Regional air pollution mortality in Poland

Master thesis

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Abstract

The fact that Eastern European countries have significant lower life expectancies than Western European countries means that Eastern Europe has a special interest when it comes to mortality and health. Some factors negatively impacting health such as smoking, usage of alcohol are widely researched. However, the impact of air pollution is less researched. By looking at the air pollution in Europe, it is clear that the south of Poland is extremely polluted. This makes Poland an interesting case to study the effects of air pollution on mortality. According to research about air pollution, air pollution has led to (lung) cancer, cardiovascular disease and respiratory diseases. Cardiovascular disease and cancer are cause of death number one and two in Poland, which makes it likely that air pollution plays a significant role in mortality. The objective of this research is to figure out to what extent air pollution affects mortality in Poland.

According to the epidemiologic transition theory and the ecological transition theory, Eastern Europe is one stage behind Western Europe. Which means West European health is more advanced than East European health and as well sustainable development in Western Europe is more advanced than in Eastern Europe. This can explain why Poland lags behind Western Europe with regard to pollution reduction, and could eventually explain the higher air pollution mortality.

According to the existing literature the relatively low life expectancy in Poland is mainly due to socio-economic factors, smoking, alcohol usage, and pollution. This research aims to figure out to what extent air pollution contributes to regional mortality differences. A quantitative research is conducted to show the relationship between air pollution and mortality, in this case different cause of death rates as dependent variables, and gaseous air pollution and particulate matter pollution as independent variables in a linear regression, on regional NUTS-2 level. This is firstly done by looking at correlations, and secondly with multiple regression analysis to test for confounding variables. Testing for confounding variables is to exclude bias, the confounding variables are: smoking, alcohol, overweight and income. Also is the analysis done separately for both sexes, males and females at all ages and also for both sexes, females and males at 65 years and older.

The analysis with the correlations makes it likely that air pollution affects mortality, especially among females. Looking at the correlations air pollution is associated with asthma and circulatory diseases, and also with all-cause mortality. Circulatory diseases were only related to particulate matter pollution. Air pollution seems to affect mortality due to asthma only among people above 65, especially women. However, looking at the multiple regression analysis, no correlations are found between air pollution and mortality. Only for smoking are significant outcomes found, neither for alcohol, overweight and income. So at the end can only be concluded that smoking is a significant factor on mortality. This means that only smoking could explain some of the regional mortality differences. This also makes it likely that smoking did disrupt the outcomes for the air pollution research as it leads to the same diseases. Also due to the big scale of the regions (NUTS-2), it is hard to determine relationship between air pollution and mortality. New research with more precise data and smaller regional scale could clarify more to what extent air pollution in Poland affects mortality.

Regardless to what extent air pollution is affecting mortality, a policy to reduce the air pollution is highly recommended, because the air pollution is anyway affecting population's health. Due to the fact that smoking is affecting mortality in a high extent, policies to reduce smoking are highly recommended.

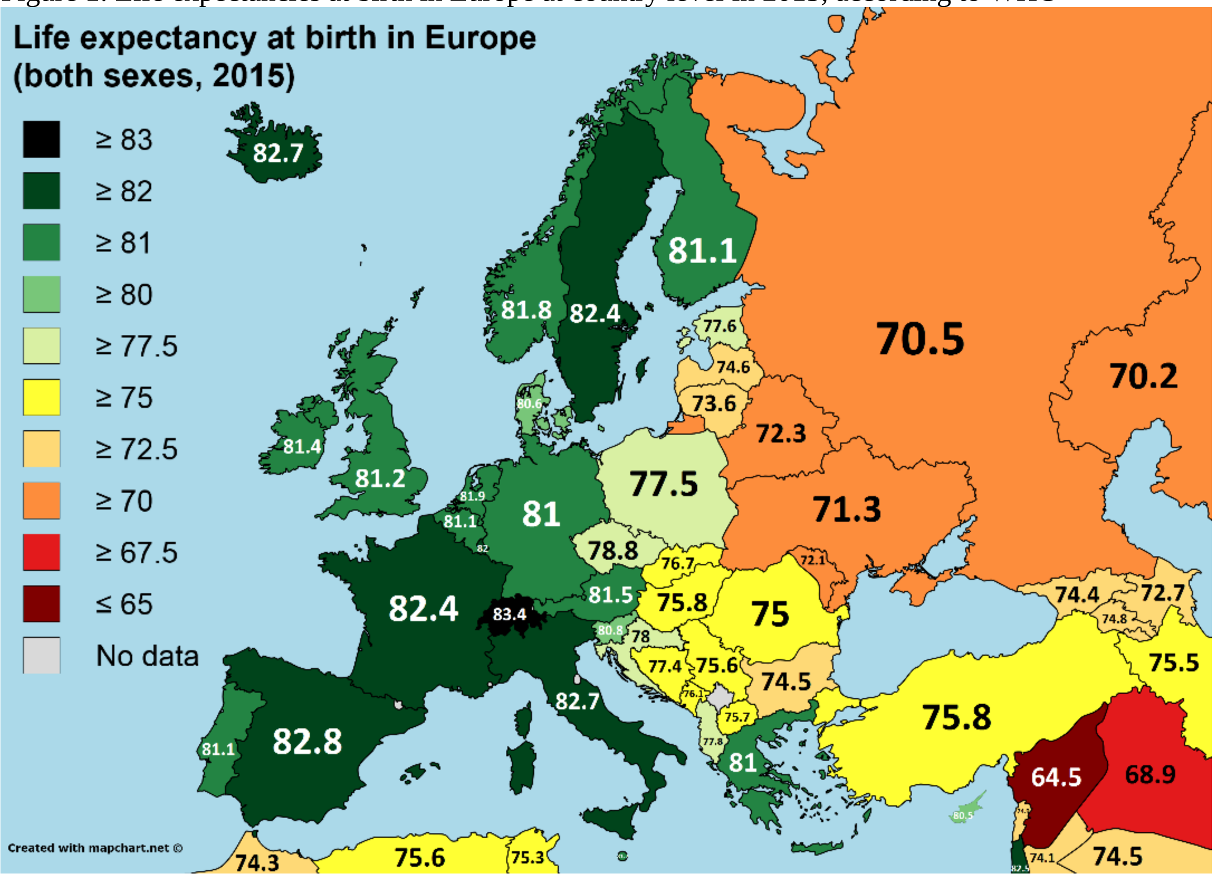
1. Problem statement

Introduction

The topic of this paper is the impact of air pollution on mortality in Poland. Figure 1 shows the life expectancies at national level and figure 2 at regional level. Figure 2 shows that almost all the regions with a life expectancy lower than 78, are in the former Eastern Bloc. These figures show there is a clear difference between the Western European countries and former Eastern Bloc countries. This also counts for adult life expectancies as well as for healthy life expectancies (see appendix 1 and 2). All these indicators show that generally Eastern Europe, including Poland, faces poor health in comparison with Western Europe (Eurostat, 2015; WHO, 2015).

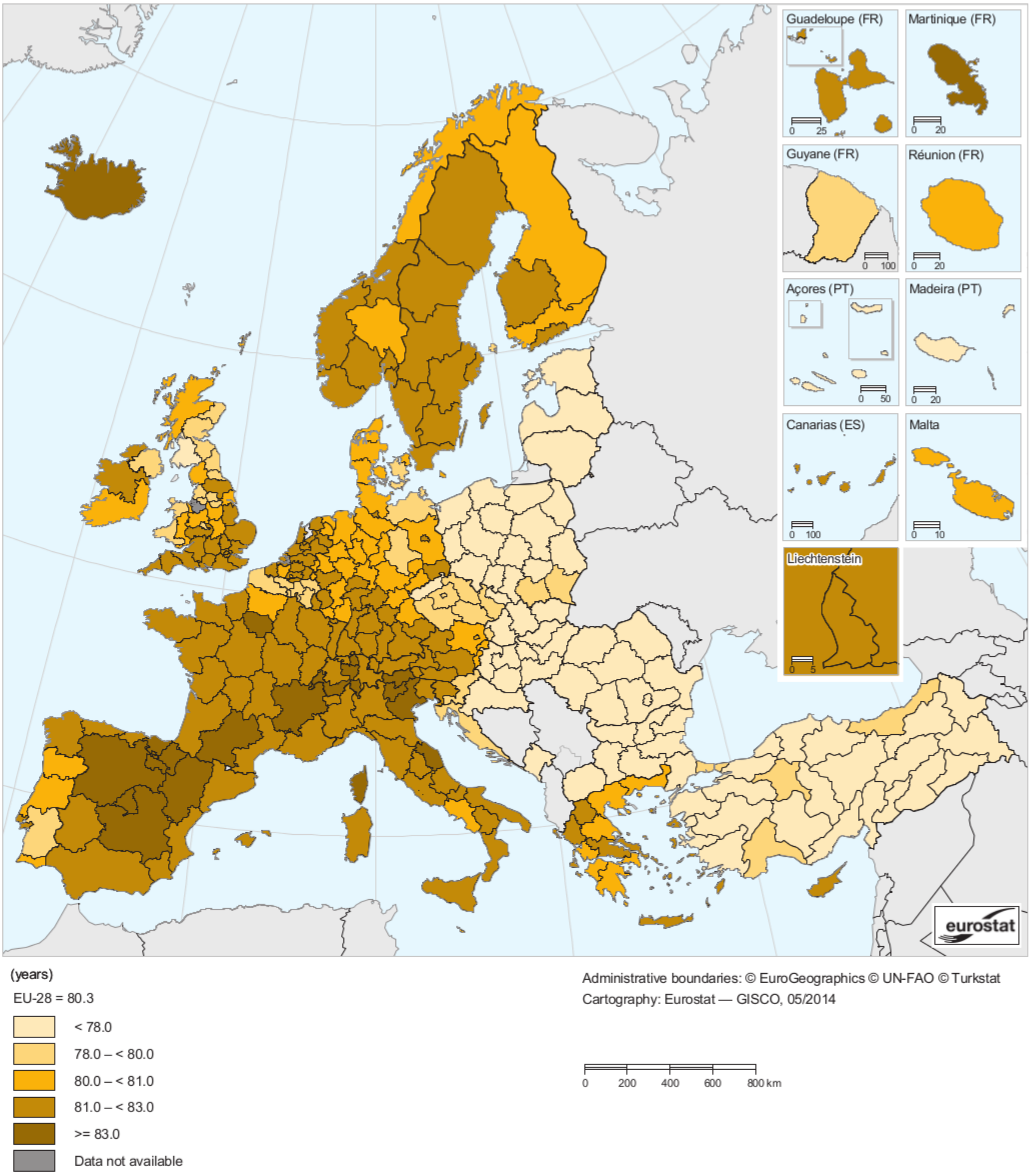
The poor health in Poland (and also in the rest of Eastern Europe) is mostly associated with lifestyle factors such as the alcohol- and tobacco consumption, these lifestyle factors are also widely researched. However, the influence of air pollution on health and mortality in Poland is less researched (Cockerham, 1999). While the widespread air pollution could also be a significant factor (Brunekreef & Holgate, 2002; Anthamatten & Hazen, 2011). During communism, and especially during mid 1980's Poland was even much more polluted. This also makes it plausible that air pollution plays a significant role in the relatively poor health in Poland, in comparison with Western Europe (Carter, & Turnock, 2002; Brunekreef & Holgate, 2002).

Figure 1: Life expectancies at birth in Europe at country level in 2015, according to WHO



Source: Mapchart (2016)

Figure 2: Life expectancy at birth in Europe at regional level (NUTS 2) in 2012, according to Eurostat



(¹) Sachsen-Anhalt (DEE0), Ireland, Romania and Turkey: 2011. Guadeloupe (FR91) and the United Kingdom: 2010. Serbia: national level.

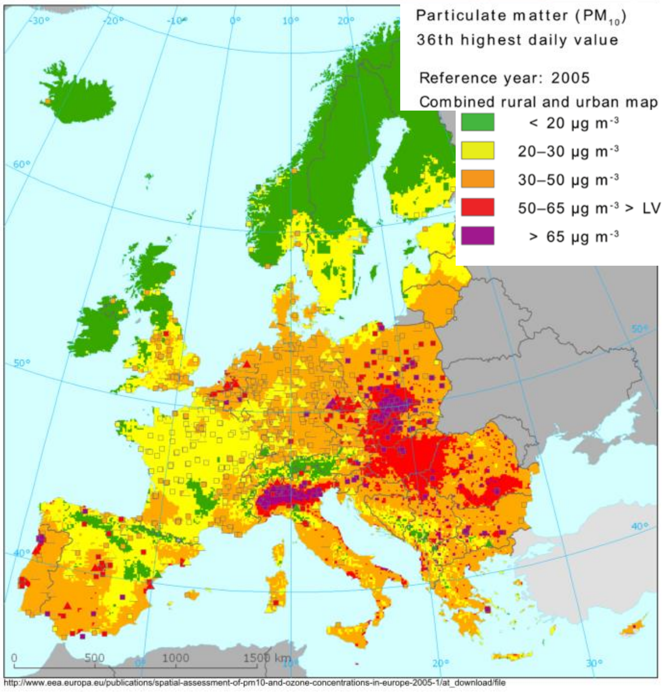
Source: Eurostat (online data code: demo_r_mlifexp and demo_mlexpec)

Source: Eurostat (2016)

Cause of death number one in Poland and in Europe, cardiovascular disease, is often associated with lifestyle factors (Eurostat, 2015; Danaei, 2009; Bobak & Marmot, 1996). However Pope et al. (2004) states that air pollution plays also an important role when it comes to cardiovascular diseases. Cancer is cause of death number two in Poland as well as in Europe, which is often associated with lifestyle factors and unhealthy diet. However many chemicals from the air could lead to cancer, especially lung cancer, even though lung cancer is mostly associated with smoking (Stewart & Kleihues, 2003). Pope et al. (2002) and Nyberg et al. (2000) state however, that a lot of cases with lung cancer are due to air pollution, in polluted areas it is estimated that a quarter of the lung cancer is due to air pollution. The regional disparities in air pollution might be able to explain the regional mortality differences.

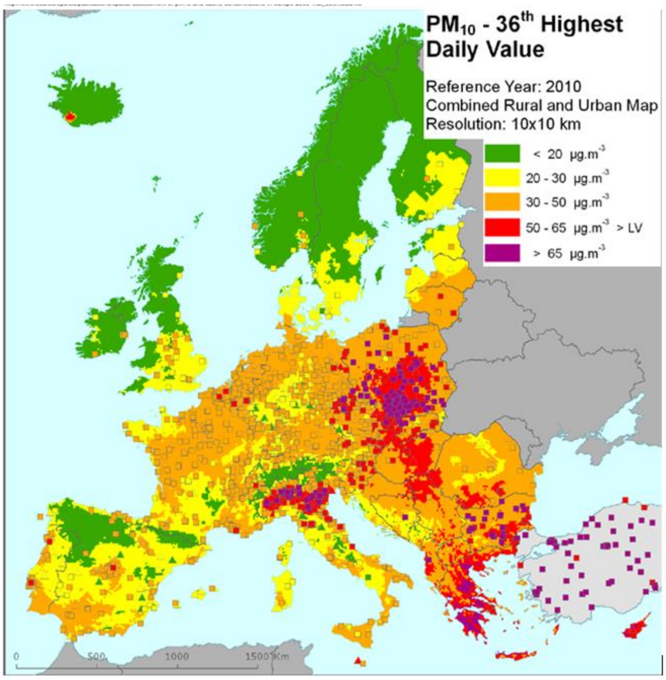
According to Pope et al. (2002), every 10 µg/m3 increase in particulate matter air pollution is associated with 8% increased lung cancer mortality. For the Polish city Krakow the average is 59 µg/m3 and for Katowice it is 50 µg/m3, which is comparable with Beijing where it is 56 µg/m3. To see it in a European perspective, the three largest cities in the EU: Paris, London and Berlin have respectively 16, 17 and 16 µg/m3. Milan in the North of Italy, which is in the second most polluted area in Europe (see also figure 3 and 4), has a value of 37 µg/m3. The third most polluted area is the Eastern coast of Greece (see also figure 3 and 4), there Thessaloniki and Athens have respectively the values 35 and 23 µg/m3 (WHO, 2016; European Environment Agency, 2016).
During communism all the Eastern bloc countries were strongly polluted due to the communist ideology in which industry had to form the main economic sector, and also because there were no environmental policies. And the low quality of technologies made it even worse. But also still nowadays approximately 25 years later Eastern Europe still faces widespread pollution (Crowley & Ost, 2001; Carter & Turnock, 2002; Waller & Millard, 1992; EEA, 2015). Especially Poland is strongly polluted due to coal burning, as coals are much more polluting than gas. In Poland houses are heated with coals and power plants use coals, whereas the rest of Europe mainly uses gas for these purposes (EEA, 2015; Financial Times, 2016). According to the Financial Times (2016) the Polish town of Skala is significantly more polluted than Beijing, and 33 of the 50 most polluted cities in Europe are in Poland. According to the European Environment Agency (2015) most of the air pollution occurs in South West Poland, figure 3 and 4 show the particulate air pollution for the years 2005 and 2010. Other types of air pollution show similar patterns in Europe (EEA, 2015). This makes it likely that air pollution in South West Poland plays an important role in mortality.
The air pollution during communism could still have a significant influence on the health of the current population, especially among birth cohorts born before 1950 when the communist industries started to grow fast. Which means that most old aged people in Poland were strongly exposed by air pollution. This makes it even more likely that air pollution has a crucial impact on mortality in Poland (EEA, 2015; Carter & Turnock, 2002).
Mortality is one of the main indicators for health and quality of life, this means that research about mortality is societally very relevant (WHO, 2015; UN, 2015). It could mean that air pollution has a crucial influence on the quality of life. Even if air pollution does not affect mortality it still does affect health as it can lead to several diseases. Therefore air pollution does also directly affect quality of life. (Brunekreef & Holgate, 2002; Anthamatten & Hazen, 2011).
The societal relevance of this research is not only that a cleaner environment contributes to the quality of life of people, but also that a healthier population could reduce the healthcare expenditures. Also could a cleaner environment directly lead to lower health care expenditures when prevalence of asthma and respiratory diseases decrease (Kampa & Castanas, 2008). Nevertheless a healthier population means anyway a higher quality of life (Lubitz et al., 2003). When it comes to healthy aging, the focus is mainly on lifestyle. However, a cleaner environment could also contribute to healthy aging (Gatrell & Elliot, 2014; Anthamatten & Hazen, 2011). Aveia & Fletcher (2000) have shown that air pollution is more harmful for people above 65, they are more susceptible to get ill and die from air pollution. This makes clear that a cleaner environment could contribute to healthy aging (Aveia & Fletcher 2000).

Figure 3:
Particulate air pollution in Europe in 2005



Source: EEA (2015)

Figure 4:
Particulate air pollution in Europe in 2010



Source: EEA (2015)

Objective
The objective is to gain insight into the relationship between air pollution and mortality in Poland. This research will focus on air pollution because during communism and also in contemporary Poland and Europe as a whole, air pollution plays by far the most significant role within all types of pollution when it comes to mortality (EEA, 2015; Carter & Turnock, 2002). Communism in Poland has left its deep marks on the environment by the heavy industry. And even nowadays, more than 25 years after the fall of communism, there is still a relatively big polluting industry with a lack of environment legislation and a weak legal enforcement (Webster, 2007 & Turnock, 2001). And the strongly polluting coals are still the main source for heating and electricity powerplants in Poland. This means that also today, Poland is still extremely polluted (OECD, 2007; Andersson et al., 2006; Webster, 2007; Turnock, 2001; EEA, 2016; Financial Times, 2016). Knowing Poland's poor health situation in combination with Poland's environmental situation, makes it very relevant to research what are the effects of this air pollution on mortality. Especially because till now the focus on the Polish health situation was mainly focused on lifestyle factors (Central Statistical Office Poland, 2016; OECD, 2007; Bobak &Marmot, 1996; Brauer et al., 2007; Zatonski, 2011; WHO, 2016). It is likely that a reduce in air pollution could give many health benefits (Andersson et al., 2006; Webster, 2007; Turnock, 2001).
This research will mainly focus on quantitative research: it will use data on mortality and air pollution at regional level, at NUTS-2 level. The research will be both descriptive and explanatory, but the main focus will be descriptive (Babbie, 2013). The different regions with different cause of death rates and degrees of air pollution will be described. The relationships between air pollution and mortality in the different regions will be explained.

Main question:
- To what extent does air pollution explain mortality differences in the different Polish regions?

Sub questions:
- What are the most prevailing types of pollution in the different Polish regions?
- What are the pollution related mortality rates in the different Polish regions?
- What are the remaining factors related to mortality rates in the different Polish regions?

2. Theoretical framework

2.1 Theories

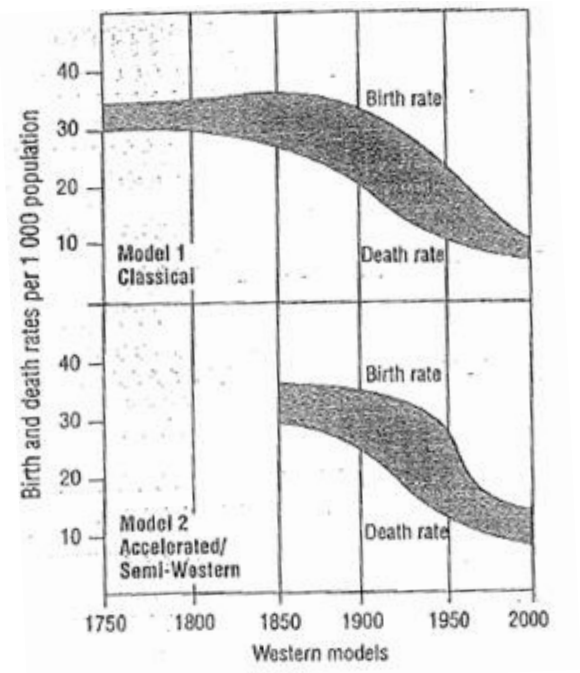
Introduction to mortality
Studies on mortality mostly distinguish three types, namely: child mortality, maternal mortality and adult mortality. Only the adult mortality will be discussed because air pollution only affects adult mortality. Despite that air pollution affects the health among children, the effect on child mortality is really negligible. Within adult mortality, air pollution does barely affect mortality among people under the age of 50. From the age of 50 the susceptibility to die due to air pollution increases with the age (WHO, 2015; Mosley & Chen 1984; Pope et al., 2004; EEA, 2015).

Determinants of adult mortality
For the determinants of adult mortality, there are fixed effects and potentially modifiable effects. Fixed effects are genetic factors and demographic factors such as age and ethnicity. Potentially modifiable effects are personal lifestyles and behaviour, physical environment, social environment, and policies and politics. Social environment contains social, cultural, and economic factors, and provision and utilization of healthcare services (Young et al., 1998).
As mentioned before, this research will mainly focus on the factor 'physical environment', but in order to understand the impact of the physical environment on mortality you have to understand all the determinants regarding mortality. (Young et al., 1998).

Epidemiological transition theory
Epidemiology is the study of distribution and causes of disease in populations. The epidemiological transition theory is based upon the systematic application of epidemiological interference to changing health, mortality, survival and fertility over time and place linked to their environmental, socio-economic, healthcare, lifestyle, and technological determinants in different societal settings. All the transitions contain both the dependent and independent variables (Omran, 1998). Epidemiologic studies incorporate the capacity to analyze the demographic, social, economic, technological, healthcare, and environmental changes as they are related to health. Health is the dependent variable of epidemiology. There is no doubt about the epidemiological change that has been taking place in the world over the last few centuries. The socio-economic developments encompasses the change in diseases and health patterns (the health transition), the change in healthcare patterns (healthcare transitions), the change in fertility and population age structure (parts of the demographic transition), the medical and technological evolutions (technological transition), the changes in lifestyle (lifestyle transition), and changing environment and ecology (ecological transition). Especially the latter is relevant for this research (Omran, 1998).
The epidemiological transition theory has been revisited from a three stage model to a five stage model. The model is applicable on the most countries in the world, especially the Western countries, which are facing a growing life expectancy. Therefore the classical model is also called the Western transition model. The Western transition model correspondents the most with the classical demographic transition model. The semi-western model or accelerated model was developed to describe the experience in the former USSR and Eastern Europe including Poland, both models are shown in figure 5. Fertility and mortality declines came later than in the Western model. And Eastern Europe and the USSR experienced temporary a decreasing life expectancy and increasing cardiovascular mortality after the fall of communism, due to economic, social and political crises (Cockerham, 1997; Cockerham, 1999; Omran, 1998). Many of the Eastern European countries have not entered yet the fourth stage of the epidemiologic transition, those countries generally have cardiovascular mortality in a high degree, which is also the case in Poland. Cardiovascular mortality is higher in Eastern European countries, due to the fact that Western European countries reduced a lot of cardiovascular diseases due to more advanced healthcare. Which also shows that Poland is lagging behind Western European countries (Maniecka-Bryła et al., 2012; Muszyńska, 2012). The epidemiologic transition theory is relevant, because it can explain mortality in comparison with socio-economic development, this counts also for Western- and Eastern Europe, and more specifically for Poland. The question however is, to what extent the previous mentioned transitions parallel the ecological transition. The epidemiologic transition theory could

explain the relatively poor health in Poland in relation with socio-economic developments. Whereas the ecological transition theory could explain the extent of (air) pollution and therefore maybe also air pollution mortality.

Figure 5: Models of the epidemiologic transition, the classical model and accelerated/semi-Western model



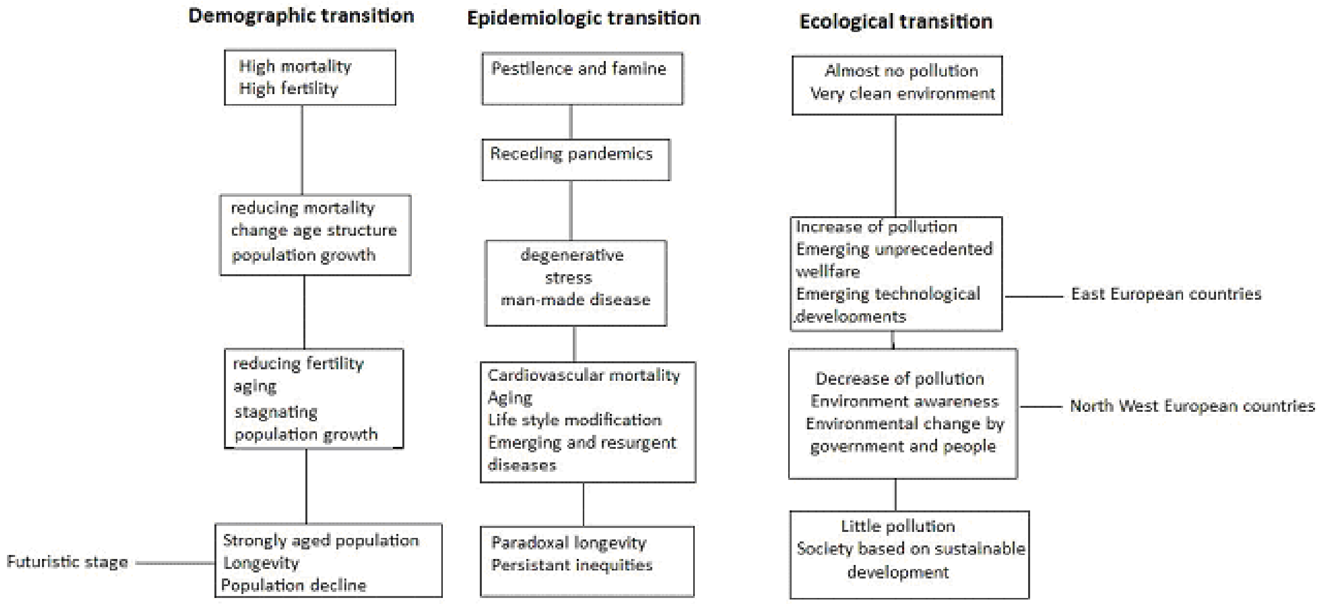
Source: Omran (1998)

Ecological transition theory

The ecological transition is defined as "the progressive incorporation into nature into human frames of purpose and action" (Bennett, 2005). The socio-economic developments are associated with the awareness of the environment, and the trends towards sustainable development. Developed countries which are in the third stage, face societies in which sustainable development is playing an increasingly important role. Developing countries, which are in the first stage, are not paying much attention to sustainable development, however their pollution is significantly lower due to their low incomes. Transition countries are in the second stage of the transition model, their awareness of the environment is higher than in developing countries but still very low. Generally the transition countries are the most polluting countries, because they are more prosperous than developing countries so can afford more luxury, but their awareness of the environment is much lower than in the most developed countries. In theory all the countries will reach a stage that sustainable development is playing a significant important role. There is even a futuristic stage in which a society is based on sustainable development (the fourth stage). When a country has been facing a lot of pollution, its environment will recover by its environmental policies and its people's awareness. Eastern European countries like Poland are in the second stage of the ecological transition, whereas most of the West European countries are in the third stage of the ecological transition. This implies that East European countries are more polluting and have less awareness of the environment and worse environmental policies. Which could be a significant impact on mortality. Theoretically, is expected that the stages of the ecological transition go hand in hand with the stages in the epidemiologic transition, as well as with the demographic-, technological-, respectively the health transition (Bennett, 2005; Omran, 1998; Popkin, 2002). Health awareness among populations goes hand in hand with environment awareness, as well do health policies mostly go together with environmental policies. Also does technological development strengthen both health development as well as sustainable development. So in short, theoretically, health development and sustainable development go parallel (Bennett, 2005; Omran, 1998; Popkin 2002). Eastern European countries, like Poland, are one stage behind Western European countries, this counts both for health and for sustainable development. For example countries like Norway, Iceland and Sweden are significantly

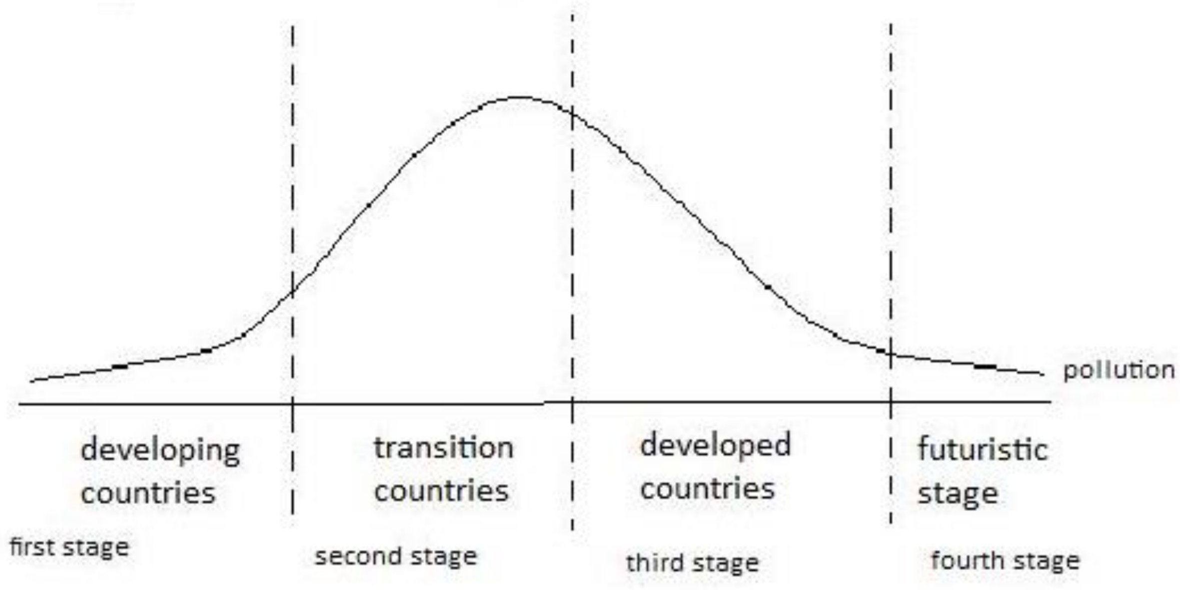
more advanced in terms of both health and sustainability than countries like Poland, Hungary and Bulgaria (Bennett, 2005; Popkin 2002, OECD, 2016).
All the stages of the transitions are shown in figure 6, as well is shown how the ecological transition parallels the epidemiologic transition and the demographic transition. In figure 7, the ecological transition is shown in relation to pollution, and also to what extent developing countries, transition countries and developed countries are polluting and their trends in increasing or reducing pollution.
The ecological transition theory exists of 4 stages:
Stage 1. *Almost no pollution.* In the first stage is no pollution or almost no air pollution, this stage is before the existence of technological development. This stage parallels the high mortality and high fertility in the demographic transition. This stage parallels the 1rst and 2nd stage of the epidemiologic transition, these two stages are before the emerging the unprecedented technological developments.
Stage 2. *Increase of pollution.* The emerge of technological development in combination with emerging unprecedented welfare caused a reduce in mortality (demographic transition), but also caused pollution. This stage parallels also the stage of degenerative stress and men made diseases in the epidemiologic transition.
Stage 3. *Decrease of pollution*. The emerge of awareness regarding health and environment leads to environmental policies and more sustainable behaviour, which leads to a decrease in pollution. This goes hand in hand with 5th stage of the epidemiologic transition with lifestyle modification and health policies, and with the 4th stage in demographic transition with reducing fertility, population aging and stagnating population growth.
Stage 4. *Little pollution*. Like in the demographic- and epidemiologic transition does the ecological transition have a futuristic stage, emerging a society based on sustainable development. Which goes parallel with paradoxal longevity in the epidemiologic transition theory, and with a strongly aged population and longevity at the demographic transition theory (see also shown in figure 6).
So in theory Poland is one stage behind North Western Europe regarding both health as well as sustainable development. Looking at the health and pollution situation Poland is indeed one stage behind Western Europe (Bennett, 2005; Omran, 1998). The ecological transition theory could explain the air pollution mortality in relation with the socio-economic developments in Poland.

Figure 6: Ecological transition with the demographic transition and the epidemiologic transition



Source: Based on Bennet (2005), Popkin (2002) and Omran (1998)

Figure 7: Ecological transition, graphic model



Source: Based on Bennet (2005)

2.2 Literature review

Mortality in Poland and Eastern Europe

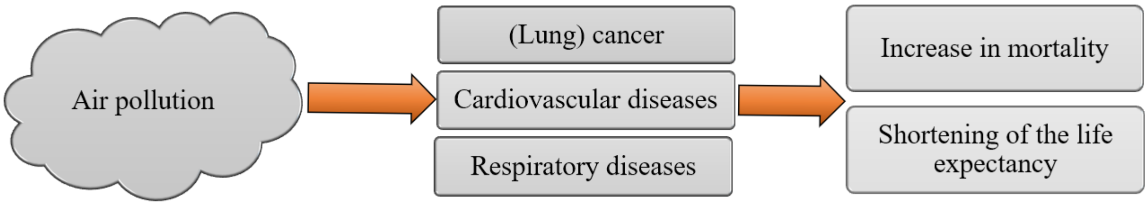
In the theoretical framework the determinants of mortality were discussed. In this paragraph will be discussed what explanations are given for the significant lower life expectancies in Eastern Europe in comparison with Western Europe, in order to gain more insight in the relatively low life expectancy in Poland. According to Bobak & Marmot (1996) health behaviour, alcohol and smoking are the most important factors for the significant lower life expectancies in Eastern Europe. From these factors smoking seems to be the most harmful. Also there is a clear evidence that the social environment plays an important role. The World Health Organization analysed the life expectancy gaps between Eastern and Western Europe in different age groups. Infant mortality had only very little differences, 43% of the gap was found in the age group of 35-64 and 23% in the age group of 65 and over. Cause of death number one is cardiovascular disease which accounts for 54%, followed by external causes with 23% and respiratory diseases with 16% (Bobak & Marmot, 1996). Another explanation seems to be the lower quality of health care in Eastern Europe. As mentioned before lifestyle seems the most important factor, which contains smoking, alcohol, nutrition and physical activity. All the lifestyle factors taken into account could explain the high prevalence of certain diseases like cardiovascular diseases. However the diets in Eastern Europe do not seem significantly more unhealthy than in Western Europe, that depends on which West European countries, only the Mediterranean countries in Western Europe seem to have a significantly healthier diet than Eastern European countries (Bobak & Marmot, 1996; Trichopoulou, 2005). Subsequently a factor which is less considered in literature is ‘air pollution’. Bobak & Marmot (1996) mention that air pollution could be a significant factor, partially because it affects whole populations. And Eastern Europe is faced with widespread pollution. The most polluted area in terms air quality was the area around South Poland and Czech Republic, in beginning of the nineties the level of particulates and sulpher dioxide became two to three times higher than was allowed by the WHO guidelines. Two to three percent of the mortality in Czech Republic was estimated as due to air pollution in 1987, which would account for 9% difference in the gap between Austria and Czech Republic. There are several clear explanations for the mortality differences between Western Europe and Eastern Europe. One of the factors is air pollution, this research aims to figure out to what extent air pollution contributes to mortality in Poland (Bobak & Marmot, 1996). Looking at regional mortality differences, the degree of urbanization and income seems to be one of the best indicators for regional mortality. Mainly by looking at cardiovascular diseases, as they prevail in a relatively high extent in Poland. Also, the regional socio-economic status is negatively correlated with cardiovascular mortality. As well did the largest

cities show the lowest prevalence of cardiovascular mortality. The reason why cardiovascular mortality is lower in the urban areas is due to better access to healthcare, and in particular to cardiology units. The lower cardiovascular mortality also explains the lower overall mortality, because cardiovascular disease is cause of death number one in Poland. Rather than other specific regional factors seem the degree of urbanization and income the main indicators in regional mortality disparities (Muszyńska, et al., 2015). The fact that the variable 'degree of urbanization' is not available online, and 'income' is available, 'income' is used as a variable in the regression analyses (Central Statistical Office Poland, 2016).
Looking specifically at cancer, in particular lung cancer, the regional variation in mortality can partly be explained by the regional variation of smoking behaviour (Fihel & Muszyńska, 2015). So smoking and income seem to be good indicators for the regional mortality disparities, they are the best indicators for regional cardiovascular mortality and regional cancer mortality, which are also causes of death number 1 and 2 (Fihel & Muszyńska, 2015; Muszyńska, et al., 2015)
This research should clarify to what extent air pollution contributes to the regional mortality disparities.

Mortality and air pollution
The extent of air pollution is a factor for health and mortality, therefore it is also important to look at the different types of air pollution, which are defined by its contaminants. The three main pollutants within air pollution are particulate matters, nitrogen dioxide and ground level ozone. Particulate air pollution is solid and has led to several diseases such as lung cancer, asthma and cardiovascular disease. Ozone and nitrogen dioxide are gases and can inflame the linings of the lungs and can reduce lung function. Also do ozone and nitrogen dioxide increase the probability of infectious diseases. Subsequently ozone could also worsen bronchitis, emphysema and asthma. Repeated exposure of ozone might cause permanently scar lung tissue. Older adults, children, people with lung disease are more susceptible to become ill due to ozone and nitrogen dioxide. The effects of nitrogen dioxide are however less well known than the effects of ozone, and the effects of ozone are less well known than the effects of particulate matters (Lippmann, 1989; Spengler et al. 1983; Kampa & Castanas, 2008; Anthamatten & Hazen, 2011). Other types of air pollution also led to lung cancer, cardiovascular diseases and different types of respiratory diseases. People with lung diseases such as asthma, children and elderly people are most susceptible to become ill, and among elderly also the most susceptible to die from this disease. This counts for all types of air pollution. The difficulty with asthma is that this disease is only diagnosed when someone got an asthma attack. This generally only happens when asthma patients are exposed to polluted air or dust. So from some people it is known that they have asthma and others could suddenly get it when they are exposed to polluted air or dust. So it means that air pollution can lead to asthma attacks, and occurs both at the people who already had the diagnosis of asthma and people who never experienced it before (Brauer et al., 2007). The most common diseases related to air pollution in general are asthma, lung cancer, respiratory disease and cardiovascular disease. And within cardiovascular disease mostly circulatory diseases, particulate matter pollution is associated with circulatory diseases (Pope et al., 2002; Nyberg et al., 2000). In contemporary Europe with its current amount of pollutants, particulate air pollution shows the biggest correlation with mortality. This also counts for Poland, which means that particulate matters will form the most important pollutant for this research (EEA, 2016; Anthamatten & Hazen, 2011; Pope et al., 2002; Nyberg et al., 2000). Asthma has a particular interest when it comes to overall air pollution, because the main types of air pollution show a clear correlation with asthma. Interesting is that data from both England and the US prove that there is a clear correlation between the shares of asthma patients and the concentrations of particulates and other types of air pollution. This means that you would expect a strong correlation between the share of asthma patients and air pollution in statistical analyses, the question however is whether this is also the case for asthma mortality (Anthamatten & Hazen, 2011; Gatrell & Elliot, 2014).

2.3. Conceptual framework

Topic of this research is mortality in Poland due to air pollution. The starting point is the air pollution in Poland, Poland is faced with widespread pollution due to its communist history and the usage of coal energy. This air pollution leads to respiratory diseases, cancer and cardiovascular diseases. This leads to an increase in mortality and a shortening of the life expectancy.



Hypotheses

- The air pollution is a significant factor on mortality in Poland, because it is widespread and can lead to certain diseases like cancer, asthma and cardiovascular diseases.
- The relatively low life expectancy in Poland is partially due to air pollution.
- The air pollution in Poland can partly explain the mortality differences in the different Polish regions.
- The air pollution in Poland can partly explain the cause of death differences in the different Polish regions.

Definitions

Life expectancy:
“the average number of years that a person can expect to live” (WHO, 2015).

Adult life expectancy
“the average number of years that a an adult aged 20 can expect to live” (WHO, 2015).

Health:
“a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO, 2015).

Air pollution:
the addition of something to the air, which changes its natural qualities (Goodnight, 1973).

Cause of death:
“the disease or injury which initiated the train of morbid events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury” (WHO, 2015)

3. Research design

Methodology

Poland is firstly one of the most polluted countries in Europe, but has also much dispersion in terms of air pollution. As well is the South West of Poland the most polluted area in Europe (EEA, 2016). The extents of air pollution do strongly differ per region. This makes Poland a suitable case to study the effects of air pollution on mortality. Which means it is easier to show the relationship between air pollution and mortality. In contrary with Hungary and Czech Republic for example where the pollution is more equally divided throughout the country, and also less regions which means a smaller sample size for statistical analysis (Eurostat, 2016).

The research will be done on regional level at NUTS-2 level. NUTS-3 would be better, however not all the data are available at NUTS-3 level. 'Particulate matter pollution' (PM pollution) and gaseous air pollution are used as the types of air pollution. Particulate matter which contains all types of particles and 'gaseous air pollution' which contains all polluting gases such as ozone and nitrogen dioxide. These air pollution data are available via the Central Statistical Office Poland. For all the regions these types of air pollution with its amounts will be shown and as well the mortality rates with the different causes of death. In this way can be figured out whether the more polluted regions have higher mortality rates and also whether some cause of death rates are related to air pollution.

Data

This research is a quantitative research because quantitative data about air pollution, diseases and mortality is necessary. You need these quantitative data to test whether there is a relation between different types of pollution and certain diseases and mortality. As well do quantitative data make the outcomes of a research stronger. These data are needed to answer the main research question and sub questions and also to test the hypotheses (Babbie, 2013; French et al., 2010). The data for air pollution are obtained from the Central Statistical Office Poland. The regional standardized mortality data are not online available via the Central Statistical Office Poland, therefore the regional mortality data are obtained from Eurostat. Vice versa regional air pollution data are not available via Eurostat, so therefore the air pollution data are obtained from Central Statistical Office Poland. So at the end, two different sources have to be used in order to complete this analysis.

Dependent variables

- All-cause mortality 2014, standardized mortality rate
- All types of cancer 2014, standardized mortality rate
- Lung cancer 2014, standardized mortality rate
- Respiratory diseases 2014, standardized mortality rate
- Asthma 2014, standardized mortality rate
- Ischaemic heart diseases, standardized mortality rate
- Circulatory diseases, standardized mortality rate
- Cebrovascular diseases, standardized mortality rate

  For each of these variables they are also divided by:
  - both sexes at all ages
  - males at all ages
  - females at all ages
  - 65 and older both sexes
  - 65 and older males
  - 65 and older females
- Life expectancy
  - At birth both sexes
  - At birth males
  - At birth females
  - At 60 both sexes
  - At 60 males
  - At 60 females

As dependent variables serve the cause of death rates, the cause of death rates are standardized for age in order to correct for age composition, this is needed because not every region has the same age composition (Preston et al., 2000). The death rates are measured in deaths per 100,000 population (Eurostat, 2016). The death rates used are from the year 2014, because this is the last year with pollution data as mentioned before. The cause of death rates used are all-cause mortality, all types of cancer, lung cancer, respiratory diseases, asthma, ischaemic heart diseases, circulatory diseases and cebrovascular diseases. Those cause of death rates will also be tested separately for both sexes, males and females at all ages, as well as for both sexes, males and females at 65 and older. This is to see whether there are differences between these groups. It might not be significant at all ages, but would be at 65 in some cases, because elderly are more susceptible to die from air pollution (Goueiva & Fletcher, 2000). There might also be differences in the outcomes between males and females, because looking at the lifestyle factors in Poland women behave much healthier than men (Central Statistical Office Poland, 2016).

Independent variables

- Particulate matter pollution, average 2010-2014
- Gaseous air pollution, average 2010-2014

As independent variables serve the air pollution data, in this case particulate matter pollution and gaseous air pollution. The average is taken of 2010-2014, this gives better indicator as there are some fluctuations over the years (Central Statistical Office Poland, 2016). And air pollution is mainly affecting on the long run, so previous years do also count (Goueiva & Fletcher, 2000). The average is taken over 2010-2014 because from 2010 until 2014 are the only available years. The types of air pollution within particulate matter pollution and within gaseous pollution are not used, because these pollutants are not available online.

Particulate matter pollution as well as gaseous air pollution obtained from the Central Statistical Office Poland, and are measured in ton per cubic kilometer per year. These values are based on measurements in the air at many points across the country (Central Statistical Office Poland, 2016).

Confounding variables

- Smoking (tobacco consumption)
- Alcohol (alcohol consumption)
- Income
- Overweight

By running a regression analysis it is important to correct for the confounding factors in order to avoid bias (Salas et al., 1999; Skelly et al., 2012). The most important confounding factor in this research is smoking as it leads to the same diseases as air pollution (Goueiva & Fletcher, 2000; Brauer et al., 2007). Smoking is measured by tobacco consumption in kilograms per person per year (Central Statistical Office Poland, 2016). Other confounding factors used in this analysis are alcohol, income and overweight. Alcohol is obviously measured by alcohol consumption in liter per person per year, overweight is measured in persons per 1000 that are overweight, and income is measured in Polish zloty per month (the average income per person) (Central Statistical Office Poland, 2016). All the confounding factors are obtained from the Central Statistical Office Poland also for the year 2014.

Descriptive Statistics

Table 1 and 2, and appendix 12 present the descriptive statistics for the independent variables (types of pollution), the confounding variables, and respectively dependent variables (causes of death), which includes the mean, the minimum, the maximum, the standard deviation, and the sample size of in this case 16 NUTS-2 regions.

Table 1 shows the descriptive statistics for PM pollution and gaseous pollution (both measured in tonne per km3 per year), which shows there is much dispersion in both types of air pollution, but more for the gaseous air pollution. Also, is shown that in terms of mass, PM pollution is prevailing in a much smaller extent than gaseous air pollution. Which seems striking, but this is normal because particles are very different types of air pollution than gases (European Environment Agency (2017).

Table 1. Descriptive statistics independent variables

	N	Minimum	Maximum	Mean	Std. Deviation
PM pollution	16	,05	,93	,1986	,20627
Gaseous pollution	16	61,95	3342,02	796,8523	881,19668

Table 2 presents the descriptive statistics for the confounding variables. From this table can be concluded that women behave much healthier than men, alcohol consumption among men is more than 5 times higher than among women, tobacco consumption is more than 1,5 times higher among men, and in a smaller extent overweight is also higher among men.

Table 2. Descriptive statistics confounding variables

	N	Minimum	Maximum	Mean	Std. Deviation
Smoking males	16	30,40	38,40	34,3125	2,45625
Smoking females	16	12,80	24,60	19,1750	3,52827
Smoking both sexes	16	21,70	30,70	26,7438	2,65756
Alcohol males	16	3,09	5,78	4,4594	,76131
Alcohol females	16	,43	1,03	,7269	,19407
Alcohol both sexes	16	1,81	3,35	2,5963	,45624
Overweight males	16	29,10	36,30	32,7125	2,13569
Overweight females	16	22,60	29,80	26,7813	1,66462
Overweight both sexes	16	25,90	33,00	29,7688	1,63124
Income	16	3223,04	4657,07	3515,5888	364,83009

Table 3 shows the descriptive statistics of the dependent variable all-cause mortality (standardized) and the life expectancies at birth and at 60, for males, females and both sexes.
According to tables 3, the life expectancy for both sexes is average 77.5, and for males and females 75.1 and 82.6, which also shows that women in Poland are much healthier than men. A gender gap of 7.5 years is high in a European context (Eurostat, 2017). This counts also for the life expectancy at 60, which is for males and females, 18.2 and 23.3, with a gender gap of 5.1 years. The difference in life expectancy between the NUTS-2 regions are in contrary quite small.
Obviously, the cause of death rates for those above 65 are much higher than for those at all ages. Also is shown that the mortality rates for males are higher than for females. Appendix 12 shows all the dependent variables, which included the causes of death and the life expectancies. For all the causes of the death included (see appendix 12), the mortality rates are higher among the men than the women. Which also shows that the general health situation is better among females.

Table 3. Descriptive statistics dependent variable all-causes mortality

	N	Minimum	Maximum	Mean	Std. Deviation
All cause mortality	16	1198,95	1426,11	1290,0050	57,74331
All cause mortality at 65	16	5030,96	5785,54	5362,5637	196,30834
All cause mortality at 65 males	16	6490,71	7618,40	6959,8169	296,13346
All cause mortality at 65 females	16	4075,24	4821,67	4450,4037	186,09587
All cause mortality females	16	907,67	1095,01	999,8331	50,40294
All cause mortality males	16	1595,23	1930,50	1716,9388	85,88906
Life expectancy at birth both sexes	16	75,90	78,75	77,5031	,74173
Life expectancy at birth males	16	71,40	75,10	73,4938	,88126
Life expectancy at birth females	16	80,30	82,60	81,5125	,74375
Life expectancy at 60 both sexes	16	20,80	22,20	21,4625	,43301
Life expectancy at 60 males	16	18,20	19,70	18,8688	,46147
Life expectancy at 60 females	16	23,30	24,90	24,0563	,47884

Ethical considerations

First of all this research uses only quantitative data to test the relationship between air pollution and mortality. All these variables are ratio variables which makes the research very objective, ratio variables make the chances of bias very small. This research does not investigate sensitive issues such as sexual behaviour or abortions, which means that this research does not have to deal with ethical issues. Subsequently because this research is a quantitative research, it does not need any interviews or focus group discussions in order to get the right data. Which means that there will be no use of any personal or sensitive information, neither any subjective information. And also the fact that power relations and positionality do not play a role, means that it cannot negatively influence the outcome of gathered data. Most of the data are quantitative and will be used from reliable scientific institutes such as Eurostat and the Central Statistical Office Poland. Which are easily available. The fact that there is no use of any personal information and all the obtained data are transparent, makes the chances of bias much smaller regarding the data provided in this research (Babbie, 2013; French et al., 2010). In order to avoid bias, it is important to test for confounding factors, other variables which also relate to mortality, and in particular variables which lead to the same diseases as air pollution (Salas et al., 1999). As mentioned before, in this case it is especially very important to test also for the variable ‘smoking’, as smoking leads to the same diseases as air pollution. Also variables like alcohol, overweight, income will be tested in order to avoid bias (Brunekreef & Holgate, 2002; Anthamatten & Hazen, 2011).

4. Results

Introduction to air pollution and mortality

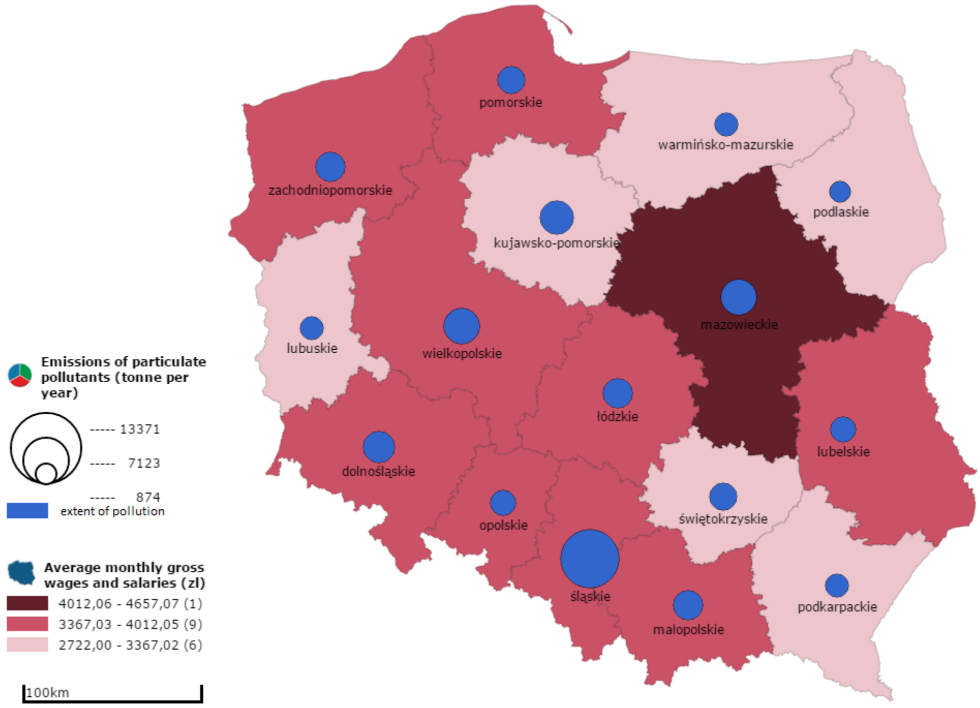
Before digging into the results of the regression, the regional mortality (NUTS-2) and regional air pollution (NUTS-2) will be shown to gain more insight in the regional mortality and regional air pollution in Poland.

Air pollution in Poland

As mentioned before, Poland is mainly so polluted due to coal burning which is much more polluting than gas burning. Coal burning causes mainly particulate matter and nitrogen oxides (also known as NOx), which is a poisoning gas. Nitrogen oxides in combination with particles and sunlight can result in ozone which is another poisoning gas strongly associated with asthma (Wu et al., 1973). Poland is strongly exposed to the nitrogen oxides and particulate matters. Among gaseous air pollution nitrogen oxides are by far the most prevailing pollutants, also ozone is one of the most prevailing gaseous pollutants. Both gases are prevailing relatively in a very high extent in Poland compared to the rest of Europe (Carter & Turnock, 2002; EEA, 2016; Ross et al., 2002). Poland has approximately 11 times more nitrogen oxides in the air than the European Union average. The data from the Central Office of Statistics Poland cannot provide information regarding the types of gases, but at least the literature could tell which are the most prevailing types of gaseous pollution.

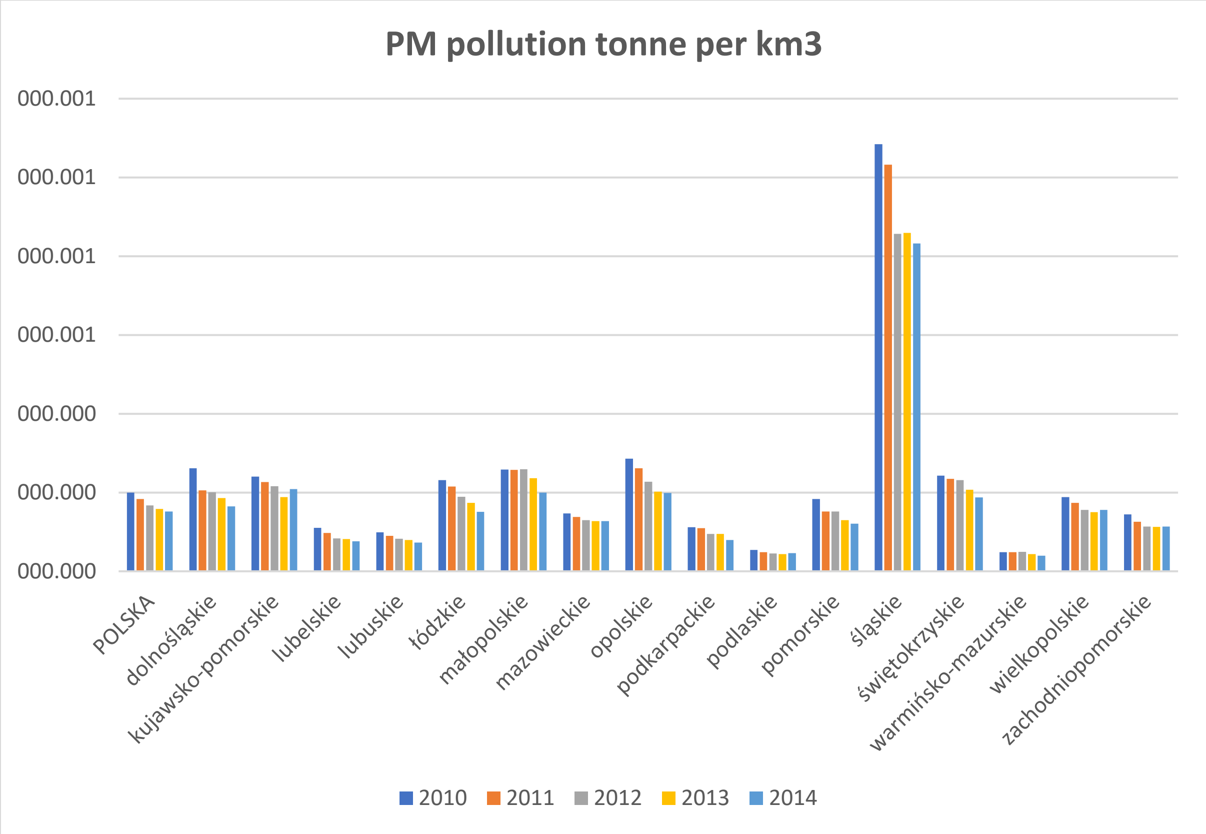
The map figure 8 shows the quantities of PM pollution by the size of the blue circles. The graph in figure 9 shows the quantities of PM pollution and the graph in figure 10 shows the quantities of gaseous air pollution, both of them for 4 different years. Both the map and the graph are based on data from Central Statistical Office Poland. Unfortunately due to lack of available data it is not possible to specify more precisely which pollutants are prevailing and in what amounts. But according to the EEA (2016) and also according to the Financial Times (2016) Poland has much more PM pollution and gaseous pollution than average in Europe. As mentioned before, Krakow has a value of 59 µg/m3, and London has a value of 16 µg/m3 and Paris a value of 17 µg/m3 particulate matter pollution. This means that the most polluted Polish regions are especially very polluted in European context. Mainly in the South West of Poland these pollutants are widely prevailing (EEA, 2016). The figures also show there is big dispersion in air pollution across the country.

Figure 8: Particulate air pollution and income per NUTS-2 region, year 2014



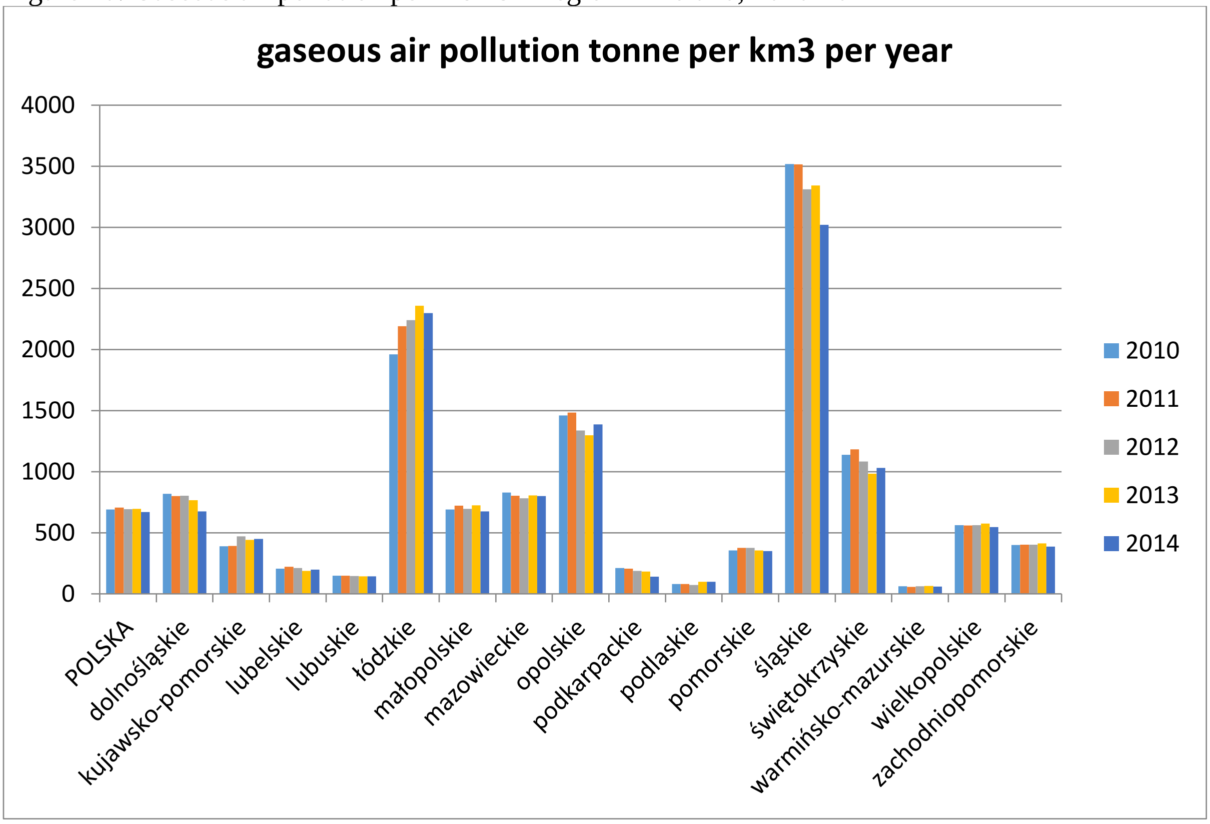
Source: Central Statistical Office Poland (2016)

Figure 9: Particulate air pollution per NUTS-2 region in Poland, 2010-2014



Data source: Central Statistical Office Poland (2016)

Figure 10: Gaseous air pollution per NUTS-2 region in Poland, 2010-2014



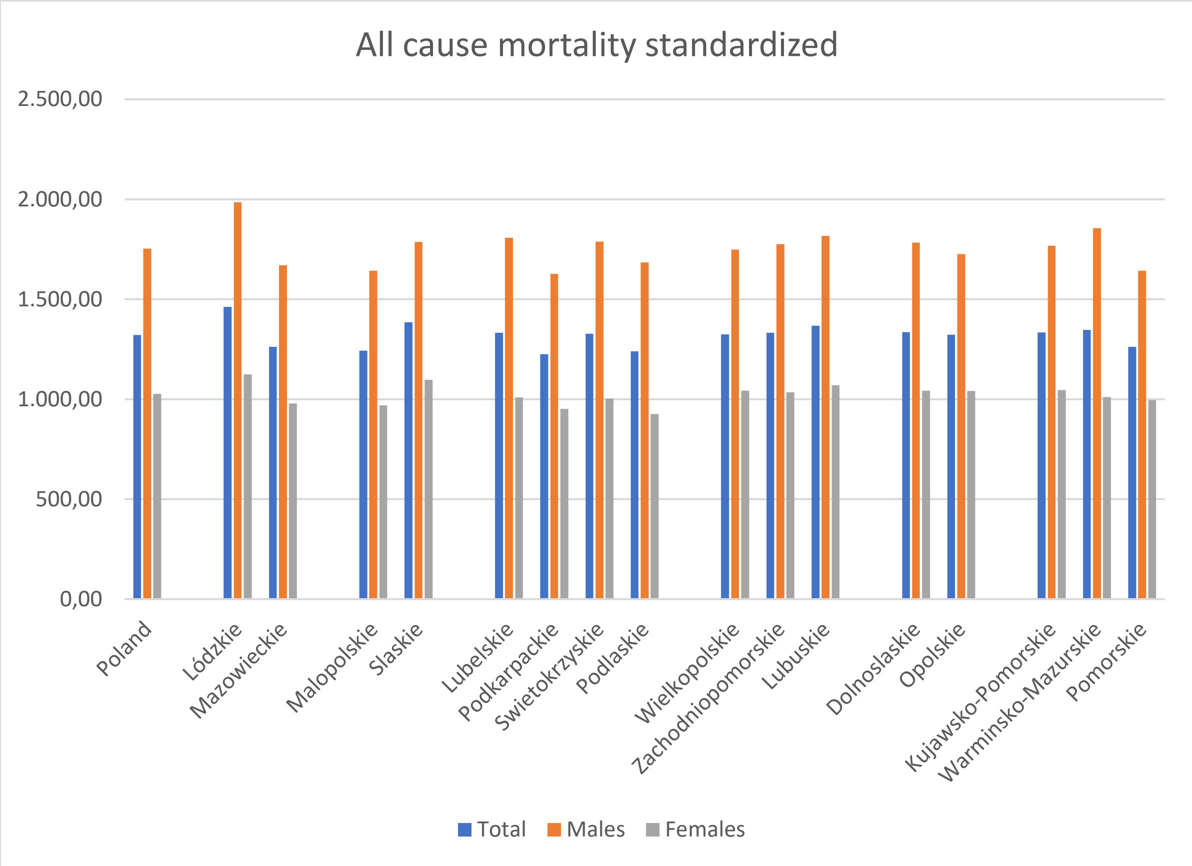
Data source: Central Statistical Office Poland (2016)

This shows Slaskie is by far the most polluted region when it comes to both particulate matter pollution and gaseous air pollution (see figure 9 and 10). At the gaseous air pollution (see figure 10), Lodzkie and Opolskie are also very polluted. At PM pollution there is not so much dispersion aside from Slaskie. Knowing this, the highest prevalence of lung cancer, asthma, respiratory diseases, and circulatory diseases is expected in Slaskie, and also a high prevalence in Lodzkie and Opolskie is expected.

Mortality and air pollution related mortality in Poland

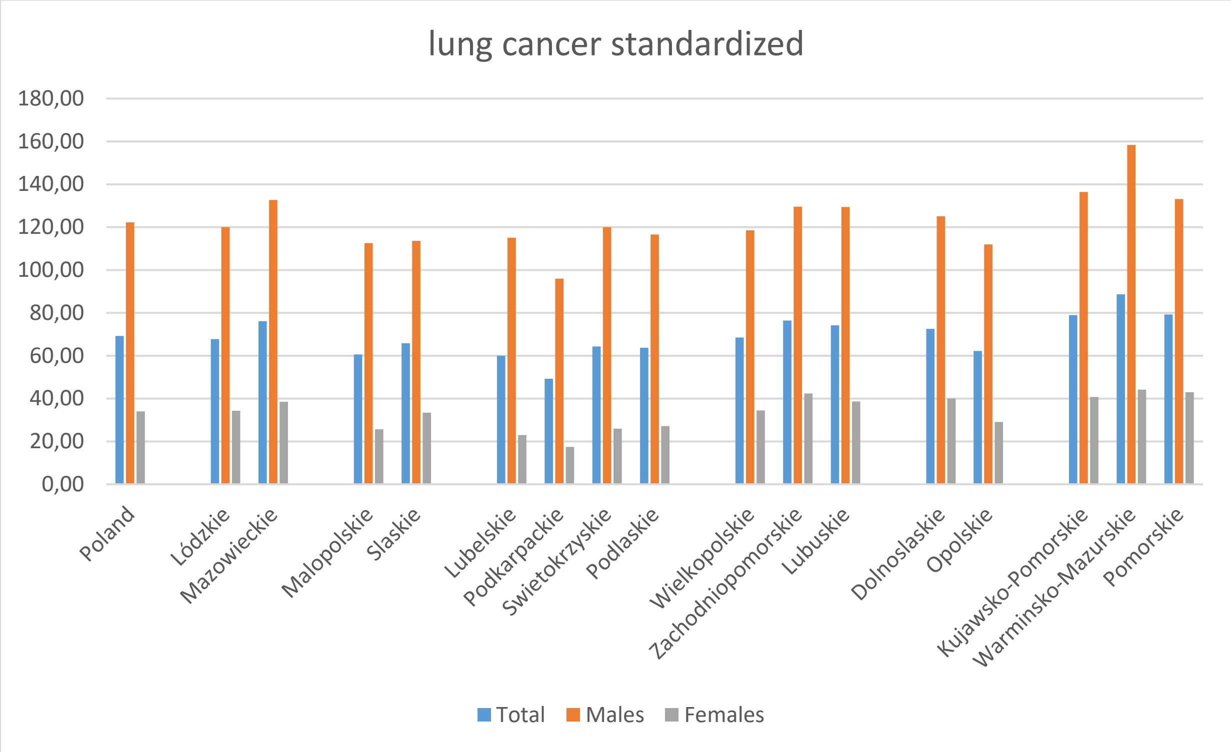
From the literature and the statistics from the Central Statistical Office Poland, it is known that cardiovascular diseases, respiratory diseases and cancer are prevailing in a relatively high extent in Poland, which could be partly explained by air pollution (Eurostat, 2016; Bobak & Marmot, 1996; Cockerham, 1999). The prevalence of these diseases is strongly differing per region, which might also be to big differences in air pollution. In the next figures graphs are shown standardized mortality rates for all-cause mortality, mortality due to lung cancer, circulatory diseases, asthma and respiratory diseases per NUTS-2 region. In this case the graphs (figures 11 until 18), also show that more men than women die in general looking at all-cause mortality, but this counts also for the specific causes of death, with exception of asthma in the regions Dolnoslaskie, Opolskie, Kujawsko-Pomorskie. This means in general but also regarding these causes of death that the health situation among women is better than among men. It also shows that Lozkie is the most unhealthy region, and Pomorskie and Podkarpackie are the healthiest regions with negligible difference.

Figure 11: All-cause mortality standardized, per NUTS-2 region in Poland, 2014



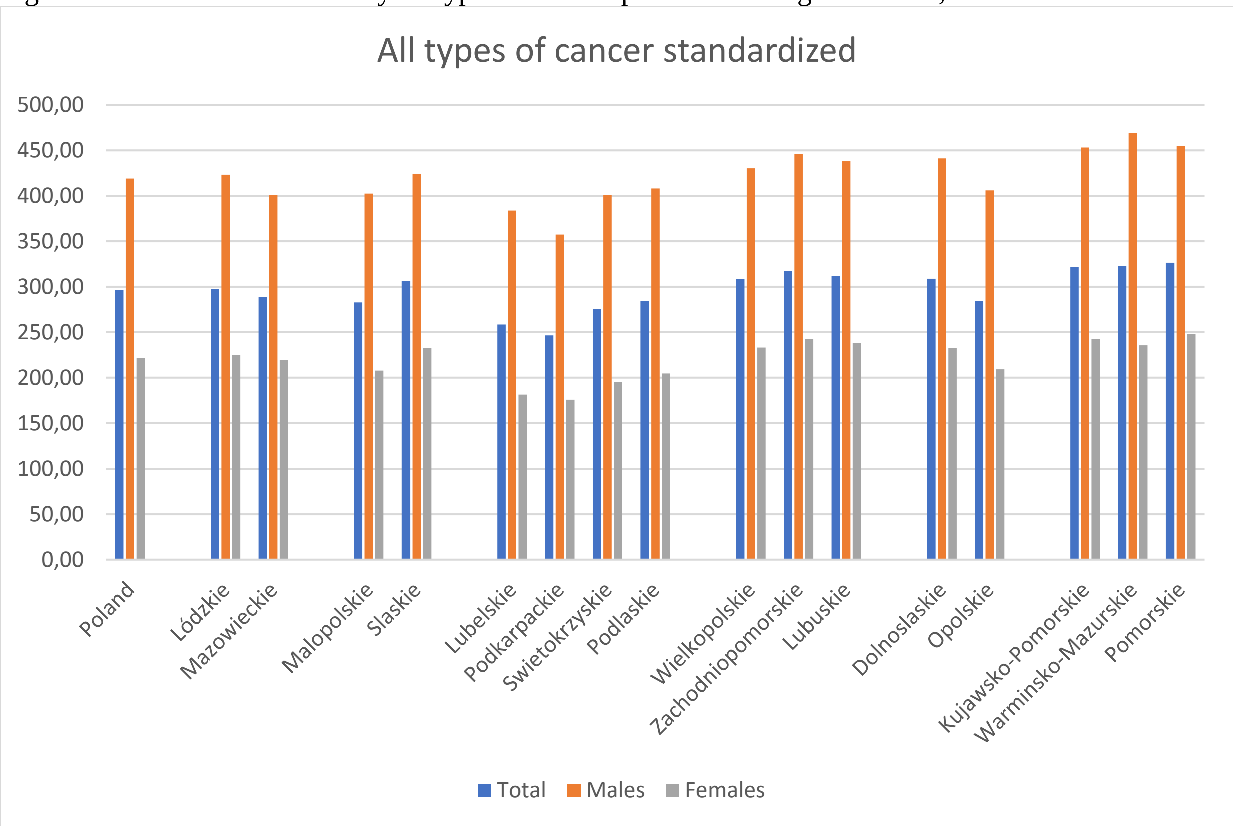
Data source: Eurostat (2016)

Figure 12: standardized mortality due to lung cancer per NUTS-2 region in Poland, 2014



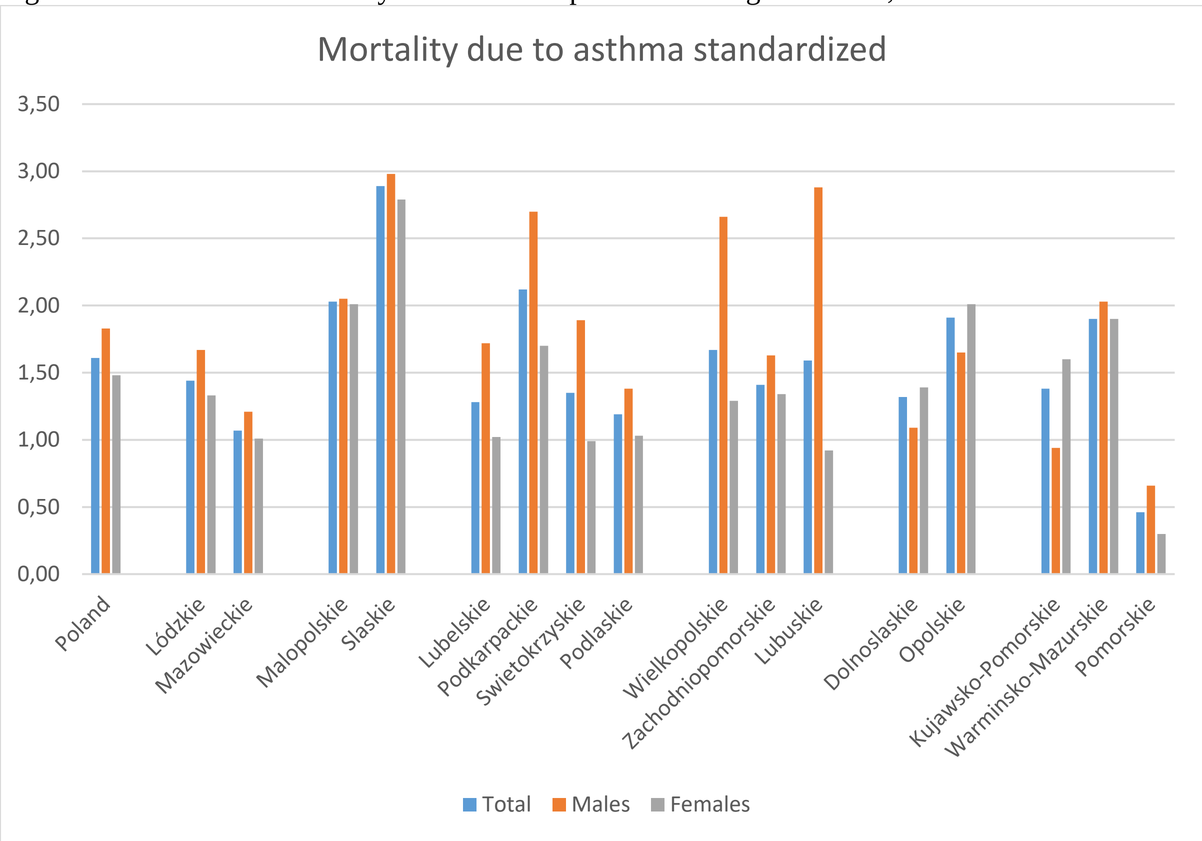
Data source: Eurostat (2016)

Figure 13: standardized mortality all types of cancer per NUTS-2 region Poland, 2014



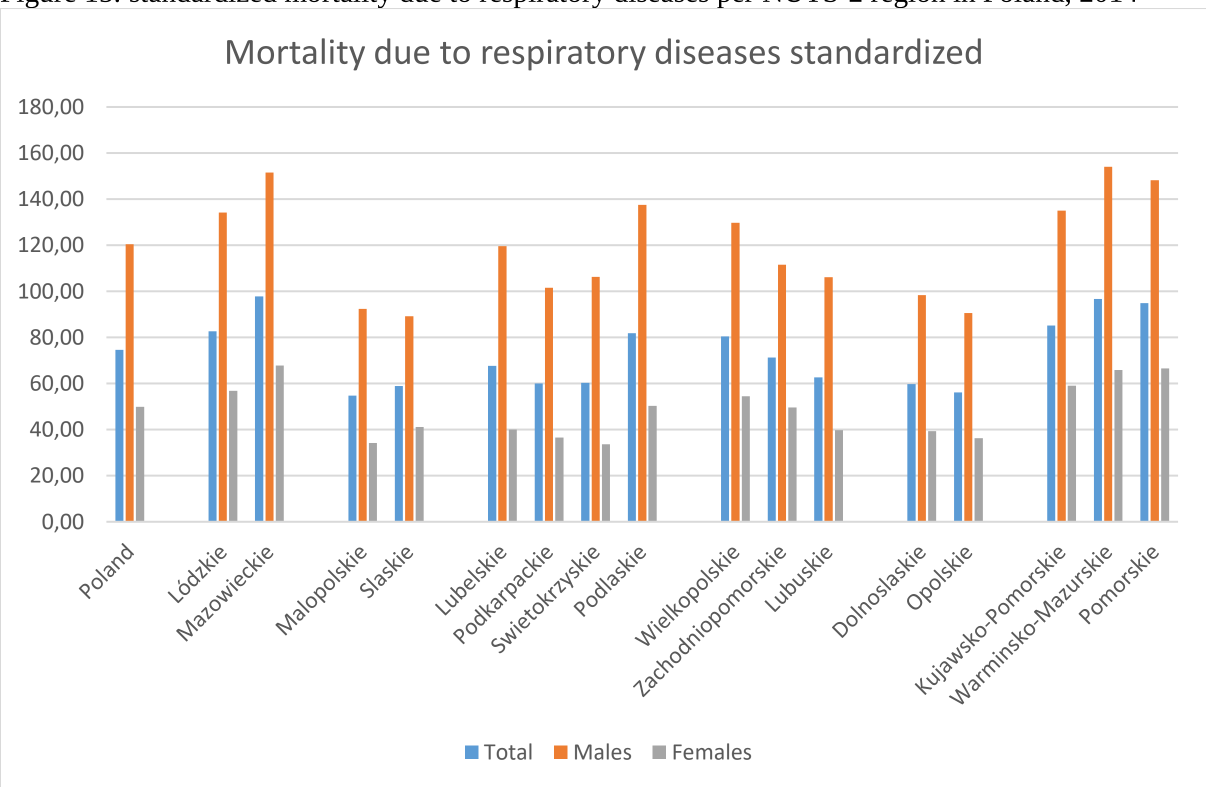
Data source: Eurostat (2016)

Figure 14: standardized mortality due to asthma per NUTS-2 region Poland, 2014



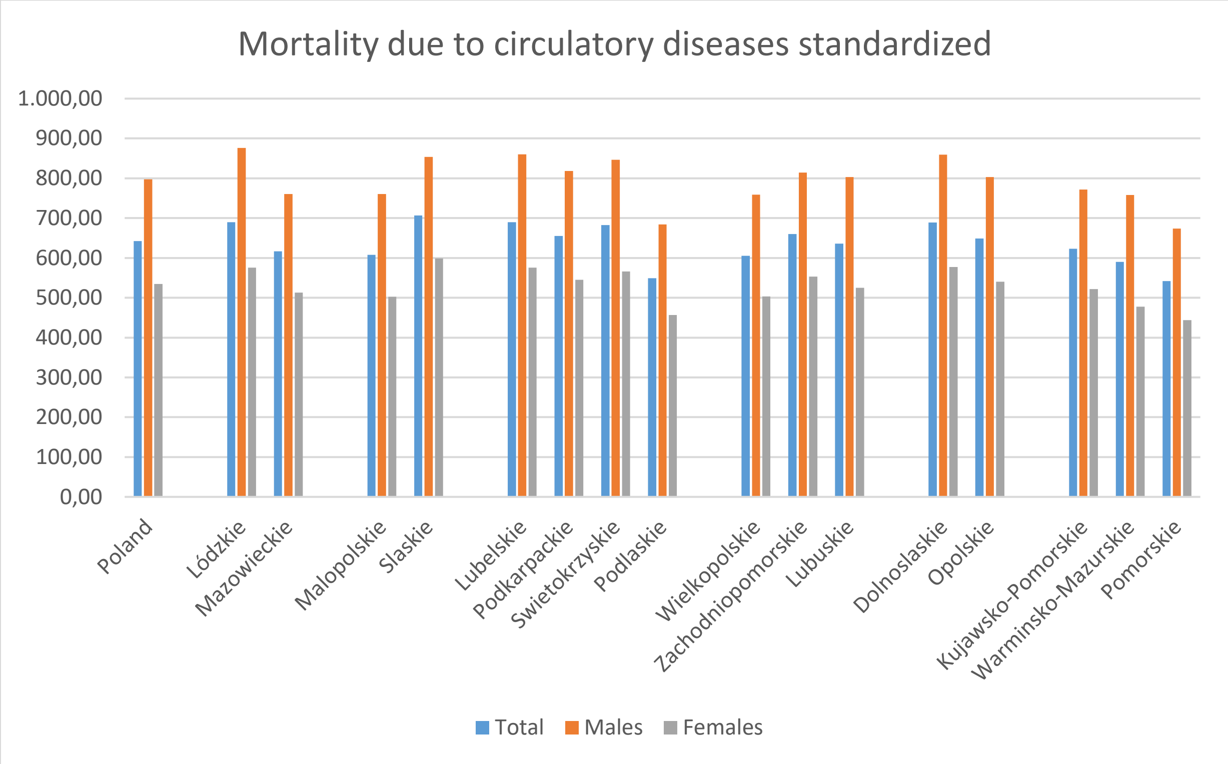
Data source: Eurostat (2016)

Figure 15: standardized mortality due to respiratory diseases per NUTS-2 region in Poland, 2014



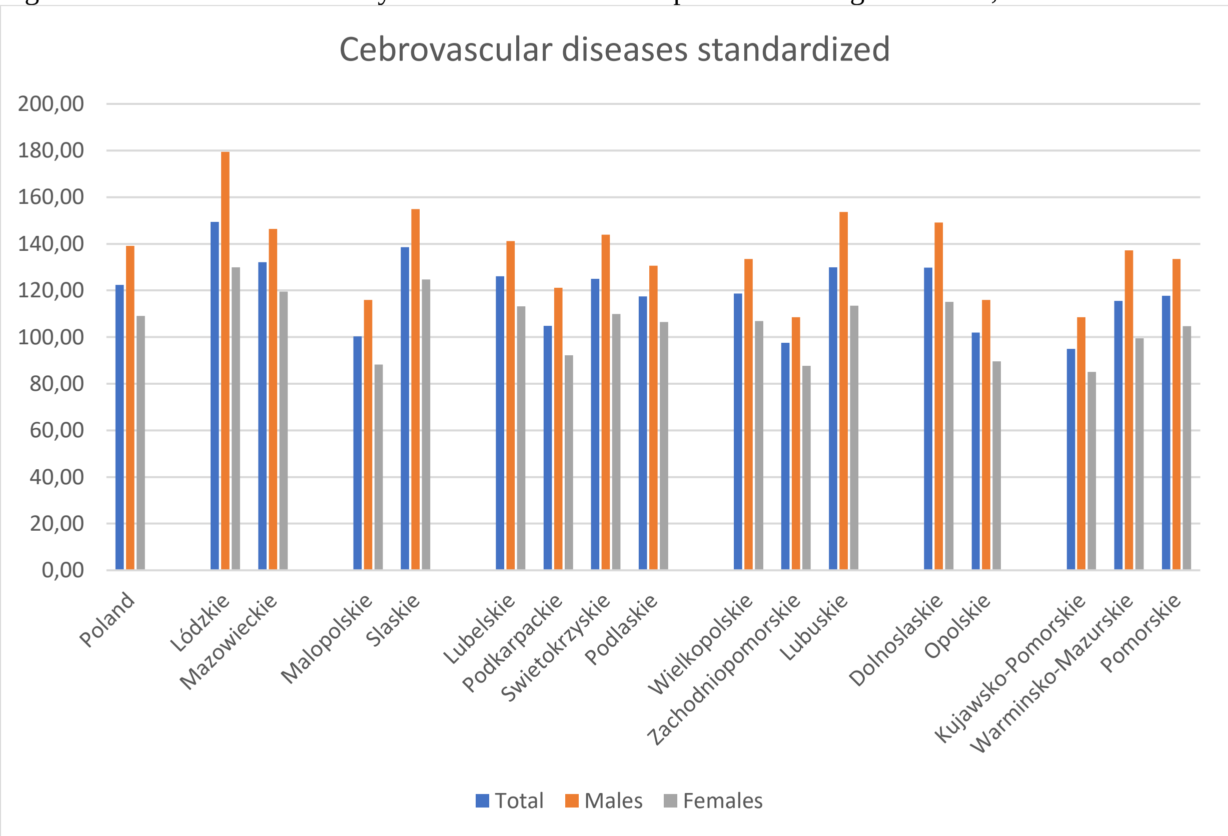
Data source: Eurostat (2016)

Figure 16: standardized mortality due to circulatory diseases per NUTS-2 region in Poland, 2014



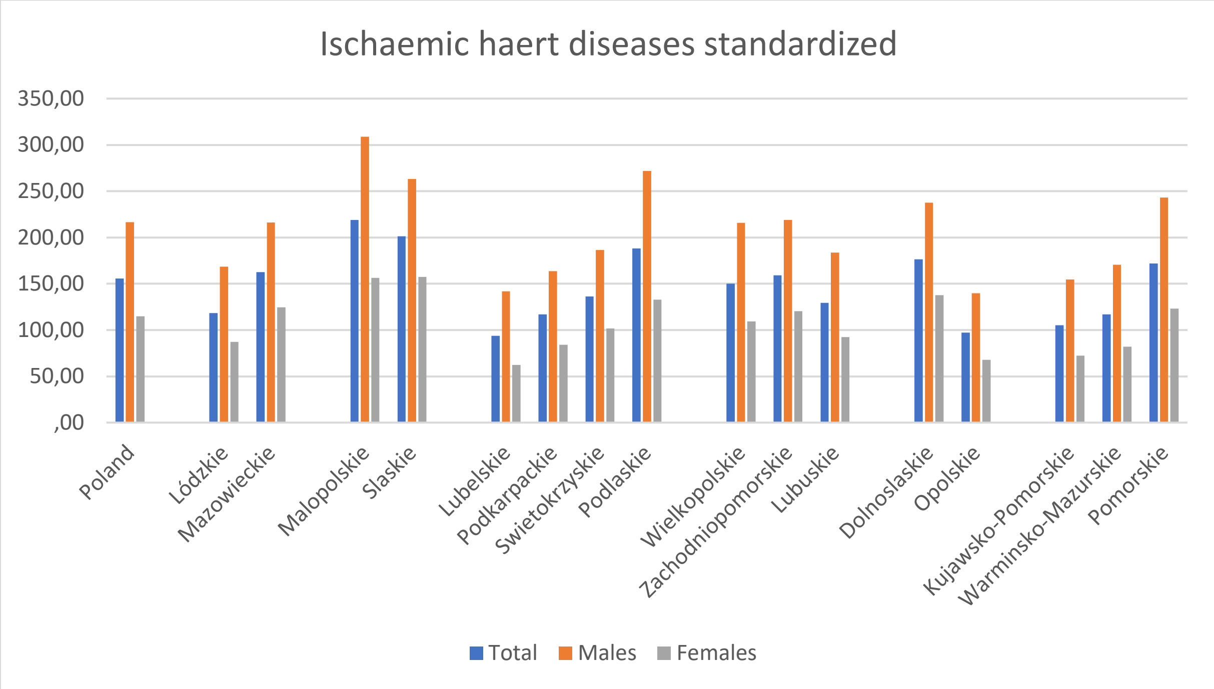
Data source: Eurostat (2016)

Figure 17: standardized mortality cebrovascular diseases per NUTS-2 region Poland, 2014



Data source: Eurostat (2016)

Figure 18: standardized mortality ischaemic heart diseases per NUTS-2 region Poland, 2014



Data source: Eurostat (2016)

Looking at the graphs it is hard to see whether any type of pollution is related to any cause of death. But it shows anyway that also like the air pollution, the cause of death rates do strongly differ per region. By looking at the graphs asthma might be related to both types air pollution as Slaskie has also by far the highest mortality rate due to asthma, but aside from that there is no clear correlation visible. Other correlations are not visible with these graphs. Therefore regressions need to be performed. Firstly, by running the correlations and secondly, by multiple regression analyses. Correlations to test whether some causes of death are correlated with the types of air pollution separately, and a multiple regression to see whether the different types of pollution and confounding variables together are related to the specific cause of death, also to exclude bias (Skelly et al., 2012).

In order to run the linear regression, the types of air pollution as dependent variables are defined as: ‘particulate matter pollution’ and ‘gaseous air pollution’. For these variables the average pollution is taken from the years 2010-2014. As mentioned before the types of air pollution cannot be specified more due to the availability of the data. And for the independent variables, serve the standardized cause of death rates, which are: all-cause mortality, all types of cancer, lung cancer, asthma, respiratory diseases, circulatory diseases, cebrovascular diseases and ischaemic heart diseases.

Results from the analyses

At the correlations, the cause of death rates serve as dependent variables and the two types of air pollution serve as independent variables. The first correlation is tested for all-cause mortality, followed by all types of cancer, lung cancer, asthma, respiratory diseases, circulatory diseases, cebrovascular diseases, circulatory diseases and ischeamic heart diseases. In order to read the results you have to look at the significance level and eventually at the Pearson correlation. With a confidence interval of 95%, outcomes below 0.05 show a significant correlation. For the Pearson correlation counts that the closer to one, the stronger the correlation (Skelly et al., 2012).

All-cause mortality

Looking at all-cause mortality with 95% confidence interval (see appendix 3), there is significant relationship between gaseous air pollution and the life expectancy among females, both for life expectancy at birth as well as life expectancy at 60.

Also is shown that gaseous air pollution and PM pollution are correlated, which is obvious as in the more polluted areas there is both more gaseous air pollution as well as PM pollution.
Figures 19, 20, and 22 show scatter plots for the correlation between gaseous air pollution and all-cause mortality among females, the female life expectancy at birth and the female life expectancy at 60 years old. And figure 21 shows a scatter plot for the correlation between PM pollution and all-cause mortality among females.

Figure 19: gaseous air pollution (ton per cubic meter per year) and the female life expectancy (in years), significant at 95% confidence interval

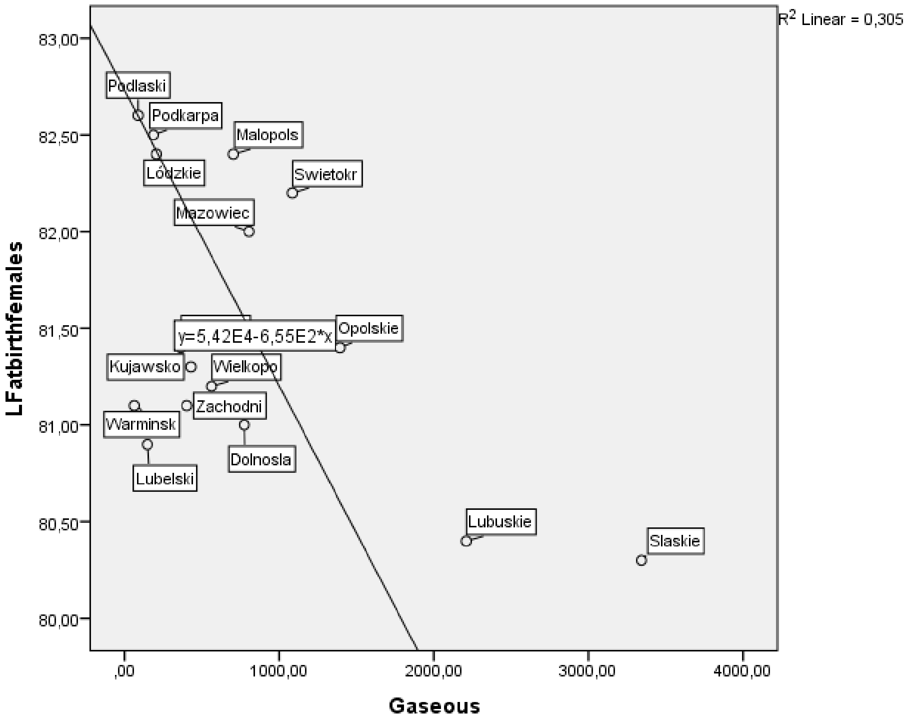


Figure 20: gaseous air pollution (ton per cubic meter per year) and the female life expectancy at 60 years old (in years), significant at 95% confidence interval

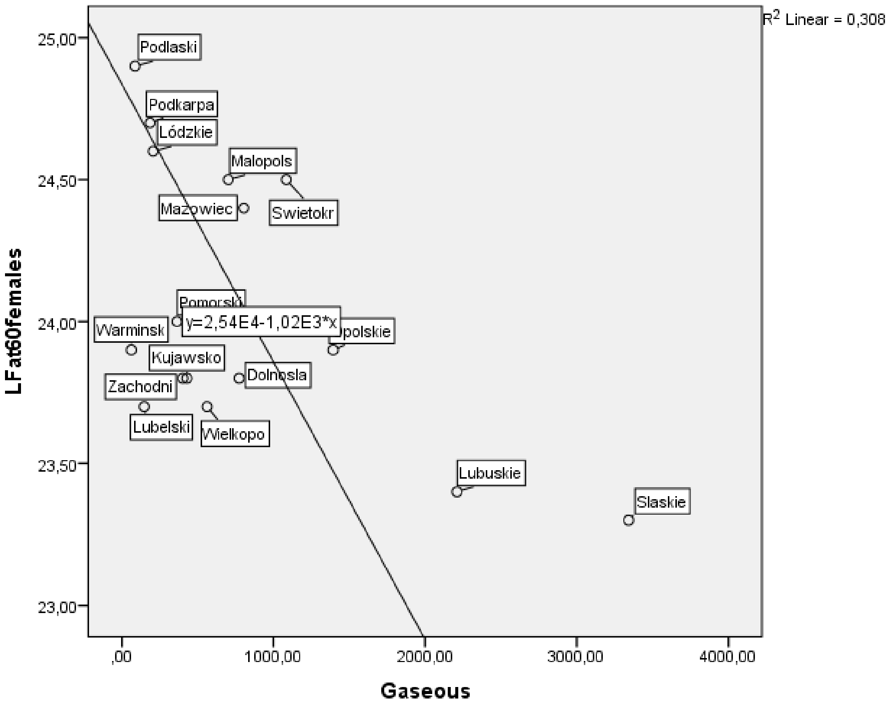


Figure 21: PM pollution (ton per cubic meter per year) and all-cause mortality among females (deaths per 100,000 population), significant at 95% confidence interval

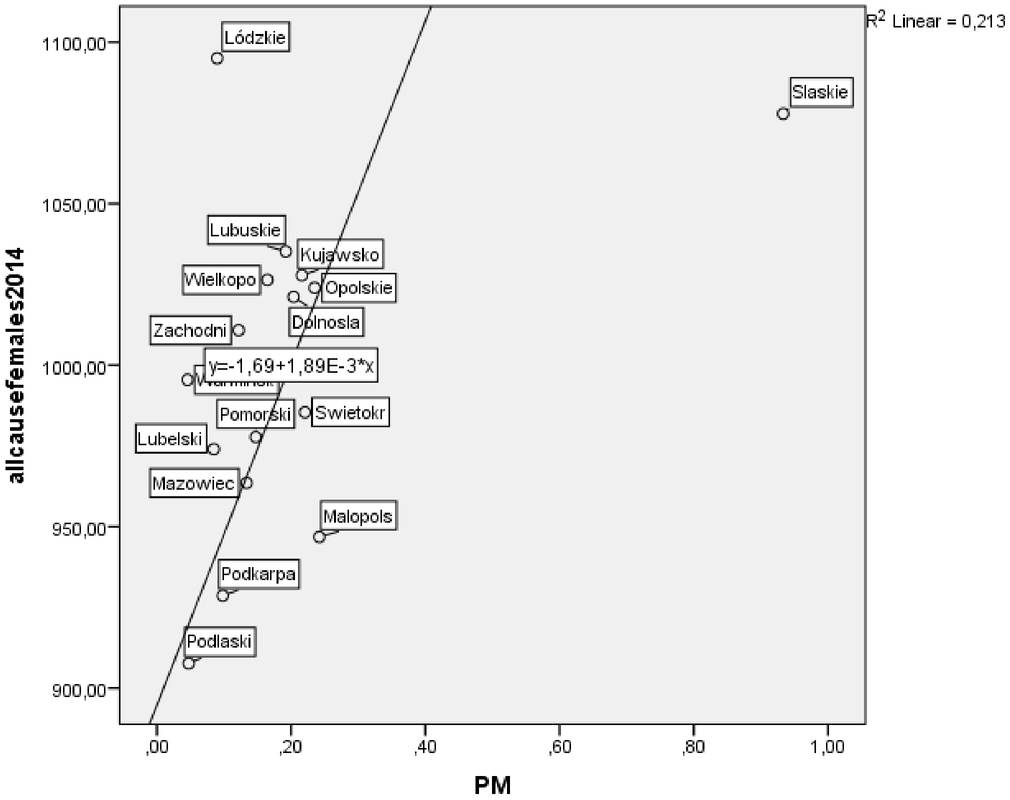
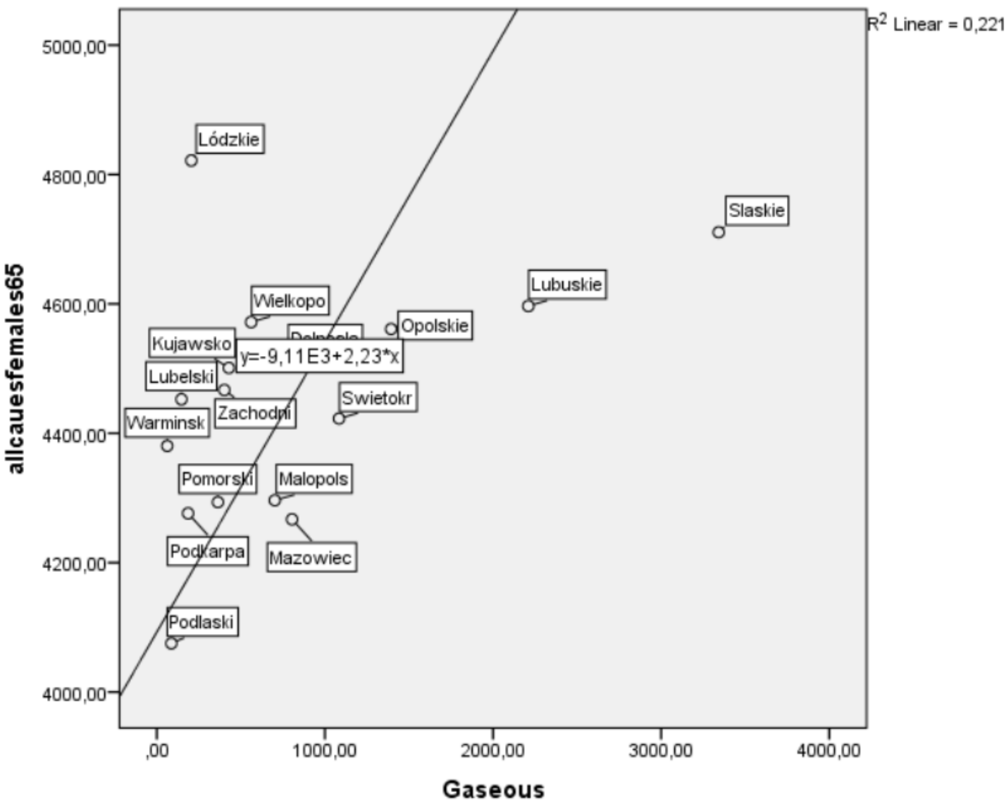
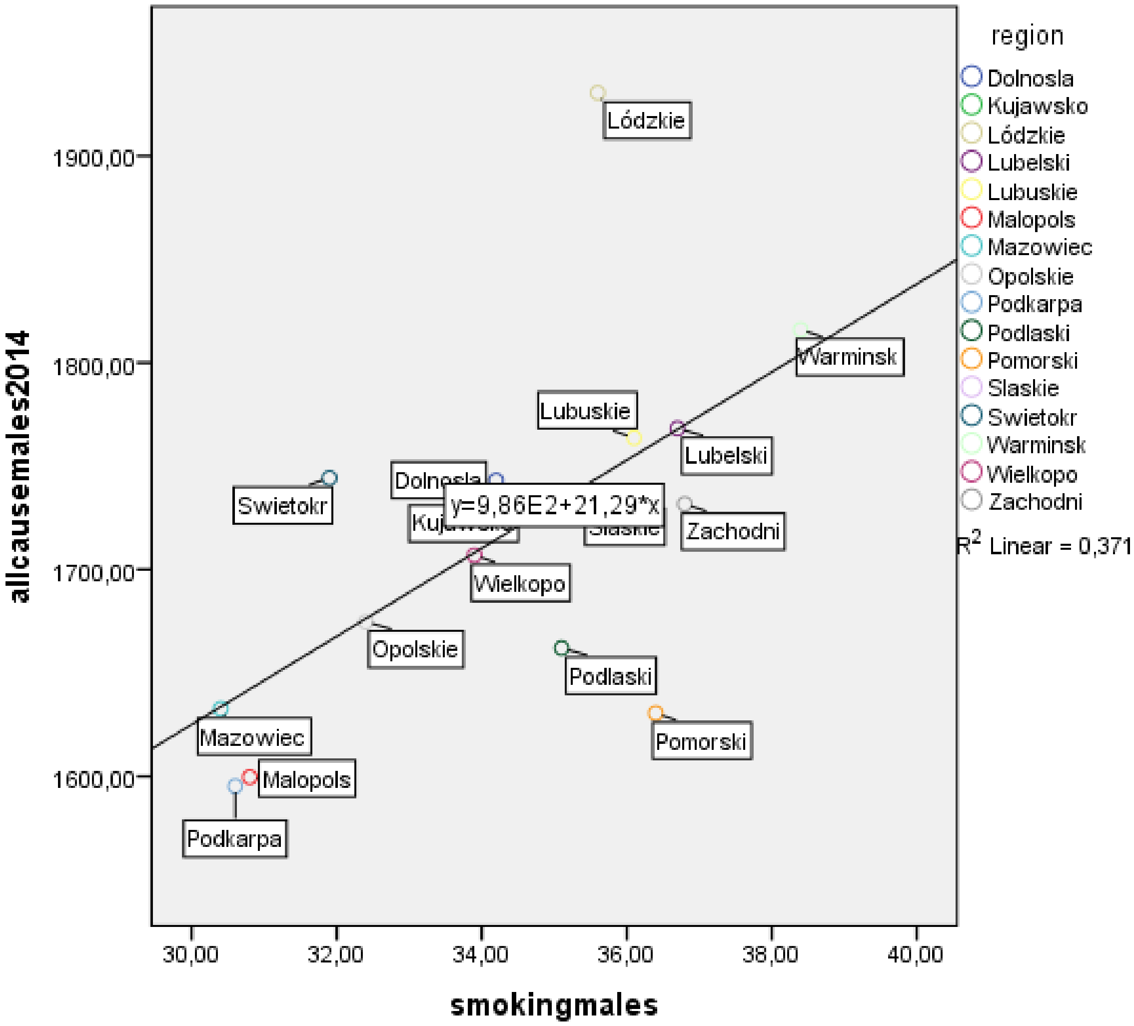


Figure 22: gaseous pollution (ton per cubic meter per year) and all-cause mortality among females (deaths per 100,000 population), significant at 95% confidence interval



Looking at lifestyle factors, smoking has a significant correlation with all-cause mortality among males at all ages as well as with all-cause mortality of males above 65, with a confidence interval of 95%. Also there is a significant negative correlation between smoking and the life expectancy, this counts both for males and for females. It counts for both life expectancy at birth and life expectancy at 60, this relationship is for females somewhat stronger looking at the Pearson correlation. There is no relationship found between alcohol and all-cause mortality or the life expectancy. Among females there is a significant relationship between overweight and all-cause mortality, this counts however only for females. Figure 23 shows the correlation between smoking and all-cause mortality among males.

Figure 23: All-cause mortality (deaths per 100,000 population) and smoking (tobacco consumption in kg per year per person) among males

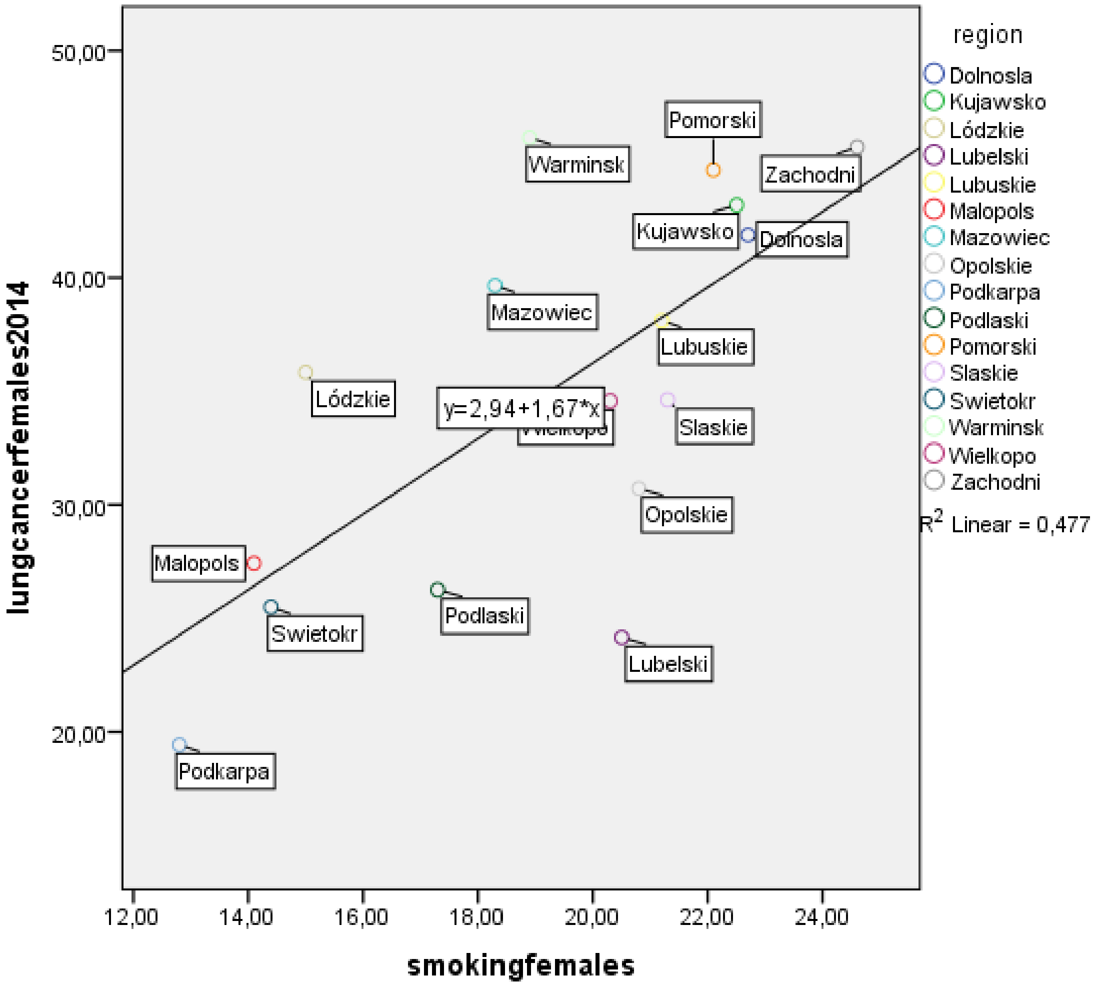


From this can be concluded that it seems likely that smoking has a stronger correlation with all-cause mortality than air pollution, or any other confounding variable. Among females overweight has a stronger correlation with all-cause mortality than air pollution. Interesting however is that in this case air pollution seems to have a stronger relationship with all-cause mortality than alcohol usage. This makes it likely that air pollution is also a significant factor on mortality. The next step is to test both types of air pollution with different causes of death, which might be related to air pollution. In this way the effects of air pollution become more clear.

Lung cancer

Looking at lung cancer (appendix 4), with a confidence interval of 95%, it is striking there is no significant relationship between air pollution and lung cancer as you might expect, not with PM pollution, neither with gaseous air pollution. The outcomes are not even coming close to significant outcomes. But there is a clear correlation between smoking and lung cancer (see figure 24), this counts both for males as well as for females. The only difference is that the relationship is for females stronger than for males. Therefore we can conclude that air pollution does not seem to have a significant effect on lung cancer, whereas it seems very likely that smoking has an effect on lung cancer.

Figure 24: Smoking (tobacco consumption in kg per year per person) and lung cancer mortality (deaths per 100,000 population) among females



Asthma

Looking at asthma (appendix 5), at a 95% confidence interval, there are only relationships with asthma aged 65 and older. Both for PM pollution and gaseous air pollution there is a significant relationship with asthma at age 65 and above for both sexes and for females (see figures 25 and 26). For PM pollution the relationship is stronger than for gaseous air pollution. Striking is that for PM pollution there is a relationship with asthma among females aged 65 and older, whereas for gaseous air pollution there is a relationship between asthma among males aged 65 and above. For asthma at all ages for either both sexes or females, the outcomes are not significant, but at least close to a significant outcome.

This indicates that air pollution seems a significant factor on mortality due to asthma. The fact that asthma above 65 is more significant than asthma at all ages is probably due to the fact that people above 65 are much more susceptible to die from asthma, as mentioned before (Goueiva & Fletcher, 2000; Brauer, 2007). If there was only tested for the prevalence of asthma at all the ages the pattern would have been different probably, and it is likely the outcome would have been significant, or at least more close to a significant outcome (Goueiva & Fletcher, 2000).

Figure 25: PM pollution (ton per cubic meter per year) and asthma at 65 years and older (deaths per 100,000 population)

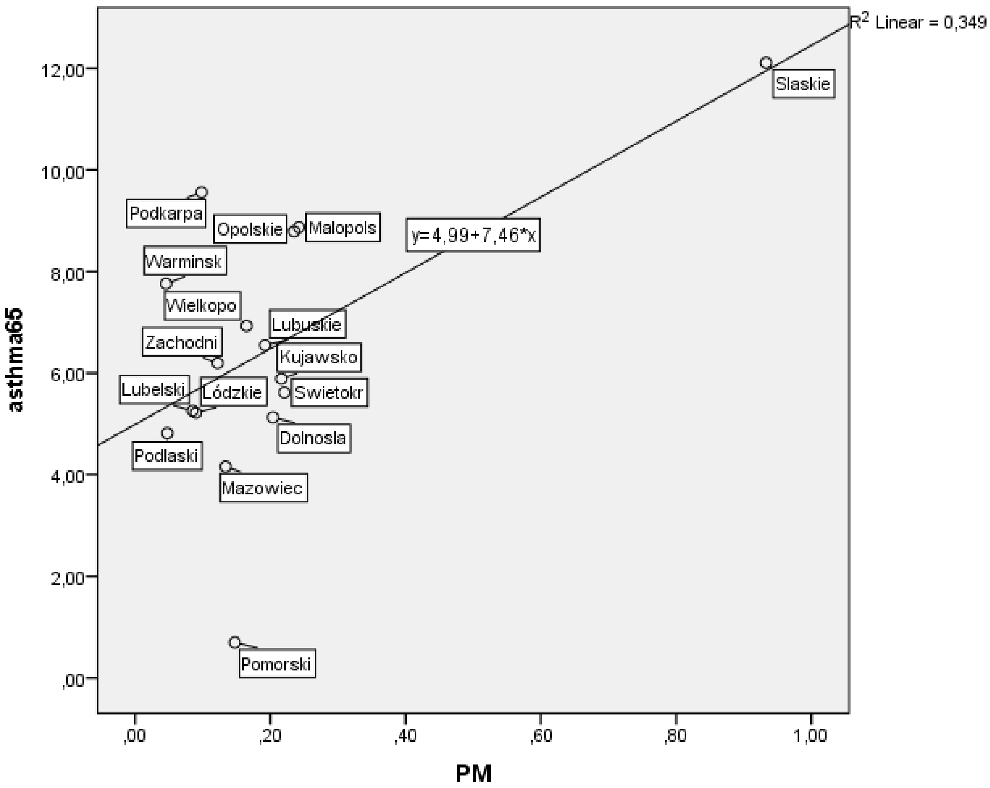
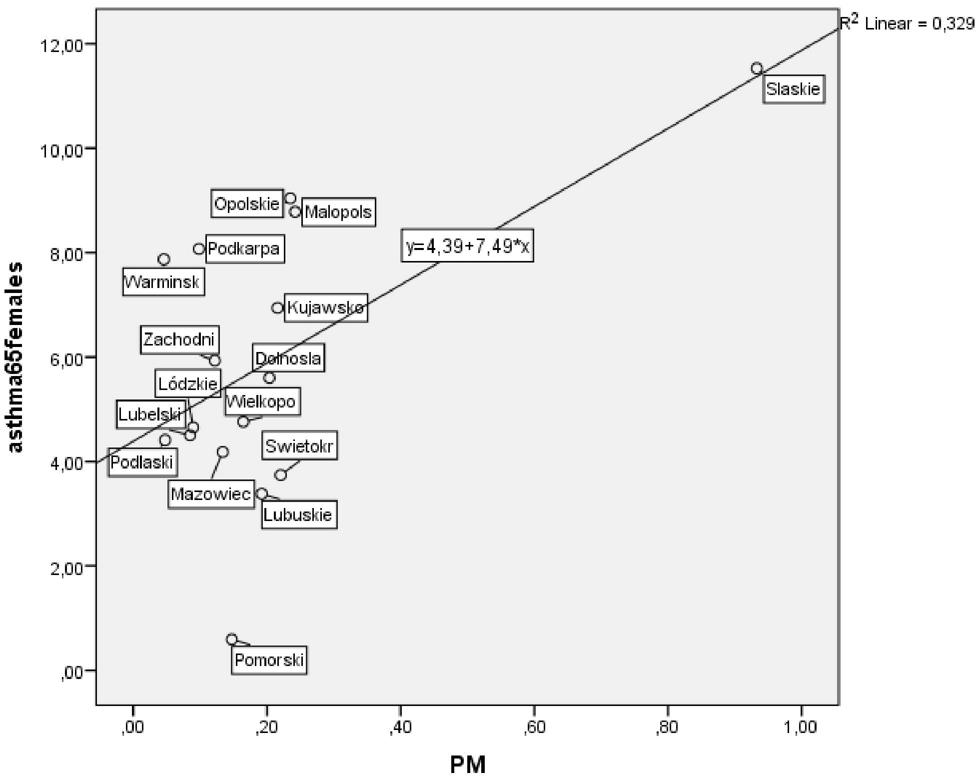


Figure 26: PM pollution (ton per cubic meter per year) and asthma among females 65 years and older (ton per cubic meter per year)



All types of cancer

For all types of cancer (appendix 6), with a confidence interval of 95%, only smoking has a correlation with cancer, smoking correlates with cancer mortality rates at all ages and also with cancer mortality rates above 65, and it counts for both males and females. From this analysis cannot be concluded that air pollution has a significant effect on cancer. Neither it did on lung cancer more specifically. But it can be concluded that smoking seems to have a significant effect on cancer. At least can be concluded that smoking has a stronger effect on (lung) cancer than air pollution, however it is not known how the pattern would have looked like without the existence of smoking. This analysis also shows that smoking and air pollution are not correlated which excludes bias.

Respiratory diseases

For respiratory diseases (appendix 7), at a 95% confidence interval, there is a correlation between PM pollution and respiratory diseases for males at 65 and above (see figure 27). Gaseous air pollution has significant relationships with respiratory diseases for males at all ages, respiratory diseases for both sexes at 65 and above (see figure 28), and respiratory diseases for males at 65 and above. The correlation is stronger for males at 65 and higher than for males at all ages. The correlations are also shown in the graphs in figures 23, 24 and 25, with respiratory diseases at the x ax and gaseous pollution at y ax. Here is also shown that the correlation is negative, which would indicate the more gaseous air pollution, the less respiratory diseases. Also striking is that there is no relationship for respiratory diseases among females separately, and also that there is no correlation between smoking and respiratory diseases as you might expect. According to this analysis gaseous air pollution has a stronger negative correlation with respiratory diseases than PM pollution, and the negative correlation is stronger among people above 65. It seems likely this would be a matter of negative bias, which might be due to smoking. This would be the case if people smoke more in the less polluted regions. If this is the case there must be a negative correlation between smoking among men and gaseous air pollution. However by looking at the correlations, this is not the case. It also might be that gaseous air pollution is positively related to the general health situation due to other factors than pollution. This should result in a positive correlation between gaseous air pollution and the life expectancy among males (at 65 and above), and a negative correlation between gaseous air pollution and all-cause mortality rate among men (at 65 and above). But by looking at the correlations the opposite is true for all of them, so this cannot be the case either (see also appendix 7). As mentioned before, mortality is lower in the urbanized areas, but at the same time the urbanized areas are also the most polluted areas. The reason for this is that in urban areas people have a higher socio-economic status and also better access to healthcare. This could explain the negative relationship between respiratory mortality and gaseous air pollution. Especially the better access to healthcare could explain why respiratory mortality is lower in urban areas, despite the prevalence of more pollution. More respiratory mortality does not necessarily equal more respiratory disease, that depends also on healthcare (Muszyńska et al., 2015).

Figure 27: gaseous air pollution (ton per cubic meter per year) and respiratory diseases among males at 65 and older (deaths per 100,000 population)

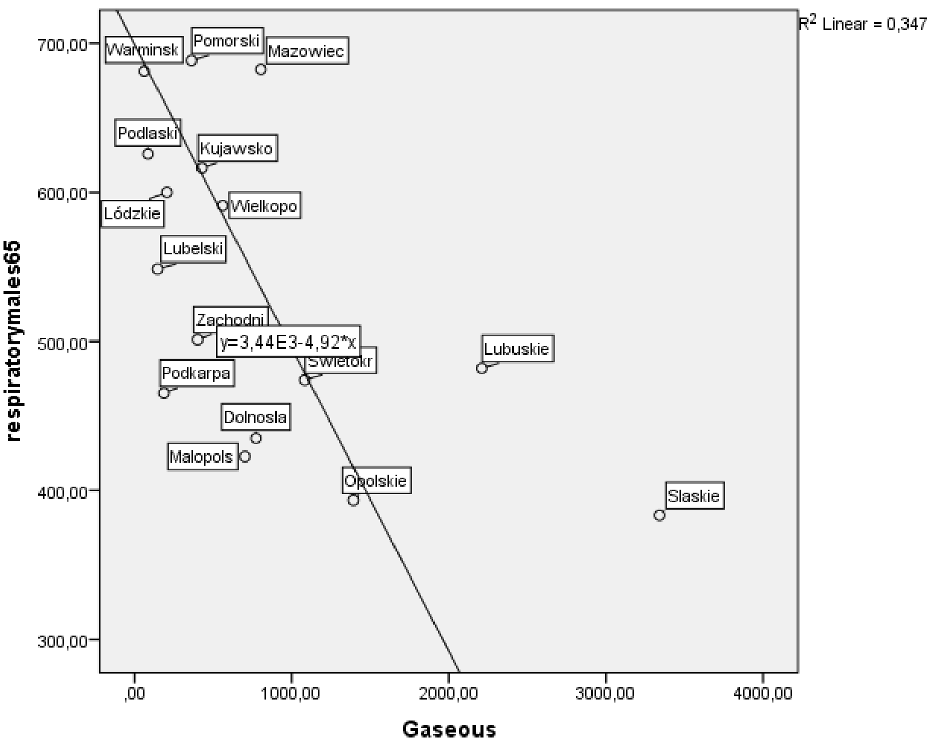
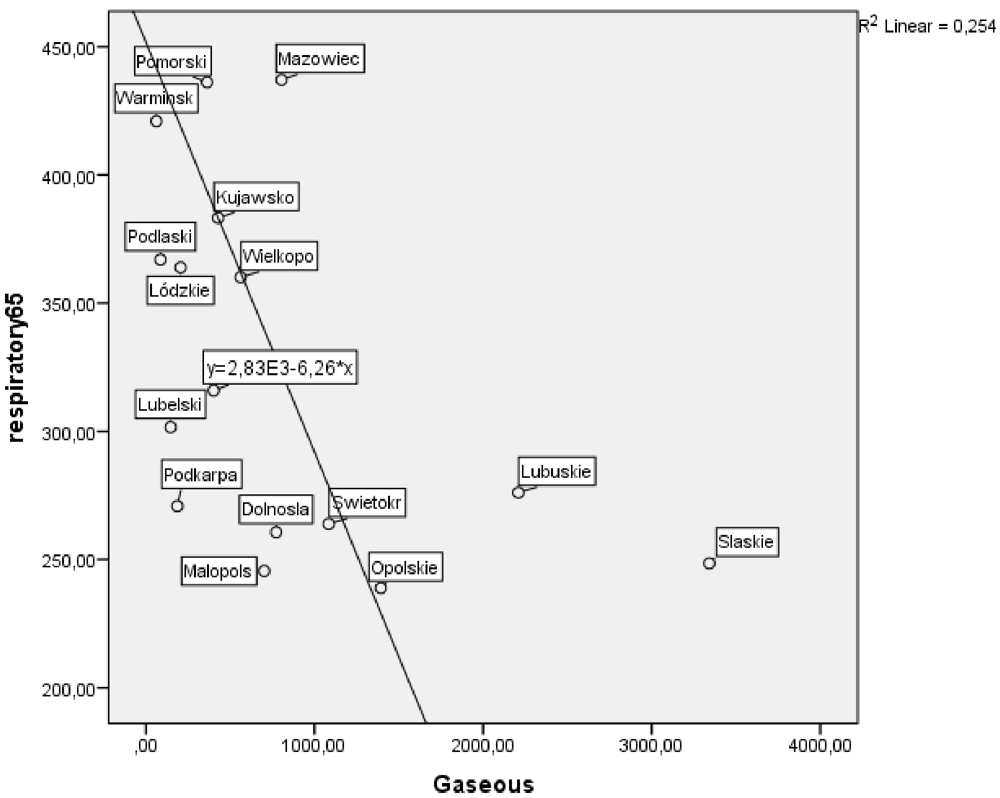


Figure 28: Gaseous air pollution and gaseous air pollution (ton per cubic meter per year) and respiratory diseases at 65 and older, both sexes (deaths per 100,000 population)

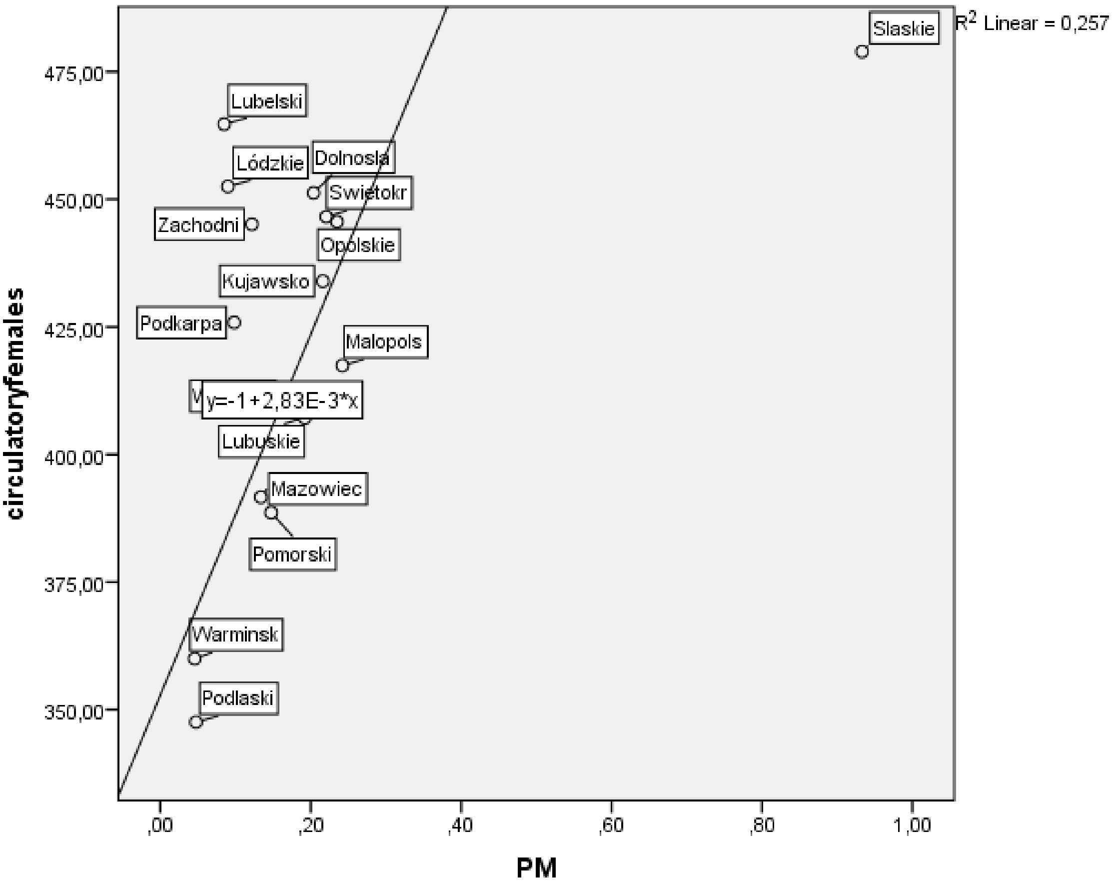


Ischaemic heart diseases
At a 95% confidence interval, looking at ischaemic heart diseases (appendix 8), only a significant correlation is found between the consumption of alcohol among females and ischaemic heart diseases. No relationship was found between ischaemic heart diseases and gaseous air pollution neither with PM pollution. It seems likely that air pollution has no effect or barely an effect on ischaemic heart diseases. Neither a correlation with smoking was shown.

Cebrovascular diseases
Looking at cebrovascular diseases and air pollution with a confidence interval of 95% (appendix 9), there are no correlations between air pollution and cebrovascular diseases. The only correlation found is between female overweight and cebrovascular disease. From this can be concluded that air pollution does not seem to affect mortality due to cebrovacular diseases.

Circulatory diseases
Looking at circulatory diseases and air pollution with a confidence interval of 95% (appendix 10), there is a correlation between PM pollution and circulatory diseases among females (see figure 29). It is known from the literature that PM pollution affects circulatory diseases in a much stronger extent than gaseous air pollution, so this outcome is expected (Pope at al., 2004; Pope et al., 2002). Striking however is that there is only a correlation between circulatory diseases among females. But even more striking is that there is no correlation between circulatory diseases among females over 65, as you would expect there even a higher correlation, as people above 65 are more susceptible to die from circulatory diseases due to PM pollution (Pope at al., 2002).

Figure 29: PM pollution (ton per cubic meter per year) and circulatory diseases among females at all ages (deaths per 100,000 population)



In short, looking at the correlations, mortality due to asthma and circulatory diseases seem to be related to air pollution. Mortality due to (lung) cancer, cebrovacular diseases and ischaemic heart diseases do not seem to be related to air pollution. For the latter smoking seems to have a much stronger effect. Looking at this analysis, smoking has the strongest correlation with all-cause mortality. For females the second strongest correlation with all-cause mortality is overweight. For males the second strongest correlation and for females the third strongest correlation with all-cause mortality is air pollution. Air pollution is a stronger correlated to mortality than alcohol. From this analysis you cannot conclude whether PM pollution is more harmful than gaseous air pollution, it only seems likely as PM pollution shows a stronger correlation with mortality. PM pollution seem to affect circulatory diseases and gaseous air pollution does not seem to affect. At least the literature says that PM pollution is more harmful than gaseous air pollution (Andersson et al., 2007; Goueiva & Fletcher, 2000). However, from this analysis no strong conclusions can be drawn as there is not tested yet for confounding variables (Skelly, 2012). Interesting is that more often significant outcomes are found for females than for males regarding mortality due to air pollution. This might be due to the fact that women live healthier (Ross & Bird, 1994). Also looking at the statistics used for this analysis can be seen that women behave healthier than men, looking at alcohol consumption, smoking behaviour and overweight. This might explain why air pollution seem to affect mortality among women in a higher extent than among men. Among men the effects of air pollution are more disrupted by lifestyle factors such as smoking (Ross & Bird, 1994; Salas, 1999).

Multiple regression analysis

In the previous analyses correlations were shown to see the relationships between two variables separately. In the next analysis a multiple regression analysis will be done. A multiple regression tests whether multiple independent variables show a relationship with a dependent variable (Skelly, 2012). So in this case whether the types of air pollution and the confounding variables together show a relationship with specific cause of death rates.

In this research cause of death rates for both sexes, males and females will be performed separately, too see whether there are differences between sexes. Also cause of death rates aged 65 and above will be performed separately, and also for both sexes, males and females. To see whether there are differences between mortality at all ages and people above 65.

The next tables show the outcomes of the multiple regression analysis. Every table has one specific cause of death and exists of six dependent variables, the specific cause of death for both sexes at all ages respectively males at all ages, females at all ages, both sexes at 65 and older, males at 65 and older, and females at 65 and older. In this way all the coefficients and t tests are put in one table. The stars mark whether the outcome is significant with a significance level of 0.90, 0.95 respectively 0.99.

Below the F statistic is shown, also marked with stars, which shows whether the model itself is significant. Also below the R square and the adjusted R square are shown. For the R square the closer the value is to one, the better the model predicts the dependent variable (Skelly, 2012).

In this way, results of 8 tables per cause of death obtained from SPSS, are summarized into one table, to give a more clear overview. The output from SPSS, which also contains, ‘the significance level’, ‘the Beta standardized’, and the ‘standard error’, is shown in appendix 11.

All-cause mortality

Looking at the multiple regression analyses for all-cause mortality (see table 4), only smoking among males at all ages is significant. So only smoking among males seems to be a significant factor on all-cause mortality. In this analysis air pollution does not seem a significant factor on all-cause mortality. The fact that smoking is only significant for males might be due to the fact that males smoke more than females in Poland (Central Statistical Office Poland, 2016). Striking in the first instance is that smoking is not significant for males at 65 and above, this might be due to the fact that the available confounding factors are for all ages, unfortunately there are no data available for the lifestyle factors at 65 years and older, neither income. The fact that smoking is significant, is line with the previous analysis. However in this analysis are no significant outcomes found for gaseous pollution and PM pollution, which was the case in the previous analysis. This could be due to collinearity between both types of pollution, as

shown in appendix 3, gaseous air pollution and PM pollution are correlated (Skelly, 2012). As shown in the previous analysis there is no collinearity between the different lifestyle factors and income.
None of the models of all-cause mortality is significant, which means that no conclusions can be made from the interpretation as there are no suitable models to predict the dependent variable all-cause mortality.

Table 4 Regressions on all-cause mortality and air pollution

All-cause mortality	both sexes		males		females		65+ Both sexes		65+ males		65+ Females	
Constant	902,274**	(2,405)	1198,092*	(2,075)	618,434**	(,027)	4826,472***	(3,886)	6554,613***	(3,399)	3435,074**	(3,399)
PM pollution	33,454	(,186)	-263,697	(-,956)	50,714	(,677)	46,296	(,078)	-976,560	(-1,059)	137,591	(-1,059)
Gaseous pollution	,018	(,403)	,072	(1,110)	,014	(,644)	,098	(,673)	,281	(1,300)	,070	(1,300)
Income	-,017	(-,350)	,002	(,032)	-,008	(,872)	-,159	(-,978)	-,206	(-,888)	-,098	(-,888)
Smoking	8,878	(1,342)	27,135**	(2,549)	4,506	(,242)	22,317	(1,019)	-131,819	(-1,023)	9,817	(-1,023)
Alcohol	-34,244	(-,719)	-42,365	(-1,098)	-41,631	(,713)	-113,672	(-,720)	-27,491	(-,654)	-111,940	(-,654)
Overweight	9,371	(,855)	-7,214	(-,573)	12,439	(,118)	23,745	(,654)	75,382*	(2,119)	43,722	(2,119)
F statistic	,845		1,387		1,629		,972		1,575		1,291	
R square	,360		,480		,521		,393		,512		,463	
Adj. R square	-,066		,134		,201		-,011		,187		,104	

This table shows the regressions (with the coefficients),estimating all-cause mortality (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

All types of cancer
For the multiple regression analyses of all types of cancer (see table 5), only a significant outcome for smoking was found. This counts also for both males and females, and as well for mortality above 65 for both males and females. And in case of the males, it is obviously more significant than with all-cause mortality as smoking is generally strongly associated with cancer (Nyberg et al., 2000). There does not seem to be a correlation between cancer and air pollution, this was also shown in the correlations. Here it seems that smoking is a significant factor on cancer. It does not seem that air pollution is a significant factor on cancer, as all types of cancer does not show a correlation with air pollution, but does with smoking. But smoking also seems to be a much stronger factor on cancer than alcohol and overweight. None of these models are significant, which means these models are not able to predict the dependent variable 'all types of cancer'.

Table 5 Regressions on all types of cancer and air pollution

Cancer	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	130,756	(1,029)	86,947	(,467)	119,920	(1,138)	485,204	(,952)	485,204	(,952)	119,920	(1,138)
PM pollution	-5,145	(-,084)	-35,075	(-,395)	17,203	(,324)	-50,441	(-,206)	-50,441	(-,206)	17,203	(,324)
Gaseous pollution	,003	(,214)	,010	(,472)	-,002	(-,180)	,011	(,177)	,011	(,177)	-,002	(-,180)
Income	,016	(,947)	,027	(1,203)	,007	(,320)	,064	(,957)	,064	(,957)	,007	(,320)
Smoking	6,835**	(3,05)	10,324**	(3,010)	3,873**	(2,387)	26,015**	(2,895)	26,015**	(2,895)	3,873**	(2,387)
Alcohol	-10,840	(-,672)	-12,253	(-,985)	6,122	(,124)	-29,367	(-,454)	-29,367	(-,454)	6,122	(,124)
Overweight	-1,616	(-,435)	-2,051	(-,506)	-,209	(-,064)	-7,974	(-,535)	-7,974	(-,535)	-,209	(-,064)
F statistic	1,783		1,624		1,418		1,620		1,423		1,360	
R square	,543		,520		,486		,519		,487		,475	
Adj. R square	,239		,200		,143		,199		,145		,126	

This table shows the regressions (with the coefficients), estimating all types of cancer mortality (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

Lung cancer

When looking at lung cancer (see table 6), also here in all cases smoking is significant, and in none of the cases gaseous air pollution or PM pollution is significant. So it seems that smoking has a significant effect on lung cancer, whereas air pollution does not seem to have a significant effect on lung cancer. This is in line with the outcomes for all types of cancer, and also in line with the correlations. The outcomes regarding the smoking are more significant for females than for males, despite that males smoke more. Maybe this is because health among males is more disrupted by other lifestyle factors as males behave unhealthier (Ross & Bird, 1994).

Also in this case, none of the models are significant, which means these models are not able to predict the dependent variable 'lung cancer'.

Table 6 Regressions on lung cancer and air pollution

Lung cancer	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	-7,308	(-,135)	-35,051	(-,374)	-19,273	(-,509)	-7,359	(-,039)	-7,308	(-,135)	-46,952	(-,411)
PM pollution	-19,873	(-,762)	-48,094	(-1,074)	-2,823	(-,148)	-91,382	(-1,019)	-19,873	(-,762)	-42,830	(-,743)
Gaseous pollution	,002	(,296)	,007	(,700)	-,002	(-,319)	,010	(,460)	,002	(,296)	,003	(,173)
Income	,010	(1,391)	,017	(1,534)	,006	(,726)	,036	(1,491)	,010	(1,391)	,024	(,954)
Smoking	2,776**	(2,900)	4,491**	(2,600)	1,680**	(2,880)	9,407**	(2,858)	2,776	(2,900)	5,252**	(2,984)
Alcohol	-4,939	(-,716)	-6,648	(1,062)	-,002	(,000)	-9,085	(-,383)	-4,939	(-,716)	,965	(,018)
Overweight	-,581	(-,366)	-,782	(-,383)	,106	(,091)	-3,350	(-,614)	-,581	(-,366)	-,957	(-,272)
F statistic	1,673		1,356		1,897		1,854		1,296		2,290	
R square	,527		,475		,558		,553		,463		,604	
Adj. R square	,212		,125		,264		,255		,106		,340	

This table shows the regressions (with the coefficients), estimating lung cancer mortality (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.

T statistics in parenthesises

**p<0.10; **p<0.05; ***p<0.01*

Ischaemic heart diseases

Looking at ischaemic heart diseases (see table 7), the only significant outcome is overweight among females over 65. Furthermore there are no significant outcomes. So no significant outcomes for air pollution, neither for smoking, alcohol and income. This is in line with the outcomes in the correlations. Also none of the models are significant, which means these models are not able to predict the dependent variable 'ischaemic heart diseases'.

Table 7 Regression on ischaemic heart diseases and air pollution

Ischaemic heart diseases	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	250,416	(,980)	91,456	(,203)	226,926	(1,723)	1330,740	(1,291)	627,485	(,350)	1134,701*	(1,977)
PM pollution	80,151	(,653)	130,410	(,605)	101,902	(1,534)	383,915	(,775)	647,365	(,756)	475,664	(1,643)
Gaseous pollution	-,025	(-,834)	-,040	(-,794)	-,027	(-1,616)	-,055	(-,457)	-,125	(-,623)	-,059	(-,805)
Income	,037	(91,113)	,050	(,928)	,008	(,292)	,139	(1,033)	,158	(,731)	,108	(,867)
Smoking	-1,042	(-,231)	-1,050	(-,126)	-1,267	(-,625)	-4,719	(-,260)	31,632	(,264)	-6,072	(-,687)
Alcohol	38,364	(1,181)	23,156	(,768)	116,315	(1,886)	79,948	(,611)	-11,862	(-,304)	231,198	(,860)
Overweight	-10,592	(-1,418)	-4,311	(-,438)	-8,136	(-2,009)	-43,561	(-1,446)	-2,946	(-,089)	-41,213**	(-2,335)
F statistic	1,295		,596		2,756*		1,325		,475		2,944*	
R square	,463		,284		,648		,469		,240		,662	
Adj. R square	,106		-,193		,413		,115		-,266		,437	

This table shows the regressions (with the coefficients), estimating mortality due to ischaemic heart diseases (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

Cebrovacular diseases

The cause of death 'cebrovascular diseases' does not show any significant outcome (as shown in table 8), this is striking because in the previous analysis there was a correlation with overweight. This might be again due to multicollinearity (Skelly, 2012). Looking at this analysis there does not seem a significant factor on cebrovascular diseases, not air pollution, neither lifestyle factors and income.
Also here none of the models are significant, which means these models are not able to predict the dependent variable 'cebrovascular diseases'.

Table 8 Regressions on cebrovascular diseases and air pollution

Cebrovascular diseases

cebrovascular diseases	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	-46,214	(-,464)	-33,059	(-,237)	-57,216	(-,944)	1330,740	(,032)	72,713	(,111)	-147,837	(,663)
PM pollution	21,362	(,446)	-34,889	(-,523)	12,992	(,425)	383,915	(,071)	-287,454	(-,915)	-16,725	(,922)
Gaseous pollution	-,004	(-,346)	,009	(,557)	-,004	(-,455)	-,055	(,224)	,083	(1,124)	,018	(,677)
Income	,017	(1,301)	,023	(1,394)	,014	(1,058)	,139	(1,045)	,097	(1,225)	,084	(,269)
Smoking	-,074	(-,042)	3,448	(1,338)	-,551	(-,591)	-4,719	(-,217)	-25,858	(-,589)	-4,629	(,384)
Alcohol	2,599	(,205)	-2,454	(-,263)	13,693	(,482)	79,948	(-,040)	-8,058	(-,562)	-23,498	(,882)
Overweight	3,063	(1,052)	-,916	(-,301)	3,994*	(2,144)	-43,561	(,743)	16,087	(1,328)	16,589	(,135)
F statistic	,670		,590		1,723		,511		,606		1,287	
R square	,309		,282		,535		,254		,288		,462	
Adj. R square	-,152		-,196		,224		-,243		-,187		,103	

This table shows the regressions (with the coefficients), estimating mortality due to cebrovascular diseases (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

Circulatory diseases

Looking at circulatory diseases (see table 9), for males at all ages and also at 65 and older, income is significant with a negative correlation. Which mean the more income, the less cebrovascular diseases. So it seems likely that income among males plays a significant role when it comes to circulatory diseases. The reason this is only the case for men might be because of the more traditional gender role, in which the men work mainly and the women stay mainly at home, especially among elderly which are more susceptible to die from circulatory diseases. Also the variable 'income' was not available separately for man or woman, so the values are more representative for the men (Central Office of Statistics Poland, 2016). Further, smoking is significant at the males at 65 and older. No significant correlations found with gaseous air pollution or PM pollution, while there were significant correlations found with PM pollution in the previous analysis. This might also be due to collinearity (Skelly, 2012). Also for circulatory diseases counts that none of the models are significant. which means none of the models are able to predict the dependent variable 'circulatory diseases'.

Table 9 Regressions on circulatory diseases and air pollution

Circulatory diseases	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	855,682**	(2,724)	1706,062***	(3,888)	404,691*	(1,968)	3956,391**	(2,359)	8441,567***	(3,888)	2116,423	(1,667)
PM pollution	65,339	(,433)	-7,166	(-,034)	114,247	(1,102)	370,256	(,459)	-204,908	(-,034)	352,911	(,551)
Gaseous pollution	,008	(,228)	,033	(,665)	-,005	(-,173)	,041	(,210)	,118	(,665)	,052	(,318)
Income	-,042	(-1,033)	-,172**	(-3,257)	-,019	(-,421)	-,158	(-,720)	-,871**	(-3,257)	,017	(,061)
Smoking	,528	(,095)	-17,385*	(-2,148)	,840	(,265)	-14,611	(-,494)	-96,033**	(40,737)	-5,055	(-,259)
Alcohol	-5,988	(-,150)	15,457	(,527)	-7,038	(-,073)	12,639	(,059)	-315,965	(,527)	-315,965	(-,531)
Overweight	-4,928	(-,537)	-12,021	(-1,256)	2,022	(,320)	-8,636	(-,176)	-96,033	(-2,357)	21,871	(,560)
F statistic	,588		1,047		,678		,443		,561		,552	
R square	,282		,411		,311		,228		,272		,269	
Adj. R sq.	-,197		,019		-,148		-,287		-,213		-,218	

This table shows the regressions (with the coefficients), estimating mortality due to circulatory diseases (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

Respiratory diseases

Income, smoking and gaseous air pollution are significant at respiratory diseases at all ages and both sexes (as shown in table 10). However, very striking is that gaseous air pollution has a negative correlation like in the previous analyses, and income has a positive relationship, which would mean the more income the more respiratory mortality and the more gaseous air pollution, the less respiratory diseases, which is very unlikely. The negative relationship with gaseous air pollution, as mentioned in previous analysis, might to be due to the fact that in the more developed areas, there is also more air pollution, which could explain the higher respiratory mortality in less polluted areas (Muszynska et al., 2015). However, the positive relationship of income suggests the other way around, as income is positively related to respiratory mortality.

Interesting is also that among the males over 65 there is also a relationship between overweight and respiratory diseases, which makes sense because overweight does increase the probability of respiratory diseases (WHO 2017).

It might be that the regions with the higher average incomes are also the regions with more overweight, as in general in Central Eastern European countries there is more overweight and obesity in the urban areas (Eurostat, 2017). This could possibly explain why income is positively related to the respiratory mortality. The statistical analyses however, found no relationship between overweight and income. Neither a relationship between income and gaseous air pollution was found, which could have explained the relationship between respiratory diseases and income.

Smoking is positively related as expected, it seems that smoking has a significant effect on respiratory diseases for males, especially because the outcomes for males are strongly significant. The fact that smoking is strongly significant for males, and not significant for females and both sexes, is probably due to the fact that in Poland men smoke much more than women (Central Statistical Office Poland, 2016). The fact that smoking is an important factor on respiratory diseases, could also possibly explain the positive relationship between income and respiratory diseases, as people in the urban areas do smoke more (WHO, 2017; Włodarczyk et al., 2013). However, the variables smoking and income are not

related, (also shown in appendix 3 until 10). At the end it stays very unclear why income is positively related and gaseous air pollution is negatively related.
The models for males at all ages and for males at 65 and older are significant, which means that the independent variables (the predictors) together predict well the dependent variable 'respiratory diseases'. So in theory it would be possible to make a suitable model. However, apart from smoking, the outcomes for income and gaseous air pollution seem more a matter of coincidence. As the more income equals in this case the more respiratory diseases, and more gaseous air pollution less respiratory diseases, which is very unlikely. So at the end the models do not seem useful.

Table 10 Regressions on respiratory diseases and air pollution

respiratory diseases	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	-174,252**	(-2,899)	-342,553***	(-5,513)	-102,330*	(-2,095)	-591,777	(-1,775)	-1166,207**	(-2,654)	-375,122	(-1,498)
PM pollution	18,012	(,624)	2,030	(,068)	10,949	(,445)	21,342	(,133)	-99,768	(-,475)	26,312	(,208)
Gaseous pollution	-,016**	(-2,322)	-,018**	(-2,647)	-,012*	(-1,904)	-,054	(-1,385)	-,047	(-,954)	-,045	(-1,388)
Income	,031***	(3,900)	,056***	(7,491)	,020*	(1,874)	,116**	(2,666)	,201***	(3,797)	,098	(1,809)
Smoking	2,370*	(2,235)	6,610***	(5,769)	1,041	(1,385)	10,340	(1,758)	67,757**	(2,307)	5,309	(1,378)
Alcohol	-4,144	(-,543)	-8,743	(-2,105)	2,640	(,115)	-48,745	(-1,151)	12,775	(1,333)	-68,585	(-,585)
Overweight	3,167	(1,803)	2,646*	(1,953)	2,458	(1,637)	13,292	(1,364)	27,358***	(3,376)	8,482	(1,102)
F statistic	5,757*		18,826***		3,173*		2,979*		6,026***		2,034	
R square	,665		,926		,679		,665		,801		,576	
Adj. R square	,442		,877		,465		,442		,668		,293	

This table shows the regressions (with the coefficients), estimating mortality due to respiratory diseases (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

Asthma
Looking at the regression analyses for asthma and considering a confidence interval of 0.95 (see table 11), only a significant outcome is found for income among people at 65 and older, with a negative coefficient which would indicate less income equals more mortality due to asthma. This makes it likely that income plays a significant role when it comes to mortality due to asthma.
There are however, no significant outcomes for PM pollution or gaseous pollution, this is striking because in the correlation there were significant outcomes found for PM pollution and gaseous air pollution. Also according to the literature 'asthma' seems to be the disease and the cause of death, which is the strongest associated to air pollution (Anthamatten & Hazen, 2011; Gatrell & Elliot, 2014; Brauer et al., 2007; Goueiva & Fletcher, 2000). It might be again due to collinearity between gaseous air pollution and PM pollution (Skelly, 2012). Looking at this analysis, there seems no significant effect on asthma, not on gaseous air pollution, and neither on lifestyle factors. Only in case of a confidence interval of 0.90, PM pollution as well smoking among both sexes at all ages and among both sexes over 65 would be significant.
Also in case of a 95% confidence interval, for asthma there are no significant models.

Table 11 Regressions on asthma and air pollution

asthma	both sexes		males		females		65+ Both sexes		65+ males		65+ females	
Constant	3,182	(1,130)	2,926	(,718)	3,197	(1,058)	18,498	(1,494)	26,388	(1,186)	11,168	(,838)
PM pollution	2,854*	(2,109)	1,845	(,948)	2,567	(1,684)	11,413*	(1,919)	,745	(,0700	12,426*	(1,849)
Gaseous pollution	,000	(-1,101)	-,001	(-,206)	,000	(-,737)	-,001	(-,377)	,002	(,983)	-,001	(-,587)
Income	-,001	(-1,879)	-,001	(-1,796)	,000	(-,760)	-,004**	(-2,262)	-,005*	(-1,904)	-,002	(-,546)
Smoking	-,110*	(-2,205)	-,076	(-1,017)	-,051	(-1,099)	-,454*	(-2,077)	-,036	(-,024)	-,123	(-,599)
Alcohol	,494	(1,380)	,162	(,595)	,590	(,416)	1,598	(1,016)	,334	(,689)	-,344	(-,055)
Overweight	,071	(,868)	,107	(1,202)	,008	(,090)	,236	(,651)	-,400	(-,975)	,044	(,107)
F statistic	1,947		1,141		,954		2,877*		1,767		1,255	
R square	,565		,432		,389		,657		,541		,456	
Adj. R square	,275		,053		-,019		,429		,235		,093	

This table shows the regressions (with the coefficients), estimating mortality due to asthma (standardized for age composition) in the 16 NUTS-2 regions in Poland. The regressions include two variables for the pollution, particulate matter pollution (PM pollution) and gaseous pollution. Confounding variables are income, smoking, alcohol, and overweight.
T statistics in parenthesises
**p<0.10; **p<0.05; ***p<0.01*

By looking at the correlations there seems a significant relationship between air pollution and mortality, by looking at all-cause mortality and also by looking at the life expectancies. Some specific causes of death are significantly related to PM pollution, which are asthma and circulatory diseases. While in the multiple regression analyses no significant outcomes are found for asthma and circulatory diseases. Also striking is that for people at 65 and higher there were several significant outcomes at the correlations whereas at the multiple regressions there were barely any significant outcomes.
At the multiple regression analysis only the models for respiratory diseases for males at all ages, and for males at 65 and above were significant. But these models were not useful due to the opposite directions of the coefficients.
After the multiple regression analysis it became really hard to say whether there is a significant relationship between air pollution and mortality. And also which causes of death are significantly related to air pollution as the correlations give different outcomes than the multiple regressions. At the correlations more significant outcomes are found for females, whereas in the multiple regression analysis there was almost no difference. Also do both analyses show clearly that smoking is a significant factor on all-cause mortality, cancer and lung cancer. At the end it is impossible to conclude whether air pollution is a significant factor on mortality, but it can be concluded that smoking is related to mortality, to cancer and lung cancer. It is also interesting that for alcohol no correlation was found, and overweight and income had barely any correlations. So it seems that the disparities within the regions and the small amount of regions as a sample size did not lead to sufficient significant outcomes apart from smoking (Kibele & al., 2015).

5. Conclusion and discussion

5.1. Conclusion

The aim of the research is to see whether air pollution is a significant factor on mortality in Poland, and whether it contributes to relatively poor health in Poland.
The epidemiologic transition theory can explain the Polish backlog in health in relation to the backlog in socio-economic development, compared with Western Europe. In the same way the ecological transition theory can explain the Polish backlog in pollution reduction, compared with Western Europe. Therefore, to the extent air pollution mortality prevails, the ecological transition theory could explain the air pollution mortality in relation to socio-economic development in Poland. The only question remains whether the relatively poor health is partly due to the air pollution.
Poland is a very polluted country within a European context due to its coal burning, among gaseous air pollution nitrogen oxides are by far the most prevailing pollutants, also ozone is one of the most prevailing gaseous pollutants. Both gases and particulate matter are prevailing relatively in a very high extent in Poland.
Air pollution seems to play a role when it comes to mortality in Poland, looking at the correlations, but not when looking at multiple regression analysis. So at the end it is impossible to say whether air pollution really plays a significant role with regards to poor health. At least air pollution does not seem to affect the health in such a strong extent that a big part of the relatively poor health can be explained by the air pollution, for smoking it does. Looking at the correlations, there are correlations between both types of air pollution and the life expectancies, but also the correlations between the types of pollution and all-causes of death make it likely that air pollution plays a significant role when it comes to mortality in Poland. Furthermore, a correlation is found between mortality among females at 65 and older, and asthma, and among females there is a correlation between circulatory diseases and PM pollution, not gaseous air pollution. Therefore, it seems likely that air pollution affects mortality among females more than among males. Also by the fact that the correlations between both the life expectancy as and the all-cause mortality at the one hand, and both types of pollution at the other hand, was much stronger for females than for males. Probably this is due to the fact that Polish women live much healthier than Polish men, among males this is more disrupted by other lifestyle factors, especially smoking. Perhaps due to smoking there are little correlations between air pollution and causes of death in general, as it leads to the same diseases. Smoking has the biggest correlation with mortality, smoking was correlated with all-cause mortality, all types of cancer, lung cancer and respiratory diseases among males. With the results of the correlations it is impossible to say whether particulate matter pollution or gaseous air pollution is more harmful in its current amounts. Particulate matter only seemed more harmful, as the correlations with all-cause mortality were higher, and as particulate matter pollution affects circulatory diseases, whereas gaseous air pollution does not or barely. At least according to the existing literature particulate matter is more harmful. The fact that circulatory diseases are only affected by particulate matter, and also the fact that particulate matter affects asthma in a stronger extent, makes it likely that particulate matter pollution is more harmful. However, looking at the correlations between all-cause mortality and life expectancies, gaseous air pollution is stronger correlated than particulate matter, which would imply that gaseous air pollution is worse. So at the end it is unclear which seems to be more harmful to human health in case of Poland.
When looking at the multiple regression analysis, no significant outcomes are found for the types of air pollution, so therefore this study cannot conclude to what extent the air pollution affects mortality. And therefore it is also impossible to explain regional mortality differences by air pollution. Neither there were significant outcomes for alcohol and just a few significant outcomes for income and overweight. Smoking was the only variable which had several significant outcomes. Therefore smoking is the only factor which can explain regional mortality differences in Poland. The fact that smoking is prevailing in a high extent could also explain why there might be so little significant outcomes with air pollution, as it leads to the same diseases. This might also explain why there were somewhat more significant outcomes for air pollution among females than among males, as females smoke less.
Looking at the correlations, the correlations between the two types of air pollution and the life expectancies and also the all-causes of death mortality, smoking has the strongest correlation with mortality, this counts both for males and females. For females the second strongest correlation is

overweight and third is air pollution. Air pollution has a stronger correlation than alcohol, alcohol is not significant. This would imply that for females air pollution is a stronger factor on mortality than alcohol. Among males there is no correlation with air pollution, only smoking is significantly correlated with mortality. The other factors alcohol and income did not show any correlations with mortality. However, apart from the smoking, there is insufficient evidence about the other factors as none of the other factors was significant in the multiple regression analysis. From this research it does not seem that air pollution is affecting mortality in such a strong extent that a big part of the relatively poor health can be explained by the air pollution, only smoking does. Neither alcohol, overweight and income. So only smoking could explain some regional mortality differences. The fact that for so few independent variables significant outcomes were found, might be due to the disparities within the regions and a small sample size, due to only 16 NUTS-2 regions as cases. As smoking leads to the same diseases as air pollution, and the fact that smoking is so widespread and such a strong factor on mortality make it likely that the effects of air pollution on mortality become almost negligible.
Due to availability of the data, the pollutants are not more specified than particulate matter pollution and gaseous air pollution, so far it is unknown which type of particles are mostly prevailing. It is known that nitrogen dioxide is the most prevailing gaseous pollutant followed by ozone, but it is not known in what amounts and what amounts the other most prevailing gaseous pollutants are.
Despite no really clear association between mortality and air pollution, it would be recommended to the Polish government to form a policy which should aim for a great reduce of air pollution. Even if it is not affecting mortality in a high extent it is still undermining people's health and quality of life. Due to the fact that smoking is affecting mortality in a high extent, policies to reduce smoking are highly recommended.

5.2. Discussion

An important aspect of air pollution is that air pollution is always very local. So in case of NUTS-2 regions, which are used for this research, there can still be very big differences within the regions when it comes to air pollution, and secondly it also depends where most people live within the region. So a smaller scale like NUTS-3 level or even NUTS-4 level would have given much more precise outcomes. Moreover this does not only count for the air pollution but also for confounding factors like smoking and alcohol usage. Also smaller scale would have been better to have a bigger sample size in the regression analyses. So for more reliable outcomes it would be better to work with smaller scale such as NUTS-3 or NUTS-4 level (Kampa & Castanas, 2008; Kibele & al., 2015).
Another issue is that for some of the most polluted areas, these are also more developed and educated areas, this counts especially for the urban areas. More advanced in terms of income and education has a negative effect on mortality, also the better access to healthcare has a strong negative effect on mortality, especially with regard to cardiovascular diseases, which is cause of death number one in Poland (Muszyńska, 2015). This does also disrupt the regression outcomes between mortality and air pollution (Central Statistical Office Poland, 2016; WHO, 2016; Kibele & al., 2015). Take Krakow for example, one of the most polluted NUTS-3 regions, but the same time also one of the most developed NUTS-3 regions and one of the most educated NUTS-3 regions in Poland, and after Warsaw the NUTS-3 region with the best healthcare facilities (Central Statistical Office Poland, 2016; Muszyńska, 2015).
In general inside is more air pollution than outside, especially in Poland where houses are heated with coals. So perhaps mortality due to air pollution is stronger determined by the time spent inside than by its regional outdoor air pollution (Wietlaw et al., 2006; Namiesnik et al., 1992)
The fact that smoking leads to same diseases as air pollution makes that effects of air pollution on mortality are hard research if smoking is highly prevailing. Which is the case in Poland. Therefore it would have been better to select another polluted country or area where smoking is prevailing in a much smaller extent, or if possible exclude all the smokers (Kampa & Castanas, 2008).
The pollution data are not specific, but only divided by gaseous and PM pollution. That means if somewhere is less gaseous pollution does not mean that this pollution is less harmful, that depends on composition of gases. As some gases are much more harmful than others (Lippmann, 2000; Kampa, & Castanas, 2008).
Regional mortality research is always disrupted by migration, both internal migration and external migration. So also in case of this research it is the question whether people who lived and died in a specific region, how long they have been exposed to the air pollution of that specific region. If possible

it would be good only to use the people who stayed those years in the same region, so excluding those who in-migrated and out-migrated (Central Statistical Office Poland, 2016; WHO, 2016; Kibele & al., 2015).
Also time is an issue, because time being exposed to air pollution counts, but also because air pollution affects mortality mainly on the long run. Some birth cohorts have been exposed to air pollution for a longer time than others, also within a certain time frame people could have migrated (Goueiva & Fletcher, 2000; WHO, 2017; Kampa & Castanas, 2008). Also the amounts of pollution change over time, Slaskie is at the moment by far the most polluted NUTS-2 region, this does not mean that Slaskie was the most polluted NUTS-2 region in 1970 (European Environmental Agency, 2017; WHO, 2017). If the data allow it, it would be possible to research per birth cohort and their exposure to air pollution. But there should be a way to correct for the air pollution over time, and for migration. This can only be done when knowing the amounts of air pollution for all the years involved, and where and when the individuals lived. As mentioned before, with regard to the migration, another solution is to exclude those who migrated within the time frame.
Due to availability of the data, this research used only data for the years 2010-2014, as the pollution differs per year, it would have been better to use data for a longer period as air pollution affects mortality on the long run (Kampa & Castanas, 2008).
The mortality selection effect plays also an important role, for individuals who survived difficult life conditions are two options, they either have relatively low mortality at older age (perspective of survival of the fittest), or relatively high mortality (so-called scar effect). The mortality selection effect is also disrupting the outcomes in regression analyses. To use an example, in places with high child mortality the strongest survive, this reduces the mortality at adult age. Whereas in areas with low child mortality also the weaker ones survives, this leads to an increase in mortality at adult age (Wrigley-Field, 2014). It is likely that in the Polish regions where child mortality used to be very high, the adult mortality, including air pollution mortality, is relatively low. And there used to be big regional disparities in infant- and child mortality in Poland, especially during communism. This does still strongly affect adult mortality as well as mortality at old age (Central Statistical Office of Poland, 2017; Eurostat, 2017).
Also population density can lead to bias, for a region with a very small population it is hard to estimate health status and mortality risk, due to a small sample size (small N-value). A small amount of deaths per year make it very difficult to draw conclusions about mortality risk and mortality factors (Statistics Netherlands, 2017; Ozdenerol, 2017).
New research with more specified pollutants and data on smaller regional level should clarify more to what extent air pollution affects mortality in Poland. Therefore, if possible, it would be useful to exclude everyone who migrated in the period researched and to exclude all the smokers.

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Appendixes

Appendix 1: Life expectancies at birth in Europe at country level

	1980	1990	2000	2010	2011	2012	2013
EU-28 (1)(2)	:	:	:	79.9	80.3	80.3	80.6
Belgium (1)	73.3	76.2	77.9	80.3	80.7	80.5	80.7
Bulgaria	71.1	71.2	71.6	73.8	74.2	74.4	74.9
Czech Republic	70.4	71.5	75.1	77.7	78.0	78.1	78.3
Denmark	74.2	74.9	76.9	79.3	79.9	80.2	80.4
Germany	73.1	75.4	78.3	80.5	80.8	81.0	80.9
Estonia	69.5	69.9	71.1	76.0	76.6	76.7	77.5
Ireland	:	74.8	76.6	80.8	80.9	80.9	81.1
Greece	75.3	77.1	78.2	80.6	80.8	80.7	81.4
Spain	75.4	77.0	79.3	82.4	82.6	82.5	83.2
France	:	:	79.2	81.8	82.3	82.1	82.4
Croatia	:	:	:	76.7	77.2	77.3	77.8
Italy	:	77.1	79.9	82.2	82.4	82.4	82.9
Cyprus	:	:	77.7	81.5	81.2	81.1	82.5
Latvia	:	:	:	73.1	73.9	74.1	74.3
Lithuania	70.5	71.5	72.1	73.3	73.7	74.1	74.1
Luxembourg (2)	72.8	75.7	78.0	80.8	81.1	81.5	81.9
Hungary (2)	69.1	69.4	71.9	74.7	75.1	75.3	75.8
Malta (3)	70.4	:	78.4	81.5	80.9	80.9	81.9
Netherlands	:	77.1	78.2	81.0	81.3	81.2	81.4
Austria	72.7	75.8	78.3	80.7	81.1	81.1	81.3
Poland (3)(4)	:	70.7	73.8	76.4	76.8	76.9	77.1
Portugal	71.5	74.1	76.8	80.1	80.7	80.6	80.9
Romania	69.2	69.9	71.2	73.7	74.4	*74.4*	75.2
Slovenia (3)	:	73.9	76.2	79.8	80.1	80.3	80.5
Slovakia	70.4	71.1	73.3	75.6	76.1	76.3	76.6
Finland	73.7	75.1	77.8	80.2	80.6	80.7	81.1
Sweden	75.8	77.7	79.8	81.6	81.9	81.8	82.0
United Kingdom	:	:	78.0	80.6	81.0	81.0	81.1
Iceland	76.8	78.1	79.7	81.9	82.4	83.0	82.1
Liechtenstein	:	:	77.0	81.8	81.9	82.5	82.5
Norway	75.8	76.6	78.8	81.2	81.4	81.5	81.8
Switzerland (1)	75.7	77.5	80.0	82.7	82.8	82.8	82.9
Montenegro	:	:	:	76.1	76.1	76.3	76.5
FYR of Macedonia	:	:	73.0	75.0	75.1	74.9	75.5
Serbia (1)	:	:	71.6	74.4	74.6	74.9	75.3

Source: EuroStat (2015)

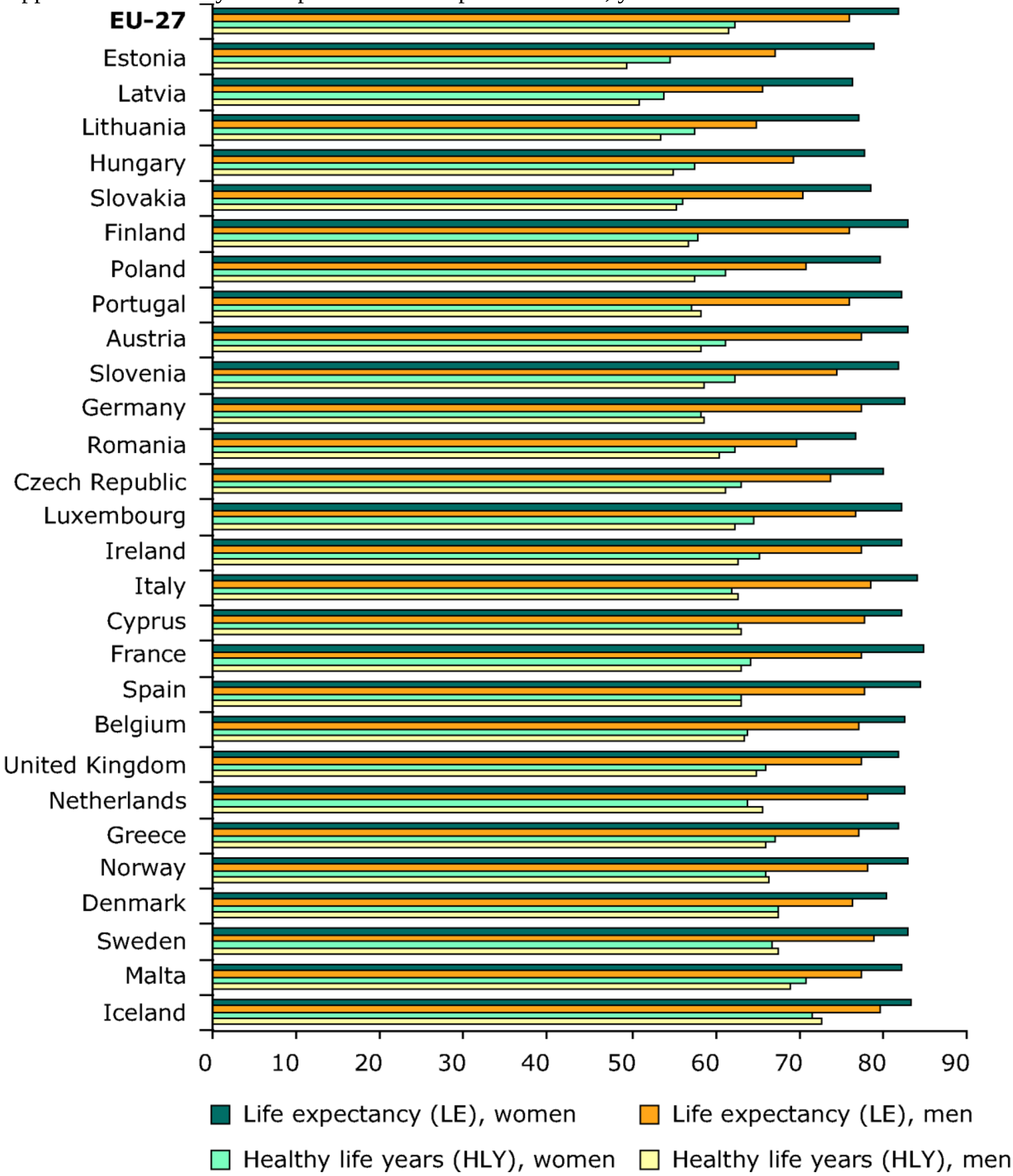
Appendix 2

Appendix 2a: Ranking European countries adult life expectancy 2013, at 20 years old

	female	male	overall
Switzerland	65,7	61,4	63,6
Italy	65,6	60,8	63,2
Spain	66,1	60,1	63,1
Iceland	64,4	61,0	62,7
France	65,6	59,2	62,4
Cyprus	64,4	60,3	62,4
Luxemburg	64,5	60,2	62,4
Sweden	64	60,3	62,2
Norway	64,1	60,1	62,1
Greece	64,4	59,3	61,9
Netherlands	63,7	59,9	61,8
Ireland	63,9	59,7	61,8
Austria	64,4	59,1	61,8
United Kingdom	63,4	59,6	61,5
Germany	63,7	59,1	61,4
Portugal	64,6	58,1	61,4
Malta	62,8	59,8	61,3
Finland	64,2	58,1	61,2
Belgium	63,4	58,5	61,0
Slovenia	63,9	57,6	60,8
Denmark	62,3	58,3	60,3
Czech Republik	61,7	55,7	58,7
Croatia	61,1	55,3	58,2
Romania	59,3	56,8	58,1
Bosnia & Herzegovina	60,3	55,5	57,9
Poland	61,5	53,2	57,4
Estonia	62,1	52,2	57,2
Slovakia	60,7	53,2	57,0
Montenegro	58,9	54,3	56,6
Albania	57,1	54,6	55,9
Hungary	59,4	52,1	55,8
Bulgaria	59,1	52,3	55,7
Serbia	57,9	52,8	55,4
Lithuania	60	49,5	54,8
Belarus	58,4	46,9	52,7
Moldova	56,1	47,9	52,0
Ukraine	56,6	46,9	51,8
Russia	56,2	44,6	50,4
Latvia	54,6	45,5	50,1

Source: Eurostat (2015

Appendix 2b: Healthy life expectancies European countries, year 2013



Source: EEA (2015)

Appendix 3: Air pollution, all-cause mortality, smoking, alcohol, overweight and income

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	Income	allcause2014	allcausemales2014	allcausefemales2014	LFatbirthmales	LFat60males	LFatbirthfemales	LFat60females	allcause65	allcause65males	allcauesfemales65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,270	,270	-,030	,461	-,118	-,156	-,457	-,478	,295	-,043	,429
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,312	,312	,912	,072	,662	,564	,075	,061	,267	,876	,097
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,290	,299	,008	,487	-,395	-,324	-,552*	-,555*	,337	,014	,470
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,277	,260	,977	,056	,130	,221	,026	,026	,202	,959	,066
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	-,324	,512*	,609*	,357	-,614*	-,678**	-,568*	-,494	,410	,549*	,269
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,221	,042	,012	,175	,011	,004	,022	,052	,115	,028	,315
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,161	,269	,133	,388	-,410	-,514*	-,798**	-,788**	,194	,086	,258
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,552	,314	,623	,137	,114	,042	,000	,000	,473	,751	,334
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,298	,074	,019	,117	-,326	-,236	-,423	-,321	,006	-,046	,066
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,263	,785	,944	,667	,218	,378	,102	,225	,981	,865	,808
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,747**	-,077	-,287	,143	-,001	,088	-,350	-,316	-,143	-,384	,060
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,001	,777	,281	,598	,998	,745	,184	,233	,597	,142	,826
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	-,098	-,003	,040	-,054	-,312	-,192	-,085	-,052	-,026	,046	-,074
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,718	,991	,883	,841	,240	,477	,753	,850	,923	,865	,786
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,071	,571*	,503*	,498*	-,369	-,353	-,148	-,107	,485	,398	,469
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,793	,021	,047	,050	,160	,180	,585	,692	,057	,126	,067
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Income	Pearson Correlation	,270	,290	-,324	,161	,298	,747**	-,098	,071	1	-,135	-,293	,029	,157	,319	-,060	-,041	-,283	-,479	-,085
	Sig. (2-tailed)	,312	,277	,221	,552	,263	,001	,718	,793		,619	,270	,917	,562	,228	,825	,881	,289	,061	,755
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcause2014	Pearson Correlation	,270	,299	,512*	,269	,074	-,077	-,003	,571*	-,135	1	,921**	,923**	-,651**	-,726**	-,434	-,440	,950**	,885**	,897**
	Sig. (2-tailed)	,312	,260	,042	,314	,785	,777	,991	,021	,619		,000	,000	,006	,001	,093	,088	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcausemales2014	Pearson Correlation	-,030	,008	,609*	,133	,019	-,287	,040	,503*	-,293	,921**	1	,710**	-,685**	-,731**	-,280	-,252	,848**	,952**	,704**
	Sig. (2-tailed)	,912	,977	,012	,623	,944	,281	,883	,047	,270	,000		,002	,003	,001	,294	,346	,000	,000	,002
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcausefemales2014	Pearson Correlation	,461	,487	,357	,388	,117	,143	-,054	,498*	,029	,923**	,710**	1	-,515*	-,611*	-,546*	-,591*	,915**	,710**	,963**
	Sig. (2-tailed)	,072	,056	,175	,137	,667	,598	,841	,050	,917	,000	,002		,041	,012	,029	,016	,000	,002	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
LFatbirthmales	Pearson Correlation	-,118	-,395	-,614*	-,410	-,326	-,001	-,312	-,369	,157	-,651**	-,685**	-,515*	1	,904**	,664**	,593*	-,594*	-,648**	-,491
	Sig. (2-tailed)	,662	,130	,011	,114	,218	,998	,240	,160	,562	,006	,003	,041		,000	,005	,015	,015	,007	,053
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
LFat60males	Pearson Correlation	-,156	-,324	-,678**	-,514*	-,236	,088	-,192	-,353	,319	-,726**	-,731**	-,611*	,904**	1	,735**	,696**	-,715**	-,752**	-,599*
	Sig. (2-tailed)	,564	,221	,004	,042	,378	,745	,477	,180	,228	,001	,001	,012	,000		,001	,003	,002	,001	,014
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
LFatbirthfemales	Pearson Correlation	-,457	-,552*	-,568*	-,798**	-,423	-,350	-,085	-,148	-,060	-,434	-,280	-,546*	,664**	,735**	1	,984**	-,451	-,309	-,495
	Sig. (2-tailed)	,075	,026	,022	,000	,102	,184	,753	,585	,825	,093	,294	,029	,005	,001		,000	,080	,245	,051
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
LFat60females	Pearson Correlation	-,478	-,555*	-,494	-,788**	-,321	-,316	-,052	-,107	-,041	-,440	-,252	-,591*	,593*	,696**	,984**	1	-,489	-,312	-,552*
	Sig. (2-tailed)	,061	,026	,052	,000	,225	,233	,850	,692	,881	,088	,346	,016	,015	,003	,000		,055	,240	,027
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcause65	Pearson Correlation	,295	,337	,410	,194	,006	-,143	-,026	,485	-,283	,950**	,848**	,915**	-,594*	-,715**	-,451	-,489	1	,902**	,959**
	Sig. (2-tailed)	,267	,202	,115	,473	,981	,597	,923	,057	,289	,000	,000	,000	,015	,002	,080	,055		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcause65males	Pearson Correlation	-,043	,014	,549*	,086	-,046	-,384	,046	,398	-,479	,885**	,952**	,710**	-,648**	-,752**	-,309	-,312	,902**	1	,756**
	Sig. (2-tailed)	,876	,959	,028	,751	,865	,142	,865	,126	,061	,000	,000	,002	,007	,001	,245	,240	,000		,001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcauesfemales65	Pearson Correlation	,429	,470	,269	,258	,066	,060	-,074	,469	-,085	,897**	,704**	,963**	-,491	-,599*	-,495	-,552*	,959**	,756**	1
	Sig. (2-tailed)	,097	,066	,315	,334	,808	,826	,786	,067	,755	,000	,002	,000	,053	,014	,051	,027	,000	,001	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 4: Air pollution, lung cancer, smoking, alcohol, overweight and income

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	Income	lungcancer2014	lungcancermales2014	lungcancerfemales2014	lungcancer65	lungcancermales65	lungcancerfemales65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,270	-,127	-,244	-,004	-,145	-,244	-,043
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,312	,640	,362	,988	,591	,362	,874
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,290	-,100	-,202	,013	-,081	-,176	,037
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,277	,711	,452	,963	,766	,514	,891
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	-,324	,539*	,517*	,522*	,507*	,521*	,478
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,221	,031	,040	,038	,045	,038	,061
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,161	,550*	,372	,691**	,562*	,420	,687**
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,552	,027	,156	,003	,023	,105	,003
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,298	,156	,068	,282	,247	,205	,342
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,263	,564	,802	,291	,356	,447	,195
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,747**	,124	-,071	,336	,235	,079	,406
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,001	,648	,793	,203	,381	,772	,119
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	-,098	,064	,094	,014	,113	,130	,073
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,718	,815	,730	,958	,678	,631	,788
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,071	,051	,046	,072	-,035	-,041	,014
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,793	,852	,864	,790	,899	,879	,958
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Income	Pearson Correlation	,270	,290	-,324	,161	,298	,747**	-,098	,071	1	,183	,043	,303	,238	,091	,364
	Sig. (2-tailed)	,312	,277	,221	,552	,263	,001	,718	,793		,498	,875	,254	,375	,738	,166
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancer2014	Pearson Correlation	-,127	-,100	,539*	,550*	,156	,124	,064	,051	,183	1	,956**	,940**	,975**	,942**	,914**
	Sig. (2-tailed)	,640	,711	,031	,027	,564	,648	,815	,852	,498		,000	,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancermales2014	Pearson Correlation	-,244	-,202	,517*	,372	,068	-,071	,094	,046	,043	,956**	1	,804**	,923**	,964**	,776**
	Sig. (2-tailed)	,362	,452	,040	,156	,802	,793	,730	,864	,875	,000		,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancerfemales2014	Pearson Correlation	-,004	,013	,522*	,691**	,282	,336	,014	,072	,303	,940**	,804**	1	,923**	,813**	,979**
	Sig. (2-tailed)	,988	,963	,038	,003	,291	,203	,958	,790	,254	,000	,000		,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancer65	Pearson Correlation	-,145	-,081	,507*	,562*	,247	,235	,113	-,035	,238	,975**	,923**	,923**	1	,963**	,930**
	Sig. (2-tailed)	,591	,766	,045	,023	,356	,381	,678	,899	,375	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancermales65	Pearson Correlation	-,244	-,176	,521*	,420	,205	,079	,130	-,041	,091	,942**	,964**	,813**	,963**	1	,810**
	Sig. (2-tailed)	,362	,514	,038	,105	,447	,772	,631	,879	,738	,000	,000	,000	,000		,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
lungcancerfemales65	Pearson Correlation	-,043	,037	,478	,687**	,342	,406	,073	,014	,364	,914**	,776**	,979**	,930**	,810**	1
	Sig. (2-tailed)	,874	,891	,061	,003	,195	,119	,788	,958	,166	,000	,000	,000	,000	,000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 5: Air pollution, asthma, smoking, alcohol, overweight and income

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	Income	asthma2014	asthmamales2014	asthmafemales2014	asthma65	asthma65males	asthma65females
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,270	,459	,303	,467	,591*	,378	,574*
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,312	,074	,255	,068	,016	,149	,020
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,290	,353	,356	,296	,522*	,509*	,389
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,277	,180	,176	,266	,038	,044	,136
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	-,324	-,223	-,036	-,273	-,218	-,117	-,198
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,221	,406	,895	,306	,418	,666	,462
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,161	-,276	-,240	-,214	-,203	-,256	-,093
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,552	,301	,371	,427	,450	,338	,731
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,298	,093	,089	,067	,081	,036	,089
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,263	,732	,742	,805	,765	,894	,744
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,747**	-,077	-,152	-,036	-,097	-,116	-,065
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,001	,776	,575	,893	,720	,668	,810
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	-,098	-,024	,238	-,114	-,040	,182	-,152
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,718	,931	,375	,674	,882	,501	,575
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,071	,046	,149	,011	,018	-,037	,040
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,793	,867	,582	,967	,947	,891	,883
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Income	Pearson Correlation	,270	,290	-,324	,161	,298	,747**	-,098	,071	1	-,163	-,289	-,093	-,194	-,270	-,094
	Sig. (2-tailed)	,312	,277	,221	,552	,263	,001	,718	,793		,545	,278	,731	,471	,312	,730
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthma2014	Pearson Correlation	,459	,353	-,223	-,276	,093	-,077	-,024	,046	-,163	1	,858**	,967**	,951**	,700**	,904**
	Sig. (2-tailed)	,074	,180	,406	,301	,732	,776	,931	,867	,545		,000	,000	,000	,003	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthmamales2014	Pearson Correlation	,303	,356	-,036	-,240	,089	-,152	,238	,149	-,289	,858**	1	,712**	,836**	,894**	,633**
	Sig. (2-tailed)	,255	,176	,895	,371	,742	,575	,375	,582	,278	,000		,002	,000	,000	,008
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthmafemales2014	Pearson Correlation	,467	,296	-,273	-,214	,067	-,036	-,114	,011	-,093	,967**	,712**	1	,899**	,517*	,946**
	Sig. (2-tailed)	,068	,266	,306	,427	,805	,893	,674	,967	,731	,000	,002		,000	,040	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthma65	Pearson Correlation	,591*	,522*	-,218	-,203	,081	-,097	-,040	,018	-,194	,951**	,836**	,899**	1	,775**	,917**
	Sig. (2-tailed)	,016	,038	,418	,450	,765	,720	,882	,947	,471	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthma65males	Pearson Correlation	,378	,509*	-,117	-,256	,036	-,116	,182	-,037	-,270	,700**	,894**	,517*	,775**	1	,465
	Sig. (2-tailed)	,149	,044	,666	,338	,894	,668	,501	,891	,312	,003	,000	,040	,000		,070
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
asthma65females	Pearson Correlation	,574*	,389	-,198	-,093	,089	-,065	-,152	,040	-,094	,904**	,633**	,946**	,917**	,465	1
	Sig. (2-tailed)	,020	,136	,462	,731	,744	,810	,575	,883	,730	,000	,008	,000	,000	,070	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 6: Air pollution, all types of cancer, smoking, alcohol and overweight

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	allcancer2014	allcausecancermales2014	allcancerfemales2014	allcancer65	allcancermales65	allcancerfemales65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,182	,059	,245	,116	,015	,155
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,499	,829	,360	,670	,955	,566
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,149	,011	,239	,096	-,001	,158
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,582	,967	,373	,724	,998	,560
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	,542*	,634**	,472	,526*	,640**	,444
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,030	,008	,065	,036	,008	,085
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,649**	,610*	,669**	,641**	,631**	,652**
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,006	,012	,005	,007	,009	,006
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,160	,103	,231	,189	,179	,236
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,553	,703	,389	,484	,506	,380
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,244	,092	,372	,280	,151	,386
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,362	,735	,156	,293	,577	,140
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	-,026	-,052	-,015	,030	,018	,040
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,923	,847	,956	,913	,948	,882
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,036	,007	,064	-,051	-,051	-,017
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,894	,978	,814	,851	,852	,950
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcancer2014	Pearson Correlation	,182	,149	,542*	,649**	,160	,244	-,026	,036	1	,972**	,983**	,982**	,955**	,965**
	Sig. (2-tailed)	,499	,582	,030	,006	,553	,362	,923	,894		,000	,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcausecancermales2014	Pearson Correlation	,059	,011	,634**	,610*	,103	,092	-,052	,007	,972**	1	,917**	,954**	,983**	,900**
	Sig. (2-tailed)	,829	,967	,008	,012	,703	,735	,847	,978	,000		,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcancerfemales2014	Pearson Correlation	,245	,239	,472	,669**	,231	,372	-,015	,064	,983**	,917**	1	,961**	,898**	,982**
	Sig. (2-tailed)	,360	,373	,065	,005	,389	,156	,956	,814	,000	,000		,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcancer65	Pearson Correlation	,116	,096	,526*	,641**	,189	,280	,030	-,051	,982**	,954**	,961**	1	,968**	,976**
	Sig. (2-tailed)	,670	,724	,036	,007	,484	,293	,913	,851	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcancermales65	Pearson Correlation	,015	-,001	,640**	,631**	,179	,151	,018	-,051	,955**	,983**	,898**	,968**	1	,903**
	Sig. (2-tailed)	,955	,998	,008	,009	,506	,577	,948	,852	,000	,000	,000	,000		,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
allcancerfemales65	Pearson Correlation	,155	,158	,444	,652**	,236	,386	,040	-,017	,965**	,900**	,982**	,976**	,903**	1
	Sig. (2-tailed)	,566	,560	,085	,006	,380	,140	,882	,950	,000	,000	,000	,000	,000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 7: Air pollution, respiratory diseases, smoking, alcohol and overweight

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	respiratorydiseases2014	respiratorymales2014	respiratoryfemales2014	respiratory65	respiratorymales65	respiratoryfemales65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	-,383	-,481	-,275	-,427	-,539*	-,321
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,143	,059	,302	,099	,031	,225
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	-,463	-,554*	-,360	-,504*	-,589*	-,417
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,071	,026	,171	,047	,016	,108
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	,339	,378	,321	,313	,325	,325
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,199	,149	,225	,238	,219	,219
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,215	,168	,274	,140	,053	,236
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,424	,533	,304	,606	,845	,380
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,038	,003	,070	-,127	-,187	-,059
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,888	,992	,798	,640	,488	,829
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,167	,067	,255	-,035	-,152	,072
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,537	,804	,340	,899	,574	,790
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	,178	,192	,133	,209	,238	,158
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,509	,477	,622	,436	,375	,559
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,234	,203	,252	,152	,124	,178
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,384	,450	,347	,575	,648	,511
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratorydiseases2014	Pearson Correlation	-,383	-,463	,339	,215	,038	,167	,178	,234	1	,978**	,978**	,946**	,904**	,954**
	Sig. (2-tailed)	,143	,071	,199	,424	,888	,537	,509	,384		,000	,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratorymales2014	Pearson Correlation	-,481	-,554*	,378	,168	,003	,067	,192	,203	,978**	1	,916**	,925**	,921**	,902**
	Sig. (2-tailed)	,059	,026	,149	,533	,992	,804	,477	,450	,000		,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratoryfemales2014	Pearson Correlation	-,275	-,360	,321	,274	,070	,255	,133	,252	,978**	,916**	1	,919**	,842**	,964**
	Sig. (2-tailed)	,302	,171	,225	,304	,798	,340	,622	,347	,000	,000		,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratory65	Pearson Correlation	-,427	-,504*	,313	,140	-,127	-,035	,209	,152	,946**	,925**	,919**	1	,979**	,978**
	Sig. (2-tailed)	,099	,047	,238	,606	,640	,899	,436	,575	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratorymales65	Pearson Correlation	-,539*	-,589*	,325	,053	-,187	-,152	,238	,124	,904**	,921**	,842**	,979**	1	,919**
	Sig. (2-tailed)	,031	,016	,219	,845	,488	,574	,375	,648	,000	,000	,000	,000		,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
respiratoryfemales65	Pearson Correlation	-,321	-,417	,325	,236	-,059	,072	,158	,178	,954**	,902**	,964**	,978**	,919**	1
	Sig. (2-tailed)	,225	,108	,219	,380	,829	,790	,559	,511	,000	,000	,000	,000	,000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 8: Air pollution, ischaemic heart diseases, smoking, alcohol and overweight

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	ischamemic2014	ischaemicmales2014	schaemicfemales2014	ischaemicheart65	ischaemicheartmales65	ischaemicheartfemales65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,167	,124	,194	,392	,300	,454
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,536	,646	,471	,134	,259	,077
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,043	,003	,068	,245	,144	,321
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,873	,990	,803	,361	,594	,226
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	-,087	-,060	-,090	-,152	-,100	-,183
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,749	,825	,741	,574	,713	,499
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	,006	-,004	,036	-,016	-,026	,003
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,983	,987	,895	,952	,923	,990
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,193	,185	,203	,094	,049	,130
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,474	,494	,450	,728	,856	,631
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,491	,446	,529*	,403	,320	,465
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,053	,083	,035	,122	,227	,070
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	-,292	-,263	-,311	-,352	-,307	-,382
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,272	,325	,240	,181	,247	,144
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	-,440	-,454	-,416	-,463	-,498*	-,422
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,088	,077	,109	,071	,049	,103
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
ischamemic2014	Pearson Correlation	,167	,043	-,087	,006	,193	,491	-,292	-,440	1	,996**	,995**	,904**	,921**	,864**
	Sig. (2-tailed)	,536	,873	,749	,983	,474	,053	,272	,088		,000	,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
ischaemicmales2014	Pearson Correlation	,124	,003	-,060	-,004	,185	,446	-,263	-,454	,996**	1	,983**	,887**	,918**	,835**
	Sig. (2-tailed)	,646	,990	,825	,987	,494	,083	,325	,077	,000		,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
schaemicfemales2014	Pearson Correlation	,194	,068	-,090	,036	,203	,529*	-,311	-,416	,995**	,983**	1	,916**	,920**	,887**
	Sig. (2-tailed)	,471	,803	,741	,895	,450	,035	,240	,109	,000	,000		,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
ischaemicheart65	Pearson Correlation	,392	,245	-,152	-,016	,094	,403	-,352	-,463	,904**	,887**	,916**	1	,986**	,989**
	Sig. (2-tailed)	,134	,361	,574	,952	,728	,122	,181	,071	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
ischaemicheartmales65	Pearson Correlation	,300	,144	-,100	-,026	,049	,320	-,307	-,498*	,921**	,918**	,920**	,986**	1	,953**
	Sig. (2-tailed)	,259	,594	,713	,923	,856	,227	,247	,049	,000	,000	,000	,000		,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
ischaemicheartfemales65	Pearson Correlation	,454	,321	-,183	,003	,130	,465	-,382	-,422	,864**	,835**	,887**	,989**	,953**	1
	Sig. (2-tailed)	,077	,226	,499	,990	,631	,070	,144	,103	,000	,000	,000	,000	,000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 9: Air pollution, cebrovascular diseases, smoking, alcohol and overweight

Correlations

		PM	Gaseous	smokingmales	smokingfemales	alcoholmales	alcoholfemales	overweightmales	overweightfemales	cebrovacular2014	cebrovascular males2014	cebrovascular females2014	cebrovascular 65	cebrovascular males65	cebrovascular females65
PM	Pearson Correlation	1	,864**	-,049	,190	,154	,349	-,329	,118	,165	,097	,203	,234	,169	,258
	Sig. (2-tailed)		,000	,857	,480	,569	,185	,213	,663	,540	,722	,451	,383	,532	,335
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,864**	1	-,059	,223	,381	,486	-,020	,197	,199	,158	,213	,311	,270	,321
	Sig. (2-tailed)	,000		,828	,407	,146	,056	,942	,466	,459	,560	,429	,241	,311	,225
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,049	-,059	1	,564*	,328	-,044	,158	,268	,216	,264	,190	,163	,209	,133
	Sig. (2-tailed)	,857	,828		,023	,215	,872	,558	,316	,423	,323	,482	,547	,437	,624
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,190	,223	,564*	1	,348	,353	,157	,105	-,042	-,126	,024	-,136	-,187	-,108
	Sig. (2-tailed)	,480	,407	,023		,186	,179	,563	,697	,878	,643	,929	,616	,488	,691
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	,154	,381	,328	,348	1	,725**	,256	,311	,258	,270	,238	,216	,216	,205
	Sig. (2-tailed)	,569	,146	,215	,186		,001	,338	,241	,334	,312	,374	,421	,421	,446
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	,349	,486	-,044	,353	,725**	1	-,039	,102	,390	,298	,441	,311	,248	,327
	Sig. (2-tailed)	,185	,056	,872	,179	,001		,886	,708	,135	,262	,087	,242	,355	,216
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,329	-,020	,158	,157	,256	-,039	1	,469	,015	,016	,002	-,015	-,017	-,014
	Sig. (2-tailed)	,213	,942	,558	,563	,338	,886		,067	,956	,953	,993	,956	,951	,958
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,118	,197	,268	,105	,311	,102	,469	1	,542*	,551*	,511*	,476	,490	,454
	Sig. (2-tailed)	,663	,466	,316	,697	,241	,708	,067		,030	,027	,043	,062	,054	,077
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovacular2014	Pearson Correlation	,165	,199	,216	-,042	,258	,390	,015	,542*	1	,976**	,989**	,954**	,921**	,951**
	Sig. (2-tailed)	,540	,459	,423	,878	,334	,135	,956	,030		,000	,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovascularmales2014	Pearson Correlation	,097	,158	,264	-,126	,270	,298	,016	,551*	,976**	1	,935**	,955**	,961**	,934**
	Sig. (2-tailed)	,722	,560	,323	,643	,312	,262	,953	,027	,000		,000	,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovascularfemales2014	Pearson Correlation	,203	,213	,190	,024	,238	,441	,002	,511*	,989**	,935**	1	,927**	,872**	,937**
	Sig. (2-tailed)	,451	,429	,482	,929	,374	,087	,993	,043	,000	,000		,000	,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovascular65	Pearson Correlation	,234	,311	,163	-,136	,216	,311	-,015	,476	,954**	,955**	,927**	1	,978**	,994**
	Sig. (2-tailed)	,383	,241	,547	,616	,421	,242	,956	,062	,000	,000	,000		,000	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovascularmales65	Pearson Correlation	,169	,270	,209	-,187	,216	,248	-,017	,490	,921**	,961**	,872**	,978**	1	,949**
	Sig. (2-tailed)	,532	,311	,437	,488	,421	,355	,951	,054	,000	,000	,000	,000		,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16
cebrovascularfemales65	Pearson Correlation	,258	,321	,133	-,108	,205	,327	-,014	,454	,951**	,934**	,937**	,994**	,949**	1
	Sig. (2-tailed)	,335	,225	,624	,691	,446	,216	,958	,077	,000	,000	,000	,000	,000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 10: Air pollution, circulatory diseases, smoking, alcohol, overweight and income

Correlations

		circulatorydisease	circulatorymales	circulatoryfemales	circulatroy65	circulatorymales65	PM	Gaseous	income	alcoholmales	alcoholfemales	overweightmales	overweightfemales	smokingmales	smokingfemales	circulatoryfeamles65
circulatorydisease	Pearson Correlation	1	,958**	,967**	,872**	,867**	,364	,284	-,234	-,106	-,090	-,433	,152	-,032	,077	,864**
	Sig. (2-tailed)		,000	,000	,000	,000	,166	,287	,384	,697	,741	,094	,574	,907	,778	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
circulatorymales	Pearson Correlation	,958**	1	,854**	,794**	,845**	,177	,126	-,419	-,127	-,220	-,348	,161	,051	-,006	,766**
	Sig. (2-tailed)	,000		,000	,000	,000	,512	,643	,106	,641	,412	,187	,551	,852	,982	,001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
circulatoryfemales	Pearson Correlation	,967**	,854**	1	,882**	,828**	,507*	,406	-,053	-,077	,032	-,478	,137	-,099	,144	,891**
	Sig. (2-tailed)	,000	,000		,000	,000	,045	,119	,847	,776	,906	,061	,614	,715	,594	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
circulatroy65	Pearson Correlation	,872**	,794**	,882**	1	,980**	,390	,350	-,094	-,003	-,094	-,337	,214	-,117	-,078	,997**
	Sig. (2-tailed)	,000	,000	,000		,000	,136	,184	,729	,993	,728	,202	,426	,665	,774	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
circulatorymales65	Pearson Correlation	,867**	,845**	,828**	,980**	1	,263	,246	-,214	-,014	-,185	-,286	,231	-,060	-,134	,964**
	Sig. (2-tailed)	,000	,000	,000	,000		,325	,359	,427	,960	,493	,283	,390	,826	,621	,000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
PM	Pearson Correlation	,364	,177	,507*	,390	,263	1	,864**	,270	,154	,349	-,329	,118	-,049	,190	,422
	Sig. (2-tailed)	,166	,512	,045	,136	,325		,000	,312	,569	,185	,213	,663	,857	,480	,103
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Gaseous	Pearson Correlation	,284	,126	,406	,350	,246	,864**	1	,290	,381	,486	-,020	,197	-,059	,223	,378
	Sig. (2-tailed)	,287	,643	,119	,184	,359	,000		,277	,146	,056	,942	,466	,828	,407	,148
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
income	Pearson Correlation	-,234	-,419	-,053	-,094	-,214	,270	,290	1	,298	,747**	-,098	,071	-,324	,161	-,032
	Sig. (2-tailed)	,384	,106	,847	,729	,427	,312	,277		,263	,001	,718	,793	,221	,552	,906
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholmales	Pearson Correlation	-,106	-,127	-,077	-,003	-,014	,154	,381	,298	1	,725**	,256	,311	,328	,348	,004
	Sig. (2-tailed)	,697	,641	,776	,993	,960	,569	,146	,263		,001	,338	,241	,215	,186	,989
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
alcoholfemales	Pearson Correlation	-,090	-,220	,032	-,094	-,185	,349	,486	,747**	,725**	1	-,039	,102	-,044	,353	-,053
	Sig. (2-tailed)	,741	,412	,906	,728	,493	,185	,056	,001	,001		,886	,708	,872	,179	,846
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightmales	Pearson Correlation	-,433	-,348	-,478	-,337	-,286	-,329	-,020	-,098	,256	-,039	1	,469	,158	,157	-,352
	Sig. (2-tailed)	,094	,187	,061	,202	,283	,213	,942	,718	,338	,886		,067	,558	,563	,181
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
overweightfemales	Pearson Correlation	,152	,161	,137	,214	,231	,118	,197	,071	,311	,102	,469	1	,268	,105	,209
	Sig. (2-tailed)	,574	,551	,614	,426	,390	,663	,466	,793	,241	,708	,067		,316	,697	,437
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingmales	Pearson Correlation	-,032	,051	-,099	-,117	-,060	-,049	-,059	-,324	,328	-,044	,158	,268	1	,564*	-,132
	Sig. (2-tailed)	,907	,852	,715	,665	,826	,857	,828	,221	,215	,872	,558	,316		,023	,626
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
smokingfemales	Pearson Correlation	,077	-,006	,144	-,078	-,134	,190	,223	,161	,348	,353	,157	,105	,564*	1	-,048
	Sig. (2-tailed)	,778	,982	,594	,774	,621	,480	,407	,552	,186	,179	,563	,697	,023		,860
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
circulatoryfeamles65	Pearson Correlation	,864**	,766**	,891**	,997**	,964**	,422	,378	-,032	,004	-,053	-,352	,209	-,132	-,048	1
	Sig. (2-tailed)	,000	,001	,000	,000	,000	,103	,148	,906	,989	,846	,181	,437	,626	,860	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

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

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

Appendix 11: SPSS output of the multiple regression analysis

All-cause mortality

Dependent variable: all-cause mortality, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	902,274	375,092		2,405	,040
PM pollution	33,454	180,246	,120	,186	,857
Gaseous pollution	,018	,044	,270	,403	,696
Income	-,017	,049	-,109	-,350	,734
Smoking	8,878	6,616	,409	1,342	,213
Alcohol	-34,244	47,659	-,271	-,719	,491
Overweight	9,371	10,965	,265	,855	,415

Dependent variable: all-cause mortality, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	1198,092	577,313		2,075	,068
PM pollution	-263,697	275,917	-,633	-,956	,364
Gaseous pollution	,072	,065	,738	1,110	,296
Income	,002	,069	,009	,032	,975
Smoking (males)	27,135	10,646	,776	2,549	,031
Alcohol (males)	-42,365	38,588	-,376	-1,098	,301
Overweight (males)	-7,214	12,590	-,179	-,573	,581

Dependent variable: all-cause mortality, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	618,434	233,989		2,643	,027
PM pollution	50,714	118,009	,208	,430	,677
Gaseous pollution	,014	,030	,252	,478	,644
Income	-,008	,051	-,061	-,166	,872
Smoking (females)	4,506	3,601	,315	1,251	,242
Alcohol (females)	-41,631	109,622	-,160	-,380	,713
Overweight (females)	12,439	7,196	,411	1,729	,118

Dependent variable: all-cause mortality, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	4826,472	1241,962		3,886	,004
PM pollution	46,296	596,809	,049	,078	,940
Gaseous pollution	,098	,145	,439	,673	,518
Income	-,159	,163	-,296	-,978	,353
Smoking	22,317	21,907	,302	1,019	,335
Alcohol	-113,672	157,803	-,264	-,720	,490
Overweight	23,745	36,305	,197	,654	,529

Dependent variable: all-cause mortality, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	6554,613	1928,666		3,399	,008
PM pollution	-976,560	921,775	-,680	-1,059	,317
Gaseous pollution	,281	,216	,838	1,300	,226
Income	-,206	,232	-,254	-,888	,398
Smoking (males)	-131,819	128,915	-,339	-1,023	,333
Alcohol (males)	-27,491	42,059	-,198	-,654	,530
Overweight (males)	75,382	35,567	,625	2,119	,063

Dependent variable: all-cause mortality, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	3435,074	914,697		3,755	,005
PM pollution	137,591	461,314	,153	,298	,772
Gaseous pollution	,070	,118	,333	,597	,565
Income	-,098	,198	-,193	-,498	,631
Smoking (females)	9,817	14,078	,186	,697	,503
Alcohol (females)	-111,940	428,530	-,117	-,261	,800
Overweight (females)	43,722	28,128	,391	1,554	,155

All types of cancer

Dependent variable: all types of cancer, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	130,756	127,042		1,029	,330
PM pollution	-5,145	61,048	-,046	-,084	,935
Gaseous pollution	,003	,015	,121	,214	,835
Income	,016	,017	,249	,947	,368
Smoking	6,835	2,241	,785	3,050	,014
Alcohol	-10,840	16,142	-,214	-,672	,519
Overweight	-1,616	3,714	-,114	-,435	,674

Dependent variable: all types of cancer, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	86,947	186,021		,467	,651
PM pollution	-35,075	88,906	-,251	-,395	,702
Gaseous pollution	,010	,021	,302	,472	,648
Income	,027	,022	,341	1,203	,260
Smoking (males)	10,324	3,430	,881	3,010	,015
Alcohol (males)	-12,253	12,434	-,324	-,985	,350
Overweight (males)	-2,051	4,057	-,152	-,506	,625

Dependent variable: all types of cancer, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	119,920	105,410		1,138	,285
PM pollution	17,203	53,162	,162	,324	,754
Gaseous pollution	-,002	,014	-,098	-,180	,861
Income	,007	,023	,121	,320	,756
Smoking (females)	3,873	1,622	,623	2,387	,041
Alcohol (females)	6,122	49,384	,054	,124	,904
Overweight (females)	-,209	3,242	-,016	-,064	,950

Dependent variable: all types of cancer, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	485,204	509,454		,952	,366
PM pollution	-50,441	244,812	-,115	-,206	,841
Gaseous pollution	,011	,060	,103	,177	,863
Income	,064	,067	,257	,957	,364
Smoking	26,015	8,986	,764	2,895	,018
Alcohol	-29,367	64,731	-,148	-,454	,661
Overweight	-7,974	14,892	-,144	-,535	,605

Dependent variable: all types of cancer, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	485,204	509,454		,952	,366
PM pollution	-50,441	244,812	-,115	-,206	,841
Gaseous pollution	,011	,060	,103	,177	,863
Income	,064	,067	,257	,957	,364
Smoking (males)	26,015	8,986	,764	2,895	,018
Alcohol (males)	-29,367	64,731	-,148	-,454	,661
Overweight (males)	-7,974	14,892	-,144	-,535	,605

Dependent variable: all types of cancer, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	119,920	105,410		1,138	,285
PM pollution	17,203	53,162	,162	,324	,754
Gaseous pollution	-,002	,014	-,098	-,180	,861
Income	,007	,023	,121	,320	,756
Smoking (females)	3,873	1,622	,623	2,387	,041
Alcohol (females)	6,122	49,384	,054	,124	,904
Overweight (females)	-,209	3,242	-,016	-,064	,950

Lung cancer

Dependent variable: lung cancer, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-7,308	54,283		-,135	,896
PM pollution	-19,873	26,085	-,422	-,762	,466
Gaseous pollution	,002	,006	,170	,296	,774
Income	,010	,007	,371	1,391	,198
Smoking	2,776	,958	,759	2,900	,018
Alcohol	-4,939	6,897	-,232	-,716	,492
Overweight	-,581	1,587	-,097	-,366	,723

Dependent variable: lung cancer, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-35,051	93,658		-,374	,717
PM pollution	-48,094	44,762	-,716	-1,074	,311
Gaseous pollution	,007	,011	,468	,700	,501
Income	,017	,011	,455	1,534	,159
Smoking (males)	4,491	1,727	,796	2,600	,029
Alcohol (males)	-6,648	6,260	-,365	-1,062	,316
Overweight (males)	-,782	2,042	-,120	-,383	,711

Dependent variable: lung cancer, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-19,273	37,899		-,509	,623
PM pollution	-2,823	19,114	-,068	-,148	,886
Gaseous pollution	-,002	,005	-,161	-,319	,757
Income	,006	,008	,255	,726	,486
Smoking (females)	1,680	,583	,697	2,880	,018
Alcohol (females)	-,002	17,755	,000	,000	1,000
Overweight (females)	,106	1,165	,021	,091	,930

Dependent variable: lung cancer, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-7,359	186,559		-,039	,969
PM pollution	-91,382	89,649	-,549	-1,019	,335
Gaseous pollution	,010	,022	,258	,460	,656
Income	,036	,024	,387	1,491	,170
Smoking	9,407	3,291	,728	2,858	,019
Alcohol	-9,085	23,704	-,121	-,383	,710
Overweight	-3,350	5,454	-,159	-,614	,554

Dependent variable: lung cancer, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-7,308	54,283		-,135	,896
PM pollution	-19,873	26,085	-,422	-,762	,466
Gaseous pollution	,002	,006	,170	,296	,774
Income	,010	,007	,371	1,391	,198
Smoking (males)	2,776	,958	,759	2,900	,018
Alcohol (males)	-4,939	6,897	-,232	-,716	,492
Overweight (males)	-,581	1,587	-,097	-,366	,723

Dependent variable: lung cancer, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-46,952	114,346		-,411	,691
PM pollution	-42,830	57,669	-,326	-,743	,477
Gaseous pollution	,003	,015	,083	,173	,866
Income	,024	,025	,317	,954	,365
Smoking	5,252	1,760	,684	2,984	,015
Alcohol	,965	53,570	,007	,018	,986
Overweight	-,957	3,516	-,059	-,272	,792

Ischaemic heart diseases

Dependent variable: ischaemic heart diseases, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	250,416	255,601		,980	,353
PM pollution	80,151	122,826	,385	,653	,530
Gaseous pollution	-,025	,030	-,511	-,834	,426
Income	,037	,033	,316	1,113	,294
Smoking	-1,042	4,509	-,064	-,231	,822
Alcohol	38,364	32,477	,407	1,181	,268
Overweight	-10,592	7,472	-,402	-1,418	,190

Dependent variable: ischaemic heart diseases, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	91,456	451,056		,203	,844
PM pollution	130,410	215,575	,470	,605	,560
Gaseous pollution	-,040	,051	-,620	-,794	,448
Income	,050	,054	,321	,928	,378
Smoking (males)	-1,050	8,318	-,045	-,126	,902
Alcohol (males)	23,156	30,149	,308	,768	,462
Overweight (males)	-4,311	9,836	-,161	-,438	,672

Dependent variable: ischaemic heart diseases, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	226,926	131,673		1,723	,119
PM pollution	101,902	66,407	,635	1,534	,159
Gaseous pollution	-,027	,017	-,729	-1,616	,141
Income	,008	,028	,092	,292	,777
Smoking (females)	-1,267	2,027	-,135	-,625	,547
Alcohol (females)	116,315	61,688	,682	1,886	,092
Overweight (females)	-8,136	4,049	-,409	-2,009	,075

Dependent variable: ischaemic heart diseases, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	1330,740	1030,557		1,291	,229
PM pollution	383,915	495,221	,455	,775	,458
Gaseous pollution	-,055	,121	-,279	-,457	,659
Income	,139	,135	,292	1,033	,329
Smoking	-4,719	18,178	-,072	-,260	,801
Alcohol	79,948	130,942	,209	,611	,557
Overweight	-43,561	30,125	-,408	-1,446	,182

Dependent variable: ischaemic heart diseases, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	627,485	1790,917		,350	,734
PM pollution	647,365	855,940	,606	,756	,469
Gaseous pollution	-,125	,201	-,501	-,623	,549
Income	,158	,216	,261	,731	,483
Smoking (males)	31,632	119,707	,109	,264	,798
Alcohol (males)	-11,862	39,055	-,115	-,304	,768
Overweight (males)	-2,946	33,026	-,033	-,089	,931

Dependent variable: ischaemic heart diseases, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	1134,701	574,085		1,977	,080
PM pollution	475,664	289,531	,666	1,643	,135
Gaseous pollution	-,059	,074	-,356	-,805	,441
Income	,108	,124	,266	,867	,408
Smoking (females)	-6,072	8,836	-,145	-,687	,509
Alcohol (females)	231,198	268,955	,304	,860	,412
Overweight (females)	-41,213	17,654	-,466	-2,335	,044

Cebrovascular diseases

Dependent variable: cebrovascular diseases, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-46,214	99,623		-,464	,654
PM pollution	21,362	47,873	,299	,446	,666
Gaseous pollution	-,004	,012	-,241	-,346	,737
Income	,017	,013	,420	1,301	,226
Smoking	-,074	1,757	-,013	-,042	,967
Alcohol	2,599	12,658	,080	,205	,842
Overweight	3,063	2,912	,339	1,052	,320

Dependent variable: cebrovascular diseases, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-33,059	139,711		-,237	,818
PM pollution	-34,889	66,773	-,407	-,523	,614
Gaseous pollution	,009	,016	,436	,557	,591
Income	,023	,017	,484	1,394	,197
Smoking (males)	3,448	2,576	,479	1,338	,214
Alcohol (males)	-2,454	9,338	-,106	-,263	,799
Overweight (males)	-,916	3,047	-,111	-,301	,770

Dependent variable: cebrovascular diseases, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-57,216	60,583		-,944	,370
PM pollution	12,992	30,554	,202	,425	,681
Gaseous pollution	-,004	,008	-,236	-,455	,660
Income	,014	,013	,382	1,058	,317
Smoking (females)	-,551	,932	-,147	-,591	,569
Alcohol (females)	13,693	28,383	,201	,482	,641
Overweight (females)	3,994	1,863	,502	2,144	,061

Dependent variable: cebrovascular diseases, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	16,049	500,948		,032	,975
PM pollution	17,055	240,724	,049	,071	,945
Gaseous pollution	,013	,059	,162	,224	,828
Income	,069	,066	,350	1,045	,323
Smoking	-1,915	8,836	-,071	-,217	,833
Alcohol	-2,540	63,650	-,016	-,040	,969
Overweight	10,879	14,644	,248	,743	,476

Dependent variable: cebrovascular diseases, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	72,713	657,056		,111	,914
PM pollution	-287,454	314,029	-,710	-,915	,384
Gaseous pollution	,083	,074	,875	1,124	,290
Income	,097	,079	,423	1,225	,252
Smoking (males)	-25,858	43,918	-,236	-,589	,570
Alcohol (males)	-8,058	14,329	-,206	-,562	,588
Overweight (males)	16,087	12,117	,473	1,328	,217

Dependent variable: cebrovascular heart diseases, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-147,837	328,507		-,450	,663
PM pollution	-16,725	165,677	-,052	-,101	,922
Gaseous pollution	,018	,042	,240	,431	,677
Income	,084	,071	,456	1,177	,269
Smoking (females)	-4,629	5,056	-,245	-,916	,384
Alcohol (females)	-23,498	153,903	-,068	-,153	,882
Overweight (females)	16,589	10,102	,413	1,642	,135

Circulatory diseases

Dependent variable: circulatory diseases, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	855,682	314,103		2,724	,023
PM pollution	65,339	150,938	,296	,433	,675
Gaseous pollution	,008	,037	,162	,228	,824
Income	-,042	,041	-,341	-1,033	,329
Smoking	,528	5,540	,031	,095	,926
Alcohol	-5,988	39,910	-,060	-,150	,884
Overweight	-4,928	9,182	-,177	-,537	,604

Dependent variable: circulatory diseases, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	1706,062	438,852		3,888	,004
PM pollution	-7,166	209,742	-,019	-,034	,973
Gaseous pollution	,033	,049	,364	,665	,523
Income	-,172	,053	-,790	-3,257	,010
Smoking (males)	-17,385	8,093	-,538	-2,148	,060
Alcohol (males)	15,457	29,333	,148	,527	,611
Overweight (males)	-12,021	9,570	-,323	-1,256	,241

Dependent variable: circulatory diseases, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	404,691	205,598		1,968	,081
PM pollution	114,247	103,690	,638	1,102	,299
Gaseous pollution	-,005	,026	-,109	-,173	,866
Income	-,019	,044	-,185	-,421	,683
Smoking (females)	,840	3,164	,080	,265	,797
Alcohol (females)	-7,038	96,321	-,037	-,073	,943
Overweight (females)	2,022	6,322	,091	,320	,756

Dependent variable: circulatory diseases, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	3956,391	1677,019		2,359	,043
PM pollution	370,256	805,870	,325	,459	,657
Gaseous pollution	,041	,196	,155	,210	,838
Income	-,158	,220	-,245	-,720	,490
Smoking	-14,611	29,581	-,165	-,494	,633
Alcohol	12,639	213,082	,025	,059	,954
Overweight	-8,636	49,023	-,060	-,176	,864

Dependent variable: circulatory diseases, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	1706,062	438,852		3,888	,004
PM pollution	-7,166	209,742	-,019	-,034	,973
Gaseous pollution	,033	,049	,364	,665	,523
Income	-,172	,053	-,790	-3,257	,010
Smoking (males)	-17,385	8,093	-,538	-2,148	,060
Alcohol (males)	15,457	29,333	,148	,527	,611
Overweight (males)	-12,021	9,570	-,323	-1,256	,241

Dependent variable: circulatory diseases, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	2116,423	1269,773		1,667	,130
PM pollution	352,911	640,391	,329	,551	,595
Gaseous pollution	,052	,163	,207	,318	,758
Income	,017	,274	,027	,061	,953
Smoking (females)	-5,055	19,543	-,081	-,259	,802
Alcohol (females)	-315,965	594,881	-,277	-,531	,608
Overweight (females)	21,871	39,048	,164	,560	,589

Respiratory diseases

Dependent variable: respiratory diseases, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-174,252	60,102		-2,899	,018
PM pollution	18,012	28,881	,228	,624	,548
Gaseous pollution	-,016	,007	-,884	-2,322	,045
Income	,031	,008	,688	3,900	,004
Smoking	2,370	1,060	,387	2,235	,052
Alcohol	-4,144	7,637	-,116	-,543	,601
Overweight	3,167	1,757	,317	1,803	,105

Dependent variable: respiratory diseases, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-342,553	62,132		-5,513	,000
PM pollution	2,030	29,695	,017	,068	,947
Gaseous pollution	-,018	,007	-,663	-2,647	,027
Income	,056	,007	,833	7,491	,000
Smoking (males)	6,610	1,146	,662	5,769	,000
Alcohol (males)	-8,743	4,153	-,271	-2,105	,065
Overweight (males)	2,646	1,355	,230	1,953	,083

Dependent variable: respiratory diseases, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-102,330	48,840		-2,095	,066
PM pollution	10,949	24,632	,176	,445	,667
Gaseous pollution	-,012	,006	-,820	-1,904	,089
Income	,020	,011	,561	1,874	,094
Smoking (females)	1,041	,752	,286	1,385	,199
Alcohol (females)	2,640	22,881	,040	,115	,911
Overweight (females)	2,458	1,502	,318	1,637	,136

Dependent variable: respiratory diseases, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-591,777	333,362		-1,775	,110
PM pollution	21,342	160,193	,062	,133	,897
Gaseous pollution	-,054	,039	-,671	-1,385	,199
Income	,116	,044	,599	2,666	,026
Smoking	10,340	5,880	,387	1,758	,113
Alcohol	-48,745	42,357	-,314	-1,151	,279
Overweight	13,292	9,745	,306	1,364	,206

Dependent variable: respiratory diseases, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-1166,207	439,450		-2,654	,026
PM pollution	-99,768	210,028	-,195	-,475	,646
Gaseous pollution	-,047	,049	-,393	-,954	,365
Income	,201	,053	,694	3,797	,004
Smoking (males)	-67,757	29,373	-,489	-2,307	,046
Alcohol (males)	12,775	9,583	,258	1,333	,215
Overweight (males)	27,358	8,104	,637	3,376	,008

Dependent variable: respiratory diseases, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	-375,122	250,401		-1,498	,168
PM pollution	26,312	126,286	,095	,208	,840
Gaseous pollution	-,045	,032	-,688	-1,388	,198
Income	,098	,054	,623	1,809	,104
Smoking (females)	5,309	3,854	,327	1,378	,202
Alcohol (females)	-68,585	117,311	-,232	-,585	,573
Overweight (females)	8,482	7,700	,246	1,102	,299

ANNOVAa

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	8358,599	6	1393,100	18,826	,000b
Residual	665,983	9	73,998		
Total	9024,582	15			

a. Dependent Variable: respiratory males2014

b. Predictors: (Constant), smoking males, overweight males, income, alcohol males, PM pollution

ANNOVAa

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	133851,741	6	22308,624	6,026	,009b
Residual	33316,383	9	3701,820		
Total	167168,125	15			

a. Dependent Variable: respiratory males at 65
b. Predictors: (Constant), smoking males, PM pollution, overweight males, income, alcohol males, gaseous pollution

Asthma

Dependent variable: asthma, both sexes, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	3,182	2,816		1,130	,288
PM pollution	2,854	1,353	1,120	2,109	,064
Gaseous pollution	,000	,000	-,608	-1,101	,299
Income	-,001	,000	-,481	-1,879	,093
Smoking	-,110	,050	-,554	-2,205	,055
Alcohol	,494	,358	,429	1,380	,201
Overweight	,071	,082	,222	,868	,408

Dependent variable: asthma, males, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	2,926	4,073		,718	,491
PM pollution	1,845	1,946	,657	,948	,368
Gaseous pollution	-9,408E-5	,000	-,143	-,206	,842
Income	-,001	,000	-,554	-1,796	,106
Smoking (males)	-,076	,075	-,324	-1,017	,336
Alcohol (males)	,162	,272	,213	,595	,567
Overweight (males)	,107	,089	,394	1,202	,260

Dependent variable: asthma, females, all ages

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	3,197	3,022		1,058	,318
PM pollution	2,567	1,524	,918	1,684	,126
Gaseous pollution	,000	,000	-,438	-,737	,480
Income	,000	,001	-,314	-,760	,467
Smoking (females)	-,051	,047	-,313	-1,099	,300
Alcohol (females)	,590	1,416	,198	,416	,687
Overweight (females)	,008	,093	,024	,090	,930

Dependent variable: asthma, both sexes, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	18,498	12,379		1,494	,169
PM pollution	11,413	5,948	,904	1,919	,087
Gaseous pollution	-,001	,001	-,185	-,377	,715
Income	-,004	,002	-,514	-2,262	,049
Smoking	-,454	,218	-,463	-2,077	,068
Alcohol	1,598	1,573	,280	1,016	,336
Overweight	,236	,362	,148	,651	,531

Dependent variable: asthma, males, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	26,388	22,241		1,186	,266
PM pollution	,745	10,630	,044	,070	,946
Gaseous pollution	,002	,002	,614	,983	,351
Income	-,005	,003	-,528	-1,904	,089
Smoking (males)	-,036	1,487	-,008	-,024	,981
Alcohol (males)	,334	,485	,203	,689	,508
Overweight (males)	-,400	,410	-,279	-,975	,355

Dependent variable: asthma, females, 65 and older

	B unstandardized	Std. error	Beta standardized	t	Sig.
(Constant)	11,168	13,325		,838	,424
PM pollution	12,426	6,720	,952	1,849	,097
Gaseous pollution	-,001	,002	-,329	-,587	,572
Income	-,002	,003	-,213	-,546	,598
Smoking (females)	-,123	,205	-,161	-,599	,564
Alcohol (females)	-,344	6,242	-,025	-,055	,957
Overweight (females)	,044	,410	,027	,107	,917

Appendix 12: Descriptive statistics dependent variables

Dependent variables

	N	Minimum	Maximum	Mean	Std. Deviation
All cancer	16	247,59	324,54	294,2463	23,14209
All cancer at 65	16	915,21	1227,05	1090,1838	90,47068
All cancer females	16	177,47	247,46	220,1213	21,92672
All cancer females at 65	16	620,96	884,91	777,6138	80,69250
All cancer males at 65	16	1398,79	1852,09	1643,6731	123,81981
All cancer males	16	357,93	459,37	415,0425	28,79017
All cause mortality	16	1198,95	1426,11	1290,0050	57,74331
All cause mortality at 65	16	5030,96	5785,54	5362,5637	196,30834
All cause mortality at 65 males	16	6490,71	7618,40	6959,8169	296,13346
All cause mortality at 65 females	16	4075,24	4821,67	4450,4037	186,09587
All cause mortality females	16	907,67	1095,01	999,8331	50,40294
All cause mortality males	16	1595,23	1930,50	1716,9388	85,88906
Asthma	16	,38	2,44	1,5038	,52553
Asthma at 65	16	,70	12,11	6,4731	2,60368
Asthma at 65 females	16	,59	11,53	5,8731	2,69338
Asthma 65 males	16	1,02	12,88	7,6238	3,52029
Asthma females	16	,33	2,39	1,4050	,57655
Asthma males	16	,47	2,48	1,7169	,57950
Cebrovacular diseases	16	85,83	140,25	110,4581	14,75365
Cebrovascular diseases at 65	16	415,97	670,08	536,9219	71,42146
Cebrovascular diseases females	16	76,16	122,07	97,5981	13,24588
Cebrovascular diseases females at 65	16	383,14	607,17	495,5350	66,78795
Cebrovascular diseases males	16	98,80	166,64	126,8081	17,68675
Cebrovascular diseases males at 65	16	466,40	781,60	595,3994	83,48831
Circulatory diseases	16	482,30	632,70	577,8438	45,51108
Circulatory diseases females at 65	16	2101,91	2871,90	2545,6675	221,49101
Circulatory diseases females	16	347,55	478,95	423,0299	36,94728
Circulatory diseases males	16	669,30	884,03	789,7045	60,09128
Circulatory diseases males at 65	16	2868,35	3857,41	3477,7687	277,63870
Circulatroy diseases at 65	16	2406,33	3211,21	2891,8463	234,98456
Life expectanct at 60 females	16	23,30	24,90	24,0563	,47884
Life expectancy at 60 males	16	18,20	19,70	18,8688	,46147
Life expectancy at birth females	16	80,30	82,60	81,5125	,74375
Life expectancy at birth males	16	71,40	75,10	73,4938	,88126
Ischaemic heart diseases at 65	16	395,04	926,40	637,7619	174,13447
Ischaemic heart diseases at 65 females	16	291,89	751,09	507,7919	147,37255
Ischaemic heart at 65 males	16	563,85	1257,40	861,9063	220,37160
Ischaemic heart diseases males	16	126,65	302,46	188,6263	57,17465
Ischamemic heart diseases	16	83,07	214,74	133,9138	42,96000

Ischaemic heart diseases females	16	54,83	153,26	96,9613	33,07951
Lung cancer	16	50,49	88,72	69,1706	9,72130
Lung cancer at 65	16	174,95	308,80	238,8475	34,35046
Lung cancer females	16	19,42	46,17	34,8731	8,50625
Lung cancer females at 65	16	53,97	136,03	105,2350	27,11062
Lung cancer males	16	96,66	155,36	120,9319	13,85980
Lung cancer males at 65	16	369,97	607,22	460,6306	55,27859
Respiratory diseases at 65	16	238,86	437,14	324,4000	70,92967
Respiratory diseases	16	50,87	99,56	71,1450	16,27704
Respiratory diseases females	16	30,97	71,04	47,5781	12,85738
Respiratory diseases females at 65	16	151,49	310,48	217,7069	57,32796
Respiratory diseases males	16	84,29	152,15	114,4250	24,52833
Respiratory diseases males at 65	16	383,35	688,41	536,9438	105,56771
Valid N (listwise)	16				