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TRAP

Health risk assessment

TRAP

Transboundary Air Pollution Health Index Development and Implementation

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CONTENTS

1. Introduction

According to the latest UN Environment Report that estimates impact of air pollution in the Western Balkans countries[1] including R.N. Macedonia (RNM), air pollution is "the most serious environmental risks with major socio-economic consequences for the entire Western Balkans region". The low-quality of solid fuels used in coal-fired power plants, domestic heating that uses mostly biomass, outdated industry and old vehicles beside the region's topography are identified as main contributors to the poor air quality. The impact of energy generation and consumption on the environment influencing energy choices in the entire region, where many of the countries aim to join EU [1].

Air pollution often serves as an indicator of the economically sustainable development of a country because sources of air pollution are also the main producers of substances that are major climate modifiers such as carbon dioxide, black carbon etc. Sustainable Development Goal (SDG 11) refers to the target to make cities inclusive, safe, resilient and sustainable. Annual mean levels of fine particulate matter in cities indicates the sustainable urban development. Also, SDG3 refers to the provision of healthy living and well-being for all. Mortality rate attributed to household and ambient air pollution is a direct indicator of the progress toward this target [2]. Achieving the pollution control, the health and well-being benefits will be significant, climate change pace will be slowed down, and social justice promoted.

However, the urban air pollution will deteriorate globally, by 2050 outdoor particulate air pollution and ground-level ozone is projected to become the top cause of environmentally related deaths worldwide [3]. Primarily, at risk are people in urban areas. 30% of the urban population in EU are exposed to air pollution levels exceeding EU standards and 98% citizens living in European cities that exceed more stringent WHO guidelines for air quality [4,5]. There is no evidence of a safety thresholds of PM concentration [6], and EU standards are not sufficiently stringent to protect human health [7].

Extensive scientific evidence established a permanent positive association between long-term exposure to air pollution and total cardiovascular mortality (mainly due to coronary artery disease, ischaemic heart disease, stroke) chronic obstructive pulmonary disease and lung cancer poses a great burden to the health systems and societies in general [8-15]. Thus, is expected that current exposures on particulate air pollution will lead to further deterioration of the health status of population, causing a variety of adverse and harmful health effects and great economic losses due to increased need of health care services, increased medication use, absenteeism from work and school, restricted activity and losses due to premature deaths and active years of life.

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[1] The Western Balkans is a political neologism that evolved in the early 1990s and refers to Albania and territory of the former Yugoslavia (with the exclusion of Slovenia). The region of the Western Balkans, a designation used exclusively in Europe, roughly corresponds to the Dinaric Alps territory [UNEP Report. 2019].

2. Methodology

Aiming to assess the burden of diseases attributable to air pollution in the regions of interest, Health Impact Assessment - the counterfactual approach has been applied, using several types of data: *basic demographic data* and *data from vital statistic - mortality* of the population (according to the causes of death) obtained from State Statistical Office (SSO), disaggregated by sex and age, and cause of death. Demographic data are based on SSO Population estimation for 2017 (as of 31.12.2017). Based on the findings of the broad scientific evidence, *mortality (natural, all cause mortality and specific mortality)* is selected as the main health outcome in this study on the health impact and effects of the air pollution. Population aged 30 years and over is used in estimation, and causes of death have been coded according to the ICD classification, tenth revision (ICD10)[2] for the 2015-2017.

The third type of data - *environmental*, are obtained from the Macedonian Environment Information Center (MEIC) within the Ministry of Environment and Physical Planning (MoEPP). We selected PM_{10} and $PM_{2.5}$ as main stressors in this study because they are identified as a priority public health and environmental issue in the country (*see the First Project Report*), expressed as daily, monthly and annual mean concentrations. Considering the fact that the AQ Monitoring system is still not established in the region of Gevgelia, the full methodological approach described below was applied to the city of Bitola only.

Meteorological data (temperature, humidity, wind speed, pressure and *global radiation)* registered in the monitoring stations of both monitoring stations in Bitola (within the state monitoring network) have been used.

Health data used in this assessment are hospital admissions from circulatory and respiratory diseases obtained from the E-health Directorate, Ministry of Health (so called *"Moj Termin"*), distributed by sex and age, place of residence (recurring by diagnosis).

The method

HIAs (Health Impact Assessment) generally apply *concentration-response functions* based on risk estimates from the existing epidemiological studies. These functions are used aiming to correlate exposure estimated by air pollution assessment and the scenarios for air quality changes to a population at risk and its baseline health status [16]. In order to assess the contribution of the particulate air pollution as a growing public health concern on the mortality, we have applied the methodology in which population exposure data and relative risk (RR) for selected health outcomes derived from epidemiological studies are used to calculate Population Attributable Fraction (PAF) [17]. This epidemiological concept - *PAF* assess "the proportional reduction in the outcome incidence if all risk factors of interest were simultaneously eliminated from the target population".

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[2] ICD10 - International Statistical Classification of Diseases and Related Health Problems, 10th Revision

The PAF calculation is shown in the following formula:

(*Equation 2*)

$$PAF = \frac{f\ x\ (RR - 1)}{f\ x\ (RR - 1) + 1}$$

where f is the fraction of the population exposed, obtained from the SSO population estimations for 2017, and relative risk (RR) for selected health outcome derived from the epidemiological studies.

Whilst epidemiologists often study the risk of a disease in the presence of exposure compared to risk of a disease in the absence of exposure, in health impact assessment on the other hand often asks how many excess cases of disease will occur in a population of a certain size due to exposure at a given exposure level [18]. The health impact of PM refers to the proportion of ill health that is attributable to the PM concentration observed in a given city or population. This is the amount of mortality and disease that would be prevented if PM were totally removed, which is an (unrealistic) counterfactual scenario of zero exposure [19].

The estimations have been done using the WHO AirQ+ software [20]. In order to estimate the potential health gain (benefit) of reducing the exposure to particulate matters (PM) and/or to assess the benefit of the potential reduction strategies and actions in the future, two cut-off concentration for $PM_{2.5}$ have been selected: 10 µg/m^3 that correspond to WHO AQG annual limit value; and 25 µg/m^3, EU AQ Directive (Directive 2008/50/EC) limit value [5,21].

It is assumed that there is a log-linear dependence between PM particles and mortality due to measured concentrations of $PM_{2.5}$ particles less than 40 µg/m^3. We assess the long-term effects od particulate air pollution ($PM_{2.5}$) as the main stressor that is highly correlated with variety of adverse health outcomes, usually recognized as a primary exposure measure.

To calculate the number of *attributable extra deaths*, the estimated mortality at no exposure (PM concentrations of 0.0 µg/m^3 - cut-off value 0), a hypothetical scenario, is deducted from the observed mortality at observed exposure levels. This scenario has been applied in the EBD study in six European countries, where no threshold was used and levels were compared to a scenario in which air pollution levels is reduced down to zero [17]. It means that observed mortality rate associated with the current exposure of suspended $PM_{2.5}$ in ambient air will be compared with the estimated mortality rate for exposure to concentrations corresponding to EU limit values (25 µg/m^3 $PM_{2.5}$, from Directive 2008/50/EC) and WHO target value (10 µg/m^3 $PM_{2.5}$ in WHO Air Quality Guideline - WHO AQG) - counterfactual scenario 1 and 2.

Concentration-response functions (CRFs) used in this assessment are based on the recommendations for CRFs developed in the HRAPIE project (*Health Risks of Air Pollution in Europe*), where Relative Risk (RR) for all-cause (natural) mortality for the age group 30 and over is 1.062 (95% CI 1.04-1.083) for 10 µg/m^3 increase of pollutant concentration.

Aiming to assess the burden of diseases due to particulate air pollution and most importantly to assess the health benefits from implementation of effective and consistent measures and policies that would reduce the concentration of the stressors to the WHO limit values (EU LV), we have applied a second method for assessing disease burden using a YLL (*Years of Life Lost*) as a selected metrics for quantification of the disease burden (WHO Methods and data sources 2017).

This method and metrics was firstly developed in the 1980s by WHO and other HIA studies [19,22,23], the data for the YLL due to premature mortality are obtained from the WHO Global Health Estimates (WHO GHE, 2016) data base. The environmental data for population exposure of $PM_{2.5}$ are obtained from state air quality monitoring network runned by MoEPP, and relevant Concentration-response Functions (CRFs) have been applied.

Data collection and period of analysis: The study period is three years (2015-2017).

Air quality in Bitola municipality

Considering that Bitola is a larger urban area in the state and an industrial city, in order to monitor the ambient air quality, two automatic monitoring stations for air quality has been set up in January 2004.

Bitola 1 station is located in the outskirts of the city with nearby minor industries like production of food and beverages (Picture 1). The major air pollutant source in Bitola is REK Bitola power plant located 13 km east of the Bitola 1 station. The station stationed at the very entrance of the city, in the yard of the Hydrometeorological Service (UHMR) monitors industrial pollution [24].

The Bitola 2 site is located in the yard of administrative buildings. The nearest local road and parking lots are beside the station at the distance of 2–3 m, but the main street is located at the distance of 45 m (Picture 2). Point emission sources are located on the southern side of the city at the distance of 0.5–2 km from the station. The station placed in the yard of the administrative building of "Strezevo" most closely monitors the emissions from the traffic and from the heating of administrative institutions and households, as well as the impact of industrial emissions [24].

Measured components in both stations are: O_3, NO_2, SO_2, CO and PM_{10}. $PM_{2.5}$ are measured since 2018 in Bitola 2 station only.

Picture 1 Monitoring station Bitola 1

Picture 2 Monitoring station Bitola 2

For determination of the health impact of air pollution in Bitola municipality, we have used measured concentration of the pollutants in both stations (Bitola 1 and Bitola 2), expressed as an average concentration of PM_{10} and $PM_{2.5}$ (daily, monthly and annual). Detailed information of the trend of the selected stressor for 2014-2018 are presented in *Annex I, Table A 1*. For the estimation of the health impact, three-year average is used (2015-2017), and only air quality data with minimum measurements of 75% of the days of the year have been considered. In 2015, 301 days with measurements (82%) are registered; in 2016, 97% of the days and 81% in 2017. During the summer months (end of May to the end of July 2017) the monitoring station Bitola 2 had not been operational.

Seasonal variations of the pollutant are presented in Table 1 where is obvious a strong seasonal variation of the PM_{10} concentration. The highest concentration of PM_{10} are measured in the winter (cold) months starting from November to February-March.

Table 1 *Seasonal variations of PM_{10} for 5-year and 3-year period in municipality of Bitola*

PM1O(µG/M³)	2014-2018	2015-2017
JANUARY	108.7	158.5
FEBRUARY	65.4	86.3
MARCH	42.5	50.4
APRIL	38.7	44.9
MAY	30.4	36.4
JUNE	29.9	27.2
JULY	31.3	29.4
AUGUST	33.8	32.4
SEPTEMBER	31.8	29.6
OCTOBER	40.8	35.4
NOVEMBER	73.8	75.7
DECEMBER	101.3	115.0
MIN	**29.9**	**27.2**
MAX	**108.7**	**158.5**
AVERAGE	**55.12**	**62.7**

Source: MEIC, MoEPP 2019.

The daily limit value of PM_{10} prescribed in EU Directive on Air Quality and the national legislation of 50 µg/m^3 has been exceeded 132 times in 2015 in Bitola; 111 times in 2016 and 117 in 2017 although the national (and EU legislation) allow/limit the number of exceedances to 35 days per year. In total, in 47 days in warm season (April to August) in the 3-year period have been registered exceedance of the daily limit value.

Having in mind that $PM_{2.5}$ are measured only at Skopje monitoring stations (Centar and Karpos), and the monitoring network has been extended with new samplers for $PM_{2.5}$ since 2018 (including Bitola 2 monitoring station), in this study we have used the estimation of the concentration of $PM_{2.5}$ (fine particles with a diameter of up to 2.5 µm) using HRAPIE Study (Health Risks from Air Pollution in Europe) formula [12]. Based upon the literature, for the determination of $PM_{2.5}$, we considered that $PM_{2.5}$ is a fraction of the total mass of the registered PM_{10} particles, where:

(***Equation 1***. *$PM_{2.5}$/PM_{10} ratio*)

$$PM_{2.5} = 0.65\ x\ PM_{10}$$

or simplified, $PM_{2.5}$ presents 65% of the total mass of measured PM_{10} concentration.

In order to compare the air quality in municipality of Bitola with some other Macedonian cities as well as with the national average, the annual mean concentration of $PM_{2.5}$ (estimated or measured) is presented in table 2.

Table 2 Estimations of the annual mean concentrations of $PM_{2.5}$ in some selected cities, for 5-year period; e (estimation); with blue are marked concentrations based on measurements

	$PM_{2.5}$ annual mean concentration (µg/m^3)					
	2014	**2015**	**2016**	**2017**	**2018**	**average**
RNM^e	45.2	44.7	38.1	36.7	31.9	**39.3**
Kocani^e	30.5	32.2	28.4	26.8	26.0	**28.8**
Kavadarci^e	52.3	36.4	30.2	31.0	35.9	**37.2**
Kicevo^e	49.8	51.5	39.0	31.0	28.9	**40.0**
Tetovo^e	87.0	95.7	62.9	37.8	40.8	**64.8**
Bitola^e	36.6	38.9	34.3	34.6	32.3	**35.3**
Skopje	44.7	43.3	42.7	43.8	37.0	**42.3**

**Annual EU Limit Value (LV) of $PM_{2.5}$ = 25 (µg/m^3); WHO LV = 10 (µg/m^3)*

Source: Macedonian Environment Information Center (MEIC), MoEPP. 2019

The annual mean concentration of $PM_{2.5}$ in all selected cities exceed the WHO limit value of 10 µg/m^3 as well as the less stringent EU limit value of 25 µg/m^3 (Table ???).

Meteorological data for Bitola municipality

Meteorological factors are playing significant role and impact the air quality. There is a vast evidence on the relation between pollutant concentration and meteorological factors, and not only on pollutant concentration but also on the correlation between different pollutants. It is well known that the pollutants associated with traffic were at highest ambient concentration levels when wind speed was low [25,26]. The increase of relative humidity, cloudiness, and lower temperature was found to be highly related to the increase of particulate matter (PM) episodic events [27]. Atmospheric dispersion conditions of emitted air pollutants are registered in summer months while lower atmospheric dispersion of the pollutants during winter months that could explain the seasonal variations of the particulate matter measured at monitoring stations.

Summarized meteorological data measured in Bitola 1 station (mostly) for 2015-2017 are shown in table 3, while the detailed information is given in the Annex 1, Table A 2. During the period of interest, monitoring station Bitola 2 has measured only global radiation. Temperature, humidity, wind speed, pressure and global variation are constantly measured in Bitola 1 (industrial) station.

Table 3 Monthly mean meteorological parameters measured (mostly) in Bitola 1 monitoring station for the period 2015-2017

Monthly mean 2015-2017	**Temperature [°C]**	**min T [°C]**	**max T [°C]**	**Humidity [%]**	**Wind speed [m/s]**	**Pressure [hPa]**	**Global radiation [W/m2]**
January	-2.8	-19.0	10.4	78.7		948.8	78.6
February	4.0	-5.3	14.4	72.7		948.6	102.7
March	7.2	1.8	13.2	65.1		946.7	135.9
April	11.4	2.1	17.3	59.9		947.0	209.5
May	14.8	8.4	21.8	64.4		946.0	228.8
June	19.2	13.6	27.4	61.5		947.3	253.5
July	22.2	14.0	27.9	54.6		947.4	273.6
August	21.3	16.1	27.0	56.1	0.2	948.4	238.9
September	15.9	10.1	23.9	65.6	0.2	948.4	166.0
October	11.0	2.5	18.3	73.8	0.2	950.5	119.1
November	5.7	-0.6	17.2	78.7	0.2	949.6	80.5
December	0.7	-5.9	11.8	74.8	0.3	955.2	68.5

Source: MEIC, MoEPP 2019.

It is very important to stress out that the lowest temperature is registered in January 2017 in most of the cities with monitoring stations. That poses a serious research interest to analyze the correlation and relation between meteorological data and analyzed health outcome - mortality together with the concentration of the $PM_{2.5}$.

Mortality

Mortality serves as the most common epidemiological indicator of health in studies where the health impact of air pollution is quantified [1]. Mortality data were collected by age groups, but only mortality of people aged 30 years and over have been used in estimation. The age-specific "natural" mortality where all causes of death are included (A00-Y89) excluding external causes of death (V01-Y89) are presented in table 4. Detailed information is provided in Annex I, Table A 3.

As expected, the highest fraction of mortality is registered in the age group 65 and over (77-80% of the total mortality, all-age groups) in the city of Bitola and Gevgelia, as well in the RN Macedonia. In the following, will be presented age-specific and cause-specific mortality only (30 years and over).

Table 4 Age-specific natural mortality in selected municipalities and RN Macedonia, for 2015-2017

	30 yrs and over								
All-cause natural Mt (excl. external)	**Bitola**			**Gevgelia**			**RNM**		
	total #	male	female	total #	male	female	total #	male	female
2015	1188	596	592	273	151	122	19599	9990	9609
2016	1109	545	564	259	124	135	19496	10137	9359
2017	1174	604	570	254	126	128	19548	10053	9495
Average	**1157**	**582**	**575**	**262**	**134**	**128**	**19548**	**10060**	**9488**

Table 5 Natural mortality rate per 10,000 population in selected municipalities and RN Macedonia, for 2015-2017

	All age-groups								
All-cause natural Mt rate per 10,000	**Bitola**			**Gevgelia**			**MKD**		
	total	male	female	total	male	female	total	male	female
2015	191.3	199.8	183.5	174.2	195.7	153.4	149.4	154.8	144.3
2016	178.6	182.7	174.8	165.3	160.7	169.7	148.7	157.0	140.5
2017	189.0	202.5	176.6	162.1	163.3	160.9	149.0	155.7	142.6
Average	**186.3**	**195.0**	**178.3**	**167.2**	**173.2**	**161.3**	**149.0**	**155.8**	**142.5**

Source: State Statistical Office (SSO). 2019

Bitola has higher all-cause (natural) mortality rate in the age group of 30 and over compared to the national average mortality rate and Gevgelia (186 per 10,000 and 149 and 167 per 10,000 respectively) (Table 5).

Ambient air pollution is a major health risk, leading to respiratory and cardiovascular mortality. Chronic exposure to enhanced levels of fine particle matter impairs vascular function which can lead to myocardial infarction, arterial hypertension, stroke, and heart failure. The latest study that analyzed the impact of air pollution on cardiovascular diseases (CVD) in EU-28, suggests that risk estimated in Global Burden of Diseases 2015 is underestimated and recommends novel hazard ratio functions, showing that air pollution is "a much larger mortality factor that previously assumed especially from

CVD" [28].

Age-specific and cause-specific mortality rate from circulatory diseases are presented in Table 6, while detailed information on age-specific mortality in the both cities and the national level is presented in the Annex 1, Table A 4.

Table 6 Age-specific mortality rate from circulatory diseases per 10,000 population in selected municipalities and RN Macedonia, for 2015-2017

/10,000	***30 and over***								
Mt rate from circulatory diseases (I00-I99)	**Bitola**			**Gevgelia**			**MKD**		
	total	male	female	total	male	female	total	male	female
2015	89.7	87.8	91.4	96.4	105.0	88.0	90.6	87.9	93.2
2016	72.3	69.7	74.7	107.2	99.8	114.4	82.9	82.8	83.1
2017	83.1	80.8	85.2	99.6	98.5	100.6	84.8	82.6	86.9
Average	**81.7**	**79.4**	**83.8**	**101.0**	**101.1**	**101.0**	**86.1**	**84.4**	**87.7**

Source: State Statistical Office (SSO). 2019

Age-specific mortality rate from circulatory diseases in Gevgelia is quite higher than Bitola and the national average (101/10,000 compared to 82 and 86/10,000) (Table 6). As expected, higher mortality rate is registered in female population in Bitola and RNM, whereas in Gevgelia there is no differences in the gender distribution for the analyzed three-year period.

In terms of age specific mortality rate from respiratory diseases (J00-J99), Gevgelia has again higher mortality rate compared to Bitola (8/10,000 and 3/10,000) while the national mortality rate is 6 per 10,000 populations. Higher specific mortality rate from respiratory diseases is registered in male population (Table 7).

Table 7 Age-specific mortality rate from respiratory diseases per 10,000 population in selected municipalities and RN Macedonia, for 2015-2017

/10,000	***30 and over***								
Mt rate from respiratory diseases (J00-J99)	**Bitola**			**Gevgelia**			**MKD**		
	total	male	female	total	male	female	total	male	female
2015	2.4	3.0	1.9	11.5	13.0	10.1	5.7	6.7	4.6
2016	2.4	3.4	1.5	3.8	2.6	5.0	6.3	7.9	4.8
2017	3.4	4.7	2.2	9.6	11.7	7.5	6.4	8.1	4.7
Average	**2.7**	**3.7**	**1.9**	**8.3**	**9.1**	**7.5**	**6.1**	**7.6**	**4.7**

Source: State Statistical Office (SSO). 2019

Gender differences are most obvious in terms od age-specific mortality rate from neoplasms of the lung (lung cancer, ICD10 code C32-C34), presented in table 9. Gender ratio is 3-4 times higher in male population in both selected municipalities and in RN Macedonia. Gevgelia has higher mortality rate (10/10,000 in comparison with Bitola) and the national mortality rate (7/10,000) (Table 8).

Table 8 Age-specific mortality rate from lung cancer per 10,000 population in selected municipalities and RN Macedonia, for 2015-2017

/10,000	***30 and over***								
Mt rate from lung cancer (C32-34)	**Bitola**			**Gevgelia**			**MKD**		
	total	male	female	total	male	female	total	male	female
2015	5.8	10.1	1.9	6.4	10.4	2.5	7.1	11.7	2.6
2016	7.6	13.1	2.5	11.5	15.6	7.5	7.6	12.1	3.2
2017	7.4	12.4	2.8	13.4	19.4	7.5	6.7	10.5	3.0
Average	**6.9**	**11.8**	**2.4**	**10.4**	**15.1**	**5.9**	**7.1**	**11.4**	**3.0**

Source: State Statistical Office (SSO). 2019

Based upon a broad scientific literature and evidence and the IARC (*International Agency for Research on Cancer*) statement from 2013, particulate air pollution is classified as a carcinogenic to human (Group 1). The most important studies that investigate the relationship between PM and lung cancer - Harvard six cities study, ACS study (American Cancer Society) and some European studies conducted in the Netherlands, France, Sweden and ESCAPE study with their findings support this fact. ACS study assessed 8-14% increment of lung cancer per 10 µg/m^3 PM$_{2.5}$, while Harvard study estimate 19% increment. Meta analysis of prospective studies estimate that risk of lung cancer due to long term exposure is increasing for 9% per 10 µg/m^3 of PM$_{2.5}$ and 5% per 10 µg/m^3 increment of PM$_{10}$ concentration [29,30,31].

However, it must be kept in mind that the development and malignant alteration of the airway cells does not occur immediately after a certain exposure and it is necessary to monitor the population for a longer period and to have epidemiological data for a longer exposure to that mixture of pollutants in order to draw a final conclusion about the link between lung cancer and polluted air.

Detailed information for age-specific and cause-specific mortality are presented in Annex 1 (Table A 3-6) for all three selected outcomes.

3. Impact of particulate air pollution on human health in Bitola municipality

Quantification of the burden of disease from particulate air pollution is based on commonly used methodologies that link exposures to current air quality and mortality of the population. Based on available scientific evidence, we selected $PM_{2.5}$ as a main stressor (pollutant) due to the growing trends of this stressor in recent years, as well for their potential to cause cardiovascular diseases and lung cancer [23]. Their small size (less than 2.5 micrometer) enable to rich distal parts of the respiratory system and to enter systematic circulation causing effects on different body systems and organs.

Obtained (estimated) results for the extra deaths attributed to air pollution from the estimations are influenced by other factors such as the age distribution of the population (those at an older age are at the higher risk) [32-34], the presence of larger groups of vulnerable populations or lower education populations or individual lifestyle (smoking, the time spent outdoor, occupational exposure, exposure to indoor air pollution) [19,35].

Correlation matrices

Correlation matrices were developed before assessing health Impact of air pollution in order to analyze correlation between pollutant (PM_{10} and $PM_{2.5}$), meteorological parameters and all-cause natural mortality (and specific mortality) or hospital admissions for certain group of diagnoses (Table 9-10). In terms of correlation between pollutants and meteorological factors, the relation is statistically strong and significant. Pearson correlation coefficient for PM_{10} and $PM_{2.5}$ and atmospheric pressure is strong *(r= .70; p<0.000)*, while their correlation with temperature and global radiation is strong but inverse *(r=- .844; p<0.000 and r=- .736; p<0.000).* That means when the temperature is low and decreasing, the concentrations of the pollutants (particulate matter) are highest (are increasing).

Correlations between other meteorological parameters shows that temperature is positively correlated with global radiation *(r= .913; p<0.000*) and negatively with atmospheric pressure *(r=- .447; p<0.01).* Global radiation and pressure are negatively correlated *(r=- .519; p<0.001)*

There is a positive and statistically significant correlation between all-cause natural mortality and particulate matter (both, PM_{10} and $PM_{2.5}$) (*r= .554; p<0.000)* and negative, inverse correlation between all cause natural mortality and temperature and global radiation *(r= - .505; p<0.003* and *(r= - .345; p<0.042).* It means when concentration of particulate matter is increasing, the natural mortality is increasing as well. When temperature is decreasing, natural mortality is increasing (Table 9).

In terms of cause specific and age specific mortality, there is a statistically strong correlation between *circulatory mortality* (30 years and over) and particulate matter (*r= .532; p<0.001*), while correlation with temperature is inverse (*r=- .465; p<0.007).* Mortality due to respiratory diseases is only negatively correlated with temperature (*r=- .469; p<0.007).*

We did not find any correlation between pollutants, meteorological factors and lung cancer mortality, probably due to statistically insignificant number of cases in municipality of Bitola (36 to 47 for the period of three years) (Table 9). For final conclusion in terms of this health endpoint is needed longer period of observation and bigger data set.

Table 9 Correlation matrix between stressors, meteorological parameters and mortality, Bitola for the period 2015-2017

		PM_{10}	$PM_{2.5}$	Temperature	Pressure	Global radiation	All-cause Mt	Mt I00-I99	Mt J00-J99	Mt Lung-cancer
PM_{10} ($\mu g/m^3$)	Pearson Correlation	1								
(N=36)	Sig. (2-tailed)									
$PM_{2.5}$ ($\mu g/m^3$)	Pearson Correlation	1.000**	1							
(N=36)	Sig. (2-tailed)	.000								
Temperature (^{0}C)	Pearson Correlation	-.844**	-.844**	1						
(N=32)	Sig. (2-tailed)	.000	.000							
Pressure (hPa)	Pearson Correlation	.700**	.700**	-.447*	1					
(N=35)	Sig. (2-tailed)	.000	.000	.010						
Global radiation (W/m^2)	Pearson Correlation	-.736**	-.736**	.913**	-.519**	1				
(N=35)	Sig. (2-tailed)	.000	.000	.000	.001					
All cause Mt,	Pearson Correlation	.554**	.554**	-.505**	.277	-.345*	1			
30 and over*(N=36)*	Sig. (2-tailed)	.000	.000	.003	.107	.042				
Mortality I00-I99,	Pearson Correlation	.532**	.532**	-.465**	.291	-.256	.795**	1		
30 and over *(N=36)*	Sig. (2-tailed)	.001	.001	.007	.090	.137	.000			
Mortality J00-J99,	Pearson Correlation	.245	.245	-.469**	-.169	-.304	.469**	.438**	1	
30 and over *(N=36)*	Sig. (2-tailed)	.150	.150	.007	.332	.076	.004	.007		
Mortality Lung cancer,	Pearson Correlation	.092	.092	.000	.098	.071	.252	-.073	.061	1
30 and over *(N=36)*	Sig. (2-tailed)	.592	.595	.999	.574	.685	.138	.672	.725	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Mt - Mortality

We correlated particulate matter and meteorological factors with hospital admissions due to respiratory diseases (J00-J99) for all age groups and younger than 5 years, and for the age group 30 and over, hospitalizations due to circulatory diseases (I00-I99) (Table 10).

Table 10 Correlation matrix between stressors, meteorological parameters and hospital admissions, Bitola for the period 2015-2017

		PM_{10}	$PM_{2.5}$	Temperature	Pressure	Global radiation	HA J00-J99, all ages	HA J00-J99, 0-5 yrs	HA I00-I99, 30 +
PM_{10} ($\mu g/m^3$)	Pearson Correlation	1							
(N=36)	Sig. (2-tailed)								
$PM_{2.5}$ ($\mu g/m^3$)	Pearson Correlation	1.000**	1						
(N=36)	Sig. (2-tailed)	.000							
Temperature (^{0}C)	Pearson Correlation	-.844**	-.844**	1					
(N=32)	Sig. (2-tailed)	.000	.000						
Pressure (hPa)	Pearson Correlation	.700**	.700**	-.447*	1				
(N=35)	Sig. (2-tailed)	.000	.000	.010					
Global radiation	Pearson Correlation	-.736**	-.736**	.913**	-.519**	1			
(W/m^2) *(N=35)*	Sig. (2-tailed)	.000	.000	.000	.001				
Hosp. admiss. J00-J99,	Pearson Correlation	.333*	.333*	-.435*	-.017	-.312	1		
all ages *(N=36)*	Sig. (2-tailed)	.047	.047	.013	.922	.068			
Hosp. admiss. J00-J99,	Pearson Correlation	.477**	.477**	-.534**	.082	-.482**	.560**	1	
0-5 yrs *(N=36)*	Sig. (2-tailed)	.003	.003	.002	.640	.003	.000		
Hosp. admiss I00-I99,	Pearson Correlation	-.138	-.138	-.100	-.164	-.155	.321	.377*	1
30 and over *(N=36)*	Sig. (2-tailed)	.423	.423	.586	.347	.375	.056	.023	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
HA - hospital admissions

Hospital admissions due to respiratory diseases for all age groups are positively and moderately correlated with particulate matter (*r= .333; p<0.47*). Correlated with the temperature, a negative correlation has been registered (*r=- .435; p<0.013*). For the age group younger than five, the correlation is also positive and strong with particulate matter *(r= .477; p<0.003),* while strong negative, inverse correlation has been registered for temperature and global radiation (*r=- .534; p<0.002 and r=- .482; p<0.003).*

With the available data set of 36 monthly data, we have not registered any correlation between hospital admissions for circulatory diseases (30 years and over) and stressors or the analyzed meteorological parameters.

Health impact of particulate air pollution

By applying the methodology for health impact assessment of the particulate air pollution, we estimate the number of premature deaths due to long-term exposure to PM$_{2.5}$ that could be avoided if the recommended limit values are respected (not exceeded). Those are extra deaths that have occurred as a result of that long-term exposure and the exceedance of the limit values out of the observed total natural mortality (all-cause mortality excluding external causes of death, ICD 10 code A00-Y89 excl. external causes of death V01-Y89) for the age group 30 and over.

The method allows estimation of the health impact of air pollution in population for which exposure estimates as well as background health data are available [36,1].

Table 11 *Estimated health impact of PM$_{2.5}$ polluted air in the municipality of Bitola, due to long-term exposure for the period 2015-2017*

<table>
<tr><th rowspan="3"></th><th rowspan="3">PM_{2.5} (µg/m³) 3-year average</th><th rowspan="3">Natural mortality /100,000</th><th rowspan="3">Natural mortality /100,000 30+</th><th colspan="8">Attributable mortality (attributable deaths)</th></tr>
<tr><th colspan="4">WHO limit value PM_{2.5} (10 µg/m³)</th><th colspan="4">EU limit value PM_{2.5} (25 µg/m³)</th></tr>
<tr><th>#</th><th>95% CI</th><th>AR[3] (%)</th><th>/100,000</th><th>#</th><th>95% CI</th><th>AR (%)</th><th>/100,000</th></tr>
<tr><td>Bitola</td><td>35.9</td><td>1,282</td><td>1,863</td><td>167</td><td>112-216</td><td>14.4</td><td>269.1</td><td>74</td><td>49-97</td><td>6.4</td><td>118.6</td></tr>
<tr><td>RNM</td><td>39.9</td><td>960</td><td>1,490</td><td>3,218</td><td>2,163-4,147</td><td>16.5</td><td>245.4</td><td>1,676</td><td>1,110-2,190</td><td>8.6</td><td>127.8</td></tr>
</table>

**Note: PM$_{2.5}$ values were converted from PM10 values with a coefficient of 0.65.*

The estimated excess number of cases at exposure to 0.0 $\mu g/m^3$ which is unrealistic (hypothetical) scenario in Bitola municipality is 225 premature death cases[4] (95% CI 152-288) and population excess incidence[5] of 362 per 100,000 population at risk (95% CI 244.9-464.1). That means that 225 death cases could be attributed to the exposure to PM$_{2.5}$, that presents 19.4% (AR%) of total all cause natural mortality for the age group 30 and over (three-year average number of death cases 1157, Table 12).

Compared to the national estimation, we calculated 4,171 excess deaths at exposure to 0.0 $\mu g/m^3$ that presents 21.3% of total all cause natural mortality (three-year average number of cases 19,548, Table 6). Population excess incidents in RN Macedonia is 318 per 100,000 (95% CI 215.9-406.2).

Table 12 *Estimated Risk percent (AR (%)) for the three scenarios*

	PM$_{2.5}$ ($\mu g/m^3$)	**Natural mortality**	**"Zero" scenario PM$_{2.5}$ (0.0 $\mu g/m^3$)**	**WHO limit value PM$_{2.5}$ (10 $\mu g/m^3$)**	**EU limit value PM$_{2.5}$ (25 $\mu g/m^3$)**

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[3] **Attributable proportion/fraction/attributable risk percent (AR%)** - it is the fraction of the population at risk that will develop a particular disease or condition as a result of that exposure. Or, to put it another way, AR is the number of cases that will be eliminated if exposure is also eliminated. https://www.statisticshowto.datasciencecentral.com/attributable-risk/

[4] Excess number of cases at a certain category of exposure

[5] Estimated number of attributable cases per 100,000 populations at risk

	3-year average	**30+**									
		#	#	95% CI #	% of total Mt	#	95% CI #	% of total Mt	#	95% CI #	% of total Mt
Bitola	35.9	1157	225	152-288	19.4	167	112-216	14.4	74	49-97	6.4
RNM	39.9	19548	4,171	2,832-5,327	21.3	3,218	2,163-4,147	16.5	1,676	1,110-2,190	8.6

**Note: PM2.5 values were converted from PM10 values with a coefficient of 0.65.*

For the city of Bitola, 6.4% of total mortality could be avoided if recommended EU Directive limit value for $PM_{2.5}$ is met, and 8.6% in RN Macedonia. The proportion of avoidable death cases is higher if WHO AQG limit values for $PM_{2.5}$ are met - 14.4% of total death cases in Bitola, and 16.5% of the total mortality in RN Macedonia, which is significant health benefit (Table 11, 12 and Figure 1).

In order to make comparisons between the cities (regions or countries), the impact of particulate air pollution (AP) is better indicated by the mortality rate per 100,000 as is shown in table 11. Bitola has higher mortality rate (269 per 100,000) compared to the national mortality rate 245/100,000 population (for cut-off value 10)[6], that shows when population size is considered, the impact of AP is higher in municipality of Bitola than in RN Macedonia. Mortality rate per 100,000 when cut-off value 25[7] is selected is higher in RN Macedonia (128/100,000) than in municipality of Bitola (119 per 100,000 population) (Table 11).

Attributable proportion (Attributable risk percent AR%) is graphically presented in the Figure 1.

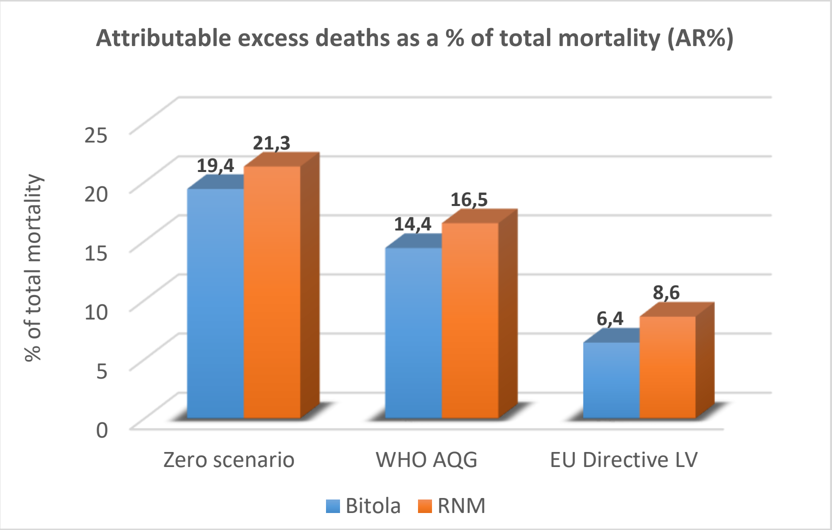

Figure 1 Proportion of all-causes (natural) mortality as percent of total mortality (AR%) due to particulate air pollution exposure, exposures exceeding WHO AQG and EU Directive limit values, for age group 30 and over

Population excess incidence per 100,000 populations is presented in the Figure 2.

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[6] Cut-off value 10 correspond to the WHO AQG limit value for PM2.5

[7] Cut-off value 25 correspond to the EU Directive limit value for PM2.5

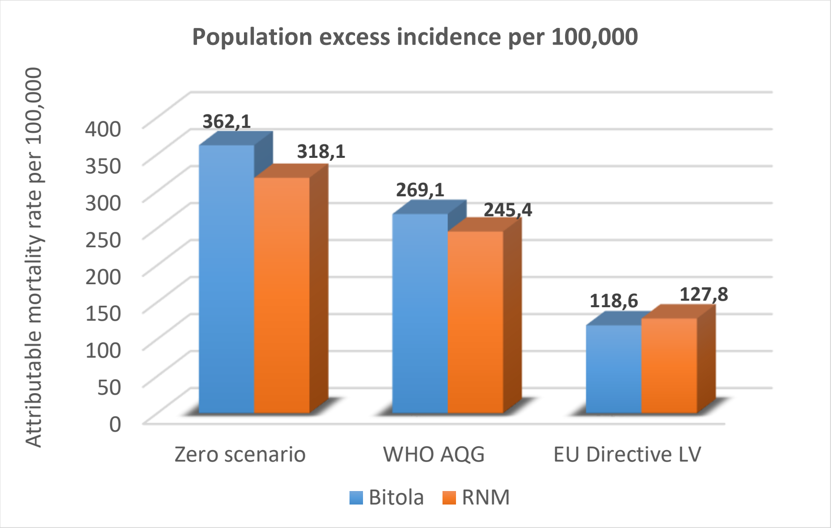

Figure 2 Excess incidence per 100,000 population due to particulate air pollution exposure exposures exceeding WHO AQG and EU Directive limit values, for age group 30 and over

Although such an estimation has been made for some Balkan's Region cities in 2019 showing that deaths attributable to AP varied between 150-250 deaths per 100,000 when cut-off value 10 is selected, the results from the study that reffers to the Macedonian cities (Skopje, Tetovo and Bitola) can not be compared with findings of our study due to different model of calculation for all-cause mortality and long term exposure (lin-log). Still, in the UNEP Western Balkan study is estimated decline in life expectancy attributed to $PM_{2.5}$ exposure of 0.8 years in the municipality of Bitola. Lelieveld and colleagues (2019) estimated that air pollution reduces the mean life expectancy in Europe by about 2.2 years, while attributable per capita mortality rate in Europe of 133 per 100,000 populations per year [28].

Dimovska & Gjorgjev in 2018 estimated 1,205 attributable deaths (95% CI 819 to 1,538; 21.8% of total mortality), mortality rate 276 per 100,000 for the Skopje Metropolitan area (Skopje Region). In Tetovo, 265 attributable death cases were estimated (95% CI 187-327; 38.6% of total mortality), with high mortality rate, 429 μg/m^3 per 100,000 populations at risk. In this study 5-year average of environmental data and vital statistic data have been used, precisely, for the period 2012 to 2016. Annual average concentration in Skopje Region is 41.8 whereas in Tetovo 81.7 μg/m^3 [37].

The recent study conducted in Serbia found that 1,796 deaths could be attributed to the exposure to $PM_{2.5}$ concentrations of 29.2 μg/m^3 in the city of Belgrade (estimated AP% is 10.9%; 191 attributable deaths per 100,000 populations at risk) for cut-off value 10.

However, as no threshold for PM has been identified below which no damage to health is observed, the recommended values should be regarded as representing acceptable and achievable objectives to minimize health effects in the context of local constraints, capabilities and public health priorities [38].

Estimated Years of Life Lost due to AP in the municipality of Bitola

The metric Years of Life Lost (YLL) is used not only as a metric for the estimation of the disease burden due to particulate air pollution exposure, as well as a metric for assessment of the health gain of introducing targeted public health action and policies.

Aiming to assess the burden and health gain, several tables have been prepared using different health outcomes: *all-cause (natural) mortality* (ICD10 code A00-Y89 excl. external causes of death V01-Y89); *cardiopulmonary mortality* (I00-I99 and J00-J99) and *lung cancer mortality* (C32-C34) for the age group 30 and over.

According to the European Environmental Agency (EEA) data for 2016, the number of premature deaths attributed to $PM_{2.5}$ in the EU-28 is 4,466,000. In relative terms, when considering YLL per 100,000 inhabitants, the largest impacts are observed in central and eastern European countries where the highest concentrations are also observed, i.e. Kosovo, Bulgaria, Serbia, the former Yugoslav Republic of Macedonia and Hungary. The lowest relative impacts are found in the countries at the northern and north-western edges of Europe: Iceland, Norway, Ireland, Sweden and Finland [39].

Table 13 Years of life lost due to premature mortality in terms of all-cause (natural) mortality

Health endpoint: All-cause mortality (excl. external causes of death), stressor $PM_{2.5}$

	Estimated YLL ('000) (WHO GBD 2016), >30 y.	3-years mean $PM_{2.5}$ ($\mu g/m^3$)	RR Macedonian exposures (10 $\mu g/m^3$)	Population attributable fraction (PAF)	Estimated burden of diseases-YLL			Years of life saved if annual mean of $PM_{2.5}$ is reduced to 10 $\mu g/m^3$ (WHO LV)	Standardized rate (YLL)/100,000 population
					#	*LCL 95% CI*	*UCL 95% CI*		
Bitola	380.7	35.9	**1.241**	**0.011**	**4,264.7**	2,686	5,839	**3,159**	**4,654**
Skopje	380.7	43.3	**1.298**	**0.069**	**26,455.5**	16,902	35,706	**20,622**	**4,804**
RNM	380.7	39.9	**1.271**	**0.213**	**81,235.0**	55,148	103,741	**59,010**	**3,914**

**WHO LV (WHO Limit value, Air Quality Guideline for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. 2005)*

The estimated disease burden from all-cause (natural) mortality (*ICD10 code A00-Y89, excluding external causes V01-Y89*) expressed as YLL is higher in Bitola (4,654/100,000) compared to RN Macedonia (3,914/100,000) (Table 13).

In this estimation we decided to include the capital city of Skopje in order to get better picture of the size of the issue and for better comparisons. As expected, the burden is highest in the capital due to higher exposure level among other (4,804/100,000). In the study from 2019 have been estimated 11,216/100,000 for Tetovo, due to high annual exposure of 81.7 $\mu g/m^3$ [40]. The recent Serbian study for the city of Belgrade, the capital of Serbia has been estimated higher rate (5,516 YLL/100,000) at exposure to concentration of $PM_{2.5}$ of 29.2 $\mu g/m^3$ [41].

EEA in the latest report estimated 30,400 YLL (1,469/100,000) at exposure to 28.7 $\mu g/m^3$ in 2015 for the Republic of North Macedonia, an average taken from urban background station only. This differences in results are primarily due to the difference in the population exposure concentrations.

The number of saved years of healthy life if WHO AQG limit values are achieved, in Bitola we estimated 3,159 years (74% of the disease burden), while the national health gain will be 59,010 years of healthy life (73% of the disease burden) (Table 13).

Table 14 Years of life lost due to premature mortality in terms of cardiopulmonary mortality

Health endpoint- cardiopulmonary mortality, stressor $PM_{2.5}$

	Estimated YLL ('000)	3-years		**Population attributable**	**Estimated burden of diseases-YLL**	Years of life saved if	**Standardized rate**

	(WHO GBD 2016), >30 y.	mean PM$_{2.5}$ (µg/m^3)	**RR Macedonian exposures (10 µg/m^3)**	**fraction (PAF)**	***#***	***LCL 95% CI***	***UCL 95% CI***	annual mean of PM$_{2.5}$ is reduced to 10 µg/m^3 (WHO LV)	**YLL/100,000 population**
Bitola	231.8	35.9	**1.358**	**0.02**	**3,403**	807	6,370	**2,538**	**3,714**
Skopje	231,8	43.3	**1.394**	**0.09**	**20,858**	5,141	37,316	**16,310**	**3,788**
RNM	231.8	39.9	**1.317**	**0.26**	**61,115**	17,762	94,435	**43,999**	**2,945**

**WHO LV (WHO Limit value, Air Quality Guideline for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. 2005)*

Our estimation for the cardiopulmonary mortality (*ICD code I00-I99 and J00-J99*) as a selected health outcome shows that estimated disease burden is higher in Bitola (3,714 per 100,000) compared to RNM (2,945/100,000), whereas the city of Skopje has the highest estimated rate (3,788 per 100,000 population).

Estimated health gain in Bitola municipality in terms of cardiopulmonary mortality will be 2,538 years while the national health gain estimated is 43,999 years (Table 14).

Table 15 Years of life lost due to premature mortality in terms of lung cancer

Health endpoint- Lung cancer mortality, stressor PM$_{2.5}$									
					Estimated burden of diseases-YLL				
	Estimated YLL ('000) (WHO GBD 2016), >30 y.	3-years mean PM$_{2.5}$ (µg/m^3)	**RR Macedonian exposures (10 µg/m^3)**	**Population attributable fraction (PAF)**	***#***	***LCL 95% CI***	***UCL 95% CI***	Years of life saved if annual mean of PM$_{2.5}$ is reduced to 10 µg/m^3 (WHO LV)	**Standardized rate YLL/100,000 population**
Bitola	24.1	35.9	**1.535**	**0.03**	**593**	174	1,123	**450**	**647**
Skopje	24.1	43.3	**1.676**	**0.15**	**3,492**	1,088	6,117	**2,751**	**634**
RNM	24.1	39.9	**1.610**	**0.38**	**9,127**	3,549	13,164	**6,417**	**439**

**WHO LV (WHO Limit value, Air Quality Guideline for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. 2005)*

The causal association between PM$_{2.5}$ and lung cancer is well documented. Aiming to assess the burden due to exposure to current level of particulate air pollution in terms of this health outcome, we applied the CRFs from Pope et al. 2002 [29] where RR 1.267 (95% CI 1.0407-1.2190) has been applied, that means 12.6% increase in mortality from lung cancer per each 10 µg/m^3 increment of the pollutant concentration (PM$_{2.5}$) over a long period.

We estimated that 593 YLL have been lost due to premature mortality from lung cancer (*ICD10 code C32-C34*), and 9,127 YLL in RNM. Considering population size, Bitola has the highest rate compared to RNM and the City of Skopje (647 per 100,000 and 439 and 634 per 100,000 respectively) (Table 15).

The findings of our estimations are summarized and graphically presented in the figures above (Figure 3 and 4).

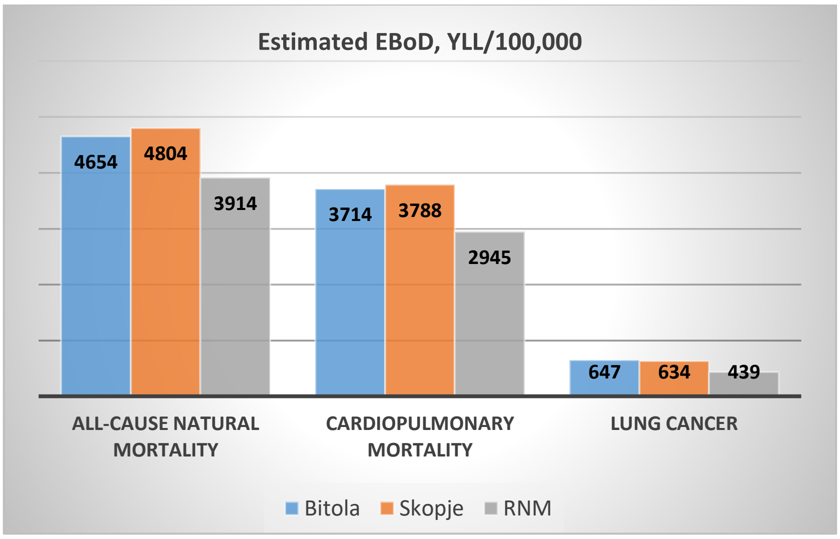

Figure 3 Estimated burden of disease expressed as YLLs per 100,000 population

This presentation allows to conclude that disease burden in the Bitola municipality is higher than the national ones, but also that health gain will be greater if WHO limit values will be achieved for all three selected health outcomes.

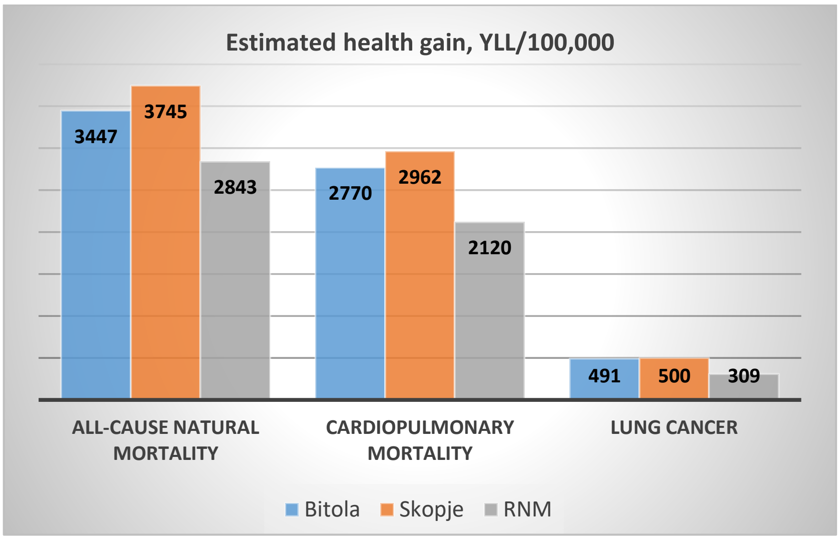

Figure 4 Estimated health gain, YLLs per 100,000 population

4. Limitations of the study/assessment

The study has some limitations. Missing environmental data have been calculated from the averages in the respective months from the other years, as well as using a formula to estimate $PM_{2.5}$ concentrations as a fraction of PM_{10} could be considered as a limitation of this study. The long-term effect of particulate air pollution observed the only through the YLL could also be a limitation because the burden of the years of life spent with some disability (expressed as YLD) is also significant.

Still, these estimates could be a good basis for conducting a further study (economic analysis) to assess economic losses and expenditures associated with air pollution, as mortality or YLL represent the largest burden from the pollution, while DALYs as recommended by WHO is better to use for cost-effectiveness of a particular project or measure.

5. Conclusions

Ambient air pollution is a major health risk, leading to respiratory and cardiovascular mortality.

During the period of observation, the annual mean concentration of $PM_{2.5}$ in Bitola exceed the WHO limit value of 10 µg/m^3 as well as the less stringent EU limit value of 25 µg/m^3 which should be considered as a serious threat to the population health.

The estimated impact of particulate air pollution on mortality expressed in absolute number or as YLLs (*Years of of Life Lost*) is significant and not negligible. For example, Bitola has higher all-cause (natural) mortality rate in the age group of 30 and over compared to the national average mortality rate and Gevgelia.

There is a positive and statistically significant correlation between all-cause natural mortality and particulate matter as well as statistically strong correlation between *circulatory mortality* (30 years and over) and particulate matter.

It was estimated that 225 death cases in Bitola could be attributed to the exposure to $PM_{2.5}$, that presents 19.4% of total all cause natural mortality for the age group 30 and over.

The estimations for the city of Bitola, shows that 6.4% of total mortality could be avoided if recommended EU Directive limit value for $PM_{2.5}$ is met, but the proportion of avoidable death cases is even higher (14.4% of total death cases) if WHO AQG limit values for $PM_{2.5}$ could be met which is of course a significant health benefit.

The results of this type of assessments must be taken into account in coping with the air pollution during the policy and decision-making process at all levels-from a local to a central level. National and local authorities must become aware of the magnitude of the problem and to take responsibility for prioritizing activities, strengthening monitoring and control of ambient air pollution and consistently to enforce legislation without exceptions.

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ANNEX 1

Table A 1 *Air quality monthly monitoring data for 2014-2018, monthly average concentration s of* PM_{10} (µg/m^3) *municipality of Bitola*

PM10 (µg/m3)	Bitola 1	Bitola 2
01/2014	80.47	
02/2014	68.52	
03/2014	49.94	
04/2014	39.85	
05/2014	33.5	
06/2014	41	
07/2014		
08/2014		
09/2014	38.72	
10/2014	52.18	
11/2014	63.49	
12/2014	95.32	
01/2015		180.9
02/2015	69.32	88.85
03/2015	38.99	59.09
04/2015	31.55	42.92
05/2015	31.39	
06/2015	22.84	21.58
07/2015	34.31	28.05
08/2015	32.44	
09/2015	30.34	30.25
10/2015	32.9	36.97
11/2015	85.55	76.55
12/2015	131.4	150.6
01/2016	61.43	127.9
02/2016	39.65	67.81
03/2016	28.71	44.78
04/2016	33.13	45.36
05/2016	22.44	29.42
06/2016	31.18	32.79
07/2016	33.31	36.25
08/2016	31.33	30.33
09/2016		33.73
10/2016	47.38	36.33
11/2016	80.56	85.43
12/2016	110.92	122.20

	Bitola 1	Bitola 2
01/2017	87.86	166.72
02/2017	70.42	102.21
03/2017	43.26	47.22
04/2017	35.11	46.44
05/2017	28.80	43.41
06/2017	35.05	
07/2017	35.77	23.95
08/2017	41.27	34.43
09/2017	31.12	24.73
10/2017	36.52	32.87
11/2017	66.48	65.20
12/2017	53.05	72.22
01/2018	73.01	91.08
02/2018	30.69	51.18
03/2018	24.96	45.50
04/2018	32.92	41.22
05/2018	25.58	28.58
06/2018		24.57
07/2018	34.04	24.67
08/2018	38.11	28.47
09/2018	40.83	24.98
10/2018	51.2	
11/2018	71.9	68.7
12/2018	92.6	83.6
min		**21.58**
max		**180.9**
average		**53.4**

Table A 2 *Meteorological data registered (mostly) in Bitola 1 monitoring station*

	Bitola 1						
	Temperature [°C]	**min T [°C]**	**max T [°C]**	**Humidity [%]**	**Wind speed [m/s]**	**Pressure [hPa]**	**Global radiation [W/m2]**
Jan-15							
Feb-15	1.4	-5.3	7.7	75.2		945.8	104.5
Mar-15						949.0	108.8
Apr-15						948.3	203.9
May-15	16.0	10.9	21.8	60.5		946.8	233.1
Jun-15	17.9	13.6	23.1	62.7		948.1	251.4
Jul-15	22.9	15.2	27.2	52.8		947.8	285.4
Aug-15	21.4	16.2	24.7	59.5		948.2	239.2
Sep-15						947.8	167.4
Oct-15	11.1	5.4	16.0	80.4		949.8	106.6
Nov-15	6.6	0.3	13.7	75.4		950.6	100.4
Dec-15	-0.3	-5.9	4.0	83.6		959.8	71.5
Jan-16	0.2	-9.9	10.4	75.7		947.5	79.5
Feb-16	7.0	-0.1	14.4	69.4		948.2	100.3
Mar-16	6.3	1.8	13.2	68.8		944.2	137.9
Apr-16	13.0	6.1	6.1	58.3		945.5	216.7
May-16	13.6	8.4	20.2	67.2		944.6	228.0
Jun-16	19.7	15.5	25.4	61.0		946.7	252.5
Jul-16	21.5	17.5	25.0	59.6		947.8	272.9
Aug-16	20.2	16.1	24.7	60.7		948.6	240.3
Sep-16	15.4	10.1	20.4	72.3		949.6	161.2
Oct-16	10.6	4.1	18.3	77.2		951.1	117.0
Nov-16	4.4	4.4	17.2	80.5		950.5	76.9
Dec-16	-1.0	-5.5	4.2	69.3		957.0	78.0
Jan-17	-5.8	-19.0	2.7	81.6		950.2	77.8
Feb-17	3.6	-3.7	8.7	73.4		951.9	103.1
Mar-17	8.0	3.4	13.1	61.5		946.8	160.9
Apr-17	9.8	2.1	17.3	61.5		947.2	208.0
May-17	14.8	11.2	19.4	65.5		946.7	225.4
Jun-17	20.0	13.6	27.4	60.7		947.0	256.7
Jul-17	22.2	14.0	27.9	51.4		946.6	262.6
Aug-17	22.2	16.6	27.0	48.2	0.2	948.5	237.2
Sep-17	16.4	10.5	23.9	58.9	0.2	947.7	169.6
Oct-17	11.2	2.5	16.6	63.6	0.2	950.6	133.7
Nov-17	6.0	-0.6	11.8	80.2	0.2	947.8	64.1
Dec-17	3.5	-3.7	11.8	71.4	0.3	948.8	56.0
Jan-18	2.1	-4.2	7.4	77.4	0.2	949.9	63.2
Feb-18	3.2	-5.4	10.1	79.7	0.3	922.1	71.1
Mar-18	7.7	-5.5	18.0	66.2	0.3	938.1	133.8
Apr-18	14.8	9.1	19.4	56.7	0.2	946.7	214.1
May-18	16.9	13.1	21.1	69.6	0.2	944.3	224.0
Jun-18	19.1	13.2	24.0	68.1	0.3	942.7	210.2
Jul-18	21.7	16.1	25.8	64.3	0.2	943.7	253.7
Aug-18	21.3	17.1	24.5	65.2	0.1	946.5	219.5
Sep-18	18.6	9.6	23.6	55.7	0.2	949.4	187.7
Oct-18	13.1	6.2	16.7	97.0	0.2	944.0	116.3
Nov-18	6.3	-1.5	16.4	79.8	0.1	934.0	56.9
Dec-18	0.5	-4.6	7.2	80.0	0.2	948.8	50.9

Table A 3 *Monthly mortality data, all age groups for selected municipalities and RNM, 2015-2017*

	All age-groups								
All-cause Mt (excl. external)	**Bitola**			**Gevgelia**			**RNM**		
	total	male	female	total	male	female	total	male	female
Jan-15	115	51	64	33	17	16	2075	1068	1007
Feb-15	111	57	54	25	16	9	1805	913	892
Mar-15	103	52	51	20	7	13	1877	949	928
Apr-15	99	54	45	34	21	13	1680	819	861
May-15	93	41	52	20	12	8	1632	855	777
Jun-15	113	63	50	21	12	9	1416	766	650
Jul-15	95	51	44	20	11	9	1561	787	774
Aug-15	95	50	45	19	10	9	1458	759	699
Sep-15	87	48	39	18	9	9	1368	697	671
Oct-15	87	45	42	14	5	9	1665	861	804
Nov-15	90	36	54	26	18	8	1627	815	812
Dec-15	122	60	62	23	13	10	1784	903	881
Jan-16	98	55	43	27	15	12	1877	982	895
Feb-16	109	57	52	21	12	9	1722	895	827
Mar-16	100	51	49	23	9	14	1669	909	760
Apr-16	86	39	47	18	11	7	1603	833	770
May-16	105	50	55	14	8	6	1562	811	751
Jun-16	81	35	46	18	9	9	1570	791	779
Jul-16	93	43	50	25	6	19	1511	796	715
Aug-16	81	40	41	21	10	11	1481	769	712
Sep-16	93	55	38	18	8	10	1497	809	688
Oct-16	89	40	49	23	11	12	1754	893	861
Nov-16	87	41	46	22	13	9	1694	870	824
Dec-16	100	45	55	34	15	19	1984	1010	974
Jan-17	168	80	88	43	25	18	2655	1321	1334
Feb-17	95	47	48	19	5	14	1571	773	798
Mar-17	86	43	43	21	10	11	1666	865	801
Apr-17	80	45	35	17	9	8	1465	774	691
May-17	87	40	47	19	11	8	1511	760	751
Jun-17	92	48	44	22	10	12	1557	816	741
Jul-17	99	52	47	18	12	6	1542	763	779
Aug-17	90	46	44	24	16	8	1591	841	750
Sep-17	94	52	42	21	7	14	1481	797	684
Oct-17	110	58	52	12	4	8	1636	867	769
Nov-17	92	54	38	21	9	12	1588	822	766
Dec-17	99	49	50	18	8	10	1634	839	795

Table A 4 *Age-specific mortality from circulatory diseases (I00-I99) for the period 2015-2017*

	30 and over								
Circulatory diseases (I00-I99)	**Bitola**			**Gevgelia**			**RNM**		
	total	male	female	total	male	female	total	male	female
Jan-15	59	28	31	16	9	7	1265	598	667
Feb-15	48	22	26	15	10	5	1076	494	582
Mar-15	60	29	31	11	4	7	1205	586	619
Apr-15	52	26	26	10	5	5	1022	467	555
May-15	39	17	22	11	6	5	921	451	470
Jun-15	53	26	27	11	8	3	811	408	403
Jul-15	39	18	21	10	5	5	885	413	472
Aug-15	39	22	17	10	4	6	825	413	412
Sep-15	43	23	20	12	5	7	795	364	431
Oct-15	28	10	18	9	3	6	975	476	499
Nov-15	35	12	23	19	12	7	987	460	527
Dec-15	62	29	33	17	10	7	1111	544	567
Jan-16	44	23	21	16	8	8	1087	507	580
Feb-16	44	22	22	12	6	6	1002	494	508
Mar-16	39	16	23	18	7	11	988	509	479
Apr-16	43	20	23	16	9	7	898	445	453
May-16	46	23	23	6	5	1	868	432	436
Jun-16	33	15	18	14	8	6	833	393	440
Jul-16	35	13	22	16	5	11	778	383	395
Aug-16	26	12	14	12	5	7	778	380	398
Sep-16	34	19	15	12	4	8	759	404	355
Oct-16	29	12	17	16	6	10	968	462	506
Nov-16	28	14	14	12	7	5	874	424	450
Dec-16	48	19	29	18	7	11	1042	510	532
Jan-17	66	30	36	36	21	15	1583	752	831
Feb-17	45	19	26	10	2	8	968	459	509
Mar-17	36	17	19	14	6	8	953	458	495
Apr-17	35	20	15	11	4	7	827	399	428
May-17	44	16	28	10	6	4	818	368	450
Jun-17	44	22	22	13	6	7	825	400	425
Jul-17	33	17	16	8	7	1	841	396	445
Aug-17	40	17	23	17	11	6	842	410	432
Sep-17	40	21	19	11	4	7	801	392	409
Oct-17	52	25	27	8	3	5	929	459	470
Nov-17	39	20	19	9	4	5	888	437	451
Dec-17	42	17	25	9	2	7	841	402	439

Table A 5 Age-specific mortality from respiratory diseases (J00-J99) for the period 2015-2017

	30 and over								
Respiratory diseases (J00-J99)	**Bitola**			**Gevgelia**			**RNM**		
	total	male	female	total	male	female	total	male	female
Jan-15	1	1	0	0	0	0	87	60	27
Feb-15	2	2	0	0	0	0	76	48	28
Mar-15	3	2	1	1	1	0	71	36	35
Apr-15	1	1	0	6	6	0	76	43	33
May-15	2	0	2	1	0	1	60	33	27
Jun-15	1	0	1	4	0	4	47	25	22
Jul-15	0	0	0	2	1	1	62	39	23
Aug-15	1	0	1	1	1	0	50	25	25
Sep-15	1	0	1	0	0	0	49	29	20
Oct-15	1	1	0	1	0	1	47	24	23
Nov-15	1	1	0	1	0	1	54	32	22
Dec-15	1	1	0	1	1	0	64	41	23
Jan-16	5	4	1	1	1	0	74	53	21
Feb-16	3	2	1	0	0	0	78	53	25
Mar-16	2	2	0	0	0	0	72	48	24
Apr-16	2	1	1	0	0	0	63	36	27
May-16	1	0	1	0	0	0	55	33	22
Jun-16	0	0	0	0	0	0	47	31	16
Jul-16	0	0	0	1	0	1	61	36	25
Aug-16	0	0	0	2	1	1	53	31	22
Sep-16	1	1	0	1	0	1	57	26	31
Oct-16	0	0	0	0	0	0	61	38	23
Nov-16	1	0	1	1	0	1	83	54	29
Dec-16	0	0	0	0	0	0	126	69	57
Jan-17	6	4	2	1	1	0	161	103	58
Feb-17	1	1	0	0	0	0	66	39	27
Mar-17	1	0	1	1	1	0	71	42	29
Apr-17	3	1	2	0	0	0	64	40	24
May-17	3	3	0	2	2	0	63	43	20
Jun-17	3	2	1	0	0	0	64	38	26
Jul-17	0	0	0	2	1	1	60	44	16
Aug-17	0	0	0	1	1	0	55	33	22
Sep-17	1	1	0	0	0	0	43	30	13
Oct-17	1	1	0	1	0	1	55	28	27
Nov-17	2	1	1	4	2	2	66	38	28
Dec-17	0	0	0	3	1	2	69	48	21

***Table A 6** Age-specific mortality from lung cancer (C32-C34) for the period 2015-2017*

	30 and over								
Lung cancer C32-34)	**Bitola**			**Gevgelia**			**RNM**		
	total	male	female	total	male	female	total	male	female
Jan-15	3	2	1	1	1	0	85	72	13
Feb-15	5	4	1	1	1	0	88	69	19
Mar-15	0	0	0	0	0	0	70	61	9
Apr-15	4	4	0	1	1	0	72	57	15
May-15	5	4	1	1	1	0	87	78	9
Jun-15	4	4	0	1	1	0	86	66	20
Jul-15	3	2	1	1	1	0	69	50	19
Aug-15	2	1	1	2	1	1	63	47	16
Sep-15	3	3	0	0	0	0	73	63	10
Oct-15	2	2	0	1	0	1	79	62	17
Nov-15	2	1	1	1	1	0	78	65	13
Dec-15	3	3	0	0	0	0	78	64	14
Jan-16	3	2	1	0	0	0	86	66	20
Feb-16	6	6	0	2	2	0	67	52	15
Mar-16	0	0	0	1	1	0	73	58	15
Apr-16	3	3	0	0	0	0	83	67	16
May-16	1	1	0	1	0	1	79	63	16
Jun-16	6	4	2	2	1	1	88	70	18
Jul-16	5	5	0	0	0	0	77	59	18
Aug-16	5	5	0	1	1	0	88	71	17
Sep-16	5	4	1	1	1	0	86	68	18
Oct-16	5	3	2	4	3	1	86	71	15
Nov-16	4	3	1	2	1	1	96	70	26
Dec-16	4	3	1	4	2	2	85	63	22
Jan-17	8	7	1	1	0	1	85	58	27
Feb-17	4	4	0	0	0	0	61	47	14
Mar-17	4	4	0	1	1	0	73	59	14
Apr-17	3	3	0	3	3	0	77	57	20
May-17	1	1	0	2	1	1	73	59	14
Jun-17	4	3	1	4	2	2	68	55	13
Jul-17	6	2	4	3	2	1	77	53	24
Aug-17	3	3	0	2	2	0	76	59	17
Sep-17	5	4	1	1	1	0	72	58	14
Oct-17	3	2	1	1	0	1	74	58	16
Nov-17	4	3	1	1	1	0	70	57	13
Dec-17	1	1	0	2	2	0	78	61	17

Interreg - IPA CBC
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TRAP

Policy Recommendations

TRAP
Transbounday Air Pollution Health Index Development and Implementation

September, 2019

- CENTER FOR CLIMATE CHANGE - ЦЕНТАР ЗА КЛИМАТСКИ ПРОМЕНИ

Contents

Executive Summary

The Report for Policy Recommendations aims to summarize the previous two Reports of the TRAP Project analyzing the air quality in municipality of Bitola (due to availability of data for this municipality only), the role of the main and various sources of emissions, available socio-demographic data, data from vital statistic (mortality) and health data (morbidity expressed through the hospital admissions due to diseases of interest). The Report provides results from the estimates of the health burden due to exposures to particulate matter ($PM_{2.5}$) for municipality of Bitola, providing estimation of the health gain if limit values (LV) for air quality of World Health Organization (WHO) or European Union (EU) Directives are achieved. Based upon the findings and conclusions from the two reports, and the broad scientific evidence about the health impact of particulate air pollution, recommendations for reducing the exposures and health impact accordingly, are provided as well.

People in North Macedonia and Balkans and Eastern Europe breathing more toxic particulate air pollution compared to the other Western European countries. In the Balkan's region, coal-fired power plants are still in use while the Western Europe had moved away from them or pledged to reduce the coal consumption.

Gevgelija

General information

The municipality of Gevgelija is located in the southern part of the Republic of North Macedonia (RNM), at the border with the Republic of Greece and consists the city of Gevgelija and additional 16 rural settlements. Total population for 2017 is 22,671 where 50.2% are female and 49.8 male. The average population age in this region is 39.6 years (RNM 39.0), while the average age where deaths occurred is 73.2 (RNM 73.1). The fraction of young population (aged 0-14) is slightly lower than the national average (14.4% and 16.5% accordingly), while the fraction of elderly (65 years and over) is slightly higher than the national (16.5% and 13.7 in RNM). The Vital Index, a ten-year average shows that municipality of Gevgelija has a negative value which means a negative trend of the population natural growth (90 live births per 100 deaths, while the national average which has a positive value (118 per 100 deaths)).

Throughout the territory of the municipality of Gevgelija, the primary axis of development passes through the Vardar valley in the north of the south and is part of the corridor 10. The railway transport is important transportation connection among Skopje and Thessaloniki. The local road network is also on a satisfactory level.

The Southeast Region where municipality of Gevgelija is located is characterized with the extensive hydrographic network and great number of sunny days. The mountain climate prevails only in the highest parts of the Kozuf Mountain. The precipitation schedules are not evenly distributed the most in the autumn, and the least in the summer. Local air circulation is more common in the warm part of the year, and the winds are slower and their occurrence is beneficial due to refreshment and constant aeration. The 'Vardarec' wind blows throughout the year mostly in January, February and December, but also occurs during July and August, and rarely in spring and winter. From time to time, this wind blows at high speed through the Gevgelija Valley. The southern wind 'Jugo' has a higher frequency in the summer and winter months; the wind comes from Kozuf Mountain, and the peak is in April and October.

If *GDP* is expressed in *denars per capita*, the national GDP in 2015 is 269,996, Southeast Region has gross domestic product per capita higher (315,717 MKD) than the average of the Republic of North Macedonia. In 2016, GDP per capita in the Southeast Region is higher again (341,870 denars) than the national (286,995 denars).

Southeast Region had the highest employment rate (59.7) in 2017 compared to the other planning regions (RNM average is 44.1). Unemployment rate is lower accordingly (12.0), compared to the national unemployment rate (22.4). The rate of unemployed urban population is higher than in rural population, and regarding to the sex, the rate is higher in the women population.

Households - recipients of social financial benefits aged 18+ (per 1,000 populations) in Southeast Region is 12.0, compared to the national average of 15.8 per 1,000 populations.

The other indicators such as composition or size of the families, fraction of illiterates are outdated.

Key sources of exposure

The national air quality monitoring network does not cover the territory of municipality of Gevgelija and any source apportionment study or some modeling techniques have not been implemented so far in order to assess the air quality in the municipality.

Still, *the industry* is very significant polluter, even though on the territory there are no heavy industries that contribute significantly towards the air pollution. Within the municipality there is only 1 A-IPPC permit issued for Poultry farm and seven B-IPPC permits issued by the Municipality. In Gevgelija there are 4 industrial zones and new economic zone where 95% of the industrial capacities of the municipality are located, especially textile and food processing industries as well as industry for plastics.

Waste management, especially the part of its final disposal (landfilling), is one of the most pressing environmental problems in RN Macedonia. Landfilling is particularly a problem for the region, given that there is no sanitary landfill, and all the waste is left to the dumps and similar locations without or with very poor control of the impacts. The waste collected by the public communal company, is carried to the landfill for industrial and communal waste, located near Suva Reka, and 1.5 km from the settlement. The new compliant temporary landfill located at Kozuf mountain near the village Novo Konsko is still not operational due to the fact that there is no access road and landfilling is still not enabled. Low awareness of the population for environmental protection, existence of a large number of unused surfaces and Ineffective implementation of the legislation on the imposition of penalties by the relevant authorities have been identified as main drivers for the occurrence of illegal landfills in the Municipality of Gevgelija.

Municipal buildings use their own source of *heating* through their own boilers that use extra light heating oil, wood stoves or electricity for heating the premises. Generally, heating systems in buildings are relatively old and require renovation, and in some of them, replacement of certain components in them.

In addition, *household sources* and *traffic* (vehicles and road dust) could be significant contributors although studies on the mode of domestic heating in the municipality have not been conducted yet.

Basic Health Profile

Morbidity data expressed through *hospital admissions*, unique (repetitive) according to the diagnosis from *circulatory diseases* in municipality of Gevgelija for all age groups, is lowest (159 per 10,000), compared to the national morbidity (Mb) rate - 166/10,000 and Bitola 206 per 10,000. *Hospital admissions due to respiratory diseases* for all ages in Gevgelija is 160/10,000, while in RNM is 164/10,000.

All-cause mortality in municipality of Gevgelija is slightly decreasing during the 2015-2017. The highest pick in mortality is registered in January 2017 not only in selected cities in this Project, but in most of the cities analyzed for some other purposes, probably due to the severely low ambient temperature registered in that period.

Average *all-cause mortality rate* per 10,000 for analyzed three-year period in Gevgelija is 117.2, compared to the national average 96.0. Annually, 266 have died in Gevgelija from all causes of deaths (including metabolic, life styles factors and environmental and occupational).

In terms of the *specific mortality from the circulatory diseases*, the rate in Gevgelija is higher than in Bitola and RNM (69.8/10,000, and 55.7 and 54.6 per 10,000 populations accordingly). In both analyzed municipalities as well as at national level, the rate is predominantly higher in female population than in male.

The *mortality rate from respiratory diseases* in general is lower compared to mortality from circulatory diseases, but higher in male population, especially in the age group 65 and over. The highest rate for all ages is registered in Gevgelija (5.7 per 10,000), and the lowest in Bitola (2.0/10,000). The national mortality rate is 3.9 per 10,000 populations.

Municipality of Gevgelija has the *highest mortality rate due to lung cancer* (7.2/10,000) as well, compared to Bitola where the rate is 4.7 and RNM with lowest mortality rate (4.5/10,000). Still, we do not have information on the smoking status of the local population that is a limitation of this study.

Bitola

General information

City of Bitola is the centre of Municipality of Bitola and also main regional centre of the south-western region of the country. The **municipality of Bitola** comprises the city of Bitola and 65 villages, with total population of 91,628 citizens of which 50.9% are female and 49.1% male. The average population age in the Pelagonia Region is 41.1, while the average deaths age is 74.8. The fraction of young population (aged 0-14) is slightly lower than the national average (14.6% and 16.5% accordingly) while the fraction of elderly (65 years and over) is slightly higher than the national (16.3% and 13.7 in RNM). Regarding the Vital Index, a ten-year average shows that municipality of Bitola is facing a serious negative trend of the population natural growth (76 live births per 100 deaths, the national average which has a positive value (118 per 100 deaths).

Specific climate and the extensive hydrographic network make this region the breadbasket of the country and the largest producer of tobacco, apples and milk. At the same time, the largest coal deposits are located in this region, making it the country's largest producer of electricity.

The difference in the elevation has a significant effect on the layout of the city and the urban landscape. On one side the city is situated in the lowland area and on the other side in the hillside and mountainous area. Characteristic of Bitola climate is dry and very warm summer, and winters and springs with abundant rainfall. During the year, precipitation is unevenly distributed. The main maximum is in November. The most frequent wind directions are north and south in Bitola and wind blows seldom from southwest and east.

The municipality of Bitola has good *traffic connections* with the neighboring and distant cities of the country and abroad, almost in all directions.

In 2015, Pelagonia Region's *GDP per capita* was lower than the national average (260,855 denars and 269,996 for RNM). The GDP per capita in 2016 is 282,381 denars, again lower than the national, 286,995 MKD.

Employment rate in the Pelagonia Region is 54.2 in 2017 compared to the RNM average (44.1). *Unemployment rate* is 16.3 accordingly, compared to the national unemployment rate (22.4). The rate of unemployed urban population is higher than in rural population, and regarding to the sex, the rate is higher in the women population.

Households - recipients of social financial benefits aged 18+ (per 1,000 population) in Pelagonia Region is 18.5 (2017) and it is higher than in Southeast Region - 12.0 and the national average of 15.8 per 1,000 populations.

The other indicators such as composition or size of the families, fraction of illiterates are outdated.

Key sources of exposure

Waste management is carried out by the public communal company and final deposition has been done in the "Meglenci" landfill, located in near the mine "Suvodol" 13 km distance from the city of Bitola. Still, there is a problem with illegal waste deposition beside the efforts and cleaning interventions of the local government.

The most important *stationary source* of emission near Bitola is the thermal power plant *REK "Bitola",* which provides 70% of the electricity for the entire country. According to the emission permit documentation, the thermal power plant and its three units uses local lignite as fuel. The contribution of this stationary source in the total annual emissions of SO_2, NOx and total dust is significant. Dispersion modeling calculations shows that the highest concentrations occur approximately 2-8 km south or eastward direction from the plant. The city of Bitola is located in approximately 14 km west from the plant and due to the prevailing wind directions, the highest concentrations of the pollutants from REK Bitola are not occurring in the city.

Besides REK "Bitola", in industrial areas near Bitola are around twenty small and medium installations, among them a sugar and yeast factory that has a heating plant for fuel oil used in the process production of lime from limestone rock and two asphalt stations and one printing house.

Traffic sources have been identified as one of the main sources of pollution. Passenger vehicles present 85% of the vehicle fleet registered in Bitola, followed by duty vehicles and towing vehicles (9%), motorcycles (3%) and other (3%). At least 55% of the motor vehicles are classified Euro 0 (Pre-Euro), Euro 1 and Euro 2. This means that in general the most part of fleet is composed of vehicles with more of 10 years of activity. For the bus sector the statistic shows that more than half of vehicles are classified Pre-Euro (more than 18 years of activity).

Non industrial sources, domestic heating especially is the third significant source of pollution in Bitola municipality since 85% of the households are stove heated, and a minority is served by a central heating system (more than a building served by the same plant) or by an individual central heating plant (referred to a single building). No data are available for the type of fuel used in central heating systems while the individual central heating plants mostly run on liquid fuels (oil, diesel etc.), wood, electricity and coal.

Considering that Bitola is a larger urban area in the state and an industrial city, in order to monitor the ambient air quality, two automatic monitoring stations for air quality has been set up in January 2004. *Bitola 1 monitoring station* is located on the outskirts of the city close to small industries producing food and beverages and The *Bitola 2 station* is located in the courtyard of the administrative buildings. Pollutant substances are measured in both stations: O_3, NO_2, SO_2, CO and PM_{10}. $PM_{2.5}$ are measured since 2018 in Bitola 2 station only.

The trend of *PM_{10}* concentrations is decreasing slightly in municipality of Bitola that is more evident in almost all cities in 2018, probably due to favorable meteorological conditions in that year. During the period of observation, the annual mean concentration of $PM_{2.5}$ in Bitola exceed the WHO limit value of

10 µg/m^3 as well as the less stringent EU limit value of 25 µg/m^3 which should be considered as a serious threat to the population health. Still, the annual mean concentrations are greater than EU limit values in all analyzed cities and the national average as well (five-year average 53.7 µg/m^3). The highest concentrations of the PM_{10} are registered in the cold months, mainly starting from November to March. Also, during the hot period of the year (April to September) the concentration levels are relatively high.

The target value of *ozone* for protection of the human health has not been exceeded in the analyzed period. On average the ozone levels in cities are relatively low due to the presence of other pollutants that consume the ozone from the air. However, as typical for these latitudes, short term ozone episodes are usual.

There is not registered exceedance of the limit values for the other pollutants such as SO_2, NO_2 and CO.

Any source apportionment study has not been implemented so far on the territory of municipality of Bitola. Some Dispersion model calculations are done for REK Bitola only.

Basic Health Profile

Morbidity data expressed through the *hospital admissions*, unique (repetitive) according to the diagnosis from *circulatory diseases* in municipality of Bitola is 206 per 10,000, which means highest than the national Mb rate and Gevgelija Mb rate (166/10,000 and 159/10,000) *Hospital admissions due to respiratory diseases* for all ages in Bitola is lower than the national average rate 116/10,000, while in RNM is 164/10,000.

All-cause mortality in municipality of Bitola has a decreasing trend during the 2015-2017. The highest pick in mortality is registered in January 2017 not only in selected cities in this Project, but in most of the cities analyzed for some other purposes, probably due to the severely low ambient temperature registered in that period.

Average *all-cause mortality rate* per 10,000 for analyzed three-year period is highest in Bitola (128.0/10,000); in Gevgelija the rate is 117.2, compared to the national average 96.0. Annually, 1,237 have died in Bitola from all causes of deaths (including metabolic, life styles factors and environmental and occupational).

In terms of the *specific mortality from the circulatory diseases*, mortality rate in Bitola is 55.7/10,000, compared to Gevgelija (69.8/10,000) and RNM 54.6 per 10,000 populations. In both analyzed municipalities as well as at national level, the rate is predominantly higher in female population than in male.

The *mortality rate from respiratory diseases* in general is lower compared to mortality from circulatory diseases, but higher in male population, especially in the age group 65 and over. The rate is lowest in Bitola (2.0/10,000), while the national mortality rate is 3.9 per 10,000 populations. Gevgelija has the highest mortality rate form respiratory diseases (5.7 per 10,000).

Mortality rate from lung cancer in Municipality of Bitola is 4.7/10,000 compared to RNM, with lower mortality rate (4.5/10,000).

During the analysis of mortality in Bitola municipality, we found that Bitola has one of the highest percent of causes of deaths classified as "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (ICD-10 code R00-R99). The percentage of those death cases classified as R00-R99 in the other analyzed cities is less than 10% in the period 2015-2018, while in the Bitola municipality the range is 25.9-33.7%. Detailed information of the findings is presented in Table A1 (*see Appendix*).

Health burden of particulate air pollution in Bitola Municipality

In this study, we *estimated impact of air pollution on human health* in Bitola municipality. We found a positive and strong *correlation* between the PM_{10} (and estimated $PM_{2.5}$) and atmospheric pressure, while their correlation with temperature and global radiation is strong but inverse.

There is a positive and statistically significant correlation between all-cause natural mortality and particulate matter (both, PM_{10} and $PM_{2.5}$) and negative, inverse correlation between all-cause natural mortality and temperature and global radiation. It means when concentration of particulate matter is increasing, the natural mortality is increasing as well. When temperature is decreasing, natural mortality is increasing. In terms of *cause specific and age specific mortality*, there is a statistically strong correlation between *circulatory mortality* (30 years and over) and particulate matter, while correlation with temperature is inverse. Mortality due to respiratory diseases is only negatively correlated with temperature. We did not find any correlation between pollutants, meteorological factors and lung cancer mortality, probably due to statistically insignificant number of cases in municipality of Bitola (36 to 47 for the period of three years).

Hospital admissions due to respiratory diseases for all age groups are positively and moderately correlated with particulate matter. Correlated with the temperature, a negative correlation has been registered. For the age group younger than five, the correlation is also positive and strong with particulate matter, while strong negative, inverse correlation has been registered for temperature and global radiation. With the available data set of 36 monthly data, we have not registered any correlation between hospital admissions for circulatory diseases (30 years and over) and stressors or the analyzed meteorological parameters.

It was estimated that 225 death cases in Bitola could be attributed to the exposure to $PM_{2.5}$ that presents 19.4% of total all cause natural mortality for the age group 30 and over. The *estimated excess number of death cases* at exposure to 10.0 $\mu g/m^3$ which is WHO limit value (LV) in Bitola municipality is 167 (112-216 95% CI) that presents 14.4% of total all-cause natural mortality for the age group 30 and over. For the city of Bitola, 6.4% of total mortality could be avoided if recommended EU Directive limit value for $PM_{2.5}$ is met (74 death cases are attributed to exposures exceeding EU LV). The impact of particulate air pollution (AP) is better indicated by the mortality rate per 100,000 populations. Bitola has higher mortality rate (269 per 100,000) compared to the national mortality rate 245/100,000 population (for cut-off value 10, WHO LV), that shows when population size is considered, the impact of AP is higher in municipality of Bitola than in RN Macedonia. Mortality rate per 100,000 when cut-off value 25 is selected (EU LV) is higher in RN Macedonia (128/100,000) than in municipality of Bitola (119 per 100,000 population). The UNEP Western Balkan study estimated decline in life expectancy attributed to $PM_{2.5}$ exposure of 0.8 years in the municipality of Bitola.

Regarding the number of saved *years of healthy life* if WHO AQG (Air Quality Guideline) limit values are achieved, in Bitola we estimated 3,159 years of life (74% of the estimated disease burden), close to the national health gain where 59,010 years of healthy life (73% of the estimated disease burden) will be saved if limit values are achieved. But expressed as a rate, the health gain in Bitola municipality would be greater compared with the one of RN Macedonia (4,654/100,000 YLL and 3,914/100,000 in RNM).

Estimated health gain in Bitola municipality in terms of *cardiopulmonary mortality* will be 2,538 years (75% of the estimated disease burden) while the national health gain estimated is 43,999 years (72% of the estimated disease burden).

We estimated that 593 YLL (174-1,123 95% CI) have been lost due to premature mortality from lung cancer and 9,127 YLL (3,549-13,164 95% CI) in RNM. Considering population size, Bitola has higher rate compared to RNM (647 per 100,000 and 439 per 100,000 respectively).

Recommendations to strengthen Air Quality Management in municipality of Gevgelija and municipality of Bitola

Ambient air pollution is a major environmental health risk (especially in Bitola) leading to (among others) increased respiratory and cardiovascular morbidity and mortality. During the period of observation, the annual mean concentration of $PM_{2.5}$ in Bitola exceed the WHO limit value of 10 µg/m^3 as well as the less stringent EU limit value of 25 µg/m^3which should be considered as a serious threat to the population health.

The estimated impact of particulate air pollution on mortality expressed in absolute number or as YLLs is significant and not negligible. For example, Bitola has higher all-cause (natural) mortality rate in the age group of 30 and over compared to the national average mortality rate and Gevgelija.

There is also a positive and statistically significant correlation between all-cause natural mortality and particulate matter as well as statistically strong correlation between *circulatory mortality* (30 years and over) and particulate matter.

The estimations for the city of Bitola, shows that 6.4% of total mortality could be avoided if recommended EU Directive limit value for $PM_{2.5}$ is met, but the proportion of avoidable death cases is even higher (14.4% of total death cases) if WHO AQG limit values for $PM_{2.5}$ could be met which is of course a significant health benefit.

The results of this type of assessments must be taken into account in coping with the air pollution during the policy and decision-making process at all levels-from a local to a central level. National and local authorities must become aware of the magnitude of the problem and to take responsibility for prioritizing activities, strengthening monitoring and control of ambient air pollution and consistently to enforce legislation without exceptions.

Other Recommendations and level of actions

1. Central and local Policy and legislative actions

- There is an urgent need for Updating the Local Action Plan for Air Quality (LAPAQ) improvement in Bitola based upon hard expertise and evidence, intensive intersectoral collaboration, close collaboration with central government and full involvement of the citizens and NGOs**.** Similar Plan should be introduced for municipality of Gevgelija following the new regulations in this field in the country; *(Local and central level government, short term action)*
- Developing an effective, measurable and relevant indicators in the LAPAQ in order to evaluate the effectiveness of the measures and actions; *(Local government, short term action)*
- The attainment of the legal limits of the air pollutants (especially PM_{10} and $PM_{2,5}$) should be the main target in the Action plan and in the whole structure of the municipality administration policy as well as one of the main indicators in following the implementation of the actions to be taken; *(Local level government, short to long term action)*

- Based upon the national emission reduction targets introducing local emission reduction targets on the key sources of pollution in the city; *(Central and local government, short to medium term)*
- In accordance to the above, strengthening and full enforcement of the legal framework, and focus on specific instruments that will progressively reduce pollution especially from the big as well as medium size industrial objects, and household heating, waste burning, burning of farming residues and wild fires large and the traffic; *(Central and local government, short to medium term action)*
- Various air pollution management instruments should be introduced, including economic and market-based instruments like subsidizing and encourage innovations and introducing BAT and BEP criteria in the technologies to be applied. *(Central and local government, medium term action)*

2. Air Quality, Monitoring and Health Impact Assessment

- Strengthen the air quality monitoring network in Bitola (and introducing new one in Gevgelija) in order to provide reliable time series data on pollutants especially PM_{10} and $PM_{2.5}$ with adequate meteorological data; *(Central and local government, short term action)*
- Expand air quality monitoring to include chemical components of PM such as elemental carbon, organic carbon, sulphates associated with combustion processes; PM2.5 precursors including SO2, NOx, ammonia and non-methane volatile organic compounds; black carbon; and metals (lead); *(Central and local government, medium term action)*
- Improving the inventories (basic data) for the technologies used in the residential and transport sectors; *(Central and local government, short to medium term action)*
- Close work with health professionals and authorities in public health to enable them to lead and inform local decision making process; *(Central and local government, short term action)*
- Improve collection and reporting of morbidity data linked with air pollution by disease and age group; *(Health and public health sectors at central and local level, short to medium term action)*
- Strengthen health and vital statistic and improve aggregation and reporting of the health data and data from vital statistic. A special focus should be on coding of the cause of death according to the ICD10 *(Statistic, health and public health sectors at central and local level, continuously)*
- Strengthen capacity for research and application of health risk assessments methods to analyze health impacts/effects of air pollution; *(Central and local government, short to medium term action)*
- Informing the public on regular basis about the basic ecological data as well for health effects of the air pollution including the information for costings and gains. *(Central and local government, short to medium term action)*

3. Reducing Pollution from different sectors/sources

- **Residential** – (i) Start the program of substitution of the traditional stoves with more efficient ones and develop a large-scale program. (ii) put in place targeted financial incentives to help poor households adopt clean, efficient stoves. (iii) introducing or expanding (if exists) district heating network (iv) introduce financial incentives to increase energy-efficiency of the households (v) implement public awareness campaign to promote stove replacements; *(Central and local level, short to medium term actions)*

- **Mobile sources** –(i) promoting the use of vehicles on eco friendly fuels; (ii) implementing and subsidizing programs to replace older, polluting vehicles with newer, less polluting vehicles; (iii) strengthening vehicle technical inspection and maintenance programs; *(Central and local government, medium to long term actions)*
- (i) Strengthen enforcement to ensure that large polluters (especially REK Bitola) develop and adopt plans to gradually reduce their emissions and comply with environmental standards should be continued and strengthened. (ii) Financial incentives for small industrial facilities to undertake air pollution control measures; (iii) Use of sanctions in case no plan is introduced or actions is taken; *(Central and local government, short to medium term action)*
- Regular review of the measures taken on every two years; *(Central and local government, continuous)*
- Transboundary sources and pollution – Establish, together with neighboring countries, a technical knowledge platform and share experience on transboundary pollution, air quality monitoring and health effects of AP *(Central and local government, short to medium term action)*

4. Organizational Framework

- Revise the current organizational structure to incorporate units that are specifically dedicated to developing, implementing, monitoring and evaluating air quality laws, policies, programs, and projects in the municipality; *(Local government, short to medium term action)*
- Improve the staff organizations in the municipalities with responsibilities for air quality management. *(Local government, short term action)*

5. Use of expert advisory services

- Enhance and use the local Public Health Council as a multi-stakeholder air quality advisory board to periodically discuss the development, implementation, and evaluation of actions to improve air quality in the municipality. *(Local government, short term action)*

6. Public participation and awareness

- To increase capacities and knowledge of the all stakeholders including public to understand the problem about the sources, exposures and health effects and measures of prevention as well as their own responsibility and contribution toward the issue; *(Central and local public health services, continuously)*
- There is a need for straightforward, practical information so that people can reduce their own emissions for the benefits of themselves and their neighbors; *(local government, short term action)*
- To provide air quality information system to inform public preferably with air quality forecast and health advices. *(Local government and public health services, continuously)*

6. Enforcement

- Expand the number of environmental inspectors and provide them with training and resources to conduct field investigations; *(central and local government, short term action)*
- Strengthen enforcement by clarifying sanctions for non-compliance, increasing fines, and expanding the range of sanctions. *(central and local government, medium term action)*

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APPENDIX

Table A1. All-cause mortality and causes of death classified under the code R00-R99[1]

City	2015			2016			2017			2018		
	вкупно	R00-R99	R00-R99 (%)	вкупно	R00-R99	R00-R99 (%)	вкупно	R00-R99	R00-R99 (%)	вкупно	R00-R99	R00-R99 (%)
RN Macedonia	20461	1335	6.5	20421	1445	7.1	20318	1318	6.5	19727	1772	9.0
Bitola	**1226**	**317**	**25.9**	**1146**	**353**	**30.8**	**1216**	**341**	**28.0**	**1138**	**383**	**33.7**
City of Skopje	5250	239	4.6	5357	254	4.7	5180	191	3.7	5065	357	7.0
Veles	669	21	3.1	608	11	1.8	599	12	2.0	586	11	1.9
Gevgelija	284	17	6.0	278	8	2.9	260	12	4.6	276	5	1.8
Kavadarci	434	16	3.7	438	16	3.7	396	16	4.0	424	25	5.9
Kicevo	506	14	2.8	510	19	3.7	489	13	2.7	441	20	4.5
Kocani	378	4	1.1	386	5	1.3	395	1	0.3	410	7	1.7
Kumanovo	1073	33	3.1	1023	18	1.8	1024	26	2.5	980	55	5.6
Ohrid	582	30	5.2	629	19	3.0	611	20	3.3	587	19	3.2
Prilep	945	127	13.4	914	118	12.9	979	158	16.1	936	230	24.6
Strumica	585	8	1.4	558	8	1.4	625	10	1.6	527	16	3.0
Tetovo	699	41	5.9	732	69	9.4	715	42	5.9	721	73	10.1
Stip	477	77	16.1	479	121	25.3	514	106	20.6	498	129	25.9

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[1] International Statistical Classification of Diseases and Related Health Problems (ICD), available on: https://www.icd10data.com/ICD10CM/Codes/R00-R99

Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified R00-R99

Note

- This chapter includes symptoms, signs, abnormal results of clinical or other investigative procedures, and ill-defined conditions regarding which no diagnosis classifiable elsewhere is recorded.
- Signs and symptoms that point rather definitely to a given diagnosis have been assigned to a category in other chapters of the classification. In general, categories in this chapter include the less well-defined conditions and symptoms that, without the necessary study of the case to establish a final diagnosis, point perhaps equally to two or more diseases or to two or more systems of the body. Practically all categories in the chapter could be designated 'not otherwise specified', 'unknown etiology' or 'transient'. The Alphabetical Index should be consulted to determine which symptoms and signs are to be allocated here and which to other chapters. The residual subcategories, numbered .8, are generally provided for other relevant symptoms that cannot be allocated elsewhere in the classification.
- The conditions and signs or symptoms included in categories R00-R94

  Consist of:

- (a) cases for which no more specific diagnosis can be made even after all the facts bearing on the case have been investigated;
- (b) signs or symptoms existing at the time of initial encounter that proved to be transient and whose causes could not be determined;
- (c) provisional diagnosis in a patient who failed to return for further investigation or care;
- (d) cases referred elsewhere for investigation or treatment before the diagnosis was made;
- (e) cases in which a more precise diagnosis was not available for any other reason;
- (f) certain symptoms, for which supplementary information is provided, that represent important problems in medical care in their own right.

Type 2 Excludes

- abnormal findings on antenatal screening of mother (O28)
- certain conditions originating in the perinatal period (P04-P96)
- signs and symptoms classified in the body system chapters
- signs and symptoms of breast (N63, N64.5)