate

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risks, hazardous industry (*m=2.73*) and hazardous waste (*m=2.95*) as a moderate risk, and as a minimum risk, they felt exposure to dangerous materials transport (*m=3.11*). Regarding the natural disasters, residents perceived extreme weather conditions (*m=2.39*), earthquakes and fires (*m=2.5* to *2.7*) be the highest risks, and floods were perceived as minimal risk with great to moderate exposure level (*m=3.25*).

Figure 2: Risk perception - exposure
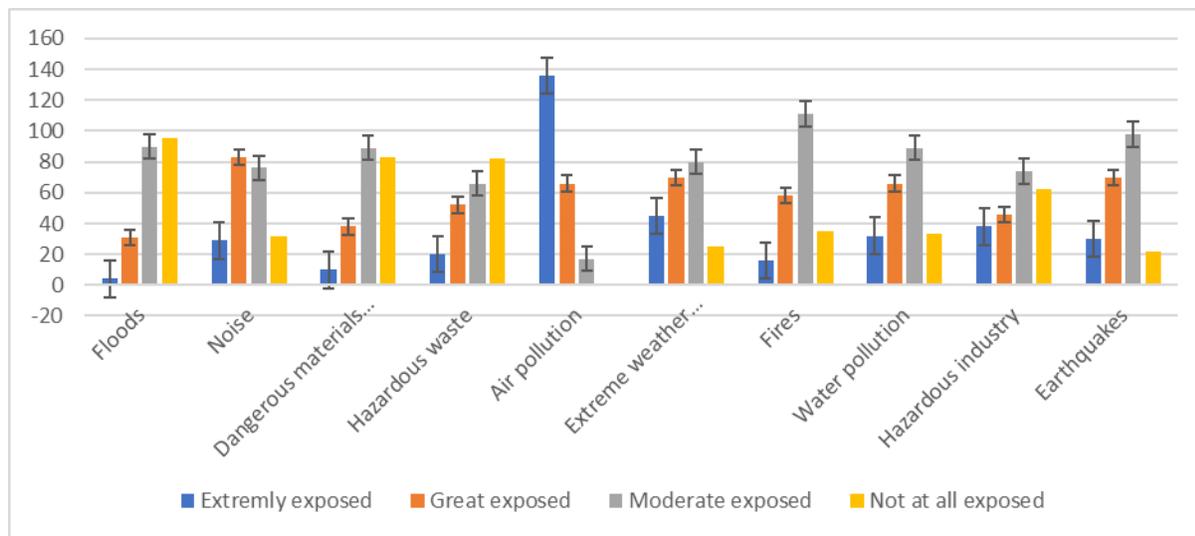
To see how biological determinants, like gender and age influence on risk perception, we tested the correlation between these factors and answers on questions about views on environmental conditions. The results are given in table 2. Analysis given in table 2 shows a positive and statistically significant correlation between age, education, and perception regarding environment. Older respondents and respondents with higher level of education perceived that environmental conditions in their living area are more serious ($r<.275$, $p<0.01$; $r<.170$, $p<0.05$, respectively).

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Table 2: Impact of age and education on risk perception

		Age	*Education*	How do you estimate the environmental conditions in your living area?	How much are you satisfied with the information about ecological risks in your living area?	Would you like to leave the present place of living?
Age	Pearson Correlation	1	.306**	.275**	0.038	0.1
	Sig. (2-tailed)		0	0	0.574	0.142
Education	Pearson correlation	.306**	1	.170*	.139*	.146*

 Note: **p<0.01, *p<0.05

As regards the gender, for these three issues, evaluation by independent sample test (t-test), showed that there was no significant difference between female and male respondents (F=2.437, F= .108, F= 4.841, p>0.05).

Discussion

In the current study, it was attempt to define the risk perception patterns in scope of environmental issues of Macedonian citizens. Inappropriate treatment and waste handling (industrial and household waste) are considered as main sources of contamination and fundamental environmental threat on the territory of North Macedonia. According to these data, dispersion of waste substances, partially or in majority is done through the air that results in contamination of soil, surface, and underground water, and by resuspension in dry soil is

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returning in the air again.[16] To our knowledge, no study was present about environmental health risk perception of citizens comparable to real environmental pollution in North Macedonian, so far. The questionnaire used in our survey allowed us to capture the local reality and possible health risks linked to global and local hazards or threats present in the environment.

During the observation period, N=220 people responded voluntarily to the survey, with female respondents being predominant. According to literature related with environmental concern, females consistently reported more pro-environmental views and greater levels of concern about specific environmental problems than man did.[17] According to gender socialization hypothesis, women were more concerned than men for environmental problems that pose significant health and safety risks for people, because women learn connecting with other people and expressing concern about their well-being through socialization into their society.[18] Nevertheless, there are studies[19] that reported opposite results or results with no differences in responses between genders, which is in agreement with our study, whereas is no difference between genders regarding perceptions of environmental risks.

As far as self-selected sample's general information is concerned, the respondents were aged between 23 and 70 years old, with an average age of 40 years. Although the survey was distributed in a way favored by people more inclined towards the use of IT tools, our respondents were represented by all age groups. Generally, men and the elderly perceive lower risks than women and younger people.[20] But, the studies shows that risk perception of air pollution may differ from other hazards due to its connection with chronic diseases. This could explain why the elderly and males, at higher cardiovascular risk, reported a greater risk perception for air pollution, aligning with previous literature.[21] In our study also, the older population perceived that environmental conditions in their living area are more serious.

In the present cross-sectional study, respondents perceived polluted air, noise, waste and hazardous industry as major risk factors for environmental exposure. This is like the results of a survey conducted by Bena *et al.*[22] who investigated the perception of local population living near the incineration plant for solid waste in Turin, Italy. In this study, anthropogenic hazards generated more concern than natural hazards. In other studies,[23] it has also been found that people in Italy feel more vulnerable to anthropogenic than natural risk. According to the literature, elevated risk perceptions frequently appear in response to events or situations directly linked to hazardous industries and large infrastructure such as industrial complexes, and landfill sites or waste incineration plants.[24] All these activities are usually thought to pollute air, water and/or soil and affect human health in several ways, and also raise concerns due to possible malfunctioning or human error that could lead to harmful events. In North Macedonia, out of a total of 16 contaminated sites from health and ecological point, three are classified as the most dangerous[25] and according to almost all categorizations, have been evaluated with the highest level of ecological and health risk, although there has been no recent evidence about these issues. It is essentially to point out that lindane dump within chemical company, in the city of Skopje, is a treat that hazardous compounds from this locality could be dispersed in all near or wider environmental media, but the risk is much higher if we take into consideration that this factory is located in the middle of a populated area of the city of Skopje.[26] From this reason, the results of exposure levels to anthropogenic hazards, that are found in our survey are in line

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with the real results for noise and waste, measured for the same period when the survey was conducted. In our study, the association between individual perception and real data of air pollution is partially positively explained. The respondents feel extremely worried about air pollution, but the real data show reducing of the pollution substances in the actual year. On the other side, the measured concentrations of PM10 and PM2,5 were higher in the winter, the period when the survey was conducted. Differences in individual experience and socio-demographic factors (e. g., gender, age, smoking, political orientation) affect perceived risk. Additionally, public acceptance of anthropogenic risk is influenced by trust and local experience.[27] Furthermore, it is conditioned and constantly revised by information from multiple sources, including the media, and by the influence of peers and others so that communication plans must have reliable tools to support such elements.

Conclusions

Biological factors like age and gender challenge the perceived risks related to specific environmental exposures among the general population. In brief, we found that the general public assigned risk scores which is in line with the officially public environmental data. For air pollution the public perceived extreme anxiety than the assessed specific parameters in air by experts within national annual monitoring activity.

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