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TRENDS OF AIR POLLUTION IN THE USA AND EUROPE, PARTICULARLY THE CZECH REPUBLIC, FROM 1950 TO THE PRESENT

Bakalářská práce

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V Praze dne 22. 5. 2012 ....

ABSTRACT - English

Air pollution represents one of the main environmental issues. It affects human health and the environment through phenomena such as smog, acid rain, ozone layer depletion and climate change. Human health is not affected only outdoors but also indoors where other sources of pollution are in effect. People were already concerned about polluted air in the past. Nowadays, people have become more aware of the harmful impacts of polluted air, particularly after a few smog episodes which resulted in numerous deaths in 1950s. Since then, a lot of has been done to improve the situation, especially in the developed world. The United States (US) led the way by early environmental movements, establishing the Environmental Protection Agency (EPA) and setting legislation to restrict polluting of the atmosphere. The European Union (EU) started later with their efforts. However, the air quality standards are much stricter now in the EU than in the US. The Czech Republic was behind on the way to cleaner air due to presence in the region of the Soviet Block where the environment was not seriously taken into consideration. Very rapid recovery has taken place establishing laws and legislation to adjust to the European standards and improve the air quality as fast as possible. Air pollution is a transboundary issue; therefore, several international agendas have been agreed on to improve the situation globally.

ABSTRAKT - Česky

Znečištění ovzduší představuje jeden z hlavních environmentálních problémů. Jevy, jako například smog, kyselý déšť, úbytek ozónu a změny klimatu, ovlivňují nejen životní prostředí,ale i lidské zdraví. Lidské zdraví není ovlivňováno pouze kvalitou venkovního ovzduší, ale také ovzduším ve vnitřních prostorách budov, kde ještě působí další zdroje znečištění a rozptyl škodlivin je limitován.

Podle historických záznamů se lidé o znečištění ovzduší zajímali již od pradávna. Nicméně až v dnešní době jsou si negativních dopadů znečištěného ovzduší více vědomi. Počátky této uvědomělosti sahají do padesátých let minulého století, kdy mnoho lidí zahynulo následkem několika smogových epizod. Od té doby, zejména ve vyspělých zemích, bylo pro zlepšení kvality ovzduší mnoho vykonáno. Spojené státy americké (USA) stály v čele pokroku ranými environmetálními hnutími, založením Agentury pro ochranu životního prostředí (Environmental Protection Agency, EPA) a přijetím zákonů omezujících znečišťování atmosféry. Evropská unie (EU) začala v tomto ohledu vyvíjet snahy později, avšak dnešní standardy kvality ovzduší jsou v EU mnohem striktnější než v USA. V minulosti byla v České republice (ČR) velmi špatná kvalita ovzduší, protože ČR byla součástí východního bloku, kde se na životní prostředí příliš nehledělo. K rychlému zlepšení kvality ovzduší došlo v devadesátých letech 20. století. Napomohla tomu legislativa přizpůsobující se evropským standardům. Problematika znečištění ovzduší je nadnárodní, a tak bylo přijato několik mezinárodních úmluv, které si dávají za cíl vylepšit situaci globálně.

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INTRODUCTION TO AIR POLLUTION

Air pollution is one of the most significant environmental problems our society and planet in general are currently facing. Our health depends on a good air quality just like breathing is essential to our lives. Good air quality is not only important to our health; adverse environmental and economic effects are accredited to the air pollution as well.

Good health represents one of the greatest values for most of the people. It is something fragile that requires constant support and protection. Prevention is very important to suppress possible causes of diseases, enhance quality of life and improve its length. The environment has an influence on a human's physical as well as mental health state. Therefore, it is in the best interest of the majority to keep the environment natural and clean, and consequently enjoy its positive influence on us which is the best prevention of diseases and other problems.

Although it is difficult to apply a health effect study on a human population because of the great amount of factors which need to be taken into consideration when assessing the health effects of air pollution (Hall, 1996); according to the World Health Organization (2012), air pollution represents a major environmental risk to health and is responsible for approximately 2 million premature deaths worldwide per year. Such diseases as respiratory infections (Heinrich et al., 2002), heart disease (Brook et al., 2004), and lung cancer (Pope et al., 2002) are caused by air pollution. There is a strong evidence of a cause-effect relationship between air pollution and impaired health. Worldwide, 800,000 deaths are estimated to occur due to urban outdoor air pollution and more than 1.6 million deaths are caused annually by indoor air pollution (Ezatti et al., 2002).

Smog episodes occur in urban areas which are heavily polluted by emissions from transportation (Fenger, 1999). Domestic fireplaces represent significant sources of toxic chemicals along with industry and power plants which also contribute to the pollution. Although most of the air pollutants are present in atmosphere naturally, human activities greatly contribute to their occurrence. In some cases, the anthropogenic contribution is widespread and leads to an increase of a substance in the atmosphere globally. In other cases, pollutants are released and captured in small areas where they become very concentrated and dangerous to human health and the environment. In urban areas, pollution is generally worse than in the countryside (Hoek et al., 1997). Urban pollution is mainly caused by transportation (Fenger, 1999) as well as domestic heating, local industry and businesses such as drycleaner's, bakeries, boiler-houses, and printing plants.

Domestic heating represents nowadays a more serious problem than, for example, waste incineration plants possessing better filters and technology to burn the waste. In the domestic fireplaces, materials such as wood and coal, and unfortunately also often domestic wastes, are burned under lower temperatures and without sophisticated filters and technologies (Hönig, 2006). Domestic burning leads to local pollution and smog creation in urban areas. If the domestic waste burned in the fireplace contains also plastic and other synthetic materials, very toxic and carcinogenic chemicals, including the persistent organic pollutants (POPs), are released into atmosphere. POPs are for example the polychlorinated biphenyls and other polycyclic aromatic hydrocarbons (Lemieux et al., 2004). Domestic heating contributes significantly to both, deteriorated air quality indoors and outdoor smog.

Especially in urban areas, people and the environment suffer from smog (smoke + fog). There are two main forms of smog: reductive and oxidizing. The reductive smog, also called the London type of smog, is a mixture of smoke, sulfur oxides (SO_X) and other pollutants released from burning coal in presence of high humidity. The reductive smog is often accompanied by dense fog and a presence of fly-ash. Increased concentration of SO_2, suspended particulate matter, and other substances present in the reductive smog have provable influence on human health (Braniš & Hůnová, 2009). The oxidizing smog, also called the summer smog, photochemical smog, or the Los Angeles type of smog, originates from combustion products when burning liquid fuels. It is related to a massive air pollution caused by automobiles' exhaust gas especially during hot, calm summer days. It is a mixture of ozone, peroxyacetylnitrates, aldehydes and sulfuric acid created by photochemical reactions from nitrogen oxides, hydrocarbons and sulfur dioxide (Calvert, 1976; Whitten, 1983). The negative effect of the oxidizing smog and particularly of the ground-level ozone is its impact on all kinds of receptors that human health, animals, plants, and also materials are adversely affected (Hůnová et al., 2012). Additionally, the smog exaggerates the heat island effect, causing higher temperatures in cities compared to the surrounding landscape

(Rosenfeld et al., 1998). Nevertheless, the pollution levels don't necessarily need to be extremely high, such as during strong smog episodes, to cause adverse health effects. The Vedal et al. (2003) study suggested that there was a relationship between increased daily mortality and increases in low concentrations of air pollutants.

Not only is the ambient air quality an issue. Because people spend significant amount of time indoors, they are increasingly exposed to pollutants in the home environment (Farrow et al., 1997). The indoor air quality is affected by both, the ambient air quality and the activities and sources of contaminants enclosed (Braniš et al., 2005). According to the National Human Activity Pattern Survey, the Americans spent about 87% of their time indoors and about 6% of their time in their vehicles in the 1990s (Klepeis et al., 2001), which shows significant exposure time to the indoor air pollutants. Indoor air quality is highly correlated with ambient air quality (Jones et al., 2000). However, many indoor sources adversely affect the air quality too. Dusty homes, insufficient ventilating, overuse of chemicals, furniture full of formaldehyde or molds in ventilation systems are examples of impaired indoor air quality. Smoking showed to be an extremely significant factor and the presence of people considerably increased the concentrations of fine particles PM_1 in enclosed areas (Braniš et al, 2002).

Although the health effects of the air pollution are prominent, the environmental problems caused by air pollutants deserve just as much attention. Phenomena related to increased levels of air pollutants are acid rain, smog, stratospheric ozone depletion and a greenhouse effect. Acid rain occurs when air pollution caused by burning fossil fuels is combined with water vapor. Through precipitation, the acid rain containing nitric acid (HNO_3), sulfuric acid (H_2SO_4) and sulfonic acid (H_2SO_3) affects plants, animals and rocks (Parungo et al., 1987). Lowered pH of lake and stream water has an impact on living organisms which of many have difficulties to adapt, especially due to higher levels of dissolved metals (Fang et al., 1990; Goyer et al, 1985). The acid rain truly affects entire ecosystems (Schindler, 1988). Structures are also affected by the acid rain and the air pollution. Decay and change in color of masonry and statues (Monte & Vittori, 1985) represent one of many negative economic effects of air pollution.

The air pollution's negative impacts on human health and the environment imply negative economic effects. It is obvious that people who are sick cannot go to work or cannot work as effectively and productively. Also the health care, which evidently costs money, needs to be provided to them. If money from taxes is used to grant public health care, this money could be spent for other public welfare such as education.

The environment is under stress from air pollution and related acid rain, ozone layer depletion and climate change (Braniš & Hůnová, 2009; Crutzen, 1999; Hepting, 1964; Metcalfe & Derwent, 2005) . Acid rain affects the economy negatively because it causes forests to suffer and decreases the quality and quantity of timber (Hepting, G.H., 1964). Visitors may not come to damaged natural reserves and tourism declines. The acidic lakes and streams lose fish which affects fishery industries (Schindler, 1988) . Entire ecosystems of incalculable value are affected. Species of plants or animals are lost due to acidification or climate change (Thomas et al, 2004). And these lost species might have been used for invention of a drug which might have saved lives. People concerned about their material properties need to take into consideration the fact that air pollution and related phenomena cause damage to materials. Buildings, statues, and above all historical monuments of great values are highly influenced (Camuffo, 1992).

The negative impacts of air pollution are obvious to most of the people; however, lots of them disregard the adverse effects or do not support the problem-solving process, because it often involves initial sacrifices on their part. People are concerned with “today” instead of “tomorrow”, are not patient and like to see change and results immediately, or do not believe in consequences resulting from current situation. Therefore, they tend to rather ignore the problems and do not engage in a solving process. Some of them, and that includes politicians and people in decision making positions, sadly do not care about the negative effects because many consequences occur later on in future and their attitude is that it will not be in their concern or responsibility anymore.

From the economical perspective, it is very difficult to calculate a price of a lost species or to exactly assess the number of people who have lung cancer caused by air pollution and not by other phenomena. Therefore, economical costs on society today and in future are not fully taken in consideration (Ackerman & Heinzerling, 2002). On the other hand, people tend to overrate the environment and perceive it as something luxurious and expensive. The public is often misinformed by the media which tend to assess environmental and economic goals as contradictory. The media stress the costs of implementation of new environmental policies over its benefits. Usually this economic data is easier to calculate, and today, people are concerned with paying these costs. However, people unfortunately underestimate the long-term costs to the ecosystems or human health if such policies were not implemented. Their inability to understand long-term consequences of the problem makes the solving process even more difficult. In order for air pollution to be eradicated, mindset and value systems need to evolve. Society needs to decrease consumption and protect the environment for future generations.

There is a will to establish economical models regarding environmental issues. For example, The United States Environmental Protection Agency (EPA) uses Integrated Planning Model to investigate the impact of policies concerning air emissions on the U.S. electric power sector over a 20-year time period. There is also an Air Benefit and Cost Group (ABCG) which provides tools such as databases and models for analyzing cost, benefit, and economic impacts (Fann, n.d.). Another institution is the National Center for Environmental Economics (NCEE) in the USA. The NCEE manages EPA's research on environmental economics and specializes in analyzing the economic and health impacts of environmental regulations and policies.

Sources of air pollution, natural or anthropogenic, are present almost everywhere. Nearly all human activity results in pollution of the environment. However, it is important to assess the activity's benefits and costs including impaired health and environmental consequences. Being informed about the sources of pollution is the first step to the elimination of their emissions. Engagement of improved technologies in industry and transportation also decreases their impact. Last but not least, people's lifestyle and behavior, their demand for energy and products, and their need of transportation influence the number of sources and amount of pollution generated by them.

The air does not obey boundaries. Air pollution is not just local but also transboundary; therefore, international agreements are necessary. However, people and nations tend to act selfishly and air pollution is one of the cases of the "tragedy of the commons." This term refers to the collective goods dilemma. The collective goods – global commons – are the shared parts of the earth, such as the atmosphere. Unfortunately, the parties sharing the resources don't have a great regard for them, and their self-interests lead to misuse of the commons and to a loss of possible shared benefits (Goldstein & Pevehouse, 2009).

OBJECTIVES OF MY THESIS AND METHODOLOGY

The main objective of this thesis is to gather data on the amounts of pollutants released into the atmosphere and show long term trends in two major geographical areas: the United States of America and Europe. In Europe, particular focus is placed on the Czech Republic. Data has been evaluated since the 1950s, because that is when air pollution issues initially came to the center of attention. The main contribution of my thesis lies within finding the almost 60 year-old, pre-internet age, data with limited accessibility. Obtained data were analyzed in order to show the long term trends graphically in a meaningful way. The revealed trends were then chronologically related to economic activities, industry, regional as well as international legislation, social movements, and changing attitudes in society towards the environment. The geographical regions were compared regarding the trends of air pollution, legislation, authorities involved, attitude, and the concentration standards of the main air pollutants. In conclusion of the project, general findings about the issue of the air pollution are addressed.

CRITERIA AIR POLLUTANTS & COMPARISONS OF STANDARDS

The topic of air pollution is very broad. Therefore, only the most significant and tracked pollutants are mapped in detail in this thesis. These are nitrogen oxides (NO_X), particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2) and lead (Pb). Emissions of these pollutants into the atmosphere occur due to natural as well as human activities such as industry or transportation.

The United States Environmental Protection Agency (EPA) divides pollutants as either criteria air pollutants or hazardous air pollutants (HAPs, air toxics). According to EPA (2012a), the criteria air pollutants are carbon monoxide, nitrogen oxides, sulfur dioxide, particulate matter, ozone, and lead. The EPA also regulates 187 HAPs which are substances with a potential for adverse effects on human health (EPA, 2012a). As required by the Clean Air Act, the EPA set the National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment (EPA, 2012b).

The European Union has also developed legislation which establishes air quality standards. The pollutants under restriction are: SO_2, NO_2, PM_{10}, CO, lead, O_3, benzene, arsenic, cadmium, nickel, polycyclic aromatic hydrocarbons, and newly also $PM_{2.5}$ (European Commission, 2012). The World Health Organization primarily focuses on PM, O_3, SO_2 and NO_2 giving guidelines (WHO, 2005).

SULFUR DIOXIDE (SO_2)

Sulfur oxides (SO_X) get into atmosphere mainly from industrial production, burning coal and other sulfur-containing fuels, and through natural processes such as volcanic activity or forest fires. Sulfur oxides are for the most part represented by sulfur dioxide, and less by sulfur trioxide (SO_3). Mankind has had problems with sulfur oxides for about 2 000 years. Ancient Romans suffered from them and later on, in the middle ages, some monarchs banned their origin: coal burning. When coal is burned, 95% of the sulfur contained in coal transforms to SO_2. Moreover, during combustion of liquid fuels, almost 100% of sulfur contained in the fuel is transformed to SO_2 (Joskow et al.,1998).

In the Czech Republic, average maximal daily concentration of SO_2 is 125 µg/m³. The concentration, by law, is not supposed to rise above 500 µg/m³ for a period of half an hour (Tab.1). World Health Organization has a stricter opinion. According to the WHO Guidelines from 2005, the SO_2 concentration of 500 µg/m³ should not remain for periods greater than 10 minutes. The WHO also reconsidered the previous 24-hour mean guideline concentration of 125 µg/m³, and reduced it to only 20 µg/m³ in the 2005 Air Quality Guideline (AQG) because the health effects of SO_2 were associated with much lower concentrations (WHO, 2005). Air Quality Standards for SO_2 in the European Union are consistent with the standards in the Czech Republic. Unfortunately the National Ambient Air Quality Standards for SO_2 in the United States are given in different units (ppm); which makes it difficult to compare with the values of standards given by other institutions.

Table 1. SO_2 concentration standards

WHO 2005 Guidelines [1]	**U.S.A. NAAQS** [2]
20 µg/m^3 24-hour mean	0.14 ppm 24-hour mean (160 µg/m^3)
500 µg/m^3 10-minute mean	0.03 ppm annual mean (35 µg/m^3)
EU Air Quality Standards [3]	**Czech Hydrometeorological Institute** [4]
125 µg/m^3 24-hour mean	125 µg/m^3 24-hour mean
350 µg/m^3 1-hour mean	350 µg/m^3 1-hour mean

Sources of data:

1 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

4 http://www.chmi.cz/uoco/isko/isko2/exceed/summary/limit2010_CZ.html

NITROGEN DIOXIDE (NO_2)

Nitrogen (N_2) is a foundation of the Earth's atmosphere and represents 78% of its volume. Nitrogen also appears in the atmosphere in forms of its oxides: N_2O, NO_2, NO, and in other compounds with oxygen. Nitrogen oxides are emitted mainly as a result of combustion of gasoline, oil, light fuel oil and coal. Combustion of these mixtures takes place under very high temperatures (above 1 000° Celsius). Under these conditions, atmospheric nitrogen reacts with oxygen, and nitrogen oxides are formed. Nitrogen oxides are also produced by chemical industries and agriculture. Some nitrogen oxides can inhibit the body's ability to resist diseases such as influenza and pneumonia, and can cause lung irritation (Spengler et al., 1983).

Nitrogen attaches to hemoglobin and is thought to contribute to the formation of tumors. Maximal tolerated daily mean concentration of NO_X is 100 µg/m³ and 30-minute mean value by law should not exceed 200 µg/m³ in the Czech Republic (Tab. 2). According to the World Health Organization 2005 Guidelines, annual mean value of NO_2 should not exceed 40 µg/m^3 in order to protect the public from the health effects. Nitrogen dioxide also significantly irritates airways over short periods of exposure with concentrations greater than 200 µg/m^3. The air quality standards for NO_2 are consistent with the WHO guidelines in the European Union as well as in the Czech Republic. The National Ambient Air Quality Standards in the United States are more than twice as high in the annual mean of concentration of NO_2 than specified by the WHO, EU and Czech Republic. When it comes to this area the United States should follow the guidelines and decrease the standard value.

Table 2. NO_2 concentration standards	
WHO 2005 Guidelines 1	**U.S.A. NAAQS** 2
40 µg/m³ annual mean	100 µg/m³ annual mean
200 µg/m³ 1-hour mean	100 ppb (190 µg/m³) 1-hour mean
EU Air Quality Standards 3	**Czech Hydrometeorological Institute**
40 µg/m^3 annual mean	40 µg/m^3 annual mean 4
200 µg/m^3 1-hour mean	200 µg/m^3 1-hour mean 5

Sources of data:

1 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

4 Balnar, 2008

5 http://www.chmi.cz/uoco/isko/isko2/exceed/summary/limit2010_CZ.html

CARBON MONOXIDE (CO)

Carbon monoxide (CO) is a colorless gas without any odor. Carbon monoxide is formed during combustion processes when the fuel containing carbon is not burned completely (so called incomplete combustion). Carbon monoxide is contained in motor vehicle exhaust; therefore, higher levels of pollution generally occur in areas with heavy traffic. In the US, vehicles contribute about 56% to the nationwide emissions of the CO. Other anthropogenic sources are industrial processes and domestic fireplaces. Carbon monoxide pollution is a part of the reductive smog that is typical for some cities and valleys in winter months during inversion conditions where warmer air is above the cold air which disables the pollution to disperse (Chan et al., 1991; Hexter & Goldsmith, 1971).

The main health impact of CO is due to its high affinity to hemoglobin. Poisoning by CO has several levels and consequences depending on its concentration and length of exposure. If a person survives severe poisoning, which is usually characterized by longer comatose, central nervous and cardiovascular systems are typically affected. Chronic exposure to lower concentrations of CO enhances the problems of people with breathing and cardiovascular illnesses (Hexter & Goldsmith, 1971; Thom et al., 2000).

WHO 2005 Guidelines do not contain a chapter on carbon monoxide, and therefore do not indicate critical values for CO assessed. In detailed materials released by the WHO in 2000, critical concentrations of CO are indicated as 10 000 $\mu g/m^3$ 8-hour mean and 30 000 $\mu g/m^3$ 1-hour mean (Tab. 3). The United States National Ambient Air Quality Standards, the European Union Air Quality Standards and the Czech Hydrometeorological Institute also perceive the 10 000 $\mu g/m^3$ 8-hour mean as a limiting value for CO. According to the US NAAQS, the 1-hour mean for CO is 40 000 $\mu g/m^3$ which is higher than WHO's recommended standard of 30 000 $\mu g/m^3$. The EU and the Czech Republic do not have a value for 1-hour mean for CO.

Table 3. CO concentration standards

WHO 2000 [1]	**U.S.A. NAAQS** [2]
10 000 $\mu g/m^3$ 8-hour mean	10 000 $\mu g/m^3$ 8-hour mean
30 000 $\mu g/m^3$ 1-hour mean	40 000 $\mu g/m^3$ 1-hour mean
EU Air Quality Standards [3]	**Czech Hydrometeorological Institute** [4]
10 000 $\mu g/m^3$ 8-hour mean	10 000 $\mu g/m^3$ 8-hour mean

Sources of data:

1 http://www.euro.who.int/document/aiq/5_5carbonmonoxide.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

4 http://www.chmi.cz/uoco/isko/isko2/exceed/summary/limit2010_CZ.html

PARTICULATE MATTER (PM)

According to the EEA Glossary (n.d.), particulate matter is“a collective name for fine solid or liquid particles added to the atmosphere by processes at the earth's surface. Particulate matter includes dust, smoke, soot, pollen and soil particles.” The solid portion of the PM naturally originates due to volcanic activity, wind erosion, and natural fires. However, man surpassed nature in the PM production. All combustion processes, transportation, agriculture and industry produce particulate matter (Hinds, 1999). The main source of the PM emissions is the burning of fossil fuels (WHO, 2012).

Particulate matter is further classified according to an aerodynamic diameter of the particle. PM_{10} indicates particles with the aerodynamic diameter smaller than 10 μm. $PM_{2.5}$ stands for all particles with the aerodynamic diameter smaller than 2.5 μm. Therefore, $PM_{2.5}$ is included in PM_{10}. $PM_{2.5}$ is the most dangerous because of the ability of the small particles to enter during inhalation into the peripheral regions of the bronchioles and there hinder gas exchange in the lungs (WHO, 2012). Particulate matter also contributes to development of cancer and other lung and cardiovascular diseases (Pope et al., 2002). According to the WHO, PM is the air pollutant with an impact on the most people. The EEA considers PM along with the ground level ozone the most harmful pollutants regarding their impacts on human health. WHO warns that currently most urban and rural populations in both developed and developing countries are exposed to the particulate matter pollution in such levels that it affects their health (WHO, 2012; EEA, 2009).

In the World Health Organization 2005 Guidelines, values for max allowance of particulate matter are recommended at 50 μg/m^3 for a 24-hour mean, and 20 μg/m^3 for an annual mean (Tab. 4). Previous WHO guideline value was 70 μg/m^3 as an annual mean. The WHO believes that air quality related deaths could be reduced by about 15% by decreasing the PM_{10} pollution from 70 to 20 μg/m^3 (WHO, 2012). The European Union Air Quality Standards are the same as the standards for the Czech Republic, and in the case of the 24-hour mean value of PM_{10}, they follow recommendations of the WHO. The annual mean limits of PM_{10} are twice as high in the EU and the Czech Republic, than the WHO advises. Surprisingly, the United States NAAQS set the 24-hour mean value of PM_{10} at 150μg/m^3 which is three times higher than the WHO, EU, or the Czech Republic. Annual mean value is not indicated by the US NAAQS.

Table 4. PM_{10} concentration standards	
WHO 2005 Guidelines 1	**U.S.A. NAAQS** 2
50 μg/m^3 24-hour mean	150 μg/m^3 24-hour mean
20 μg/m^3 annual mean	
EU Air Quality Standards 3	**Czech Hydrometeorological Institute**
50 μg/m^3 24-hour mean	50 μg/m^3 24-hour mean 4
40 μg/m^3 annual mean	40 μg/m^3 annual mean 4

Sources of data:

1 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

4 http://www.chmi.cz/uoco/isko/isko2/exceed/summary/limit2010_CZ.html

For the particulate matter with an aerodynamic diameter smaller than 2.5 µm ($PM_{2.5}$), the WHO suggests stricter limits than for PM_{10} (Tab. 5). For $PM_{2.5}$, the 24-hour mean value should not exceed 25 µg/m^3 which is half of the value for PM_{10}, and the annual mean value should not surpass 10 µg/m^3 which is also half of the value for PM_{10}. The European Union agrees with the WHO on the 24-hour mean value; however, annual mean value is not appointed. The United States set the limit values for $PM_{2.5}$ higher than the WHO recommends. The Czech Hydrometeorological Institute does not indicate any limits for $PM_{2.5}$.

Table 5. $PM_{2.5}$ concentration standards	
WHO 2005 Guidelines 1	**U.S.A. NAAQS** 2
25 μg/m^3 24-hour mean	35 μg/m^3 24-hour mean
10 μg/m^3 annual mean	15 μg/m^3 annual mean
EU Air Quality Standards 3	**Czech Hydrometeorological Institute**
25 μg/m^3 annual mean	no standard set

Sources of data:

1 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

WHO also states in the 2005 Guidelines, that the guideline values for PM do not represent a threshold below which there is no adverse health effect. The threshold has not been recognized and the guideline values are assessed to minimize impacts on health. The WHO recommends attaining the lowest concentration of PM possible (WHO, 2012).

GROUND LEVEL OZONE (O_3)

Ozone is a colorless gas with a characteristic odor even in small concentrations. Ground level ozone, also called tropospheric ozone, is formed by photochemical reactions of its precursors – pollutants such as nitrogen oxides and volatile organic compounds (VOCs). The ground-level ozone is a major component of photochemical smog. The tropospheric ozone pollution and the photochemical smog reach their highest intensity during warmer months. Quantity of ground level ozone also changes throughout the day. In cities, there could be five times more ozone during the day than at night (Hůnová & Horálek, unpublished).

Ground level ozone has significant impacts on human health. It can cause respiratory problems, headaches, incite asthma, reduce lung function, induce lung diseases and irritate eyes (Hůnová et al., 2012; WHO, 2012). Environmental risks are also known; ozone limits growth of plants due to its impact on photosynthesis. Forest tree defoliation due to increased levels of the ground-level ozone has been observed (Reich, 1987).

The World Health Organization guideline value for ground level ozone is 100 µg/m^3 8-hour mean (Tab. 6). Prior to the 2005 AQG, the WHO's recommended limit was 120 µg/m^3 8-hour mean. The 2005 AQG have reduced the limit by 20 µg/m^3 8-hour mean because of the "recent conclusive associations between daily mortality and ozone levels occurring at ozone concentrations below 120 µg/m^3" (WHO, 2012).

Table 6. O_3 concentration standards	
WHO 2005 Guidelines 1	**U.S.A. NAAQS** 2
100 µg/m^3 8-hour mean	0.075 ppm 8-hour mean
	0.12 ppm 1-hour mean
EU Air Quality Standards 3	**Czech Hydrometeorological Institute** 4
120 µg/m^3 8-hour mean	120 µg/m^3 8-hour mean

Sources of data:

1 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

2 http://www.epa.gov/air/criteria.html

3 http://ec.europa.eu/environment/air/quality/standards.htm

4 http://www.chmi.cz/uoco/isko/isko2/exceed/summary/limit2010_CZ.html

In the United States, there is a new norm since 2008 which tightens the limit to 75 ppb in 8-hour mean (calculating with 1200g of air (solvent) / m^3, the converted value is 90 µg/m^3). In the near future, the limit is planned to be reduced to 70 ppb (84 µg/m^3). It would be better and easier to compare if the US NAAQS used the same units as the WHO, EU and the Czech Republic. In the European Union and the Czech Republic, the limit is set for 8-hour mean at 120 µg/m^3 as the WHO guideline was prior to 2005. In Europe, the ground level O_3 is currently one of the air pollutants of the greatest concern.

ANALYSIS OF DATA, HISTORY AND LEGISLATION

UNITED STATES OF AMERICA

In 1948, a severe smog episode occurred in Donora, Pennsylvania. Six thousand people, which represented a third of the town's population, got sick or were hospitalized. After the Donora and similar air pollution incidents in the middle of the 20th century, the way many people thought about air pollution changed. Americans began to realize that impaired air quality threatened their health (Ciocco & Thompson, 1961). For their protection, emissions needed to be monitored and controlled, and regulations were designed in the United States for this purpose. Some legislation regarding the air pollution has been in effect since 1950s (Tab. 7).

Table 7. Major federal air pollution legislation in the USA

Year	Legislation
1955	Air Pollution Act
1963	Clean Air Act
1965	Motor Vehicle Pollution Control Act
1967	Air Quality Act
1970	Clean Air Act (establishing National Ambient Air Quality Standards, NAAQS)
1977	Further Clean Air Amendments
1978	Ban of fluorocarbon gases in aerosol products
1982	Emission Trading policy
1987	Ratified Montreal Protocol
1990	Clean Air Act Amendments
1991	Air Quality Agreement (USA and Canada)
1991	Rule giving right to buy and sell SO_2 emissions
1997	Clean Air Act revisions

Source: Metcalfe & Derwent, 2005

In the 1950s, attention was mainly focused on the most visible pollution: smoke and particulate emissions. Major progress was made in reducing air pollution after the Clean Air Act (CAA) was amended in 1970. The 1970 amendments created the Environmental Protection Agency and required it to set National Ambient Air Quality Standards, set New

Source Performance Standards, and develop motor vehicle emissions standards (EPA, 1997).

In the United States, the EPA provides emission estimates for all kinds of pollution sources and particular pollutants, and also conveys local and regional trends. The EPA has developed methodologies to assess the emissions even on the national scale. The emissions of air pollutants have been assessed far back, some as late as 1900, according to the methods of the day. However, the changing methodology of assessment doesn't allow constructing coherent graphs to show emission trends throughout the history of emission estimates.

In the first graph (Fig. 1), trends of emissions of particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, non-methane VOCs and lead are displayed since 1940 until 1990.

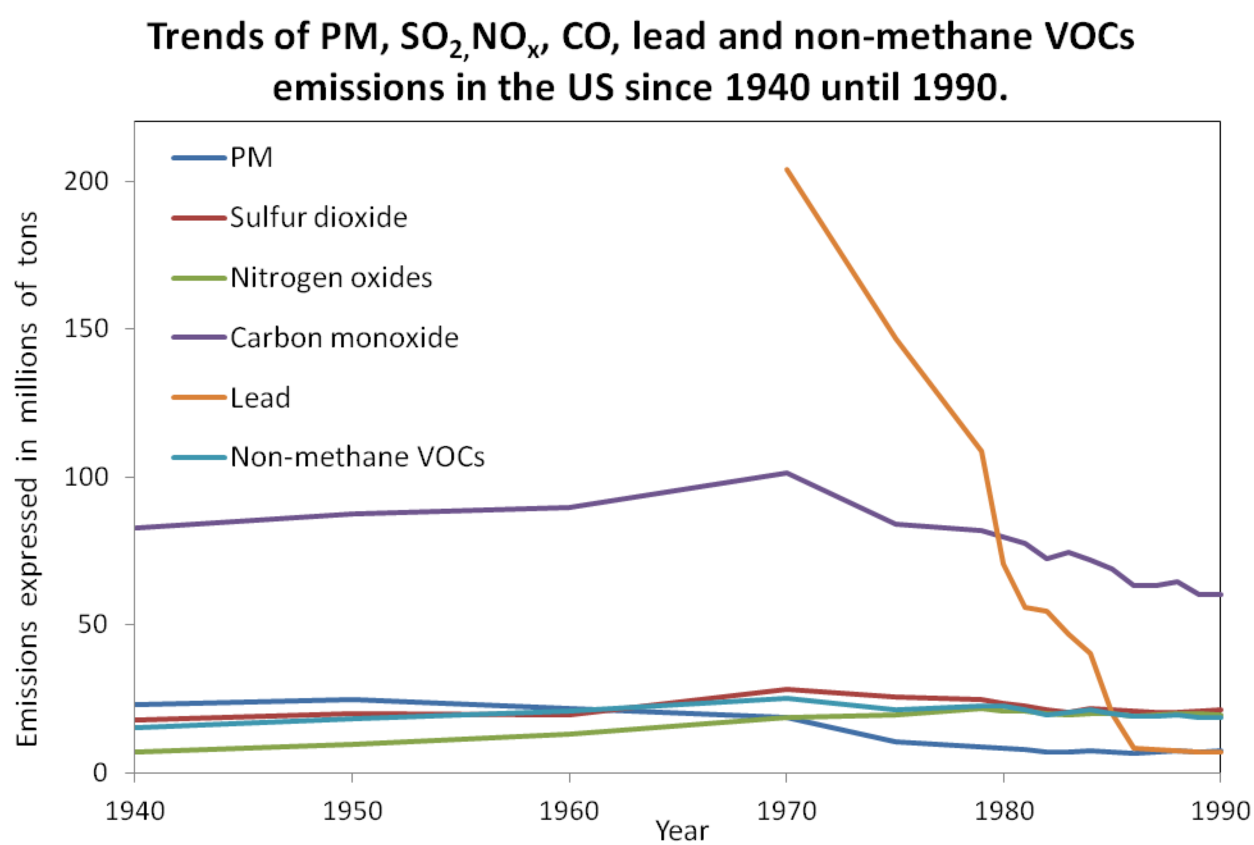

Figure 1. Trends of air pollution in the USA since 1940 until 1990

Source of data: EPA, 1991

The EPA (1991) points out that the trends shown in the graph above are divided into two parts; 1940 through 1970 when significant changes in technology, activity patterns, and fuel use occurred, and 1970 through 1990 when emissions were being controlled. Most of the coordinated efforts to control the emissions of pollutants on the national level began in 1970 with the Clean Air Act. Since then remarkable progress has been made in reducing emissions of SO_X, NO_X, VOC, CO, lead and fine particulate matter. Emission control devices were installed on automobiles, electric power plants, industrial processes and other sources of air pollution.

Until the 1950s, the greatest influences on emissions were economic and demographic. Emissions grew as the economy and population increased; emissions declined in periods of economic recession (EPA, 1997). Before the Clean Air Act, in the 1950s and 1960s, particulate matter and smoke emissions were among the first pollutants to be controlled by local air pollution abatement programs. The declines in the 1940s through 1970s in residential wood combustion which resulted from the abundant supply, low prices, and convenience of fossil fuel-generated electricity also significantly figured into the trends. Because of the control and decrease in the residential wood combustion, the PM_{10} emissions peaked around 1950 whereas the other pollutants peaked around 1970.

As the graph above shows, the greatest decreases are evidently in lead emissions especially prior to the 1980s. In the 1970s, health and environmental risks of lead were discovered, and consequently government agencies such as the EPA began to ban the use of leaded gasoline. In 1975, catalytic converters were introduced in new cars which disabled use of the leaded gasoline in these cars (EPA, 1991).

The second graph displays the national emission trends in the United States with the newest data available (Fig. 2).

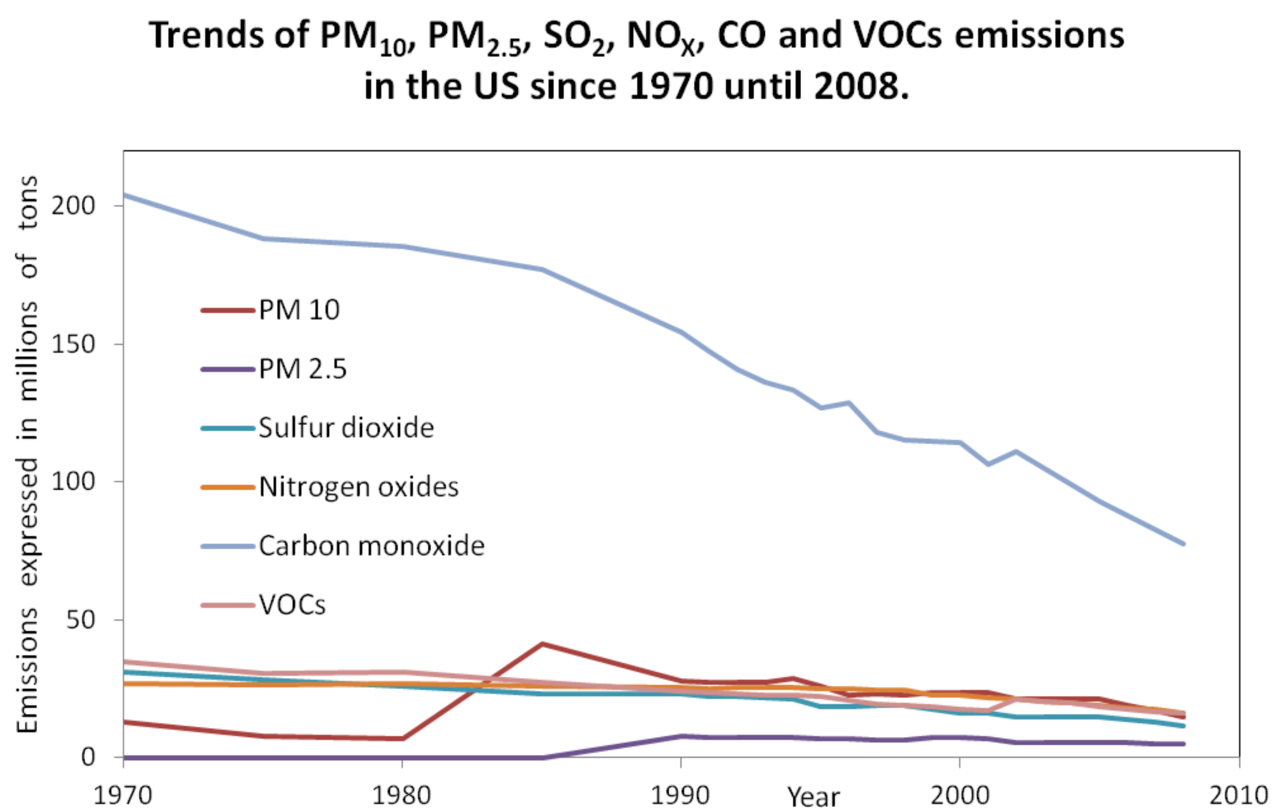

Figure 2. Trends of air pollution in the USA since 1970 until 2008

Source of data: EPA, http://www.epa.gov/ttnchie1/trends/

Units converted from Kilo short tons to metric tons

According to the EPA (1997), most of the criteria air pollutant emission levels peaked around 1970 and since then they have declined. These air pollution decreases are mainly due to the Clean Air Act (CAA) regulations beginning in 1970. Changes in the business cycle and improved manufacturing practices have also played a role. Vehicle miles traveled increased which caused no significant change in emissions of NO_X because the pollution from other sources was eliminated. The reduction in CO and VOC emissions is a result of a decrease in mobile sources emissions. It is because new fuels such as reformulated gasoline, oxygenated fuels, and fuel with lower Reid vapor pressure have been used and also catalytic converters installed. Particulate fugitive dust emissions from construction sources, paved roads, and tilling of agricultural crops increased evidently between 1980 and

1985 due to the increases in construction, vehicle miles traveled, and enlarged number of acres of land cultivated.

National trends in air pollutant emissions depend on a number of factors. These factors are the level and composition of economic activity, demographic influences, meteorological conditions, and air pollution control (EPA, 1997). A lot of successes such as decrease in lead from 173,000 tons in 1970 to 560 tons in 2000, and reduction of CO, NO_X, and VOCs by about 90% after installation of the modern three-way catalyst, were accomplished by major social efforts to clean the air (Lave & Griffin, 2008). Unfortunately, air pollution regulations are still a part of a controversy and a debate between those concerned about human health and the environment and those in American industry continues.

EUROPEAN UNION

The air pollution has been an issue in Europe since the start of modern industrialization. However, most people have started realizing the significance of this problem no earlier than in 1950s. Occurrence of severe smog episodes in London in 1948, 1952, and 1956 and related mortality and morbidity are recorded in contemporary as well as current reports (Bell et al., 2004; Bell & Davis, 2001; Logan, 1953; Logan, 1956; Scott, 1953). One of them written in 1953 by J. A. Scott is termed “Fog and deaths in London, December 1952”. Scott described in detail the smog conditions and related health problems between December 5th and 8th 1952 in London. He observed increased mortality of London inhabitants to the heavy winter smog remaining in the city those days.

A new report on the subject termed “A retrospective assessment of mortality from Lodon smog episode of 1952: The role of influenza and pollution” suggests that the previous studies even underestimated the extent of negative effect of the event. The researchers concluded that only a small portion of the deaths in the months after the smog could be attributed to influenza and supposed that the 1952 London smog could have been responsible for about 12,000 deaths rather than 3,000-4,000 deaths which were generally reported (Bell et al., 2004; Bell & Davis, 2001).

In another report, Logan (1956) stated the facts about air pollution in January 1956. He described the fog being so thick that it even caused traffic problems. Logan discussed the health effects evoked by the air pollution. He mentioned that main causes of death were bronchitis, pneumonia, lung cancer and other diseases; and deduced, from the fact that there was no epidemic influenza prevalent in London that time, that they were caused by the smog incident. About 1 000 deaths occurred in the Great London area in less than a week, in winter 1956 between January 4th and January 10th. Mainly newborn children and elderly persons were affected. It is estimated that the previous severe London fog of 1952 caused about 4 000 deaths in London area.

On the other hand, the positive side of these air pollution episodes is that they not only brought attention to the issue to scientists, but also to the general public and national governments (Bell et al., 2004). However, when in 1957 preceding institution of the European Union, the European Economic Community (EEC) was established, the environment was not considered as a community issue at that time, and therefore, it was not a concern of the organization. Individual countries in Europe established their own environmental laws. For example, in the United Kingdom the Clean Air Act was introduced in 1956. There was no common legislation regarding air pollution in the European Community. The Single European Act of 1986 set out the essential principles for addressing pollution issues within the European Community. The Maastricht Treaty of 1992, the Treaty on European Union (EU), explicitly required community policies to consider protection of the environment. In 1990, the European Environment Agency (EEA) was established and started work in 1994 (Metcalfe & Derwent, 2005).

Within the EU, the European Commission is responsible for preparing environmental legislation and directives (Tab. 8), signing selected international protocols on behalf of the member states, and ensuring that the member states comply with the EU's environmental laws.

Table 8. Major EU directives relating to air pollution

Year	Directive	Topic
1980	80/779/EEC	Standards for SO_2 and suspended particulates in air
1981	81/462/EEC	Decision on the Geneva Convention on Long Range Transboundary Air Pollution
1982	82/884/EEC	Set limit value of 2 $\mu g/m^3$ lead as annual mean concentration
1984	84/360/EEC	Framework directive to prevent and reduce air pollution from industrial plants
1985	85/203/EEC	Directive establishing limit value for NO_2 and lower guide values for special protection zones
1987	87/217/EEC	Directive controlling asbestos in air, water and land from point sources
1988	88/609/EEC	Large Combustion Plant Directive - emissions reduction targets for SO_2, NO_2 and dust
1989	89/369/EEC	Directive setting limit values and operating requirements for new waste incinerators
1989	89/429/EEC	Directive setting limits fir existing incinerators
1992	92/72/EEC	Directive on Ozone - monitoring, information and public alerts
1994	94/67/EC	Directive on hazardous waste incineration
1994	94/63/EC	Directive to reduce VOC emissions from evaporative fuel losses
1996	96/62/EC	Framework Directive on Ambient Air Quality and Management
1996	96/61/EC	Integrated Pollution Prevention and Control Directive
1999	99/13/EC	VOC Solvents Directive
1999	99/32/EC	Sulfur content of liquid fuels
2001	2001/80/EC	Large Combustion Plant Directive (revised)
2001	2001/81/EC	National Emissions Ceiling Directive

Source: Metcalfe & Derwent, 2005

The first air quality directive came about in 1980 and was related to SO_2 and smoke concentrations in urban areas. This directive was followed by other concerning examples such as transboundary air pollution and limits to lead concentrations. The 1996 Framework Directive on Ambient Air Quality and Management was designed to provide a comprehensive strategy for air quality management in the member states of the EU. Although criteria for the air pollution are set out by the EU, the individual member countries have the responsibility to measure and assess air quality in their area (Metcalfe & Derwent, 2005).

Because of this fact, unlike in the United States, there are no coherent data available in the European Union over a longer period of time regarding estimates of emissions or averages of pollutant concentrations for the area as a whole. Data, graphs, maps, and reports regarding air pollution are available on the EEA website. The datasets are very detailed and complicated; therefore, it is difficult to figure out trends for the geographical area as a whole, and from 1950 to the present, as it was done for the United States.

The EEA provides, among other information, sectional graphs (Fig.3). An example of such a graph is this one featuring emission trends of sulfur dioxide in the EU-27 Member States since 1990 till 2007. Another example of graphics provided by the EEA is this graph representing change in emissions of primary PM_{10} and secondary PM precursors by country between 1990 and 2007 (Fig. 4).

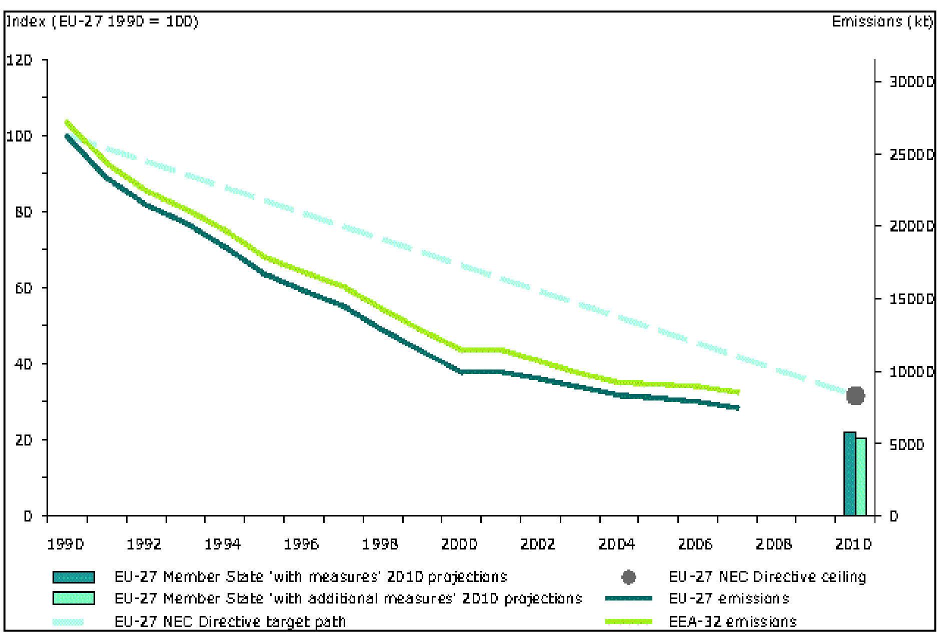

Figure 3. Emission trends of SO_2 in EU-27 Member States

Source: EEA, http://www.eea.europa.eu/data-and-maps/figures/emission-trends-of-sulphur-dioxide-eea-

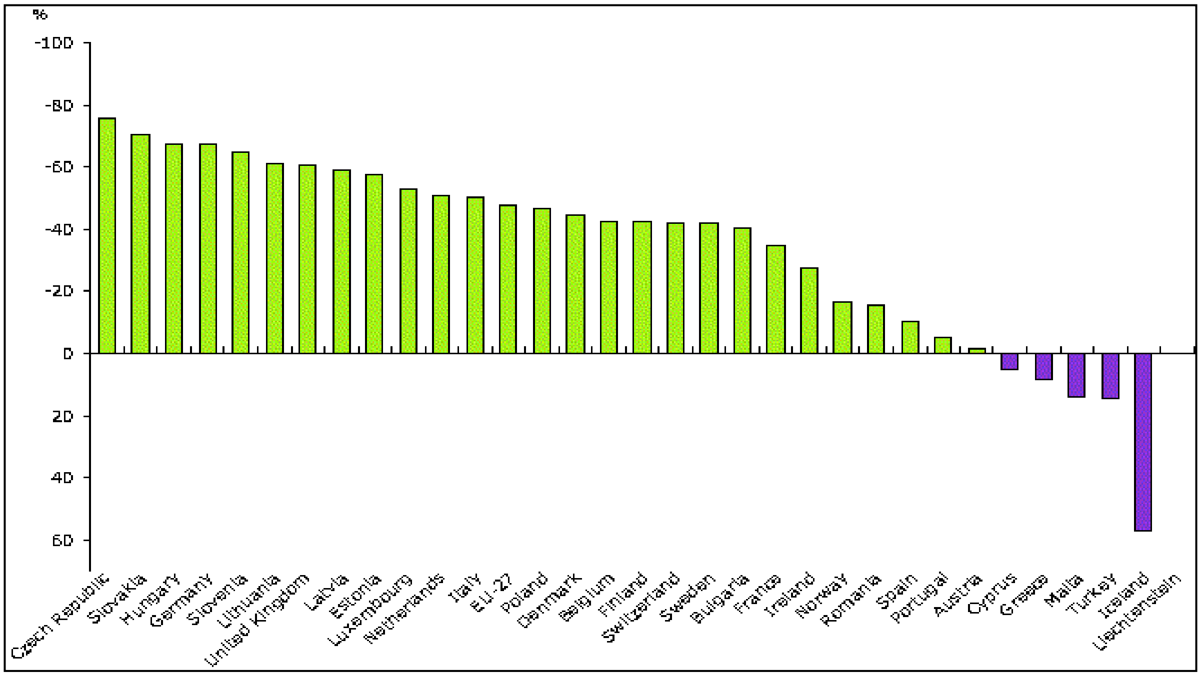

Figure 4. Change in emissions of primary PM_{10} and secondary PM precursors by country between 1990 and 2007

Source: EEA, http://www.eea.europa.eu/data-and-maps/figures/change-in-emissions-of-primary-pm10-and-secondary-particulate-matter-precursors-by-country

The Czech Republic, country with the highest green bar depicted in the graph, improved the most, and the emissions of primary PM_{10} and secondary particulate matter precursors recorded the greatest decrease of all EEA member countries between 1990 and 2007. On the other hand, emissions of PM grew in a few countries depicted with a purple bar on the graph. This figure shows the progress but it is not suitable for comparing air quality in countries included in the graph because the stage in 1990 for each individual country is not given.

The European Environment Agency informs about the air pollution situation and trends, and does so, for example, in article termed “Every breath you take – air quality in Europe”, written in 2009 and available on their website. The EEA informs that there has overall been a great success of the EU’s environmental efforts regarding air quality. Nowadays, the air quality is much better than for example 30 years ago. For example, historically the acid rain came to popular attention in the 1970s. Since then, environmental policies of the EU significantly cut emissions of sulfur – the main component of acid rain (EEA, 2009). Before 1970s, the European emissions of sulfur dioxide and also urban concentrations of SO_2 in many cities rose (Fenger, 2009). Since 1970s, emissions and concentrations of other air pollutants have been decreasing along with SO_2.

In 1980s, discoveries such as the one about reasons of acidification of Swedish lakes showed that the air pollution is not just a local issue. Cooperation among countries regarding air pollution was considered to be necessary to limit effects of transboundary air pollution. The United Nations Convention on Long-range Transboundary Air Pollution (LRTAP Convention) agreed upon in 1979, has been signed by 51 countries, including the countries of the European Union, and forms the basis of the international approach to air pollution issue.

In the 1990s, improvement of air quality has been reported. For example in a German study conducted by Heinrich et al. (2002), cause-effect relationship has been demonstrated between improved air quality and decreases in respiratory symptoms. However, the researchers noted that whereas the concentrations of total suspended particulates and SO_2 in eastern Germany in 1990s declined, the nucleation-mode particles (10 – 30 nm) increased (Heinrich et al, 2002).

Comparative studies have also been conducted within the European continent. For example, the article written by Hoek et al., 1997, shows results from the PEACE study indicating regional differences within Europe with regard to air quality, specifically the detected concentrations of PM_{10} and black smoke during wintertime. Researchers concluded that the ambient particulate matter concentrations significantly differed among the countries. Similar levels of PM_{10} were found in Western and Central Europe, the lowest in Scandinavia and generally the highest in Southern Europe (Hoek et al., 1997). Another example of an international cooperation within Europe on the subject of air pollution is a newer compere - contrast study examining chemical composition of $PM_{2.5}$ and $PM_{2.5-10}$ at six urban sites across Europe (Sillanpää, 2006).

Currently, air pollution remains problematic in the European Union. $PM_{2.5}$ and ground level O_3 are generally recognized as the most significant regarding their health impacts. European Environment Agency believes that since 1997, up to 50 % of Europe's urban population may have been exposed to concentrations of particulate matter above the EU limit. Similarly, up to 61 % of people living in European cities may have been exposed to levels of ozone exceeding the EU target. Nitrogen oxides also continue to cause major problems serving as O_3 precursors and also contributing to creation of acid rain (EEA, 2009).

The EEA has noted that emissions of pollutants have decreased, but concentrations in the ambient air of some of them, for example of PM, remained largely the same (EEA, 2009). The fact that the air quality in the EU has not significantly improved since the end of 1990s could be partially explained by meteorological variability and increasing problem of long distance transfer of pollutants from other countries in the northern hemisphere (EPA, 2008). Unfortunately, a lot of people within the European Union still live in cities where EU air quality limits are regularly exceeded. The European goal of achieving levels of air quality that do not cause any health problems has still not been reached (EEA, 2009).

CZECH REPUBLIC

Czechoslovakia, former union of the Czech Republic and Slovakia, was a part of the Soviet Bloc until 1989. Severe air pollution problems first became apparent after World War I and intensified through the 1960s and 1970s. It was mainly due to the burning of soft, brown coal (with sulfur content of 1.5-2.4 % and sometimes even more) and intensive development of metallurgical and chemical industries. The worst affected area especially by SO_2 and PM was northern Bohemia, part of the well-known “Black Triangle.” High energy consumption in inefficient industrial plants was a result of the communist regime ensuring low cost energy (Metcalfe & Derwent, 2005).

The constitution of the Czechoslovak Republic (1960) included the principle of care for the human environment. The federal government took responsibility for international cooperation and coordination, developing the supporting science and initiating legislation. In 1967, the first federal law concerning air pollution set out areas of responsibility, monitoring requirements and scales of fines which were low (Tab. 9). In 1975 and 1977, further legislation relating to air pollution from vehicles and the protection of forests was adopted. Through the 1980s, environmental issues came increasingly more considered in Czechoslovakia. In 1981, Czechoslovakia signed the Convention on Long Range Transboundary Air Pollution prepared by the United Nations Economic Commission for Europe (UNECE) (Metcalfe & Derwent, 2005).

Table 9: Legislation in the Czech Republic (Czechoslovakia)	
1967	First federal law (Czechoslovakia) relating to air pollution, *35/1967 Sb.*
1975 1977	Further legislation relating to air pollution from vehicles and the protection of forests, *80/1975 Sb., 100/1975 Sb., 96/1977 Sb.*
1981	Czechoslovakia signed the UNECE: Convention on Long Range Transboundary Air Pollution
1991	Clean Air Act (CAA), *309/1991 Sb.*
1992	CAA amended, *218/1992 Sb.*
1994	CAA amended: vehicle emissions, *158/1994 Sb.*
1995	State Environmental Policy of the Czech Republic - long term priorities, wide range of issues
1997	CAA amended: stationary sources, *117/1997 Sb.*
2001	State Environmental Policy of the Czech Republic - high priority issues
2002	New Clean Air Act, *86/2002 Sb.*

Source: Metcalfe & Derwent, 2005

In the 1980s and early 1990s, widepsread burning of brown coal resulted in winter smog episodes. Although the cause-effect analysis was challenging due to specifics of the Czech population‘s exposure, the extreme pollution events were associated with increased mortality just like in the studies concerning severe smog episodes in the 1950s and 1960s in the United Kingdom and the United States (Jelínková & Braniš, 2001).

In the early 1990s, dramatic changes leading to improved air quality were initialized in emissions from the Czech Republic. The main factors allowing the improvement were the restructuring after the end of the communist era and the implementation of new legislation. In 1991, the Clean Air Act was introduced to the Czechoslovak Federal Republic. The Clean Air Act defined pollutants which needed to be regulated, and set emission limits for stationary and mobile sources. The Clean Air Act was then adopted by the Czech Republic which was established in 1993. The Environmental year-book, which gives information on all issues concerning the environment in the country, has also been published since 1993. Higher fines and stricter penalties have been in force following the "polluter pays" rule. The 1991 Clean Air Act has been amended to tighten controls on vehicle emissions (1994) and stationary sources (1997) (Metcalfe & Derwent, 2005).

In 1992, a smog regulation system was set up and a national Air Quality Information System (ISKO) was established (Czech Hydrometeorological Institute, n.d.). In 1995, the State Environmental Policy of the Czech Republic was approved by the government. The policy set out long-term priorities and principles of environmental protection for a wide range of issues. In 2001, high priority issues, such as high emissions of greenhouse gases, were identified in the State Environmental Policy. In 2002, a New Clean Air Act was adopted using the European Union limits to meet the EU standards. Some of the standards set in 1991, particularly for measures not covered by the EU, are still used. At present, administration regarding the environmental protection in the Czech Republic is mainly conducted by the Ministry of the Environment, district offices and municipal authorities. The Ministry of the Environment also directs the Czech Environmental Inspectorate and through the Czech Hydrometeorological Institute monitors the air quality and provides information (Metcalfe & Derwent, 2005).

The Czech Republic joined the European Union in 2004. It has been necessary to unify the environmental legislation of the EU with the legislation of new members including the Czech Republic. The Czech Republic is a member of the EU Phare Programme which addresses environmental, health, education, and other issues relevant to economic and political restructuring as part of the process of European integration (Metcalfe & Derwent, 2005).

Emissions of air pollutants have been decreasing in the Czech Republic (Fig. 5). The most dramatic decrease is noticeable in SO_2 emissions. In 2004, the amount of SO_2 emissions represented 21.8 kg per capita in the region, whereas in 1996, it was about 90.6 kg per capita. Overall, production of SO_2 in the Czech Republic decreased from 2 million tons in 1988 to 0.265 million tons in 2000, and it keeps decreasing. This significant shift to the better is given by desulfurization of coal power plants' chimneys (coal contains about 5% of sulfur), upgrading nuclear power plants, and improvements in the technology of processing metal ores. The decrease in emissions of SO2 and also PM is due to a decline in consumption of brown coal. Between 1990 and 1999, its consumption fell by 49%. Gas use has been increased to substitute solid fossil fuels; however, the burning of solid fuels still contributes about 50% of the country's energy supply (Kopáček & Veselý, 2005; Metcalfe & Derwent, 2005, Miller, 1986). The Czech Republic and other countries have committed by international treaties to limit production of SO_2 by the end of the year 2010. They should limit the production to one fifth of the production in 1980 when production of SO_2 in the Czech Republic was about two and half million tons (Kopáček & Veselý, 2005).

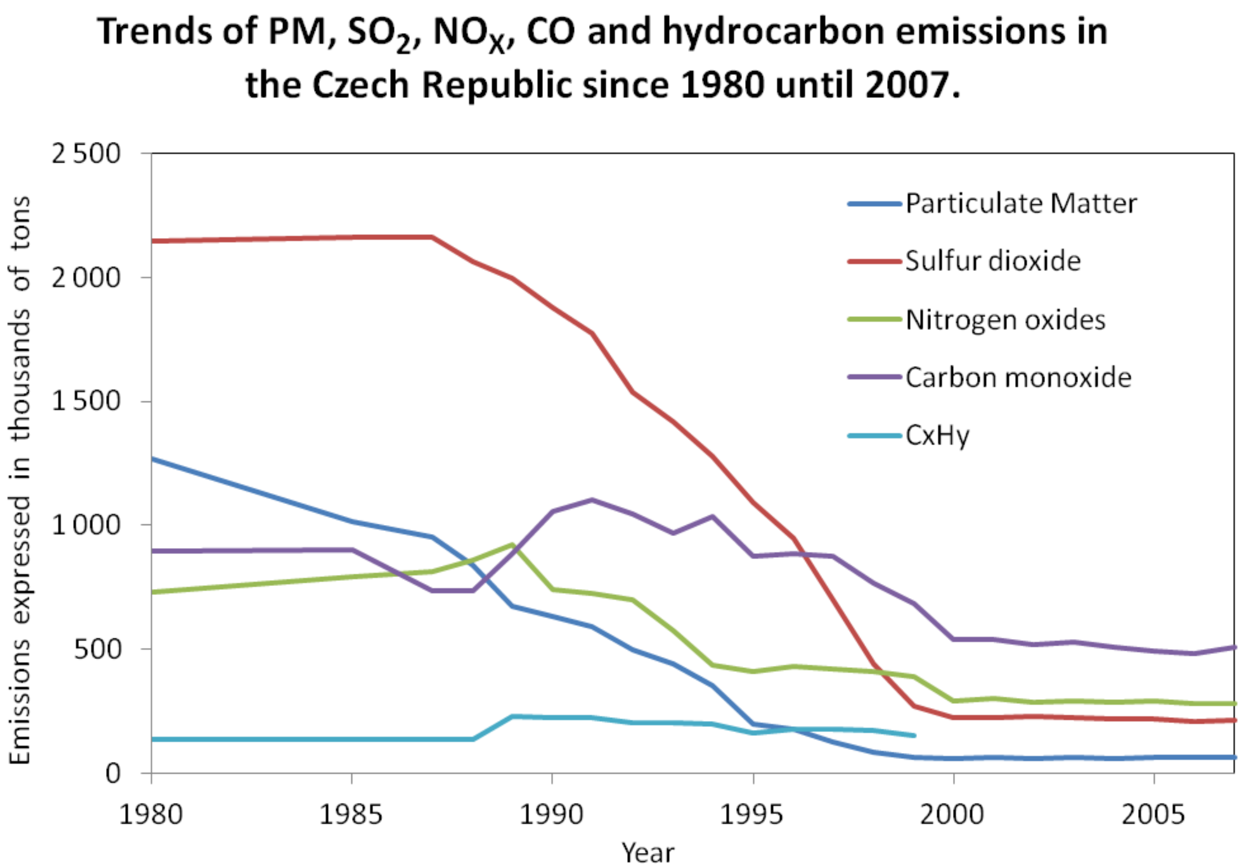

Figure 5. Trends of emissions in the Czech Republic, 1980-2007

Source of data: Czech Hydrometeorological Institute

Particulate matter emissions have also been decreasing over past years for similar reasons as SO_2. According to the graph above, levels of PM emissions are approximately constant since 1999. Carbon monoxide and nitrogen oxides emissions grew after 1989, most probably because of the increase in number of motor vehicles and traffic. These emissions have been decreasing since then due to improved technologies limiting pollution from motor vehicle exhaust. However, the level of emissions of CO and NO_X remained almost the same since 2000.

Unfortunately data older than from 1980 were not possible to include in the graph. Czech Hydrometeorological Institute which conducts assessments of emission data and also measures concentrations of air pollutants was established in 1993. The assessments of air quality have been performed only back to year 1980. The Ministry of the Environment of the Czech Republic also does not possess such data. A few experts at air pollution who were contacted expressed their doubts about the existence of coherent data of emissions in the Czech Republic before 1980 which would be usable for the graph to show trends. Some information about the air quality stage before 1980 is known (Kopáček & Veselý, 2005); however, it could not be used for the graph.

Nevertheless, national emission levels do not accurately represent the air quality in a region. Due to uneven distribution of their sources, there are areas with very heavy air pollution in which air quality might have not significantly improved over the past years. New areas with strong air pollution are along main transport arteries. The air quality is also generally worse in winter. Transportation of air pollutants in the atmosphere also causes higher concentrations of pollutants in areas without any major sources of such substances (Eliassen, 1978; EPA, 2008) . Because of these reasons, the air pollutant concentrations serve as a better indicator of the air quality in a given location.

Monitoring of the air quality is performed for specific air pollutants. Measuring in selected locations is either continuous or single sampling. Sometimes mathematical modeling is also used. Measuring is done by the Ministry of the Environment of the Czech Republic and entrusted to authorized organizations such as the Czech Hydrometeorological Institute. Air quality assessment is conducted on the basis of the results of the air quality monitoring and pollutant concentration limits. In the Czech Republic, limits of air pollution for human health protection are defined for SO_2, PM_{10}, NO_2, Pb, CO and benzene. Air pollution limits for human health protection are defined for cadmium, arsenic, nickel, organic compounds and ground-level ozone. Air pollution limits for ecosystem and vegetation protection are set for SO_2, NO_X, and ground level ozone (MŽP, 2012).

In the Czech Republic, there are about 100 stations for measuring air pollution. Most of them measure SO_2, NO, NO_2, PM_{10}, O_3, and CO. A few of them measure toluene, benzene, and xylene. For the pollutant concentrations, monitoring methods are mainly customized for measuring the urban smog, the main source being traffic (Braniš, 2008). Domestic burning is a significant cause of downgraded air quality as well, but it is more challenging to monitor.

RESULTS AND DISCUSSION

GEOGRAPHICAL REGIONS IN COMPARISON

The United States led the way to cleaner air by an earlier onset of social movements and the introduction of legislation regarding air pollutants. The fact that the EPA was established in 1970 whereas the EEA was established in 1990 shows that the United States was more advanced in their attitude and means. The emissions have started declining sooner in the US than in Europe. Decrease in emissions has been in both areas gradual, and no sudden changes in the global scale occurred immediately after any new environmental policy was implemented. The fastest response to environmental policy is recorded for lead emissions which dramatically decreased.

The European Union started with its efforts to improve the situation later, learning from the US about the early steps in making a progress. Nowadays, the European Union puts more effort into solving the air pollution issue and related phenomena than the United States is doing at this time. The United States is a little bit behind the European Union regarding the air pollution standards and policies. For example, the US limits for annual mean of NO_2 are more than twice as high as the limits held by the WHO, EU and the Czech Republic. For PM_{10}, the standard limit of 24-hour mean is in the US three times as high as in the EU. On the other hand, administration is better organized in the US than in the EU due to longer tradition and experience when dealing with the issues and data from such a large area. The European Union should also learn from the US on how to address the issues and convey information so they are understood by wider public, not just environmental professionals.

Although the Czech Republic was a part of the Soviet Bloc until 1989, it has adopted a very responsible attitude. Industrial decline in the immediate post-communist period led to reduction in the emissions of most pollutants. Recently, new environmental policies have been developed and improved. This evolution has been mainly due to a positive influence of the EU.

Currently in all three studied areas, the “significant” sources have an obligation to register and also give information on the emissions they produce. It is possible to view maps with the source location and data, and find out about potential sources nearby place of residence. In the Czech Republic, the Czech Hydrometeorological Institute provides a map and a list of sources of air pollution in every region in the Czech Republic (for example, in

Prague: http://portal.chmi.cz/files/portal/docs/uoco/web_generator/plants/praha_CZ.html). For the European Union, the information about sources of the air pollution can be found in the European Pollutant Release and Transfer Register (E-PRTR) at http://prtr.ec.europa.eu/PollutantReleases.aspx. For the United States, the U.S. Toxics Release Inventory (TRI) provides information about chemical releases reported by major industrial facilities in the U.S. The pollution locator is provided by server Scorecard and can be found at http://scorecard.org/env-releases/us-main-map.tcl. However, the information sources given above do not count for mobile sources of air pollution. In cities, such as Prague, the pollution comes mainly from traffic (Braniš, 2008). Pollutants emitted by transportation are: CO, NO_X, SO_X, VOC, PM and others. In the past, lead was also a significant contaminant (Tong et al., 2000).

DISCUSSION ON DATA

It is important to keep in mind that the emission levels provided by the EPA, EEA or the Czech Hydrometeorological Institute are estimates which may be far from the true values. Various methods are involved in estimating the amounts of air pollutants emitted. This fact is shown in this thesis when comparing the two graphs, Fig. 1 and Fig. 2. In the Figure1, Trends of air pollution in the USA since 1940 until 1990, the estimated value of CO emissions in 1970 is 101.4 millions of tons and the EPA prepared this estimate in 1991. However, newer emission values estimated by EPA in 2010 and shown in Figure 2, Trends of air pollution in the USA since 1970 until 2008, indicate the emission levels of CO in 1970 above 200 millions of tons. Despite the high level of uncertainty regarding estimated emission levels, I believe that as long as the assessment methods remain consistent, the revealed trends are trustworthy.

Additional difficulty arises when comparing specific items between the regions. The data acquired through the various assessment methods used by the providers of raw data may not always be comparable. For example, the EPA gives data on particulate matter which are based on a seasonally weighted annual average in the United States as a whole, whereas the European Environment Agency (EEA) doesn’t provide a trend for the entire European Union in the same manner as the EPA does. The EEA, however, provides information on the EU air quality thresholds, and each member country separately gives data on emissions of air pollutants. Integrated monitoring system collecting data on air pollution, concentrations and emission of air pollutants, is something the European Union could implement. Closer cooperation between EPA and EEA, mutual education on methods, public outreach, current priority issues and their solutions would bring progress and efficiency into environmental management concerning air quality.

CONCLUSIONS

Air pollution still represents a serious issue although a lot has been done for its improvement in all studied regions. Good air quality is important as it affects human health, the environment, and the economy. Climate change, stratospheric ozone depletion, and tropospheric (mainly urban) air pollution result from emitted air pollutants. Related phenomena are acid rain, smog episodes and indoor air pollution. The issue is very complex and needs to be viewed and solved globally. Not only neighboring countries affect each other by transboundary pollution, but there is a transfer of air pollution between whole continents (EPA, 2008).

My recommendations are following: Regions should more cooperate and collectively commit to further improve the situation. Greater focus should be placed also on other than the main (criteria) air pollutants. For example, dioxins, even in very small concentrations, are very dangerous chemicals. Sources of dioxins are, among others, traffic and domestic heating. I propose, in this case, that pollution from domestic burning to be better controlled as it has shown that such a pollution source has significant impacts on human health similar in magnitude to risks from exposure to tobacco smoke (Koning et al., 1985).

People spend considerable amount of time indoors (Klepeis et al., 2001), therefore focus on exposure assessment to air pollutants within enclosed buildings is a priority issue which needs more attention. The indoor air quality is affected by both, the ambient air pollution and the enclosed pollution sources. Most of the indoor pollutants are directly controlled by us unlike the outdoor air quality. Public outreach may significantly help to educate individuals on how to mitigate air pollution at homes. Outdoor air is a determinant which we personally cannot choose or easily alter on a large scale, but we can demand from our governmental representatives to make decisions leading to improvement of the ambient air quality.

Another priority issue is the long-range transport of air pollutants. Negotiations and problem solving efforts need to increase on the international level. The example of successful international dealings with stratospheric ozone depletion shows that international negotiation can be successful and behaviors of producers and consumers can be directed for the common good and benefit the majority.

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