HEALTH IMPACTS OF COAL FIRED POWER GENERATION IN TUZLA

centar za ekologiju i energiju

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CONTENT

SUMMARY 4
1 INTRODUCTION 5
1.1 Air pollution and health 5
1.2 Objectives of this report 6
2 TUZLA AND THE SURROUNDING AREAS 6
2.1 The region 6
2.2 Air quality in and around Tuzla 7
3 METHODS 9
3.1 Scenarios 9
3.2 The impact pathway approach 9
3.3 Health impact assessment 10
3.4 Exposure assessment 11
3.5 Baseline data on the incidence of health impacts 12
3.6 Monetisation of impacts 12
4 RESULTS 12
4.1 Scenario 1: Total impact of the coal fired power plants at the European scale 12
4.1.1 Health impacts 12
4.1.2 Monetized values 16
4.2 Scenario 2: Total impact of exposure to pollution in the Tuzla region (irrespective of the source of pollution) 17
4.2.1 Health impacts 17
4.2.2 Monetized values 18
5 DISCUSSION 18
6 REFERENCES 19
Appendix 1: Further information on health impacts 21
Appendix 2: Annual emissions of air pollutants by plant 22

SUMMARY

This report assesses the health impacts of an existing coal-fired power plant in Tuzla and two new coal-fired plants that are planned to be built in the region. Emissions need to be seen against a background of very high ambient concentrations. These are much in exceedance of the WHO Guideline for $PM_{2.5}$ levels, here regarded as the key air quality indicator, though we note that air quality limits for other pollutants, notably SO_2 are also exceeded. High exposure to SO_2 is now very unusual in much of Europe, with concentrations of the gas a small fraction of those in Tuzla in almost all EU cities.

The importance of air pollutant effects on health is emphasised by the recent decision by IARC (the International Agency for Research on Cancer) to classify air pollution as a Group 1 carcinogen, with no qualification on source or global region. The REVIHAAP (Review of Evidence of Health Aspects of Air Pollutants) and HRAPIE (Health Risks of Air Pollution in Europe) studies led by WHO-Europe on behalf of the European Commission provide a consensus view from European and North American experts that air pollution has significant and varied impacts on health in addition to the cancers of concern to IARC. These include reduced life expectancy, increased hospital admissions from respiratory and cardiac effects, the development of bronchitis, and various lesser impacts, for example on lost working days. The HRAPIE recommendations have been used for the analysis presented here.

The analysis presented in this report is performed from two perspectives. The first considers impacts of the air pollutants released from the coal-fired power stations of the Tuzla region at the European scale, bearing in mind the long-range transport of pollutant emissions and associated atmospheric chemistry. The second considers the health impacts associated with current exposure of the population of the Tuzla region, irrespective of source. Results at the European scale indicate that the existing power plant caused an **estimated 4,900 lost years of life** expectancy to **131,000 lost working days** and **over 170 hospital admissions** for cardiac and respiratory illness **in 2013**. Although emissions associated with the proposed new plant are lower, they will of course continue for many more years to come. Analysis addressing the time series of emissions data for the plant over the period 2015 to 2030 indicate that total European scale **damage would be of the order €810 million**, with over **39,000 life years lost** and of course many more new cases of chronic bronchitis, hospital admissions, lost working days and so on.

The following table shows annual impacts associated with population exposure in the Tuzla region assuming that the monitoring sites provide a reliable indication of average conditions. Analysis is based only on exosure to fine particles ($PM_{2.5}$), so there is potential for additional effects from other pollutants. Impacts are collectively **valued at €61 million/year** (prices adjusted for the Bosnian situation). We have not been able to assess the effect of the power plants, specifically, on the local people, as this would require further detailed dispersion modelling.

Table i) *Annual impacts associated with $PM_{2.5}$ concentrations in the Tuzla region*

Tuzla and Banovići		Impact
Chronic Mortality (All ages) LYL median VOLY	Life years lost	2,875
Infant Mortality (0-1yr) median VSL	Deaths	3
Chronic Bronchitis (27yr +)	Cases	187
Bronchitis in children aged 6 to 12	Added cases	361
Respiratory Hospital Admissions (All ages)	Cases	113
Cardiac Hospital Admissions (>18 years)	Cases	81
Restricted Activity Days (all ages)	Days	272,914
Asthma symptom days (children 5-19yr)	Days	5,355
Lost working days (15-64 years)	Days	69,924

In conclusion, air quality in the Tuzla region is poor and estimated here to have significant impacts on population health. One source of this air pollution is the reliance on coal fired power generation which is forecast to continue for many years to come as things stand. The effects of new power plant development need to be seen against this background.

1 INTRODUCTION

1.1 Air pollution and health

Air pollution is increasingly recognized as a significant threat to public health. A very recent development is the decision by IARC (the International Agency for Research on Cancer) to classify outdoor air pollution as carcinogenic to humans (Group 1), in relation to lung cancer (IARC, 2013). The Group 1 classification is used where it is considered that the evidence of causality between an agent and an effect is clear. They also noted a positive association with an increased risk of bladder cancer. Particulate matter, a major component of outdoor air pollution, was evaluated separately and was also classified as carcinogenic to humans (also Group 1). Although the composition of air pollution and levels of exposure can vary dramatically between locations, the conclusions of the IARC Working Group apply to all regions of the world. Further review work by WHO-Europe through the REVIHAAP and HRAPIE studies demonstrates that the health impacts of air pollutants are not restricted to cancer, but include also respiratory and cardiac mortality, bronchitis, hospital admissions, and various other effects.

Table 1 provides further information on the health risks of the pollutants with which this report is mainly concerned, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM). It includes reference to WHO guidelines and EU air quality limit values for the three pollutants, expressed in $\mu g.m^{-3}$ (microgrammes, 10^{-6} g, per cubic metre of ambient air) and EU emission limit values for industrial plant expressed in $mg.m^{-3}$ (milligrammes, 10^{-3} g, per cubic metre of discharged gas). Information is based on both WHO recommendations (see Krzyzanowski and Cohen, 2008) and Directives of the European Union. These limit values can be compared with information for the Tuzla region and associated thermal power plants in the sections that follow.

Further information on the health risks of air pollution is provided in Appendix 1.

Table 1. *Health risks from various pollutants, pollutant guideline values for ambient air and limit values (WHO recommendations, 2013)*

Pollutant	Related Health Risks (WHO)	Air quality guidelines and limit values
Sulfur dioxide (SO_2)	Can affect respiratory system and lung functions, aggravation of asthma and chronic bronchitis, makes people more prone to infections of the respiratory tract; irritation of eyes; cardiac disease aggravated; ischaemic stroke risk.	*WHO Guidelines.* 20 $\mu g/m^3$ (day) 500$\mu g/m^3$ (10min) *EU Directive 2008/50/EC:* 125 $\mu g/m^3$ (24 hours) , not to be exceeded > 3 times/year 350 $\mu g/m^3$ (1 hour) , not to be exceeded > 24 times/year
Nitrogen oxides (NOx)	Asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development; cardiac arrhythmias, ischemic stroke. Reacts with VOCs in sunlight to form ground- level ozone which is also harmful to health.	*WHO Air Quality Guidelines and EU Directive 2008/50/EC:* NO_2: 40 $\mu g/m^3$ (annual) NO_2: 200 $\mu g/m^3$ (1 hour)

Particulate matter: Coarse particulates (PM_{10}) Fine particulates ($PM_{2.5}$)	Respiratory: asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development ($PM_{2.5}$); lung cancer Cardiovascular: cardiac arrhythmias, acute myocardial infarction, congestive heart failure ($PM_{2.5}$) Nervous system: ischaemic stroke.	*WHO Guidelines:* $PM_{2.5}$: 10 μg/m^3 (year) PM_{10}: 20 μg/m^3 (year) *EU Directive 2008/50/EC:* $PM_{2.5}$: 25 μg/m^3 target (year) PM_{10}: 40 μg/m^3 (year) limit PM_{10}: 50 μg/m^3 (day) limit, not to be exceeded on > 35 days

Differences are apparent in the WHO Guideline and EU limit values for the concentration of pollutants in ambient air. These differences reflect a view on the feasibility of achieving the WHO Guidelines in the EU on the timescale of Directive 2008/50/EC. As will be seen below, the guideline/limit values do not reflect thresholds for effects on health; impacts will still occur amongst sensitive individuals at lower concentrations.

1.2 Objectives of this report

Extensive coal and lignite deposits around Tuzla have led to a reliance on these fuels for power generation and wider industrial use. The following power stations are either in use, or planned, for the area:

- Tuzla Thermoelectric power plant (TET) blocks G3 to G6, with total installed capacity 730 MW, using brown coal and lignite;
- Replacement block 7 of TE Tuzla with an installed capacity of 450 MW (Tais, 2010; Krstović, 2010; Merić, 2011);
- A new 300 MW thermoelectric plant in the Municipality of Banovići.

The purpose of this report is to quantify the health impacts associated with the existing plant and the two additional plants that are planned to be developed in the coming years. This analysis is performed at two scales. The first considers impacts of the power plants across Europe, recognizing that air pollutants can be transported over distances in excess of 1000 km. The second seeks to describe the local impacts of pollution. The methods used for this quantification reflect the latest advice provided by the World Health Organization (WHO), as recommended in the HRAPIE (Health risks of air pollution in Europe) Project performed for the European Commission, and accounting for the views of European and North American health experts.

2 TUZLA AND THE SURROUNDING AREAS

2.1 The region

The Municipality of Tuzla is one of the 13 municipalities of the Tuzla Canton and covers an area of 294 km^2 with a population of 132 000 inhabitants. The city of Tuzla is the administrative centre of the Canton and is the largest economic centre of north-eastern Bosnia and Herzegovina. Around 75% of the population of the municipality lives in the urban zone and the remaining population is located in rural local communities.

The Municipality of Banovići is located approximately 15 km southwest of Tuzla and has a population of 32,140. In addition to the urban areas of Banovići city, the Municipality includes the following villages: Omazići, Turija, Čubrić, Breštica, Seona, Grivice, Banovići-village, Tulovići, Pribitak, Treštenica and Hrvati. The area includes surface-coal-mines and the Turija and Grivice underground-coal-mines (Pranjić and Salihović, 2003).

The Tuzla region has substantial coal reserves, thought to be sufficient for 200 to 250 years use. These reserves are estimated at 316 million tons of dark coal and 2.66 billion tons of lignite, equivalent to 24% of Bosnia and Herzegovina's total dark coal reserves and 66% of its lignite reserves. The mines are facing technical and economic problems that reflect the competitiveness of thermal power plant electricity production (Merić, 2011; Kazagić i sar., 2012).

2.2 Air quality in and around Tuzla

Figure 1 shows the location of the air pollutant monitoring stations in the Tuzla region relative to the Thermal Power Plants (TPP).

Inspection of air quality data from these stations shows a significant number of exceedances of alert levels (Musemić et al, 2012). Air quality during the heating season (winter) in the urban areas of Tuzla reaches national category II or III (polluted or very-polluted air) with exceedance of permitted SO_2 levels of 400 µg/m³ (3 to 4 times the maximum allowable concentration). Levels of $PM_{2.5}$ are also significantly higher in Tuzla in winter (Hadžić et al, 2009). The same applies to Banovići (Figure 2).

Each year $PM_{2.5}$ concentrations exceeded permissible limits in Tuzla (from +39 µg/m³ in 2004 on 4 occasions) to +52 µg/m³ in 2009 (> 5 times).The Air Quality Index (AQI) calculated during the period from 2003 to 2006 exceeded the 100 µg/m³ on up to 174 days per year and the 300 µg/m³ level up to 32 days per year (Musemić et al. 2012).

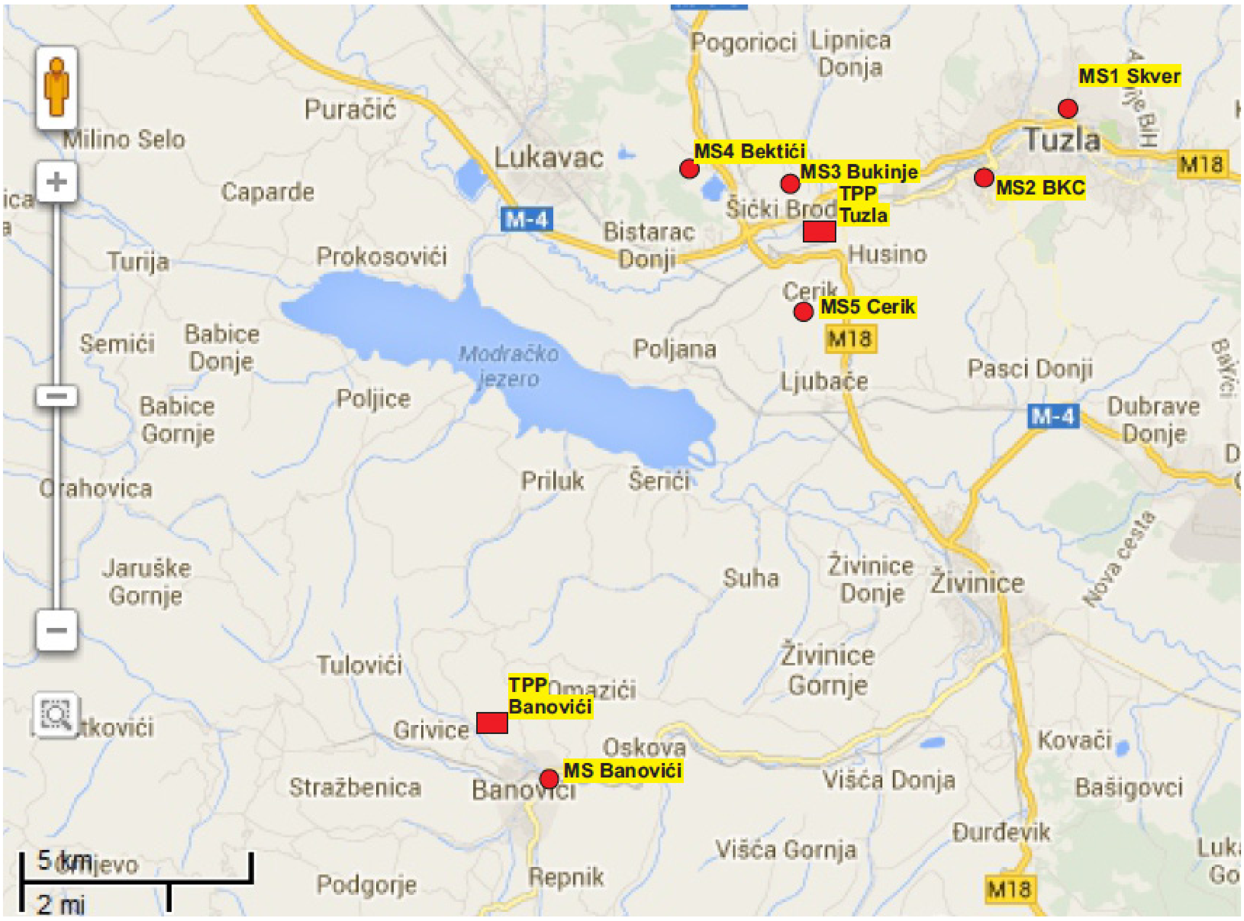

Figure 1. *Location of TPP Tuzla, TPP Banovići and the pollution monitoring stations.*

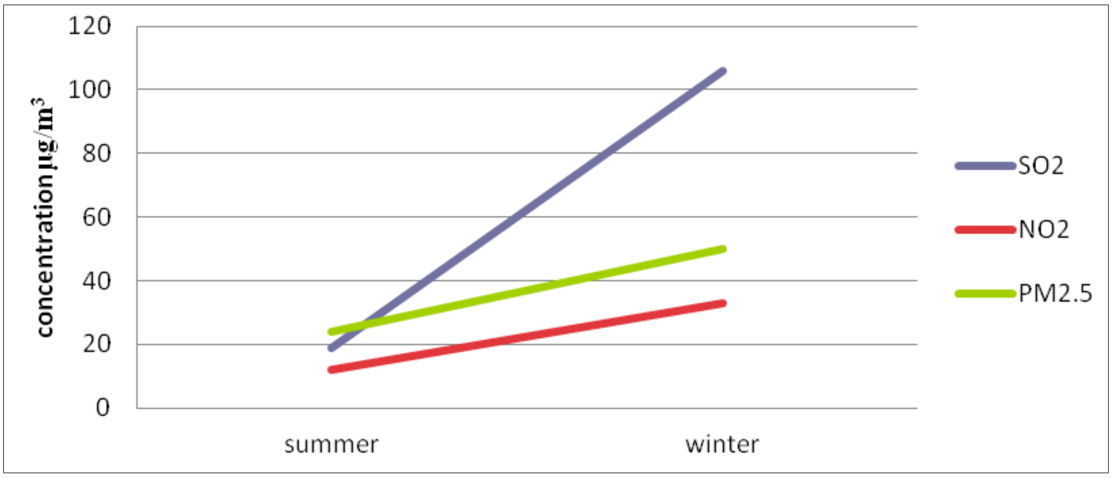

Figure 2. *Variation in concentrations of SO_2, NO_2 and $PM_{2.5}$ in 2012 in Banovići.*

Summary data on air quality in terms of annual average concentrations for 2012 are provided in Table 2. Trends in $PM_{2.5}$ concentrations from 2008 to 2012 are shown in Figure 3, demonstrating persistent and substantial exceedance of both the EU target value for annual average concentration of 25 µg/m³ and, even more notably, the WHO Guideline of 10 µg/m³.

Table 2. *Annual average concentrations of air pollutants in the Tuzla region in 2012 (µg.m⁻³).*

Monitoring station	SO_2	$PM_{2.5}$	NO_2
Skver	55	52	38
BKC	56	40	35
Bukinje	58	41	23
Bektići	No data	44	No data
Cerik	43	No data	40
Banovići	61	38	21
Average for all sites	**55**	**43**	**31**

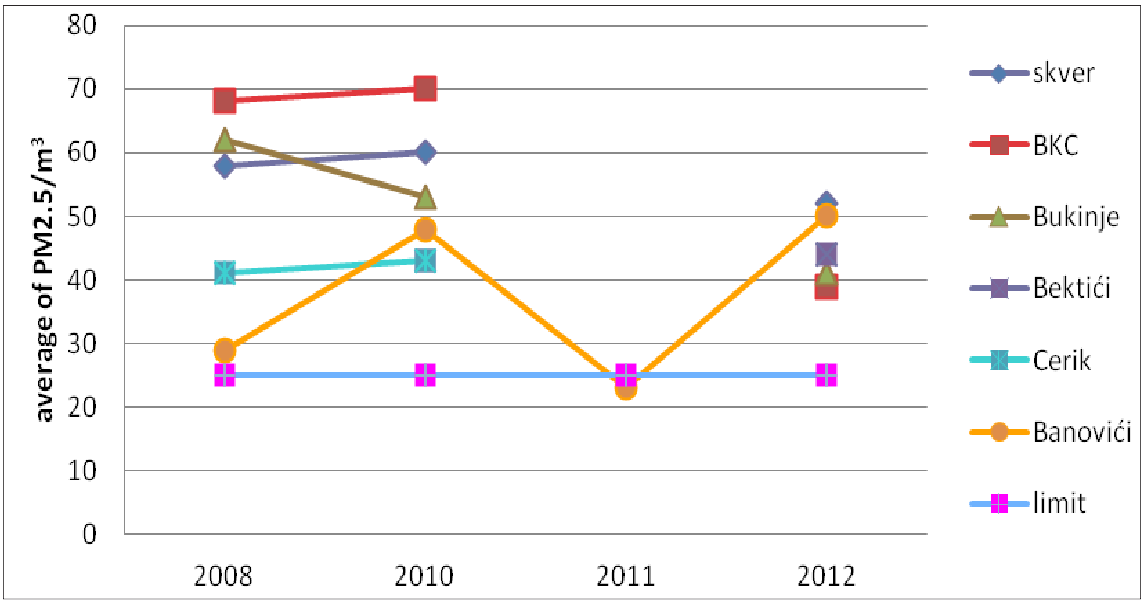

Figure 3. *Mean $PM_{2.5}$ µg/m³ per year for the air quality monitoring stations in Tuzla and Banovići from 2008 to 2012.*

The results demonstrate that air quality in the Tuzla region is poor, and thus likely to have a significant impact on the health of the local population. It is against this background that the impact of additional coal-fired power generation capacity must be considered.

3 METHODS

3.1 *Scenarios*

The health effects of air pollution are considered for the following situations:

Scenario 1: The total annual impact associated with the emissions from the three power plants at the European scale;
Scenario 2: The total impact associated with exposure to air pollution in the Tuzla region, irrespective of source;

3.2 *The impact pathway approach*

Analysis follows the Impact Pathway Approach developed in the ExternE Project funded by the European Commission through the 1990s. The IPA describes a logical pathway from emission through exposure of the population to pollution to impact assessment and finally monetisation.

1. Activity (e.g. demand for electricity)

↓

2. Emission (e.g. tonnes of SO_2)

↓

3. Dispersion and atmospheric chemistry
(e.g. including formation of secondary aerosols such as ammonium sulphate, $\mu g.m^3$)

↓

4. Exposure of the general population (people. $\mu g.m^3$)

↓

5. Exposure of population at risk from a specific effect
(people at risk. $\mu g.m^3$)

↓

6. Incidence of the health effect under analysis linked to the pollutant under investigation (e.g. hospital admissions)

↓

7. Monetisation of health impacts (€)

Figure 4. *The impact pathway approach (ExternE, 1995; 1998; 2005)*

The example shown in the Figure deals with assessment of the impacts of sulphur dioxide (SO_2) emissions on health, mediated through the formation of 'secondary' ammonium sulphate aerosols in the atmosphere[1]. However, the same general approach works for any air pollutant.

1 'Primary' particles, in contrast, are those emitted directly from combustion sources and numerous other activities.

3.3 Health impact assessment

The core reference for the health impact assessment is the HRAPIE (Health Response to Air Pollutants In Europe) Project coordinated by WHO-Europe for the European Commission, and bringing together a large number of senior experts on the health effects of air pollution from Europe and North America (WHO-Europe, 2013; and Holland, 2013, for a description of the practical implementation of the recommended response functions). This is the most up to date review of the science available. For analysis for the European Commission it supersedes the earlier work of Hurley et al (2005) developed under the Clean Air For Europe (CAFE) Programme.

HRAPIE provides response functions for exposure to three pollutants, fine particles ($PM_{2.5}$ or PM_{10}), NO_2 and ozone. No account was taken of effects of SO_2 specifically, largely on the grounds that concentrations of SO_2 in EU cities are now very low (unlike the situation in Tuzla). The omission of effects of SO_2 may well lead to underestimation of the health impacts of air pollution in the Tuzla region. The following health outcomes are considered (Table 3):

Table 3. *Summary of information from HRAPIE showing endpoints for health impact assessment.*

Effect	Pollutant	Exposure period	Relative risk from a 10μg.m^{-3} change in exposure
All cause mortality, age 30+	PM	Long	1.062
All cause mortality, age 30+	NO_2	Long	1.055
All cause mortality	O_3	Short	1.0029
Respiratory mortality	O_3	Long	1.014
Post -neonatal infant mortality	PM	Long	1.04
Respiratory hospital admissions	PM	Short	1.019
Respiratory hospital admissions	NO_2	Short	1.018
Respiratory hospital admissions	O_3	Short	1.0044
CVD hospital admissions	PM	Short	1.0091
CVD hospital admissions	O_3	Short	1.0089
Bronchitic symptoms in asthmatic children	NO_2	Long	1.021
Prevalance of bronchitis in children	PM	Long	1.08
Incidence of chronic bronchitis in adults	PM	Long	1.117
Restricted activity days	PM	Short	1.047
Work loss days	PM	Short	1.046
Asthma symptoms in asthmatic children	PM	Short	1.028
Minor restricted activity days	O3	Short	1.0154

The response functions shown are not fully additive. This applies especially to effects of long term exposure to PM, NO_2 and O_3 on mortality, and to effects of PM on restricted activity days (RADs), work loss days and childhood asthma. For effects of long term exposure on mortality, at the present time it is recommended only to perform the quantification for PM. For the effects of PM on RADs (etc.) it is recommended to subtract results for work loss days and childhood asthma from the result for RADs to avoid double counting.

The HRAPIE recommendations do not propose use of a threshold for quantification of impacts, except (effectively) in the case of ozone. For ozone, only exposure above a level of 35 parts per billion is factored into the analysis. This is stated to be an analytical ‘cut point’, above which the quantification of impacts can be done with greater confidence than below. The authors are, however, quite clear that this is not a threshold. Given the relative magnitude of impacts, however, the view that there is no threshold for effects of exposure to particles is especially important. This has been re-inforced by the publication of Canadian research that found no evidence for a threshold of effect even in areas where concentrations of particles were very low indeed (<5 µg.m^{-3}) (Crouse et al, 2012). This is an important conclusion in its own right, as it indicates that statutory limits for air pollution, and even the lower guidelines published by WHO, are not fully protective of the population.

With respect to mortality assessment, two indicators are available. The first, not surprisingly, is the number of deaths linked to air pollution exposure. The second is the loss of life expectancy. For assessment of long term impacts the second indicator is considered more robust. This then leads to a question that at first sounds strange: When, in effect, does the loss of life expectancy occur? Does it simply curtail the final days or months of life, when quality of life may be very low, or does it reduce one's healthy life expectancy? There is general agreement amongst health experts that it is the latter, a reduction in healthy life expectancy.

3.4 Exposure assessment

The exposure assessment is performed differently for each of the scenarios identified above:

Scenario 1: The total impact associated with emissions of SO_2, $PM_{2.5}$ and NOx from the three power plants at the European scale;
For this scenario, analysis is based on results from the Unified EMEP model[2], the dispersion and atmospheric chemistry model that underpins most European air quality analysis. The EMEP Model has been used to generate a transfer matrix based on a large number of model runs. Each run describes the effects of releasing a quantity of a specific pollutant (ammonia [NH_3], NOx, $PM_{2.5}$, SO_2 and volatile organic compounds [VOCs]) from one country on the pollution climate of Europe as a whole. The transfer matrix has been used to provide damage per tonne of emission estimates as used by the European Environment Agency in assessing the external costs of industrial facilities in Europe (EEA, 2011; 2013). Effects are quantified against exposure to primary $PM_{2.5}$, secondary $PM_{2.5}$ linked to emissions of SO_2 and NOx and ozone formed as a consequence of NOx emissions.

Scenario 2: The total impact associated with exposure to air pollution in the Tuzla region, irrespective of source;
For this scenario the results from the monitoring stations are used, on the assumption that they provide an appropriate estimate of population exposure to air pollution. Analysis is based only on exposure to $PM_{2.5}$. This would appear to bias results to underestimation of effects, but is unavoidable given data limitations.

This part of the analysis uses the following data for the existing and proposed power plants (Table 4). Total annual emissions from the plants are shown in Appendix 2.

Table 4. *Production characteristics and pollutant emissions for TE Tuzla (Blocks G3-G6) and the proposed new replacement block 7 and TE Banovići.*

Parameter	Block TE Tuzla G3-G6 (for year 2013)	Block of TE TuzlaG7 (also G8)	TE Banovići
Capacity	730 MW	450 MW	300 MW
Fuel	Coal Lignite Brown Coal	Coal Lignite/ Hd=9,500 KJ/kg	Brown Coal Hd=14,050 KJ/kg
Sulphur content of fuel **	0.39 to 2.3%	0.51 to 0.6%	1.46%
Ash content of fuel **	10 to 26%	7 to 28%	21%
Emission of SO_2	51,661 t/year	877 t/year* <200 mg/µm^3	1,050 t/year*** <200 mg/µm^3

2 http://emep.int/mscw/index_mscw.html

Emission of NOx	9,843 t/year	1,316 t/year* <200 mg/μm³	590 t/year*** <200 mg/μm³
Emission of PM_{10}	1,990 t/year	132 t/year* <30 mg/μm³	60 t/year*** <30 mg/μm³

Sources: FIPA energy sector, 2012: *Merić, 2011 (and appendix 1): Sulphur and ash content: **Studija energetskog sektora u BiH – Modul 8 – Rudnici uglja. *** Calculated from difference in energy density of fuel and plant output, and sulphur/ash content (where appropriate).

3.5 Baseline data on the incidence of health impacts

To the extent possible, these data (mortality rates, hospital admissions, etc.) are specific to the region or to Bosnia and Herzegovina. For some effects (restricted activity days, prevalence of bronchitis) it is necessary to use data from the original epidemiological studies.

3.6 Monetisation of impacts

Monetisation of impacts is useful in the context of cost-benefit analysis, to test the extent to which society is willing to pay for (in this case) improvement in air quality. Monetary valuation reflects the 'willingness to pay' (WTP) of the population for reduced health risk. WTP will vary from country to country, reflecting differences in income and other factors (perhaps collectively defined in terms of attitude to risk). This variation in health values does not signify that one set of people are any more valuable than any other: it simply reflects the fact that in a world where resources and money are not evenly distributed, preference for expenditure will vary. Analysis for the European Commission uses estimates of average willingness to pay for the EU as a whole, irrespective of the location of impact. For the present case, however, we are considering the situation from the perspective of Bosnia and Herzegovina, and so should seek to adopt an estimate of WTP to avoid risks to health that is in line with the Bosnian average. For this, we multiply results calculated at the EU average by the ratio of Bosnian Gross Domestic Product per head of population (GDP per capita) to EU GDP per capita (both GDP per capita estimates being adjusted for purchasing power parity, PPP), a factor of 0.28 ($US9,235/$US33,527, based on World Bank data for 2012). An elasticity of 1 is used, on the assumption that income and WTP for health protection will vary together (e.g. a 50% change in income will lead to a 50% change in WTP). The question of what elasticity to select in this situation is discussed by Hammitt and Robinson (2011). An elasticity of 1 is broadly central to figures adopted across the literature.

4 RESULTS

4.1 Scenario 1: Total impact of the coal fired power plants at the European scale

4.1.1 Health impacts

This part of the analysis models the impacts of the 3 power plants across Europe, recognising the transboundary nature of the emitted air pollutants. Emissions data are taken from Table 4 above, with $PM_{2.5}$ emissions calculated by multiplying PM_{10} emissions by a factor of 0.65, a factor commonly employed elsewhere. Dispersion modelling is based on the EMEP transfer matrices. Response functions are from the WHO-led HRAPIE Project. Results for each power plant are described in the following tables, dealing first with annual effects for Tuzla Blocks G3 to G6 (Table 5), Tuzla Block 7 (Table 6) and Banovići (Table 7).

Table 5. *Annual emissions and associated health impacts at the European scale for the Tuzla power station, Blocks G3-G6 in 2013.*

TET Blocks G3-G6	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*9,843*	*1,990*	*51,661*	
Chronic mortality (life years lost)	755	327	3,835	4,918
Infant mortality (1 – 11 months, cases)	0	0	1	1
Chronic bronchitis, population aged >27, cases	35	15	180	231
Respiratory hospital admissions, all ages	3	1	13	17
Cardiac hospital admissions, all ages	24	10	122	157
Restricted activity days (RADs) working age	76,571	33,154	388,748	498,473
Work loss days	20,124	8,713	102,171	131,008
Child asthma	1,895	820	9,620	12,335
Child bronchitis	176	76	892	1,143

For TET Blocks G3-G6, damage is dominated by the high emissions of SO_2, which are modelled through the long range formation of sulphate aerosols in the $PM_{2.5}$ size fraction. The effects of NOx (via the formation of secondary nitrate aerosols) and direct emissions of $PM_{2.5}$ generate about 20% of total estimated health impacts for the plant.

Table 6. *Annual emissions and associated health impacts at the European scale for the Tuzla power station, proposed Block 7.*

TET Block 7	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*1,316*	*86*	*877*	
Chronic mortality (life years lost)	101	14	65	180
Infant mortality (1 – 11 months, cases)	0	0	0	0
Chronic bronchitis, population aged >27, cases	5	1	3	8
Respiratory hospital admissions, all ages	0	0	0	1
Cardiac hospital admissions, all ages	3	0	2	6
Restricted activity days (RADs) working age	10,237	1,429	6,599	18,266
Work loss days	2,691	376	1,734	4,801
Child asthma	253	35	163	452
Child bronchitis	23	3	15	42

For the proposed block 7 addition to the Tuzla power plant it is emissions of NOx that are considered likely to dominate, providing 56% of estimated health impact.

Table 7. *Annual emissions and associated health impacts at the European scale for the proposed Banovići power station.*

TPP Banovići	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*590*	*39*	*1,050*	
Chronic mortality (life years lost)	45	6	78	130
Infant mortality (1 – 11 months, cases)	0	0	0	0
Chronic bronchitis, population aged >27, cases	2	0	4	6
Respiratory hospital admissions, all ages	0	0	0	0
Cardiac hospital admissions, all ages	1	0	2	4
Restricted activity days (RADs) working age	4,590	650	7,901	13,141
Work loss days	1,206	171	2,077	3,454
Child asthma	114	16	196	325
Child bronchitis	11	1	18	30

SO_2 emissions are again dominant for the proposed plant at Banovići. These results are dependent on estimates of emissions made above in this report (Table 4), and reflect the factor 3 higher fuel sulphur content between Banovići and Tuzla Block 7.

Results for all operational and proposed Blocks at the Tuzla power station are provided for the years 2013, 2015, 2020, 2025 and 2030 in Table 8, based on the emissions data provided in Appendix 2, noting the retirement of old plant and introduction of new plant according to the following schedule:

G3: Up to 2016
G4: Up to 2019
G5: Up to 2023
G6: Up to 2025
G7 and Banovići: 2017
G8: 2024 to 2030

Table 8. *Annual damage at the European scale from the power plants for Tuzla and Banovići, 2013 and 2015 to 2030 at 5-year intervals.*

2013	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*9,843*	*1,294*	*51,661*	
Chronic mortality (life years lost)	755	213	3,835	**4,803**
Infant mortality (1 – 11 months)	0	0	1	**1**
Chronic bronchitis, population aged >27	35	10	180	**226**
Respiratory hospital admissions, all ages	3	1	13	**17**
Cardiac hospital admissions, all ages	24	7	122	**153**
Restricted activity days (RADs) all ages	76,571	21,550	388,748	**486,869**
Work loss days	20,124	5,664	102,171	**127,959**
Child asthma, days	1,895	533	9,620	**12,048**
Child bronchitis, cases	176	49	892	**1,117**

2015	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*9,588*	*1,278*	*50,799*	
Chronic mortality (life years lost)	736	210	3,771	**4,717**
Infant mortality (1 – 11 months)	0	0	1	**1**
Chronic bronchitis, population aged >27	35	10	177	**222**
Respiratory hospital admissions, all ages	3	1	13	**16**
Cardiac hospital admissions, all ages	23	7	120	**151**
Restricted activity days (RADs) all ages	74,587	21,290	382,262	**478,139**
Work loss days	19,603	5,595	100,466	**125,664**
Child asthma, days	1,846	527	9,459	**11,832**
Child bronchitis, cases	171	49	877	**1,097**
2020	**NOx**	**$PM_{2.5}$**	**SO_2**	**Total**
Emissions (tonnes/year)	*8,234*	*1,051*	*32,723*	
Chronic mortality (life years lost)	632	173	2,429	**3,234**
Infant mortality (1 – 11 months)	0	0	0	**1**
Chronic bronchitis, population aged >27	30	8	114	**152**
Respiratory hospital admissions, all ages	2	1	8	**11**
Cardiac hospital admissions, all ages	20	6	78	**103**
Restricted activity days (RADs) all ages	64,054	17,511	246,240	**327,805**
Work loss days	16,835	4,602	64,717	**86,153**
Child asthma, days	1,585	433	6,093	**8,112**
Child bronchitis, cases	147	40	565	**752**
2025	**NOx**	**$PM_{2.5}$**	**SO_2**	**Total**
Emissions (tonnes/year)	*5,606*	*529*	*16,938*	
Chronic mortality (life years lost)	430	87	1,257	**1,775**
Infant mortality (1 – 11 months)	0	0	0	**0**
Chronic bronchitis, population aged >27	20	4	59	**83**
Respiratory hospital admissions, all ages	1	0	4	**6**
Cardiac hospital admissions, all ages	14	3	40	**57**
Restricted activity days (RADs) all ages	43,610	8,815	127,458	**179,883**
Work loss days	11,462	2,317	33,498	**47,277**
Child asthma, days	1,079	218	3,154	**4,451**
Child bronchitis, cases	100	20	292	**413**

2030	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*3,222*	*197*	*2,804*	
Chronic mortality (life years lost)	247	32	208	**488**
Infant mortality (1 – 11 months)	0	0	0	**0**
Chronic bronchitis, population aged >27	12	2	10	**23**
Respiratory hospital admissions, all ages	1	0	1	**2**
Cardiac hospital admissions, all ages	8	1	7	**16**
Restricted activity days (RADs) all ages	25,065	3,281	21,100	**49,446**
Work loss days	6,587	862	5,546	**12,995**
Child asthma, days	620	81	522	**1,224**
Child bronchitis, cases	57	8	48	**113**

Table 9 shows total impacts estimated for the emissions profile of Appendix 2, Again including emissions from Banovići) from 2017 through to 2030.

Table 9. *Total impacts from all plant, European scale, 2015-2030.*

Total impacts, 2015-2030	NOx	$PM_{2.5}$	SO_2	Total
Emissions (tonnes/year)	*104,444*	*12,080*	*394,143*	
Chronic mortality (life years lost)	8,015	1,985	29,259	**39,260**
Infant mortality (1 – 11 months)	1	0	5	**6**
Chronic bronchitis, population aged >27	377	93	1,375	**1,845**
Respiratory hospital admissions, all ages	28	7	101	**136**
Cardiac hospital admissions, all ages	256	63	934	**1,253**
Restricted activity days (RADs) all ages	812,495	201,259	2,965,919	**3,979,673**
Work loss days	213,539	52,895	779,501	**1,045,935**
Child asthma, days	20,106	4,980	73,393	**98,479**
Child bronchitis, cases	1,864	462	6,803	**9,128**

4.1.2 Monetized values

Converting the health impacts from Table 5, Table 6 and Table 7 to a monetary equivalent gives the following results (valued using data for the EU average, adjusted by Bosnian PPP adjusted GDP/ capita)[3]:

3 Given the assumption of an elasticity of 1 in the costing between EU averages and Bosnian willingness to pay and the broad range considered in the paper of Hammitt and Robinson, these figures should be regarded as uncertain, but we can have reasonable confidence that public willingness to pay to avoid impacts at this level would broadly be of this order of magnitude.

- Tuzla Blocks G3 to G6: **€99 million / year**
- Tuzla Block 7: **€3.7 million / year**
- Banovići: **€2.7 million / year**

It is clear that Tuzla Blocks G3 to G6 generate substantially higher damage than the two proposed plants. However, together the two new plants would generate an **annual health externality of €6.4 million/ year**. Also, in the event that Tuzla Block G8 is also constructed, additional emissions (and hence damage) equivalent to those calculated for Tuzla Block G7 would arise, bringing total damage for the **new facilities to €10 million / year**.

Turning to the results for the time series from 2013 to 2030, monetised equivalents, adjusted for Bosnian conditions are as follows:

- **2013: €99 million**
- **2015: €97 million**
- **2020: €67 million**
- **2025: €37 million**
- **2030: €10 million**
- **Total, 2015 to 2030: €810 million**

4.2 Scenario 2: Total impact of exposure to pollution in the Tuzla region (irrespective of the source of pollution)

4.2.1 Health impacts

Given a small level of variation in the $PM_{2.5}$ concentrations reported from the monitoring sites (average 43 $\mu g.m^{-3}$ in a range of 38 to 52 $\mu g.m^{-3}$, see Table 2), it is assumed that the full population for the region (132,000 in Tuzla, 32,140 in Banovići) is exposed to the average of 43 $\mu g.m^{-3}$. This of course assumes that the monitoring stations are representative of exposure for the population rather than peak ('hot-spot') concentrations. The response functions applied are again taken from the HRAPIE Project led by WHO-Europe.

Table 10. *Health impacts associated with exposure to air pollution in Tuzla and Banovići.*

Tuzla and Banovići		Impact
Chronic Mortality (All ages) LYL median VOLY	Life years lost	**2,875**
Infant Mortality (0-1yr) median VSL	Deaths	**3**
Chronic Bronchitis (27yr +)	Cases	**187**
Bronchitis in children aged 6 to 12	Added cases	**361**
Respiratory Hospital Admissions (All ages)	Cases	**113**
Cardiac Hospital Admissions (>18 years)	Cases	**81**
Restricted Activity Days (all ages)	Days	**272,914**
Asthma symptom days (children 5-19yr)	Days	**5,355**
Lost working days (15-64 years)	Days	**69,924**

4.2.2 Monetized values

Applying the EU valuations adjusted by per capita PPP adjusted GDP gives a total damage associated with these **impacts of €61 million/year**. The mortality result in the top row of the table should be put in context of the number of deaths over which it is aggregated. Dividing by the number of deaths expected in the region gives an **estimated loss of life expectancy per person of 3.2 years**. Similar estimates have been derived for cities in China and India (IIASA, 2011), though there are questions as to the linearity of the response functions at higher concentrations. Whilst this may imply a bias to overestimation in the impacts, it is to be remembered that results exclude assessment against SO_2, NO_2 and ozone exposure.

5 DISCUSSION

The report summarises evidence of poor air quality as recorded at the pollution monitoring stations in the Tuzla region. There are frequent exceedances of alert thresholds in the area, emphasising the problems that exist.

This is a matter of considerable concern given that air pollution is linked to a wide range of health problems, from days of restricted activity all the way through to mortality (WHO, 2013). At the time that this report was being written, the International Agency for Research on Cancer (IARC) published new findings, concluding that air pollution is carcinogenic. It is notable that effects will occur even when air quality limit values are being complied with, given the conclusion that there is no threshold for the effects of some important pollutants, including fine particles ($PM_{2.5}$, see for example, Crouse, 2012).

The existing power plant in Tuzla has high emissions of NOx, SO_2 and $PM_{2.5}$. It is estimated that this plant **is linked to 4,918 'years of life lost'** (an expression of longevity) across Europe **each year** and a variety of effects on morbidity. In total, and adjusting valuation to Bosnian conditions, **this and other health impacts are valued at €99 million/year,** based on current day values. **Two further power plant units** are proposed, **at Tuzla and Banovići**. Being more modern these plants would emit less pollution per unit of electricity generated, but **are still estimated here to be associated with 310 years of life lost annually**, and **damage of €6.4 million/year** (increasing to €10 million/year if Block G8 is included). These damages would continue for as long as each plant is operational, potentially 40 years or more for the proposed facilities, and 10 or more years for the existing plant. **Over the period 2015 to 2030 it is estimated that the Tuzla and Banovići plants would cause cumulative impacts of 39,260 years of life lost, numerous cases of morbidity and damage totaling €810 million.**

Analysis of the health impacts of local air pollution on the population of Tuzla and Banovići is also provided, with an **estimated 2,875 years of life lost** and various other health impacts, combining to give **a monetary value of €61million/year**.

The analysis has not sought to apportion the impacts of poor local air quality between the power stations and other sources (e.g. domestic burning) as this would require further data and modeling. However, the plants will contribute to poor air quality in the region as well as further afield.

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Appendix 1: Further information on health impacts

Fine particles in the PM_{10} size class[4] are readily inhalable and because of their small size are not filtered and penetrate deeply into the cardiovascular system where they cause damage. Those smaller than 2.5 µm ($PM_{2.5}$) penetrate deeper than those closer to 10 µm. These particles have strong associations with most types of respiratory illness and mortality. They also have a strong association with circulatory (heart disease and strokes) disease and mortality. Particles allow many chemicals harmful to human health to be carried to many of our internal organs causing a wide range of illness and mortality including cancer, especially lung cancer, brain damage and damage to the unborn child (EEA, 2010; Lim et al, 2012; WHO, 2013; Mehinović et al, 2004).

A broadly similar list of health effects for elevated particulate concentrations has been compiled by the US Environmental Protection Agency (EPA):

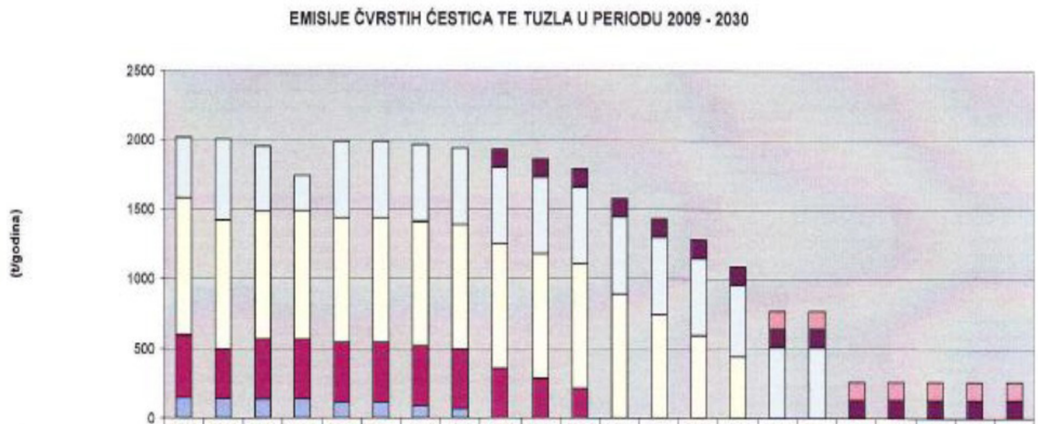
- Increased total mortality, respiratory deaths; cardiovascular deaths, cancer death;
- Increased risk of premature births and infant mortality;
- Increased risk of pneumonia;
- Increased hospital admissions and emergency room visits;
- Exacerbation of asthma attacks;
- Increased bronchodilator use;
- Increased respiratory symptoms in both lower and upper respiratory tract;
- Decreased lung function;
- Increased incidence of rhinitis;
- Increased absenteeism/number of days of restricted activity

Older people, children and patients with chronic respiratory or cardiovascular diseases experience the largest threat to their health and well-being from air pollution (Pranjić, 2006; EEA, 2010; Brunekreef et al., 2012), as they are more susceptible to the damage done by the pollutants. Children, even before birth, are particularly susceptible to air pollutants (Dadvand et al, 2013; Pranjić and Begic, 1998; Begic et al, 2002). Recent studies found associations between exposure to outdoor air pollution during pregnancy and lower birth weight, as well as higher rates of preterm birth and pre-eclampsia. Across the EU it is estimated that air pollution is responsible for an average reduction in life expectancy of 8.6 months or, in other words, for 492 000 premature deaths every year.

With the exception of a few countries, cardiovascular disease is the leading cause of death in Europe and accounts for approximately 40% of deaths or 2 million deaths per year. Public health costs related to cardiovascular disease were estimated at €196 billion a year for the EU, the respective estimate for chronic respiratory diseases, coming from the European Lung Foundation (ELF) and the European Respiratory Society (ERS), being €102 billion per year.

4 PM_{10} = fine particles with an aerodynamic diameter of less than 10 microns. $PM_{2.5}$ = fine particles with an aerodynamic diameter of less than 2.5 microns.

Fine Particles



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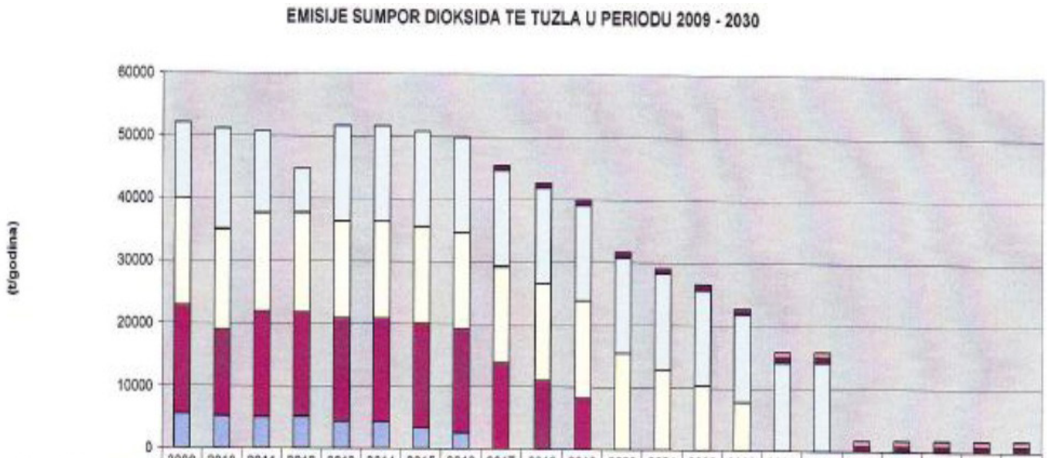
Tuzla G8 (2024)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132	132	132	132	132	132	132
Tuzla G7 (2017)	0	0	0	0	0	0	0	0	132	132	132	132	132	132	132	132	132	132	132	132	132	132
Tuzla G6 (1978)	438	586	474	255	553	553	553	553	553	553	553	553	553	553	511	511	511	0	0	0	0	0
Tuzla G5 (1974)	985	926	912	923	893	893	893	893	893	893	893	893	744	595	447	0	0	0	0	0	0	0
Tuzla G4 (1971)	447	355	433	427	427	427	427	427	356	285	214	0	0	0	0	0	0	0	0	0	0	0
Tuzla G3 (1966)	151	142	138	140	117	117	93	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Godina

Tuzla G3 (1966) Tuzla G4 (1971) Tuzla G5 (1974) Tuzla G6 (1978) Tuzla G7 (2017) Tuzla G8 (2024)

Tuzla, 24.06.2011 Autor: Jusuf Merić, dipl. ing. el.

Sulphur dioxide



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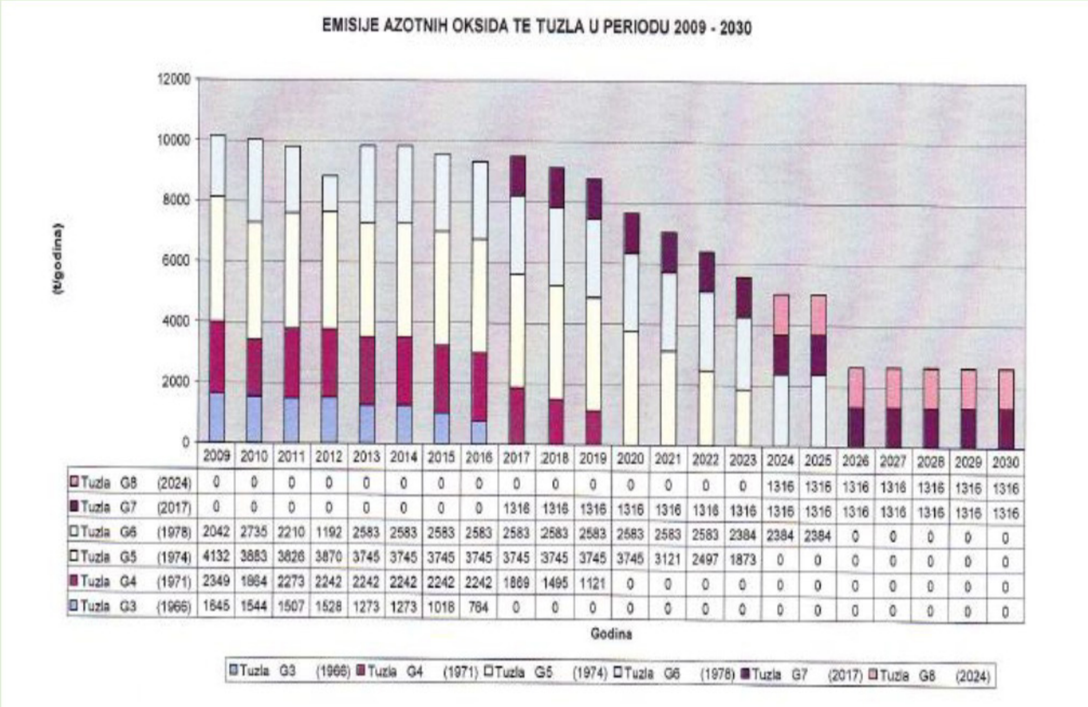
Tuzla G8 (2024)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	877	877	877	877	877	877	877
Tuzla G7 (2017)	0	0	0	0	0	0	0	0	877	877	877	877	877	877	877	877	877	877	877	877	877	877
Tuzla G6 (1978)	12109	16214	13100	7067	15311	15311	15311	15311	15311	15311	15311	15311	15311	15311	14134	14134	14134	0	0	0	0	0
Tuzla G5 (1974)	17084	16055	15818	16001	15485	15485	15485	15485	15485	15485	15485	15485	12904	10323	7743	0	0	0	0	0	0	0
Tuzla G4 (1971)	17342	13762	16783	16556	16556	16556	16556	16556	13797	11037	8278	0	0	0	0	0	0	0	0	0	0	0
Tuzla G3 (1966)	5567	5225	5102	5171	4309	4309	3447	2585	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Godina

Tuzla G3 (1966) Tuzla G4 (1971) Tuzla G5 (1974) Tuzla G6 (1978) Tuzla G7 (2017) Tuzla G8 (2024)

Tuzla, 24.06.2011 Autor: Jusuf Merić, dipl. ing. el.

Nitrogen oxides (NOx)



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tuzla G8 (2024)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1316	1316	1316	1316	1316	1316	1316
Tuzla G7 (2017)	0	0	0	0	0	0	0	0	1316	1316	1316	1316	1316	1316	1316	1316	1316	1316	1316	1316	1316	1316
Tuzla G6 (1978)	2042	2735	2210	1192	2583	2583	2583	2583	2583	2583	2583	2583	2583	2583	2384	2384	2384	0	0	0	0	0
Tuzla G5 (1974)	4132	3883	3826	3870	3745	3745	3745	3745	3745	3745	3745	3745	3121	2497	1873	0	0	0	0	0	0	0
Tuzla G4 (1971)	2349	1864	2273	2242	2242	2242	2242	2242	1869	1495	1121	0	0	0	0	0	0	0	0	0	0	0
Tuzla G3 (1966)	1645	1544	1507	1528	1273	1273	1018	784	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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