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AIR QUALITY MONITORING, FUSHUN-KOKKOLA

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CENTRAL OSTROBOTHNIA UNIVERSITY OF APPLIED SCIENCES
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Thesis Abstract

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This research was motivated by the current problems that are faced due to air pollution. Despite urbanization and industrialization, air quality has improved in both cities of Fushun and Kokkola, but there are still some problems regarding air pollution. The object of the thesis was to compare and access the air quality conditions in the two cities. This work was based on information collected from Fushun and Kokkola cities over the last few years of the air quality monitoring.

The overall results obtained from the study indicated that there are some similar characters such as air emission sources and pollutants because Fushun and Kokkola are both industrial cities. But the total emission levels in Fushun show significant differences in tonnage when compared with the ones in Kokkola. The expertise accumulated in Kokkola might be applicable to Fushun and in the future prove to be a useful tool to monitor environmental impacts. In the end this thesis presents suggestions for future air quality monitoring.

Key words

air quality monitoring (AQM), nitrogen oxides (NO_X), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), PM_{10}, the air pollution index (API), total suspended particles (TSP), dust fall

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1 INTRODUCTION

Air quality is important simply because we have to breathe the air around us. People who live in industrial cities should be especially concerned, since we are exposed to a greater amount of pollutants coming from industries, automobile traffic, commercial, as well as other sources. (Environmental assessment and policy 2010.)

Air pollutants can cause a variety of health problems - including breathing problems; lung damage; bronchitis; cancer; and nervous system damage. Air pollution can also irritate the eyes, nose and throat, and reduce resistance to flu and other illnesses. Air pollution causes haze and smog, reduces visibility, dirties and damages buildings and other landmarks, and harms trees, lakes and animals. (Environmental assessment and policy 2010.)

Air pollution is responsible for thinning the protective ozone layer in the upper atmosphere that protects us from harmful ultraviolet radiation from the sun, and may be contributing to the phenomenon known as global warming- the steady increase in average temperature of the global climate. (Environmental assessment and policy 2010.)

Air quality monitoring is important so as to determine whether a limit value or guideline has been exceeded. Air quality monitoring systems should mainly address population exposure to air pollution. Exposure to air pollution may result in a variety of effects on human, animal and vegetation, varying from mild to fatal depending on the types of pollutants. Information about the relationship between exposure and response is necessary in order to estimate the potential health risks.

The major objectives of monitoring air pollutant levels are to provide an early warning system for pollutant levels which may have the potential to endangering public health; to assess air quality in light of established public health and welfare standards; to track air pollution trends and changes in ambient air quality due to changes in the amount of pollutants emitted; to produce information for city planning, e.g. location of new industries and housing and to access the environmental impact of industry and other activities. (Wainaina 2007.)

Kokkola is known for its large industrial area in Finland. Chemical industry has existed in Kokkola for several decades. With rapid industrial development, the pollution in Kokkola rose to a very high level, but with time the pollution level dropped significantly due to various technical developments in the industries.

In China, a large number of industries were set up in the 1950s. Fushun, which is situated in Northeast, is a city with a lot of heavy industry. At that time, industrialists and the government were less aware of environmental problems, and strategies for the control of industrial waste were neglected. Heavy industry became the prime culprit of environmental pollution (Li & Isaac 1996). With China's rapid development, accommodating economic growth with a clean environment has become a new challenge.

In the early 1970s and until 1990s, as the sister city of Fushun, Kokkola has experienced an extremely high level of pollution but nowadays this pollution level has been lowered down. Fushun can learn from the experiences and expertise in the case of Kokkola, and help Fushun for cleaner and better environment.

This research will focus on air quality monitoring both in Fushun and Kokkola. Hopefully this thesis provides valuable information comparing air quality measurements and results between Kokkola and Fushun and finally helps authorities to take necessary actions to improve the air quality in these two cities.

1.1 Objectives of study

This research was motivated by the current problems that are faced due to air pollution. This work is based on information collected from Fushun and Kokkola cities over the last few years of air quality monitoring. Along the urbanization and industrialization, air quality has improved in the cities of Kokkola and Fushun, but still there are some old and new air pollution problems.

This report will introduce the air quality monitoring both in Fushun and Kokkola. Therefore the object of the thesis is to compare and asses the two cities, what is the air quality in these two cities and how are the air quality monitoring system built? What kinds of environmental tools have been used in both Fushun and Kokkola in the past few years? What is the future of air quality monitoring in these two cities?

1.2 Significance of study

The need for clean air has been recognized globally because air pollution damages both human health and the environment we live in. This thesis represents an overview of the air quality monitoring practice in the cities of Kokkola and Fushun. Based on the air quality monitoring results in these two cities, the primary analysis in this report includes those for nitrogen oxides, carbon monoxide, sulphur dioxide, and particulate matter. These pollutants are the most prevalent and have the greatest overall health impacts. $PM_{2,5,}$ O_3 and monitoring of metals are also mentioned in this study.

One of the basic missions of the environmental protection authorities in Kokkola and Fushun is to preserve and improve the quality of the municipality’s air. The status of the ambient air is evaluated and then compared to clean air standards.

The research on the air quality comparison between Kokkola and Fushun is far from maturation; much more study can be done in this field. This thesis attempts to give a helpful trial. It helps authorities to take necessary actions to improve the air quality in these two cities. Without doubt, this study is still limited, but the result of this research could serve as a reference for further investigations.

1.3 Organization of thesis

This thesis contains nine sections. Section one presents an overview of the study. In addition, the significance of the study and air quality monitoring objectives are presented. Section two introduces the cities of Fushun and Kokkola, which includes the basic information of these two cities such as history, location, population and meteorological character. Section three discusses prominent air pollutants and their effects on humans. Section four illustrates and compares the air emission sources in the two cities. Section five presents what are the main air emissions in Fushun and Kokkola. Air quality monitoring in the two cities is discussed in section six, which includes monitoring station, methods of analysis and evaluation criteria. Section seven compares the concentrations of the main pollutants in ambient air both in Fushun and Kokkola during the last few years. Section eight presents what kind of tools is used in air quality monitoring in the two cities. Section nine draws the conclusions of this research and discusses the future of air quality monitoring.

2 THE CITIES OF FUSHUN AND KOKKOLA

2.1 The city of Fushun

Fushun city belongs to the province of Liaoning located in the northeast of China. The area of Fushun is 65300 km^2 with an urban area spanning 675 km^2 with the population of 1, 4 million and urban 3 million. (Fushun Environmental Monitoring Central Station 2006a.)

Fushun city has several heavy industries such as coal mines, petroleum refineries, chemical refineries, aluminum refineries, rubber factories, steel makers, machine manufacturers and power stations. (Fushun Fareast International Trade Inc.)

Fushun occupies an advantageous location, 200 km from the Port of Yingkou and 400 km from the Port of Dalian with an expressway and a railway linking them. The capital city of Liaoning, Shenyang, is only 45 km from Fushun. In the east of Fushun there is the Dahuofang reservoir, which is the most important water resource of the city. The HunHe River is the major river and flows through the city area. (Travel China Guide 2008.)

Fushun lies in a fairly mountainous region surrounded by the Chan Bai Mountain western edge, which creates a valley where in the middle Fushun is located. Because the Fushun urban area is characteristic of low mountain knoll in three sides, long in east to west and narrow from south to north, ambient air is affected greatly by flow field change. (Fushun Environmental Monitoring Central Station 2006a.)

Fushun has the continental climate character with four distinct seasons: cold and dry in winter, rainy in summer, quick warm in spring with strong wind, fast temperature falling down in autumn with less rain. (Fushun Environmental Monitoring Central Station 2006a.)

The leading wind direction in Fushun is to north-northeast. Northern winds affect the climate in winter. In summer the East Asian monsoon affects the climate the most. The annual wind speed average is 15.3 m/s and the strongest level is 21 m/s. When the eastern wind is blowing, the pollution will increase, which causes the western part of Fushun. Strong western winds are dominant during summer time, when pollution is lighter and the dilution of the pollutants is better. During the four seasons, spring and winter pollution is heavier than autumn and summer. The temperatures in Fushun range from a maximum monthly temperature 28.7 C° to a minimum of -20,5 C°, the average being 7,6 C°. (Fushun Environmental Monitoring Central Station 2006a.)

2.2 The city of Kokkola

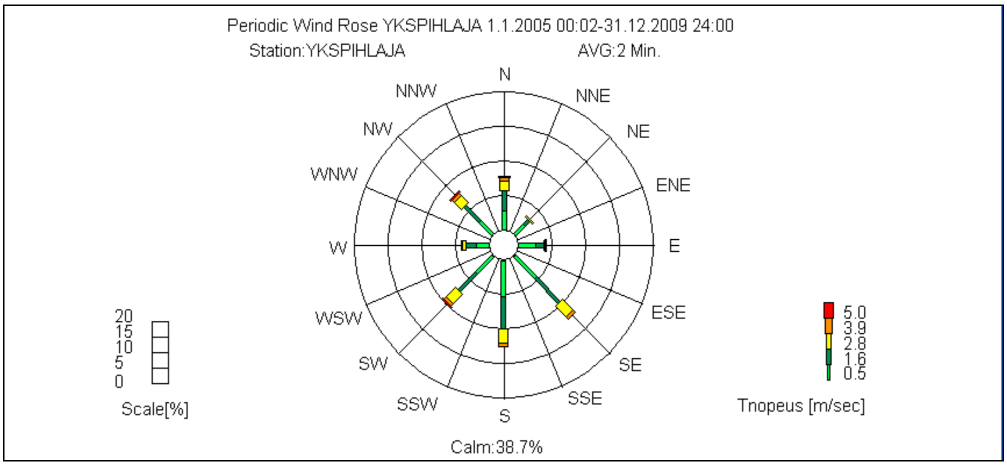
Kokkola is a medium sized city in Finland with a population of around 47,000. Kokkola is located in Finland on the west coast at the Gulf of Bothnia, and it is the economic, cultural and provincial centre of Central Ostrobothnia. The area of Kokkola is 1 444 km^2. The vicinity of the sea has a significant impact on the weather in Kokkola, making winters relatively mild with some snowfall. Kokkola is mainly lowlands with some rivers and only a few lakes. (Kokkolan Kaupunki 2009.)

Kokkola is known for its large industrial area in Ykspihlaja. The Ykspihlaja industrial area is the largest concentration of inorganic chemical industry in the Scandinavian countries and the third largest in Europe. The metal refining industry is also a significant field of technology as well as boat manufacturing industry. The harbour in Kokkola is very significant to the industry. Also important logistic factors that have made Kokkola an important city for industry are its location by the main railroad and highways. (Kokkolan Kaupunki 2009.)

In Kokkola the land-sea breeze phenomenon is dominant. This is a common phenomenon in coastal cities. The land-sea breeze occurs during late spring to early summer, when the land is warming up after winter and the sea is still very cold. The cold airflow from the sea to land causes an unstable situation and the pollution from the factories by the shore is drawn down to the ground and towards populated areas. During late autumn and early winter the circumstances are opposite. (Kokkolan Kaupunki 2009.)

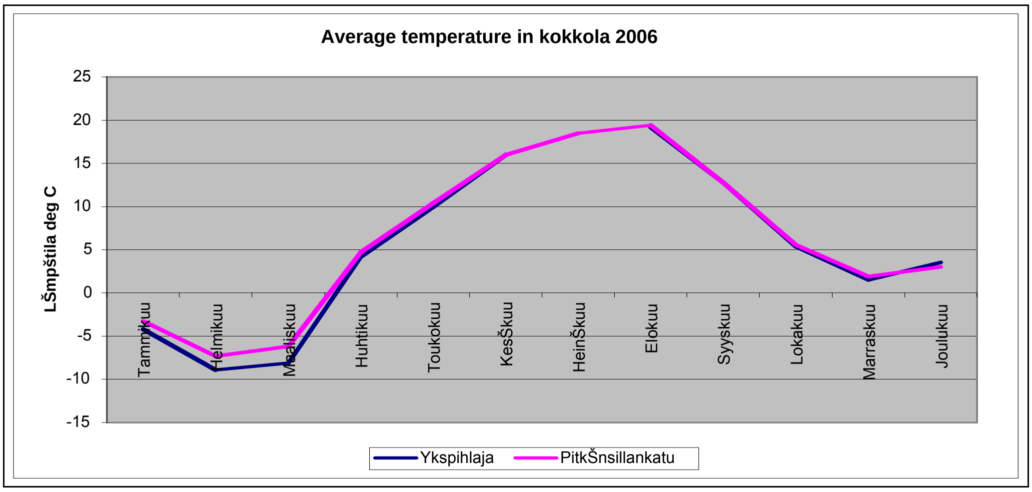
Air quality is often related to the meteorology in the local area because the movements and characteristics of the air mass, into which they are emitted, influence the level of air pollutants. If the air is calm and pollutants cannot dilute, the concentration of these pollutants will build up. The opposite happens if a strong, turbulent wind is blowing. Any pollution generated will be rapidly dispersed into the atmosphere and will result in lower concentrations near the pollution source. This phenomenon is not suitable for particles. Strong wind can lift particles up from the ground and raise the PM_{10} concentrations. The measurements of wind speed, direction and the temperature are all necessary and vital parameters used in the study of air quality monitoring results.

The wind rose of Kokkola from 2005 to 2009 showed that the dominating winds were from the south, followed by south-most winds in similar wind speed ranges.



GRAPH 1. Kokkola periodic wind rose 2005-2009 (adapted from Koljonen 2009)

Temperature measurements are recorded as a part of air quality monitoring to support assessment and forecasting. Favorable conditions can lead to increased concentrations of certain compounds (pollutants). In 2006, Kokkola's highest recorded monthly average temperature was 19°C at both Ykspihlaja and Pitkänsillankatu. The lowest temperatures were –9 °C and –7 °C at Ykspihlaja and Pitkänsillankatu.



GRAPH 2. Kokkola mean monthly temperatures in 2006 (adapted from Koljonen 2006)

3 AIR POLLUTANTS

3.1 Sulphur dioxide

Sulphur dioxide (SO_2) is a colorless gas released as a by-product of combusted fossil fuels containing sulphur. It smells like burnt matches. A variety of industrial processes such as the production of iron and steel and crude oil processing produce this gas.

Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defenses, and worsening cardiovascular disease (Green Facts 2005). Even moderate concentrations of SO_2 may result in a fall in lung function for asthmatics.

SO_2 and nitrogen oxides are the main precursors forming nitric and sulphuric acids when oxides of nitrogen and sulphite combine with moisture in the atmosphere. Acid rain is an issue that cannot be overlooked as it damages anything it touches or interacts with, such as buildings, lakes, and trees. Acid rain can be defined as any precipitation with a pH lower than usual (pH at 7) (Brimblecombe 1996).

3.2 Nitrogen oxides

A major source of nitrogen oxides (NO_X) is motor vehicle exhausts as they are formed as a by-product of the high-temperature combustion processes in the engine. The majority of NO_X emitted from vehicles is in the form of NO, which is oxidised in the air to NO_2.

NO_X gases are recognized as indirect greenhouse gases and are one of the main contributors to acid deposition. The health effects of NO_2 exposure can be chronic or acute. Studies show that exposure to NO_2 in certain concentration might be change lung structure and metabolism and reduce resistance of the lungs to bacterial infection.

3.3 Total suspended particles, PM_{10} and $PM_{2,5}$

The total suspended particulates (TSP) refer to tiny subdivisions of solid or liquid matter suspended in a gas or liquid with size smaller than 100 micrometers and may remain suspended in the air a few seconds to several months. Particulate emissions come from coal-burning power plants, industrial processes, mining operations, municipal waste incinerators and fuel combustion. A large part of TSP comes from natural sources. The particulate matter is harmful due to the presence of dozens of toxic substances carried on the tiny particles. TSP includes PM_{10} and $PM_{2.5}$ fractions.

PM_{10} is particulate matter with an aerodynamic diameter less than or equal to a nominal 10 microns. Larger particles than this are not readily inhaled and are removed relatively efficiently from the air by sedimentation. The principal source of airborne PM_{10} matter is road traffic emissions, particularly from diesel vehicles. PM_{10} pose health problems because it has the capability to penetrate the thoracic region of the human respiratory system into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases.

$PM_{2.5}$ refers to particulate matter that is 2.5 micrometers or even smaller. The sources of $PM_{2.5}$ include fuel combustion from automobiles, power plants, wood burning, industrial processes, and diesel-powered vehicles such as buses and trucks. $PM_{2.5}$ is also formed in the atmosphere when gases such as SO_2, NO_X, and VOCs are transformed in the air by chemical reactions. $PM_{2.5}$ can cause even worse health problem because $PM_{2.5}$ can enter from the bronchial respiratory into blood. (U.S. Environmental Protection Agency 2009.)

3.4 Carbon monoxide

Carbon monoxide (CO) is produced by incomplete combustion of carbon compounds. High concentrations of CO generally occur in areas with heavy traffic congestion. Other sources of CO emissions are often produced in domestic or industrial settings by motor vehicles and other gasoline-powered tools, heaters, and cooking equipment. Carbon monoxide survives in the atmosphere for a period of approximately one month but is eventually oxidised to CO_2 (The Environmental Yellow Pages 2010).

Carbon monoxide is a colorless, odorless, tasteless, and non-irritating gas. Carbon monoxide enters the bloodstream through the lungs. It reduces oxygen delivery to the body's organs and tissues. The health threat from levels of CO sometimes found in the ambient air is most serious for those who suffer from cardiovascular diseases. Visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, and difficulty in performing complex tasks are all associated with exposure to elevated CO levels (Air pollution control district 2007).

3.5 Ozone

Ozone (O_3) can be classified into two very different levels. One is ground level ozone. It is formed when vehicle exhaust and some other chemicals commonly used in industry mix in strong sunlight. When these ozone concentrations get high enough, they can make breathing difficult, especially for people with asthma and other respiratory diseases. The other kind of ozone is stratospheric ozone depletion. About 90% of all ozone occurs in the ozone layer, a region of high concentrations approximately (10-25 miles) in the stratosphere. The ozone layer protects all life from ultraviolet radiation (UV) from the sun. (Wainaina 2007.)

3.6 Other hazardous air pollutants

Volatile organic compounds (VOCs) are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH_4) and non-methane VOCs (NMVOCs). Methane is an extremely efficient greenhouse gas, which contributes to enhance global warming. Benzene toluene xylene (BTX) is the important compounds.

Polyaromatic hydrocarbons (PAH) are a large group of compounds. They consist of two or more fused aromatic rings made entirely from carbon and hydrogen. PAH is a term encompassing a wide range of compounds that are emitted from a number of sources. Airborne PAH include substances when inhaled, are believed to produce lung cancer in humans. The most important PAH is benzopyrene (European Communities 2001.)

Airborne toxic metals include arsenic, cadmium, chromium, lead, mercury and selenium present in coals and wastes. Toxic metals can be classified as non-volatile, semi- volatile and volatile. Metal emissions can cause many health problems such as retardation and brain damage; learning disabilities; heart disease; damage to the nerve system, hearing loss, lung disease.

4 SOURCES OF EMISSIONS IN FUSHUN AND KOKKOLA

4.1 Sources of emissions in Fushun

4.1.1 Industry

Fushun city has got about one hundred years' history of heavy industry. Fushun is rich in many types of resources including wood, coal, oil shale, iron, copper, magnesium, gold, silver, nickel, platinum, isinglass, marble, titanium, and marl. Fushun is commonly known as the capital of coal. (Fushun Environmental Monitoring Central Station 2006a.)

Due to the large size of the Fushun area, industrial enterprises are the most significant pollution sources. The most important companies include the Fushun Mining group, Fushun Petrochemical Company, cement-manufacturing plants along with chemical industry and heavy manufacturing of machinery. The Fushun area has several foundries and smelters of various metals.

Several heavy industries exist in the Fushun area because the area is rich from raw materials. In 2000 there were about 24 000 industrial enterprises. The main polluting industries are energy production, steam and heat water supply, ferrous metal melting and calendaring, non ferrous smelting and calendaring, petroleum processing and coking, chemical feedstock and chemical manufacturing, pit coal picking and choosing, and non-metallic minerals manufacturing. These enterprises contribute the most to the economical development of Fushun but at the same time they are the main pollution sources. (Ge 2004.)

In 2006, there were fourteen industrial enterprises, which were listed below as main industrial waste gas pollution sources.

- Liaoning Orient Power Co.,Ltd
- Fushun power plant
- Liaoning power plant
- Liaoning Nenggang power Co., Ltd
- Fushun petro thermal power plant
- Fushun power plant
- Fushun new steel Co., Ltd
- Fushun petro detergent chemical plant
- Fushun Petroleum Factory of Petrochemical Company
- Fushun Special Steel Co., Ltd
- Fushun Dahuofang Cement Co., Ltd
- Heating Plant of Fushun Mining Group Co., Ltd
- Fushun Thermoelectric Heating Co., Ltd
- Fushun Aluminum Factory.

(Fushun Environmental Monitoring Central Station 2006.)

4.1.2 Traffic

During the years from 2001 to 2005, with rapid economic development of Fushun city, the number of motor vehicles rapidly increased, from about 83 000 in 2000 to 130 000 in 2005 (Zou 2006). With the increase of the vehicles and the oil consumption, the hydrocarbon and the nitrogen oxides also constantly increase, which aggravated the air pollution. At the same time, more traffic results also in more road dust lifted up in the air that increase the PM_{10} concentrations.

About 50% of the key pollutants in urban air came from traffic and there were 70% of nitrogen oxides in the air caused by traffic (Ge 2004). In order to improve the supervision level of the motor vehicle exhaust testing system. In 2006, Fushun Environment Protection Bureau used the random testing method to test around 30 000 vehicles. The results show that 83％ of the samples vehicles reached the standard emission level. For those vehicles, which did not reach the standard level，the owners have to do rectification for the vehicles in order to reach the stand in a limited time. This system is very effective and after the rectification 4000 vehicles reached the standard emission level. (Fushun Environmental Monitoring Central Station 2006.)

In China, cars in private use should be inspected once every two years within the first 6 years. The cars age from 6 to 15 years need to be inspected once per year and more than 15 years old should be inspected once per six months.

4.1.3 Energy structure and consumption

The energy structure of the city of Fushun was unreasonable. In 2006, for example, the energy generation was still mainly based on coal, oil and gas. The consumption of industrial used coal was 9. 4 million tons. The consumption of oil, which does not include traffic was 210 thousand tones. The consumption of gas was 547 million standard cubic meters (Fushun Environmental Monitoring Central Station 2006).

Coal smoke is the major source affecting ambient air pollution, all because of the oversized proportion of coal consumption. Coal is used to heat homes for about five months of the year and industrial centers also depend mostly on coal burning. Particulates and SO_2 as byproducts of coal combustion are the main pollutants of ambient air which need our concern. During the heating time of 2005 the sulfur dioxide is 101μg/m^3, which is 2,7 times higher than during non-heating time (Fushun Environment Office 2005). Burning coal during heating periods is the main source of pollution characteristically the main source of pollution in Fushun is coal burning during heating periods.

TABLE 1. The contrast of air pollution density between heating time and non-heating time in the Fushun urban area, 2005 (Fushun Environment Office 2005) Unit: $\mu g/m^3$

Project	Heating period	Non-heating period
PM_{10}	158	107
SO_2	101	38

4.1.4 Boilers and kilns

Boilers and kilns are another source of air pollution. Besides larger industries, there are very many smaller manufacturing plants in Fushun such as over 1 300 industrial boilers and more than 400 kilns (Ge 2004). Industrial boilers alone consume 30 percent of all coal used in Fushun. These boilers are very often highly inefficient and their smoke stacks are low. Therefore they are contributing major part of the pollution, especially small particulates and SO_2. Inefficient and dirty boilers in particular are problematic because many of the industries that use them are located in extensive densely populated metropolitan areas, exposing the population in these areas to air pollution. The residential sector stands for approximately 15 percent of the total coal use, which is estimated to contribute to more than 30 percent of urban ground-level air pollution (Ge 2004).

In 2006, there were 473 industrial used boilers and 394 kilns in Fushun (Fushun Environmental Monitoring Central Station 2006). Some of the boilers and kilns are in backward combustion process level. This is one of the main reasons that contribute to the air pollution. Installation of desulfurization devices and reforming the precipitators in boilers and kilns are necessary and useful methods to reduce their pollution level.

4.2 Sources of emissions in Kokkola

4.2.1 Industry

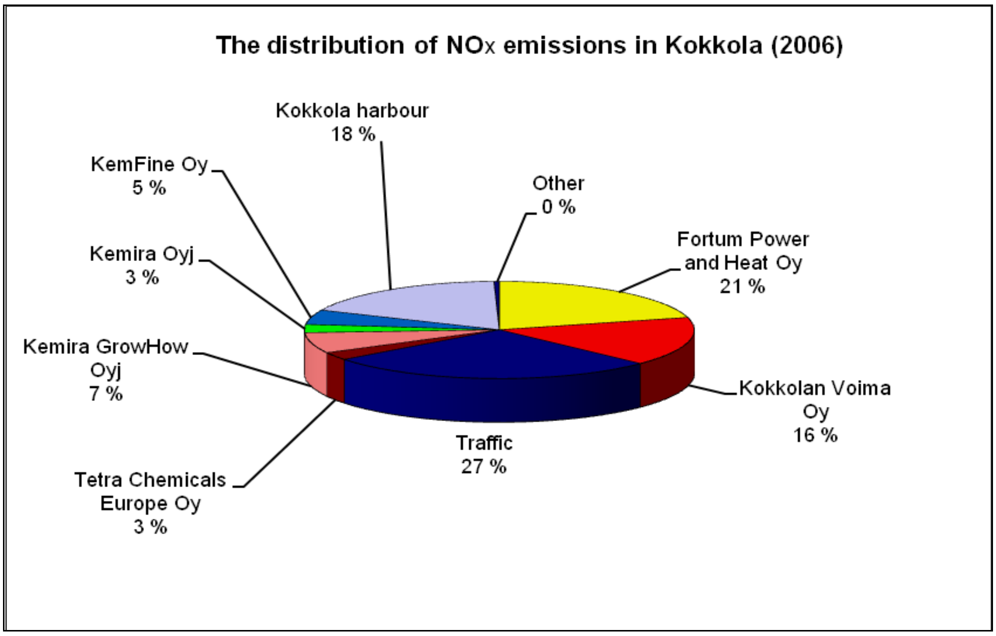
In Kokkola, the sources of nitrogen oxides (NOx) and sulphur dioxide (SO_2) are mainly from energy production, owing to the municipality multiple industrial companies. There are several large chemical industry companies in the Kokkola region including:

- Tetra Chemicals Europe Oy: the largest calcium chloride road salt plant in the EU region
- OMG Kokkola Chemicals Oy: produces the most cobalt in the world (20%)
- Boliden Kokkola Oy: second biggest zinc plant in Europe in production capacity
- Kokkolan Voima Oy, power plant
- Neste Oil Oyj, fuel supply
- Fortum Power and Heat Oy, power plant
- Kemira Oyj, sulfuric acid factory
- Kemira Grow-How Oy, fertilizer factory
- KemFine Oy, fine chemicals factory
- Kokkolan Satama, harbour.

(Wainaina 2007.)

4.2.1.1 Oxides of nitrogen (NO_x)

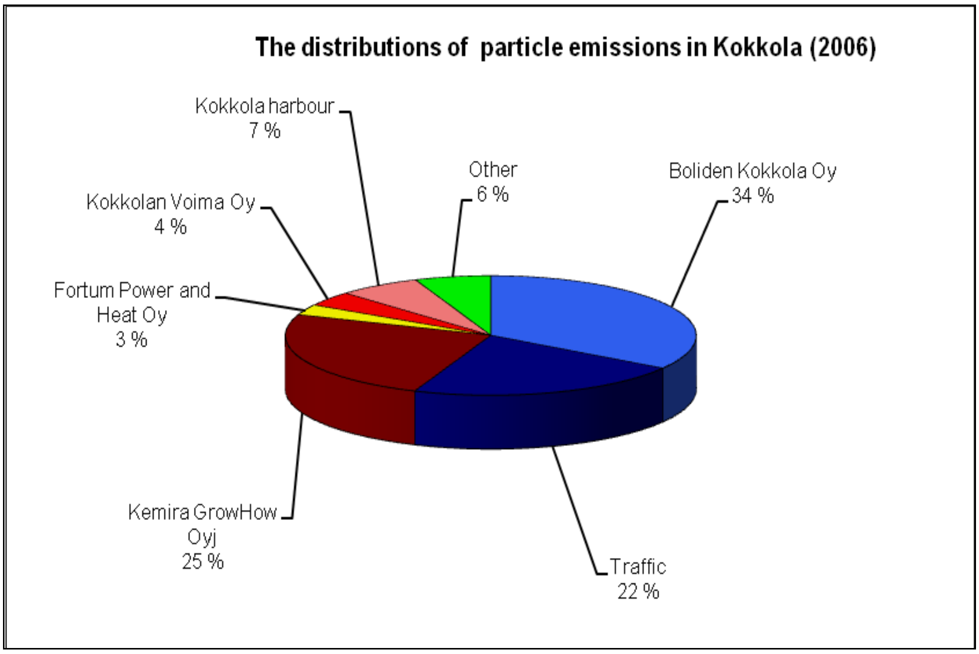
Highest NOx emissions from traffic which accounted for 27%. The following notable emission sources of NO_X were Fortum Power and Heat Oy (21%), the Harbor of Kokkola (18%) and Kokkolan Voima Oy (16%). Graph 3 represents emissions in percentages according to industry involved.



GRAPH 3. Distribution of the emissions of NO_X in Kokkola 2006 (adapted from Koljonen 2006)

4.2.1.2 Particulate matter

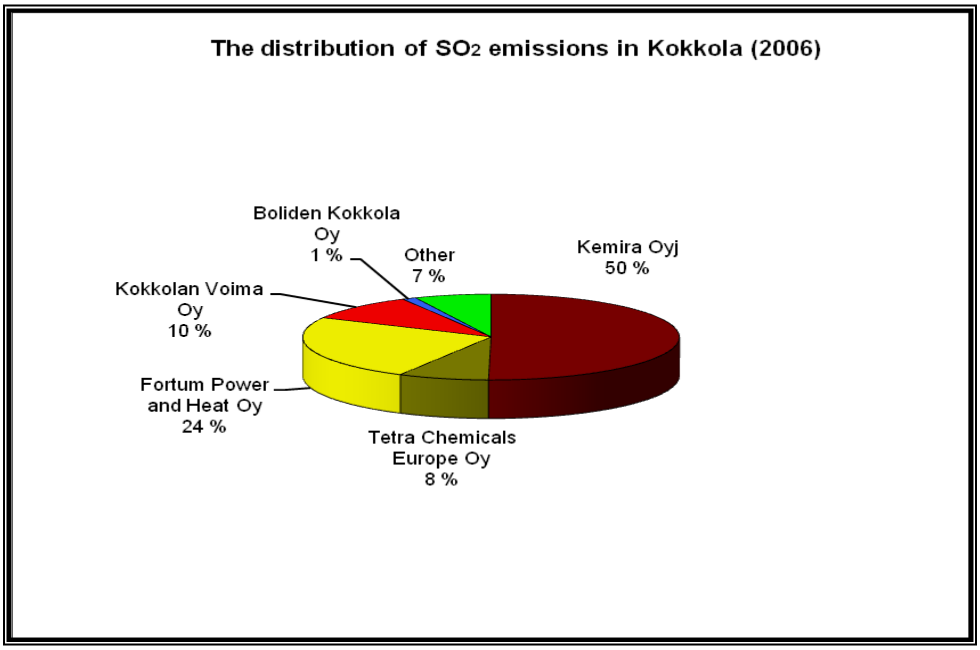
Particulate matter with the obtained results show Boliden Kokkola Oy accounted for 34% of the total emissions followed by Kemeira Growhow Oyj (25%) and traffic (22%) respectively. Graph 4 presents emissions in percentages according to industry involved.



GRAPH 4. Distribution of the PM emissions in Kokkola 2006 (adapted from Koljonen 2006)

4.2.1.3 Sulphur dioxide (SO_2)

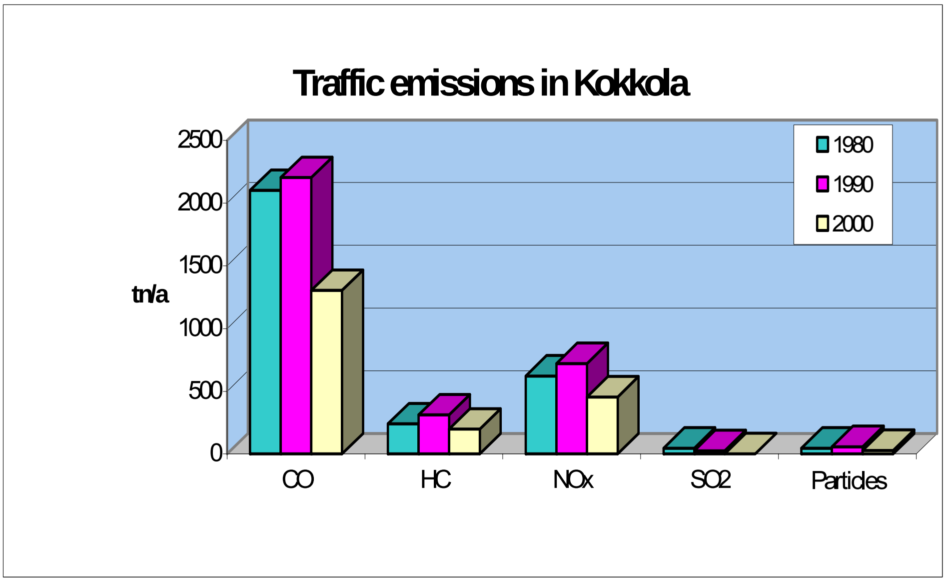
Kemira Oyj accounted for 50% of the total value. Fortum Power and Heat Oy (24%); Tetra Chemicals Europe Oy (8%); and Kokkolan Voima Oy (10%) followed by other (7%) and Boliden Kokkola Oy with 1% each. See graph 5.



GRAPH 5. Sulphur dioxide total emissions by Industry in Kokkola 2006 (adapted from Koljonen 2006)

4.2.2 Traffic pollution

Nitrogen oxides and carbon monoxide are also generated in the transport sector. Considerable improvements have been achieved since the starting of air quality monitoring in Kokkola. The levels of carbon monoxide, nitrogen oxides, sulphur dioxides and particulate matter have gone down and kept improving as shown. In particular NO_x and CO emissions from traffic have significantly reduced over the years.



GRAPH 6. Traffic emissions in Kokkola 1980 – 2000 (adapted from Wainaina 2007)

It can be assumed that the levels have gone on dropping after rising from the 1980s and a decreasing towards the year 2000. This decline can be attributed to various reasons such as: reducing traffic related emissions, technical improvements of vehicles and fuels, better urban planning, catalyses used in cars and traffic management.

5 AIR EMISSIONS

5.1 Air emissions in Fushun

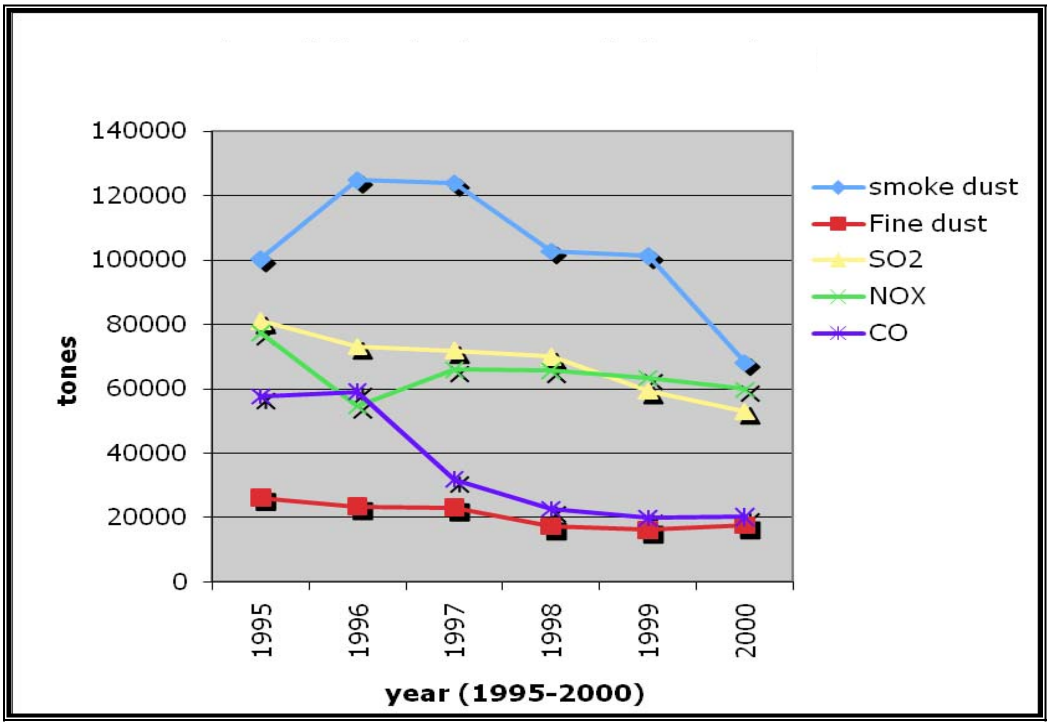
5.1.1 Industrial emissions

In the year 2000, the amount of pollution in discharged exhaust gas in Fushun was about 182 tones, accounting 82, 4% of the total discharged amount of the whole city's industrial emissions (Ge 2004). The emissions of industrial waste gas during the years from 1995 to 2000 are listed in Table 2.

TABLE 2. Industrial emissions in Fushun (Ge 2004)

Emission of industrial waste gas in Fushun	Unit: tones						Decrease in amount in tons	Decrease in %
	1995	1996	1997	1998	1999	2000	1995-2000	1995-2000
Fume(billion m^3)	124.97	125.36	125	113.16	111.17	113.33	1.64	9.3
Smoke dust	100389	124962	124000	102985	101378	68055	32334	32,2
Fine dust	26172	23370	23000	17145	16178	17500	8672	33,1
SO_2	81188	73279	71950	69951	59423	53090	28098	34,6
NOX	77567	54567	66000	65733	63474	59861	17706	22,8
CO	57491	59083	31720	22507	19879	20332	37159	64,6

Graph 7 shows that the five major industrial gas emissions from the year 1995 to 2000 were in obvious decreasing trend. The most significant decrease is CO emission with the amount 37 159 tones accounted 64, 6 in percentage. SO_2, fine dust, fume and NO_X all showed a big declining tendency.



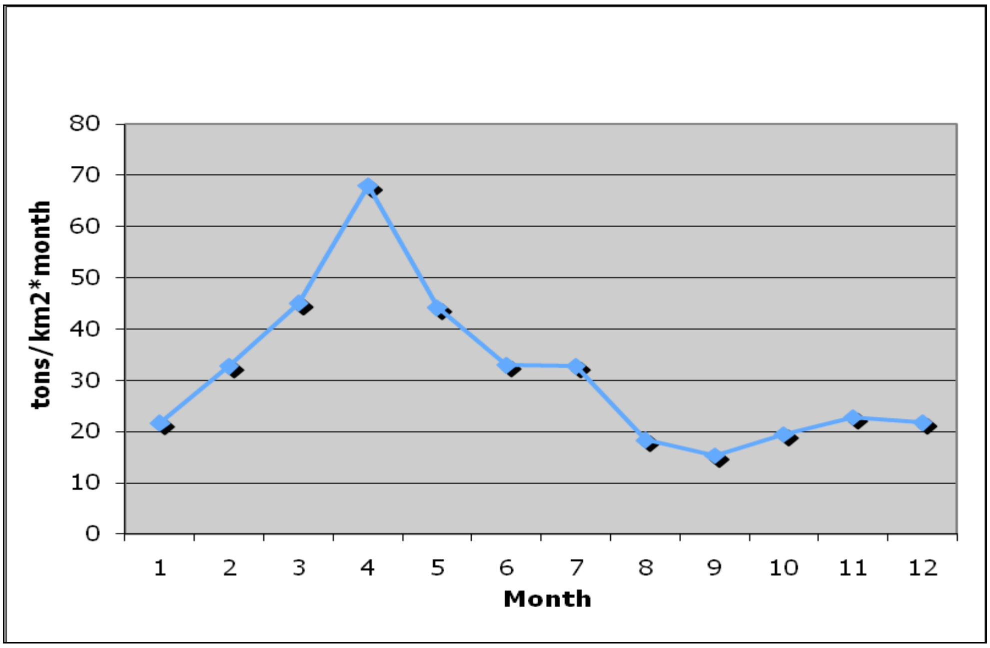
GRAPH 7. Industrial emission trends in Fushun 1995-2000 (Unit: tones)

In 2006, sulphure dioxide, nitrogen oxides, dust and industry fine dust were monitored as main pollutants of industrial gas emissions. The amount of SO_2 yearly emissions in 2006 is 81468 tones increased 3360 tons compared with the SO_2 emission amount in 2005 (Fushun Environmental Monitoring Central Station 2006). The dust emission was 28 822 tones and industrial fine dust emission was 16 252 tones.

Air pollution in Fushun is typical coal-burning pollution. Because of the energy structure, PM_{10} is the major pollutant in Fushun. PM_{10} means particles with an aerodynamic diameter smaller than 10 μm. PM_{10} can enter the respiratory system when inhaling. The PM_{10} fraction is often also called as inhalable particles. Moreover, the ambient air quality seasonal change is significant. During heating time, coal is the main fuel used for energy production, which is increasing the SO_2 concentration.

5.1.2 Dust fall

Dust fall as a criterion of air cleanness is also monitored in Fushun. Dust fall refers to thicker granule depending on its own weight, which can fall fast on the ground. The particle radium size scope is from 100 μm to 1 000 μm. Dust fall amount refers to the tonnage of dust landing on per square kilometer each month. In general, middle level pollution refers to the amount of dust fall over 30 tones/ km^2*month. If the values over 50 t/km^2*month, it is severe air pollution. The natural dust fall ratio of different months is different due to sand storm, blowing dust and floating dust weather. Graph 8 shows Fushun monthly average value of natural dust fall in 2006.



GRAPH 8. Monthly average value of natural dust fall in Fushun 2006 (adapted from Fushun Environmental Monitoring Central Station 2006)

From the monthly natural dust fall changes in 2006, it can be concluded that the concentration is much higher during spring than summer or autumn. The highest value occurred in April reached 68 t/km^2*month. This value surpassed the province standard 7,5 times. The lowest value occurred in September with the amount 15,3 t/ km^2*month which was still over the standard level. Natural dust fall pollution in Fushun was serious.

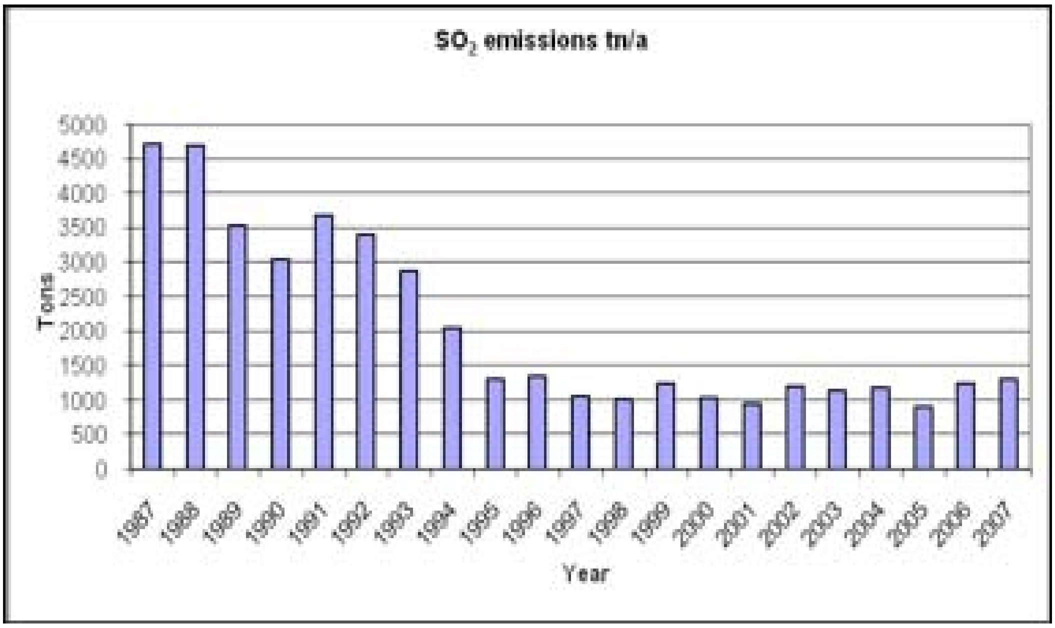
5.2 Air emissions in Kokkola

There is one large-scale industrial area in Kokkola, located in Ykspihlaja. Many different types of companies are situated in Ykspihlaja. There are hydrometallurgical factories, chemical factories and energy production units. Also the Port of Kokkola is located in the industrial area, with many different types of port activities. (Koljonen 2007, 9.)

The industries, energy production and port activities mentioned above are the main air emission sources for sulphur dioxide, metal emissions and nitrogen oxides in Kokkola. Road traffic is the largest single emission source for nitrogen oxides. However, the amount of nitrogen oxide emissions from the Ykspihlaja industrial and port area is clearly higher than from road traffic. (Koljonen 2007, 9-10.)

5.2.1 Sulphur dioxide (SO_2)

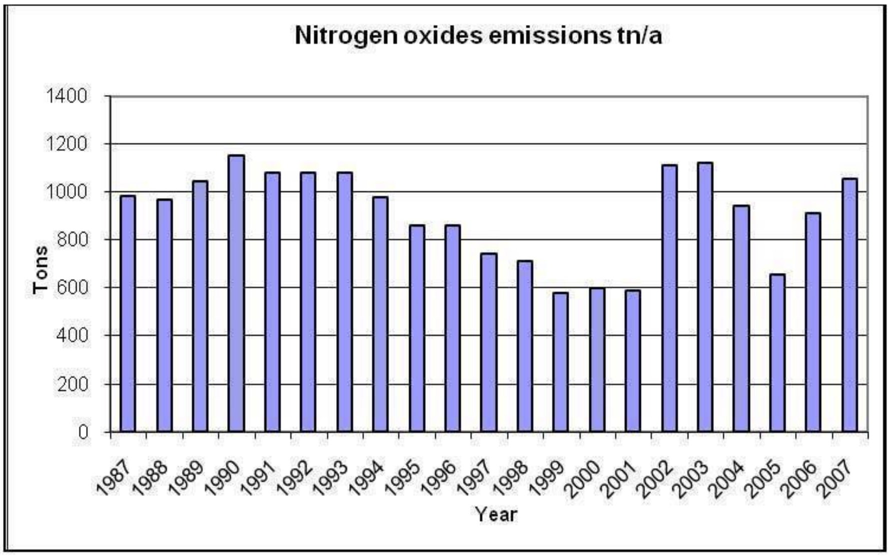
In the beginning of the 1970's the sulphur dioxide air emissions in Kokkola were almost 70 000 tons per year. Air quality was very poor during this time. Due to various improvements in cleaning technology, enhanced process control and outlet restrictions, the amount of sulphur dioxide emissions in 2007 was only 1314 tons (Koljonen 2007). Although the SO_2 emission levels are normally low nowadays, high concentrations can be experienced in Ykspihlaja sometimes because of the emissions from the industry. This results when the industries involved face a problem with the process and sometimes heightened by the meteorological conditions. High emission happens especially in late spring because of the geographical location of Kokkola. Graph 9 shows that there has not been any considerable change in the amount of sulphur dioxide emissions in Kokkola since 1995.



GRAPH 9. Emission trend of SO_2 in Kokkola 1987-2007 (adapted from Koljonen 2007, 10-11)

5.2.2 Nitrogen oxides (NO_x)

The main emission sources for nitrogen oxides are road traffic and energy production units, but also the port activities in Ykspihlaja contribute largely to the emissions. Combustion produces mainly nitrogen monoxide, but it oxidizes by time to NO_2, which is more harmful to health. (Koljonen 2007,11.)

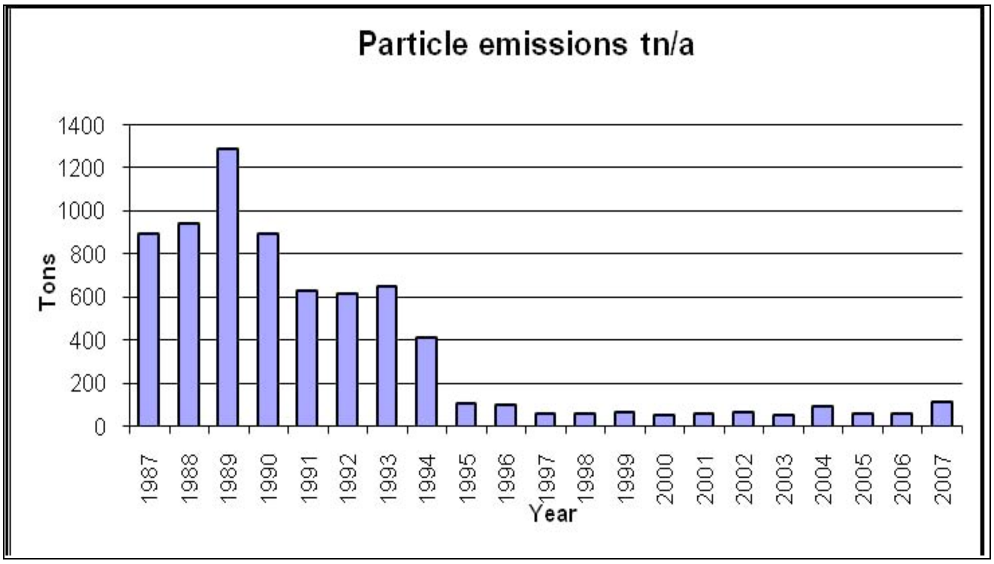


GRAPH10. Emission trend of NOx in Kokkola 1987-2007 (adapted from Koljonen 2007)

Graph 10 presents the NO_X emission trend from 1987 to 2007 in Kokkola. Traffic emissions concerning NO_2 have been decreased while those form energy production and the port have been on an increase in Kokkola. Even though the highest amounts of nitrogen oxides emissions are from energy production, the emissions from road traffic play a significant part to air quality. The emission height is much lower in road traffic, and the emissions are mainly formed in highly trafficed areas, such as in the city centre (Koljonen 2007, 11). NO_X concentrations may also increase quickly if the temperature drops fast and there is no or only little wind. It happens mainly in wintertime when temperatures drop. If temperatures rise fast, it can create inverse situations. Normally the levels are quite low.

5.2.3 Particulate matter

In 2007, the total amount of particle emissions was 118 tons per year. In 2006, the amount was only 60 tons per year. The increase of emissions amount compared to previous years was due to the fact, that it was the first time one of the larger industries had to report their particle emissions and that year industry was responsible for 34% of the total emissions of particles. However, over a longer time period, the particle emissions have reduced significantly even though they have been on the same level since the 1995. Graph 11 presents the particle emissions where dust and particles from ship have not been take into consideration. (Koljonen 2007, 13.)



GRAPH 11. Emission trend of PM_{10} in Kokkola1987-2007 (adapted from Koljonen 2007, 13-14)

5.2.4 Metal emissions

Most of the metal emissions come from the activities in the Yksipihlaja industrial area; however some metals originate from traffic and soil.

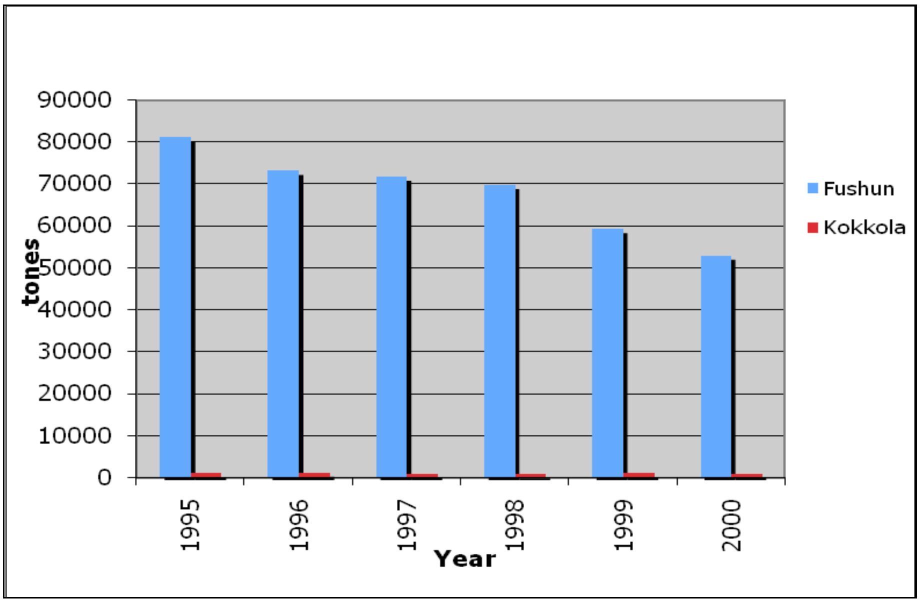
Table 3 shows the emissions from only heavy industry. The emissions are the highest for zinc, cobalt and nickel. However, a decrease in the emissions can be seen for zinc, arsenic and mercury. Since 1994 the emission trend for metals has been declining, even if production has increased. This is because of better process control. Most of the metal emissions come from disturbances in the metal processes. The emissions for cobalt have slightly increased, while for other metals not mentioned the emission trend has been stable. (Koljonen 2006.)

TABLE 3. The metal emission trend in Kokkola 2002 – 2006 (Koljonen 2006.)

Metal (kg/a)	2002	2003	2004	2005	2006
Mercury (Hg)	2,4	4,7	5,2	6,7	7,1
Cadmium (Cd)	58	64	101	104	108
Lead (Pb)	269	91	128	113	102
Arsenic (As)	711	448	335	170	26
Cobalt (Co)	3475	2900	3690	2789	3937
Crom (Cr)	12,1	12,7	11,6	9,1	12,7
Nickel (Ni)	1191	557	1422	58	189
Iron (Fe)	362	466	837	402	328
Copper (Cu)	124	216	255	225	215
Zinc (Zn)	23911	7034	7497	8106	8549
Vanadium (V)	130	162	31	34	25

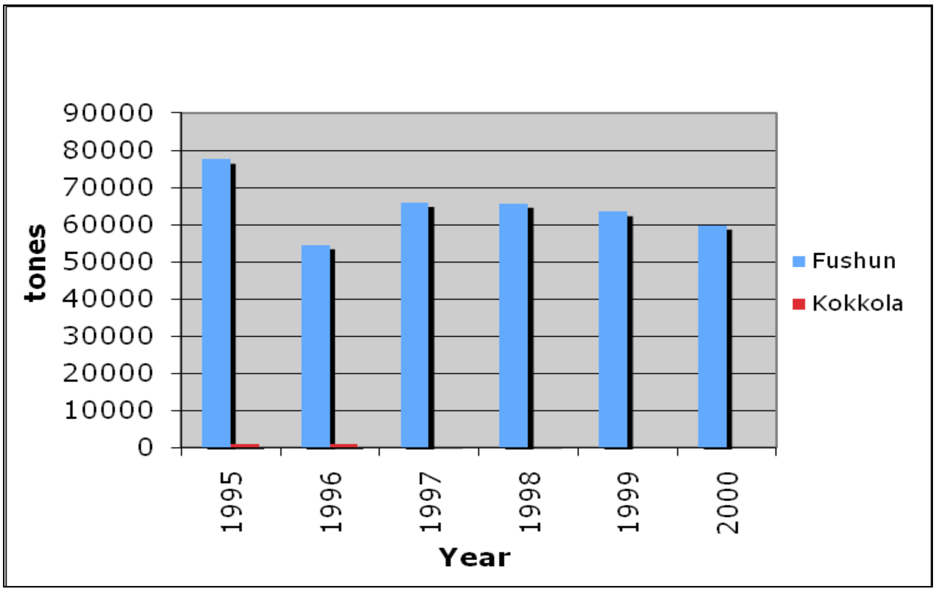
5.3 Comparisons of air emission levels

The total emission levels in Fushun show significant differences in tonnage when compared with the ones in Kokkola. In 2000 the total Fushun emissions of SO_2 were 53 ktons whereas in Kokkola approximately 1 ktons, with a slight increase in 2007 to 1,314 ktons. This suggests that the emissions differences in tons are approximately 53 times higher in Fushun.



GRAPH 12. SO_2 emissions comparison between Fushun and Kokkola

Similar trends apply to nitrogen oxides (NO_x) emissions, approximately 60 ktons in Fushun whereas the Kokkola emissions totalled 0,6 ktons in 2000 and slightly over 1 kton in 2007. This difference is approximately 100 times more in Fushun.



GRAPH 13. NO_2 emissions comparison between Fushun and Kokkola

6 AIR QUALITY MONITORNING (AQM)

6.1 AQM in Fushun

6.1.1 Monitoring stations

The Fushun central monitoring station was established in 1974, as subordinate to the Fushun Environmental Protection Bureau. Its function is to provide information to the environmental bureau by monitoring the quality of environment. The Fushun central monitoring station is actively measures air and water quality, providing technical expertise, investigating pollution sources and developing environmental research. There are over 70 persons working at the central monitoring station. (Fushun Environmental Monitoring Central Station 2006a.)

The central monitoring station has nine separate branches that include the integrated management office, quality assurance office, pollution control office, central laboratory, ecology lab, environmental monitoring office, automatic monitoring office, instrumental analysis office and the logistics office. They supervise the quality of air, water, soil, ecology, noise, oscillation and radiation. (Fushun Environmental Monitoring Central Station 2006a.)

In total there are five automatic monitoring stations in the Fushun area for air quality, one of them operating as a mobile monitoring station. (Fushun Environmental Monitoring Central Station 2006b.) The monitoring stations are listed as below.

TABLE 4. Fushun AQM stations (Fushun Environmental Monitoring Central Station 2006b.)

Station Name	Pollutant Monitored	Functions
DahuoFang reservoir AQM station	PM_{10}, SO_2, NO_2, O_3, temperature, pressure, wind speed, wind direction and rain amount	Operates as a clean area measuring station
Dongzhou AQM station	PM_{10}, SO_2 and NO_2	Operates as a residential area measuring station.
Zhanqian AQM station	PM_{10}, SO_2, NO_2, O_3, temperature, pressure, wind speed, wind direction and humidity	Operates as a commerce communication residential area measuring station.
WangHua AQM station	PM_{10}, SO_2, NO_2, O_3, temperature, pressure, wind speed, wind direction and rain amount	Operates as a industrial area measuring station.
Mobile monitoring station		

6.1.2 Methods of analysis

Fushun urban air quality monitoring system consists of two major categories. One is an automatic detection method and the other is a manual detection method. SO_2, NO_2, CO and PM_{10} are monitored by automatic method. The monitoring frequency is daily continuous monitoring throughout the year. TSP is monitored once per month. The monitoring project and method is listed as below.

TABLE 5. The ambient air automatic monitor project and analysis method

Equipment	Measurement	Method	Standard
β-ray particle analyzer	PM_{10}	β Radiation	GB3095-1996
UV fluorescence SO_2 analyzer	SO_2	Ultraviolet fluorescence	
Chemiluminescence NO_X analyzer	NO_X, NO, NO_2	Chemiluminescence	
Non-dispersive infrared CO analyzer	CO	IR-Absorption	
Ultraviolet Ozone Analyzer	O_3	Ultraviolet radiation	

6.1.3 Evaluation criteria

Ambient air quality assessment using "The ambient air quality specification (GB3095-1996)" the centre two levels of standards."

TABLE 6. The ambient air quality specification (GB3095-1996) the centre two levels of standards

Name of pollution	Limit value of concentration ($\mu g/m^3$)	
	Time of value taking	Second level standard
SO_2	Year average	60
	Day average	150
NO_2	Year average	80
	Day average	120
PM_{10}	Year average	100
	Day average	150
CO	Day average	4000

6.2 AQM in Kokkola

6.2.1 Monitoring stations

Continuous air quality monitoring in Kokkola was started in 1992. At present, there are two monitoring stations in Kokkola, one in Ykspihlaja close to the industrial area and the other one in the city centre. The Ykspihlaja air quality monitoring station is an industrial monitoring unit where the impact of the air emissions from the industries in Ykspihlaja on the air quality is monitored. The monitoring station in the city center monitors the impact of the air emissions from the road traffic on the air quality in the lively trafficed city centre. (Koljonen 2007, 1.)

TABLE 7. Kokkola AQM stations (Koljonen 2007)

Name	Pollutant Monitored	Type of monitoring
Pitkänsillankatu	NO_x, PM_{10}, (O_3, SO_2, CO)	Urban traffic AQM site
Ykspihlaja	SO_2, NO_x, PM_{10} (TSP)	Industrial AQM site

In Kokkola, sulphurdioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and particles with a diameter less than 10 µm (PM_{10}) are monitored at the Ykspihlaja station. SO_2, PM_{10} and NO_x are monitored continuously and at the city centre station PM_{10}, CO and NO_x are being monitored. (Koljonen 2007, 5-6.)

Pitkänsillankatu—This location being in the central business area – close to everyday traffic and closes to pedestrians, thus general population, makes it an ideal location for a monitoring site.

Ykspihlaja— Ideal, being at the seaside and the main port of Kokkola containing ship traffic and other heavy traffic activities, serving the chemical and metallurgical industries and power plants. This station is also equipped with a meteorological station, which gives vital information on temperature and wind direction.

6.2.2 Methods of analysis

In Kokkola, automatic sampling methods were used in collecting data in this study. By using these techniques, pollutants were continuously collected and analyzed every hour. The samples were analyzed on-line and the data are stored within the analyzer or a separate data logger and may be downloaded remotely by a modem or by other means of data transfer. The two computers at the monitoring sites are connected to the main computer in the Environment protection office. Calibration, quality assurance and control procedures were required to ensure data accuracy.

TABLE 8. The ambient air automatic monitor method in Kokkola (Wainaina 2007)

Equipment	**Measuring project**	**Method**	**Standard**
TEOM Series 1400a monitor	PM_{10}	β-radiation	EU Council Directive 1999/30/EC of 22 April 1999: ISO 7996: 1985 Ambient air
The Thermo ESM Andersen FH 62 I-R		Micro balance (gravimetrical)	
The API Model 100E SO_2 and The Thermo Electron TE 43A	SO_2	Ultraviolet fluorescence method	
ML® 9841B oxides of nitrogen analyser	NO_X	Chemiluminescence method	
API Model 300 carbon monoxide analyser.	CO	Non-dispersive infra-red spectrometry (NDIR), gas filter correlation method.	EU council directive 2000/69/EC 16 November 2000 ISO 4224: 2000
API Model 400	O_3	Ultraviolet photo metric method	ISO/FDIS 13964

6.2.3 Evaluation criteria

The ambient concentrations of air pollutants are regulated through limit threshold and target values as well as long term objectives adopted by the European Parliament and Council. Finnish air quality objective is the mandatory and binding air quality limit values correspond to those of the European Framework Directive (96/62/EC) and the four daughter directives (1999/30/EY, 2000/69/EY, 2002/3/EC and EU 2004/107/EC). (Wainaina 2007.)

TABLE 9. European Union, air quality limit values for the protection of human health

Compound	**Averaging time for limit value**	**Limit value (293K , 101,3 kPa)**
Sulphur Dioxide (SO_2)	Hour Day Year	350 µg/m^3 125 µg/m^3 20 µg/m^3
Nitrogen Dioxide (NO_2)	Hour Year	200 µg/m^3 40 µg/m^3
Particulate matter (PM_{10})	Day Year	50 µg/m^3 40 µg/m^3
Carbon Monoxide (CO)	8-hour	10 mg/m^3

7 CONCENTRATIONS IN AMBIENT AIR

7.1 Sulphurdioxide (SO_2)

7.1.1 SO_2 Concentration in Fushun

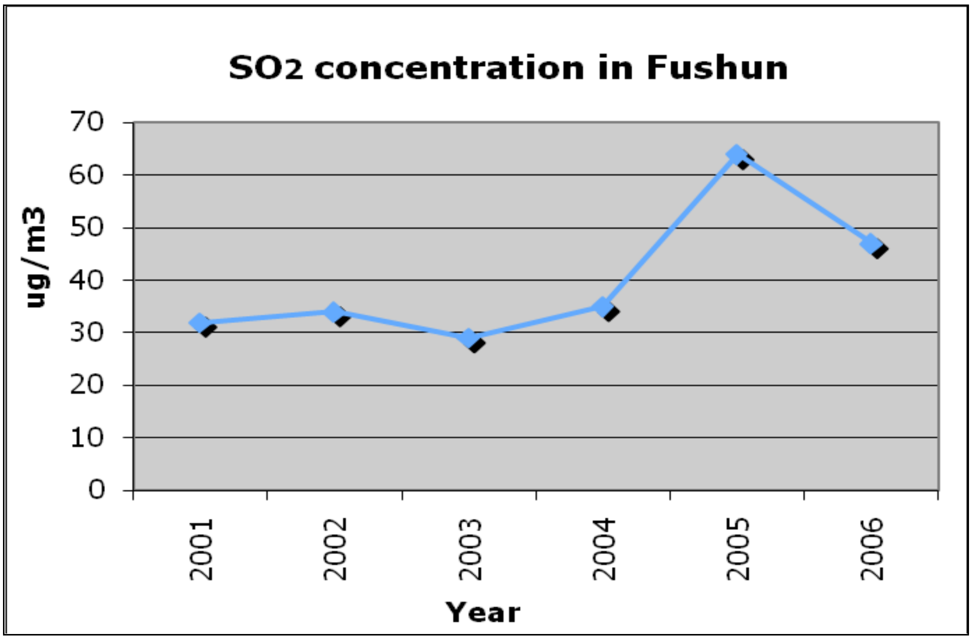
From 2001 to 2005, the average value of sulfur dioxide was 39 $\mu g/m^3$ in Fushun. The biggest year average value was 64 $\mu g/m^3$ in 2005, surpassing the second ranking standard of national ambient air quality 1. 9 times. The biggest spot day average value was 429 $\mu g/m^3$, surpassed the second ranking standard of national ambient air quality 1, 9 times.

TABLE 10. SO_2 inspection results in Fushun urban area 2001-2005 (Fushun Environmental Monitoring Central Station 2005b Unit: $\mu g/m^3$)

Project	Year	Daily point data	Average value of year	Max value	Min Value	Super Scale %
SO_2	2001	240	32	192	2	2,5
	2002	240	34	260	2	3,3
	2003	240	29	191	2	1,2
	2004	240	35	219	2	3,3
	2005	1810	64	429	0	7,0

In 2006, the average value of sulfur dioxide was 47 $\mu g/m^3$, which conformed to the second ranking standard of national ambient air quality. The daily average ranking exceeded the allowed figure rate 0, 3%. The highest daily average ranking was 302 $\mu g/m^3$ (Fushun Environmental Monitoring Central Station 2006).

Sulfur dioxide seasonal changes showed that the highest value occurred in winter and lowest in summer. In three seasons, the value conformed to the standard except winter. Sulfur dioxide concentration was 70% higher during heating periods than non-heating periods. There were two reasons contributing to sulfur dioxide exceeding. During heating time the coal using amount increased and the other reason was that meteorological character of winter is not so conducive to pollutant dispersion.



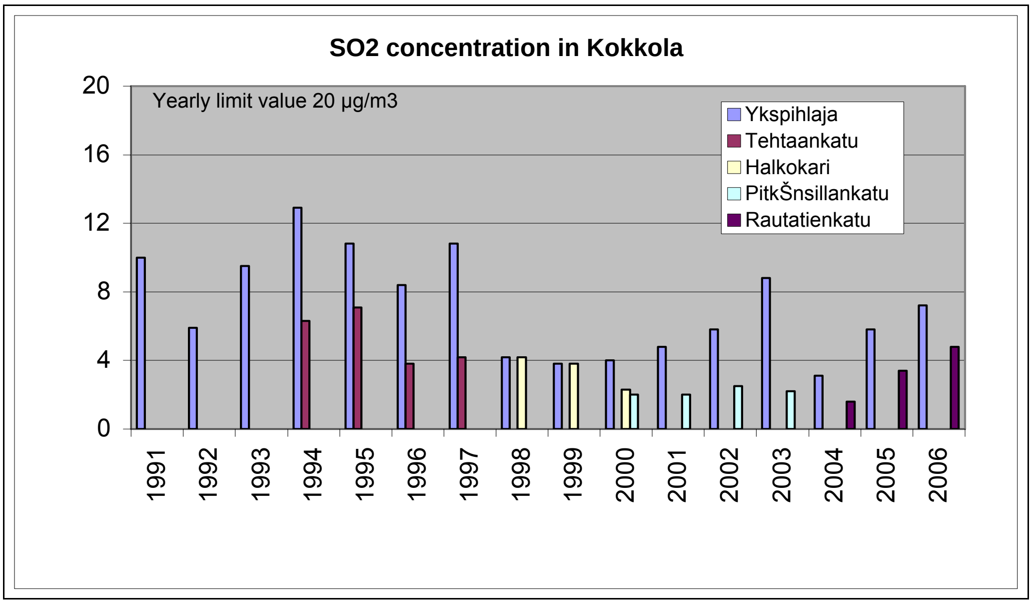
GRAPH 14. Annual average concentration of SO_2 in Fushun 2001-2006

Sulfur dioxide concentration level was in upward trend in the first four years from 2001 to 2005. In 2005, the value reached its highest point at 64 μg/m^3 but this trend fell down again in year 2006.

7.1.2 SO_2 Concentration in Kokkola

The sulphur dioxide concentrations in Kokkola showed a decreasing trend. Overall the concentrations are significantly below the limit values set by the EU, which has set an annual limit value of 20 µg/m^3, daily limit value of 125 µg/m^3 and an hourly limit value of 350 µg/m^3. The few high peaks can be explained by the weather conditions experienced in Kokkola during early summer. This is because of the earth-sea wind effect.

The declining sulphur dioxide concentrations are primarily due to development of the gas cleaning in the chemical industry. Also the adoption of district heating schemes has been cutting the emissions produced by separate heating systems for individual homes and buildings.



GRAPH 15. Annual average concentration of SO_2 1991-2006, Kokkola (adapted from Koljonen 2006)

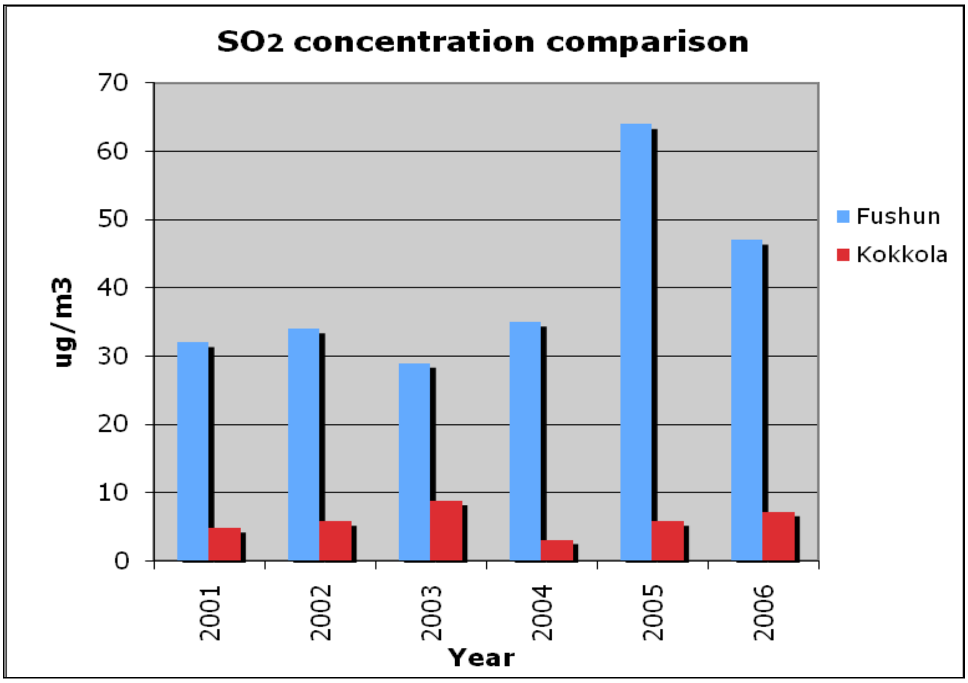
7.1.3 Comparison

Table 11 shows a considerable difference of SO_2 day average limit value and year average limit value between Fushun and Kokkola. The year limit value in Fushun is 60 μg/m^3 which is three times of the value in Kokkola.

TABLE 11. SO_2 Limit value of concentration comparison, Fushun and Kokkola

City	SO_2 Limit value of concentration (μg/m^3)	
	Time of value taking	Limit value
Fushun	Year average	60
	Day average	150
Kokkola	Day	125
	Year	20

The sulphur dioxide concentrations in Graph 16 demonstrate a significant difference of year average value between Fushun and Kokkola city from the year 2001 to 2006. SO_2 level was in upward trend during the first four years from 2002 to 2005 in Fushun while a good level of decrease trend was found in Kokkola.



GRAPH 16. SO_2 concentration comparison, Fushun and Kokkola

7.2 Nitrogen Dioxide (NO_2)

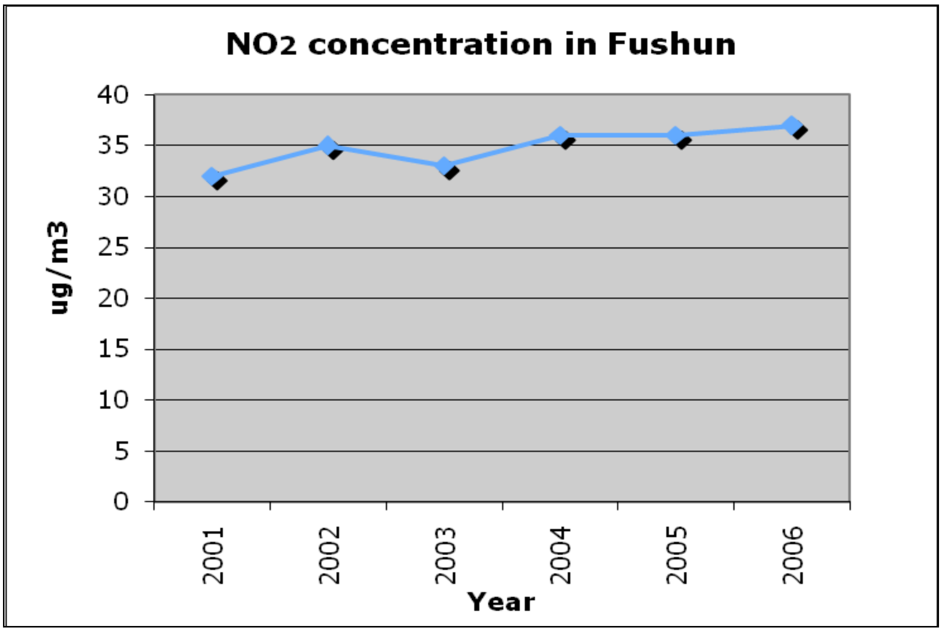
7.2.1 NO_2 Concentrations in Fushun

The yearly average value of nitrogen dioxide was 34 $\mu g/m^3$ in the period from 2001 to 2005 in Fushun, which conformed to the second ranking standard of national ambient air quality. In 2005, the yearly average value of nitrogen dioxide was 36 $\mu g/m^3$. The daily average value exceeded the allowed figure rate 1, 0%, and the highest spot daily average value was 246 $\mu g/m^3$ (east continent), surpassed the second ranking standard of national ambient air quality 1, 0 times.

TABLE 12. Fushun urban area air pollutant inspection results, 2001-2005 (Adapted from Fushun Environmental Monitoring Central Station 2005b) Unit: $\mu g/m^3$

Project	Year	Daily point data	Average value of year	Max value	Min Value	Super Scale %
NO_2	2001	240	32	84	2	0,0
	2002	240	35	152	1	0,4
	2003	240	33	88	2	0,0
	2004	240	36	105	2	0,0
	2005	1810	36	246	0	1,0

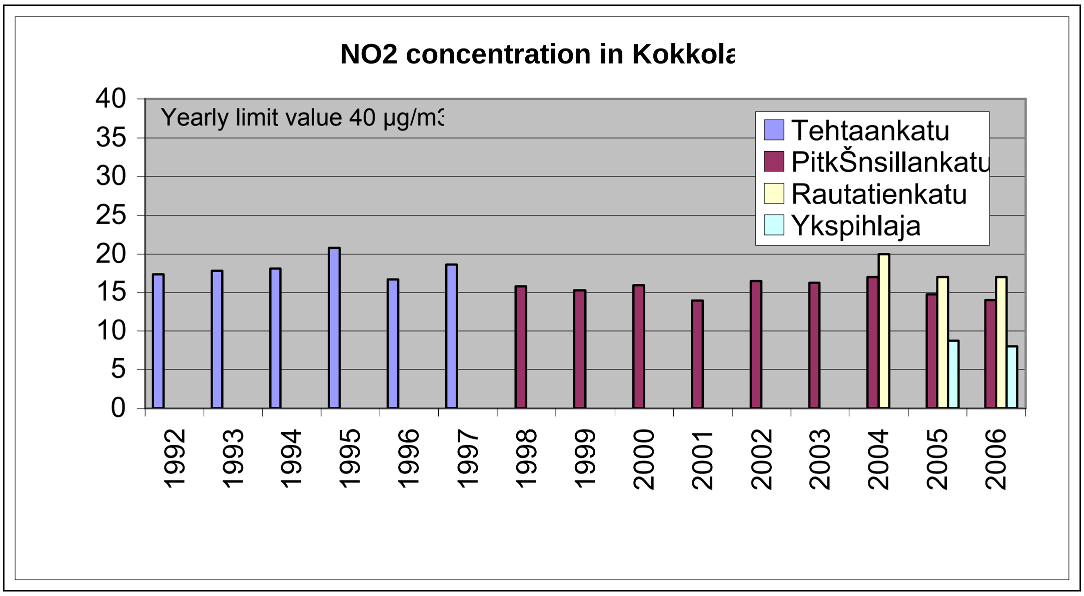
In 2006, the yearly average value of nitrogen dioxide was 37 $\mu g/m^3$, which conformed the second ranking standard of national ambient air quality (Fushun Environmental Monitoring Central Station 2006). Nitrogen dioxide seasonal changes showed that the highest value occurred in winter and spring. The lowest values were measured in summer. The concentration of nitrogen dioxide in all four seasons was in line with the national standard. Graph 17 shows the nitrogen dioxide concentration level changes from year 2002 to 2006 which were in steady increase except the year 2003.



GRAPH 17. Annual average concentration of NO_2 in Fushun 2001-2006

7.2.2 NO_2 concentrations in Kokkola

The maximum annual average value was 20, 8 µg/m^3 at Tehtaankatu monitoring station in 1995. The annual concentrations in general have been 50 % below the limit values, as can be seen in Graph 18.



GRAPH 18. NO_2 concentration in Kokkola, 1992-2006 (adapted from Koljonen 2006)

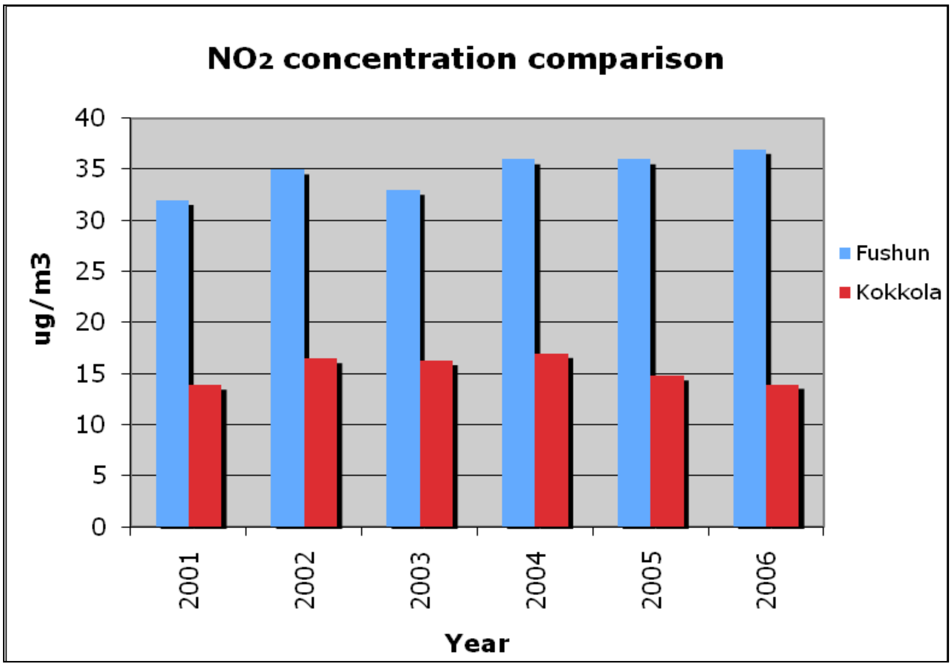
7.2.3 Comparison

The limit value of NO_2 in Fushun is 80 $\mu g/m^3$, which is double times of the value in Kokkola.

TABLE 13. NO_2 Limit value of concentration comparison, Fushun and Kokkola

City	NO_2 limit value of concentration ($\mu g/m^3$)	
Fushun	Year average	80
Kokkola	Year average	40

From 2001 to 2006, the year average concentration value in Fushun was almost two times of the values in Kokkola. The overall concentration level trend in Kokkola was in steady decrease while the opposite trend can be seen in Fushun city.



GRAPH 19. NO_2 concentration comparison, Fushun and Kokkola (2001-2006)

7.3 Particulate Matter (PM_{10})

7.3.1 PM_{10} concentration in Fushun

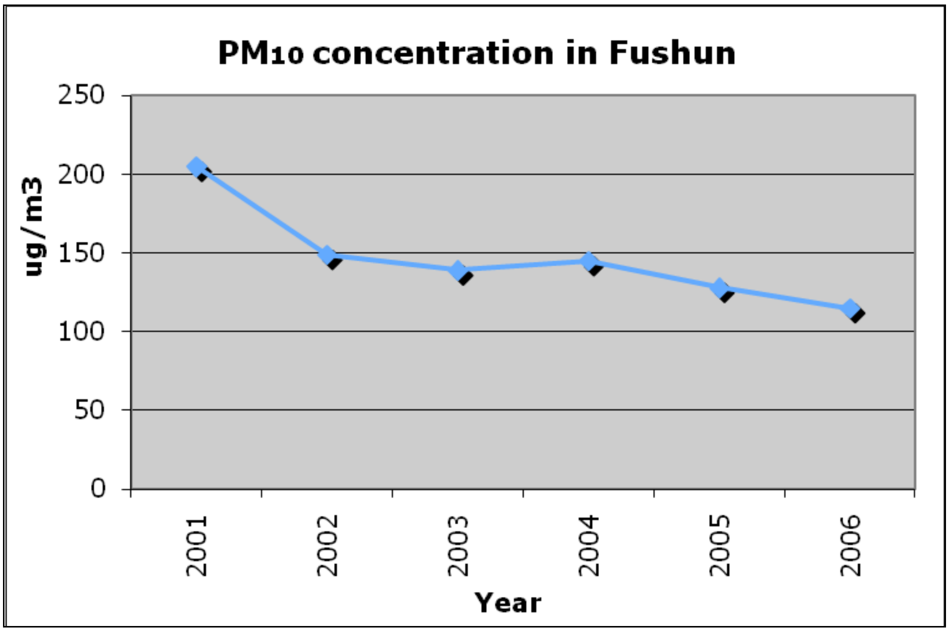
The average yearly value was 153 $\mu g/m^3$ in the year 2001-2005 which surpassed national ambient air quality standard 0,5 times. The highest yearly average value was 205 $\mu g/m^3$ (in 2001), exceeding the second ranking standard of national ambient air quality (100 $\mu g/m^3$) 2 times. Daily average value exceed the allowed figure rate 41, 3%, and the highest spot daily average value was 1234 $\mu g/m^3$ (in 2001) which surpassing the second ranking standard of national ambient air quality 12 times. In

2005 the yearly average value was 128 μg/m^3, surpassing the second ranking standard of national ambient air quality with 30 %. The spot daily average value exceed the allowed rate 26, 9%, and the highest spot daily average value was 830 μg/m^3, surpassing the second ranking standard of national ambient air quality 8 times. In 2006, the yearly average concentration level decreased to 115 μg/m^3, which is closer to the limited value (Fushun Environmental Monitoring Central Station 2006).

TABLE 14. Fushun urban area air pollutant inspection result during 2001-2005
Unit: μg/m^3 (Fushun Environmental Monitoring Central Station 2005b)

Project	Year	Daily point data	Average value of year	Max value	Min Value	Super Scale %
PM_{10}	2001	240	205	1234	14	55,4
	2002	240	149	622	28	42,9
	2003	240	139	378	6	41,4
	2004	240	145	325	32	40,0
	2005	1807	128	830	140	26,9

Graph 20 shows that the PM_{10} concentration in Fushun has been in steady decrease from 202 μg/m^3 in 2001 to 115 μg/m^3 in 2006.



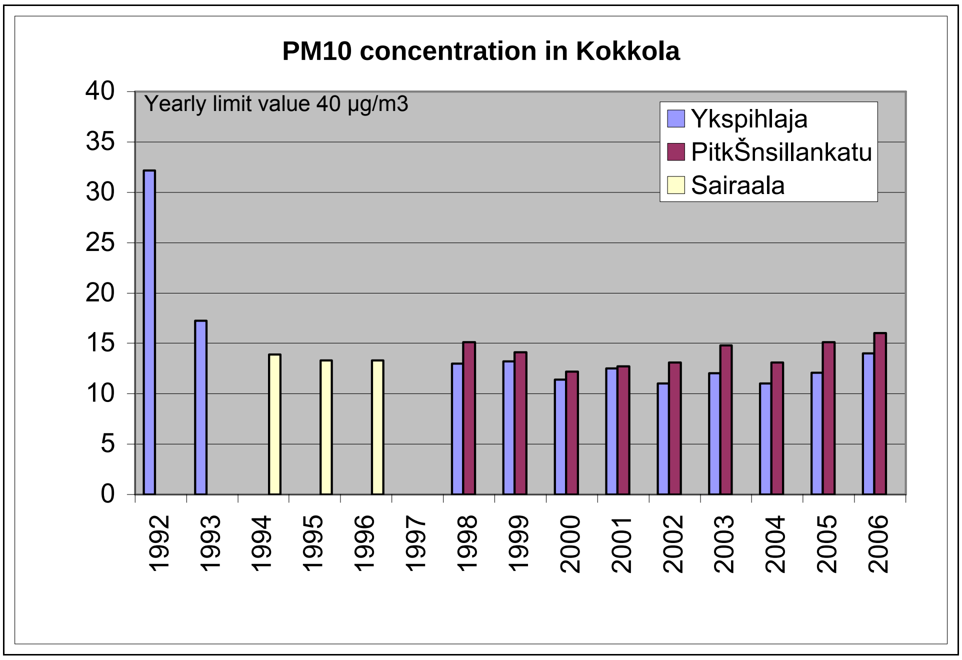
GRAPH 20. Annual average PM_{10} concentration in Fushun, 2001-2006

7.3.2 PM_{10} concentration in Kokkola

Particulate pollution comes from diverse sources as factory and utility smokestacks, vehicle exhaust, wood burning and construction activity. Government regulations, municipal administration, set laws and local innovations have contributed to the level of PM_{10} achieved.

PM_{10} is the main air quality problem faced in Kokkola and most other cities in Finland. During spring, the particulate matter level in the air is usually high. Use of road sand (grit material) and studded winter tyres is typical for Kokkola and Finland as a whole. Consequently these traffic safety measures often lead to high PM concentrations, especially during spring. The contribution of re-suspension of road sand is the major source of suspended particulates. Improvement in road cleaning related to timing has had a very positive effect on leveling the amount of peaks experienced. There are only a few days when the PM_{10} daily limit values have been exceeded. (National reporting on atmosphere Finland 2005).

At Ykspihlaja results showed trends of consistency as well, with the highest recorded PM_{10} value of 32, 3 µg/m^3 in 1992. The low levels occurred in 2002 and 2004 both at 11µg/m^3. The results of the concentrations were satisfactory when compared to the alert threshold levels. PM_{10} is the main air quality problem faced in Kokkola. During spring, the particulate matter level in the air is usually high because the use of road sand.



GRAPH 21. PM_{10} concentration in Kokkola, 1992-2006 (adapted from Koljonen 2006)

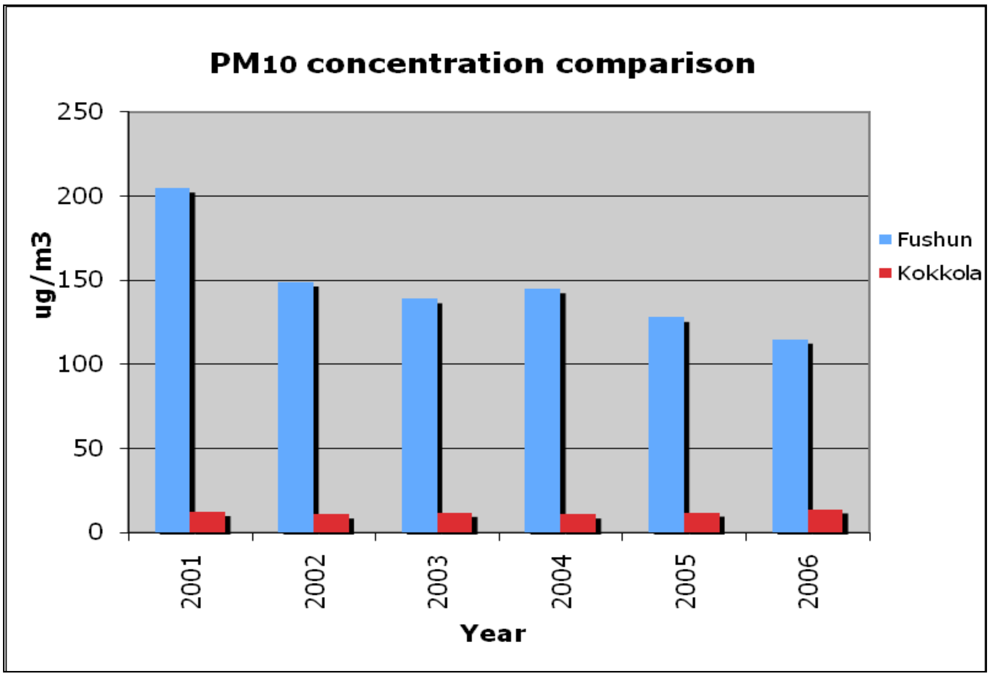
7.3.3 Comparison

The comparison of limit values for concentrations of pollutants showed big differences between China (Fushun) and Finland (Kokkola). The yearly limit value in Kokkola is 40 µg/m^3 while the value in Fushun is 100 µg/m^3

TABLE 15. Comparison of PM_{10} limit values in Fushun and Kokkola

Name of pollution	PM_{10} Limit value of concentration ($\mu g/m^3$)	
Fushun	Year average	100
	Day average	150
Kokkola	Year	40
	Day	50

Comparing the PM_{10} concentration in Fushun with the value in Kokkola during year 2001 to 2006. Tremendous difference can be seen by Graph 22. Take year 2006 for example, the yearly average value in Fushun was 115 $\mu g/m^3$ while the value in Kokkola was 14 $\mu g/m^3$ the result difference was over 100 $\mu g/m^3$.



GRAPH 22. PM_{10} concentration comparison, Fushun and Kokkola (2001-2006)

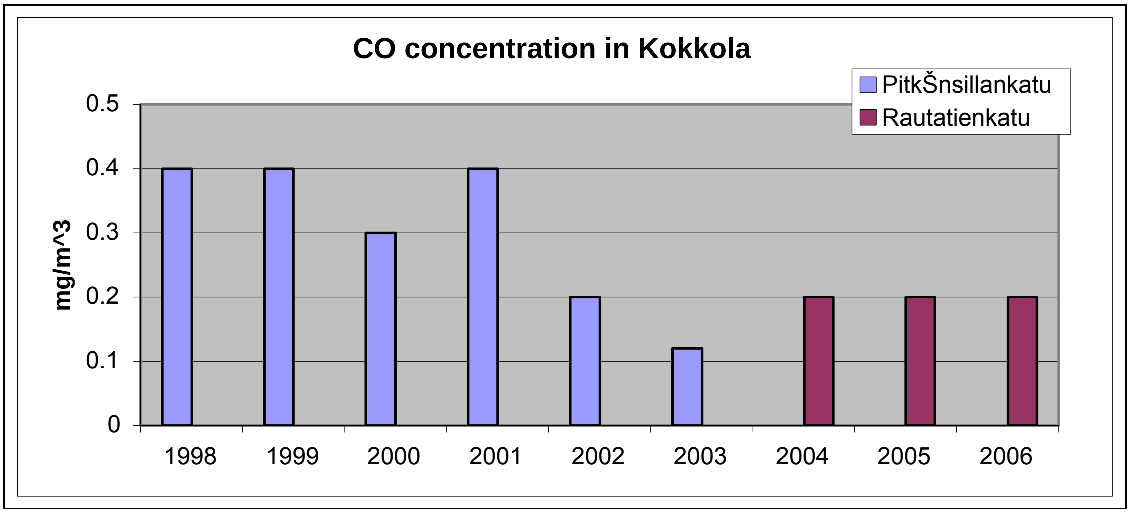
7.4 Carbon Monoxide (CO)

7.4.1 CO concentration in Fushun

In Fushun, the yearly average value was 1.71 mg/m^3 below the limited value in the year 2006. The highest daily average value was 5 mg/m^3 which exceeded the standard with 30 %. It happened in the industry area in summer time. The CO emission quantity was highest in winter and lowest in spring. The yearly average values reached the national air quality standard. (Fushun Environmental Monitoring Central Station 2006.)

7.4.2 CO concentration in Kokkola

In Kokkola, the yearly average value remained at 0, 2 mg/m^3 from 2004 to 2006 (Koljonen, 2006). CO measurements are becoming unimportant in Finland because almost all cars are equipped with catalyzers. CO levels have dropped drastically. This is also the situation in Kokkola.



GRAPH 23. Yearly CO concentrations in Kokkola, 1992-2006 (adapted from Koljonen 2006)

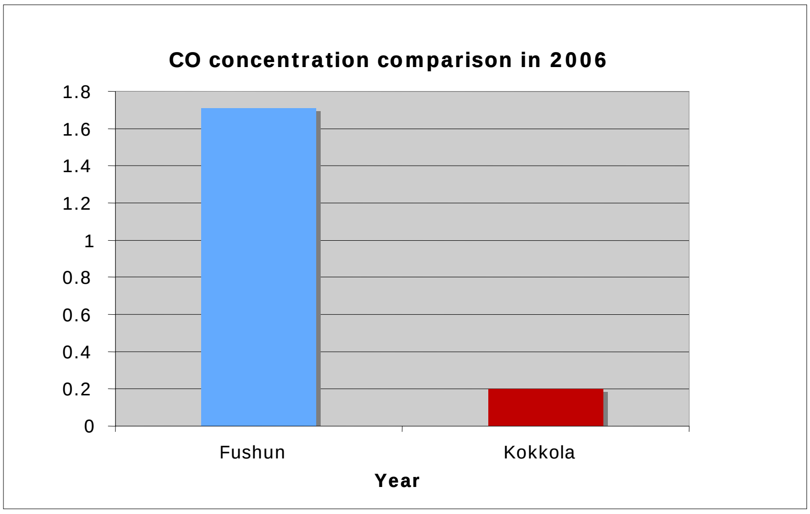
7.4.3 Comparison

The time period used for calculating limit values is different in China (Fushun) and Finland (Kokkola). In China daily averages are used but in Finland an 8-hour average value is used.

TABLE 16. CO Limit value of concentration comparison, Fushun and Kokkola

Name of pollution	CO Limit value of concentration (mg/m^3)	
	Time of value taking	Second level standard
Fushun	Day average	4
Kokkola	8-hour	10

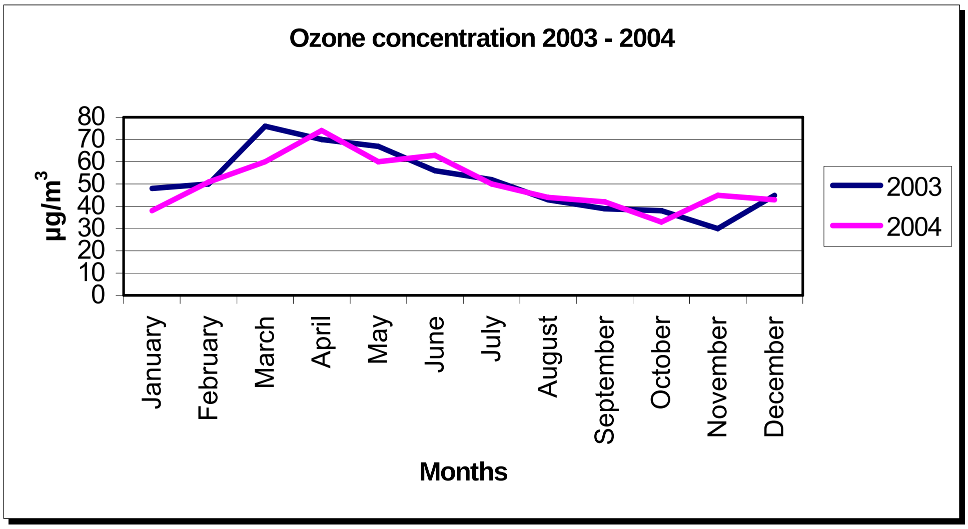
In 2006, the carbon monoxide concentration in Fushun was 8.5 times higher than the values in Kokkola. The reason should be that there was more traffic in Fushun than in Kokkola.



GRAPH 24. Yearly CO concentration between Fushun and Kokkola in 2006 (Unit: mg/m^3)

7.5 Ozone (O_3)

Ozone was monitored in 2003 and 2004 in Kokkola. A summary of the concentrations measured at Pitkänsillankatu monitoring site are provided in Graph 25.



GRAPH 25. Monthly ozone concentrations in Kokkola for the years 2003 and 2004 (adapted from Koljonen 2004)

The hourly alert threshold for ozone was 240 $\mu g/m^3$. In Kokkola the monitoring of ozone began in 2003, as the months progressed the concentration level had been getting lower and remained at a manageable level. Ozone levels are highest during spring and early summer. In Fushun, ozone monitoring is also conducted by using ultraviolet ozone analyzer.

8 ENVIRONMENTAL TOOLS

8.1 Environmental tools in Fushun

8.1.1 Fushun environmental protection authority

The Fushun environmental protection authority is in charge of carrying out the national and provincial policy, laws, regulations and acts related to environmental protection; supervising and evaluating the quality of municipal environment and pollution sources; conducting the environmental information; organizing the scientific study and technology demonstration of science in environmental protection; developing the international cooperation of environmental protection.

8.1.2 The environmental protection law

The environmental protection law declares: “Local government shall be responsible for the environment quality of areas under their jurisdiction and take measures to improve the environment quality.” The law states: “ units that cause environmental pollution and other public hazards shall incorporate the work of environmental protection into their plans and establish a responsibility system for environmental protection, and must adopt effective measures to prevent and control the pollution and harms caused to the environment by waste gas, waste water, waste residues, dust, malodorous gases, radioactive substances, noise, vibration and electromagnetic radiation generated in the course of production, construction or other activities. ” (Environmental Protection Law of P.R.C 1979.)

8.1.3 Information tools

Like the weather forecasts, Fushun TV also presents city air quality daily report everyday. This report is used for inform citizens about the air pollutions levels. According to law, China's current air quality daily report must be based on three pollutants: sulfur dioxide, nitrogen dioxide, and PM_{10}.

The daily air quality report relies mainly on ambient air quality monitoring systems. Real-time monitoring data is continuously and automatically transmitted to a central control room. The air quality monitoring system includes automated analysis technology, automatic control technology, computer technology, telecommunications technology and other fields of high-tech. The daily air quality information can also be found on the website of the Fushun environmental protection bureau.

8.1.4 The air pollution index (API)

API (air pollution index) is to predigest several air pollutants regularly monitored into a single national index form and to show the status of air pollution degree and air quality by grade. The index is fit for expressing the status and trend of urban short-term air quality. (Ge 2004)

The API is a simple and generalized way to describe air quality. The API is commonly used in China for informing the public in an easy way.

TABLE 17. Air pollution index used in Fushun (Ge 2004)

API	Air Pollution Level	Air Quality Grade	Notes on Health Effects
0-50	Excellent	I	Daily activities will not be affected
51-100	Good	II	
101-200	Slightly Polluted	III	The symptom of susceptible slightly aggravated, while the healthy people will have stimulated symptom
201-300	Moderate Polluted	IV	The symptoms of the patients with cardiac and lung disease will be aggravated remarkably. Health people will experience a drop in endurance and increased symptoms
300+	Severely Polluted	V	The exercise endurance of the healthy people drops down, some will have strong symptoms, Some disease will appear.

8.2 Environmental tools in Kokkola

8.2.1 Kokkola environmental protection authority

The local environmental protection authority in the City of Kokkola promotes and supervises environmental protection on a local scale. It is also responsible for environmental assessments such as air quality monitoring, and issuing environmental permits needed by smaller plants and facilities with concern to air quality. All monitoring is carried out according to the European Union Directives.

8.2.2 The environmental protection act

Under Finland's environmental protection act, the government may issue necessary executive orders for the purpose of preventing and reducing environmental pollution. These are imposed as to regulate emissions into the environment, restrict emissions and enforce emission limits.

The act states that if the use of a substance gives rise to emissions in the atmosphere causing harm to health or the environment, the responsible authority should intervene by limiting or prohibiting the manufacture; import; placing on the market; export; transfer or use the substance. However, the relevant authority should be competent enough as to provide and enforce rules and regulations as these are the very rules that determine and affect the community's life directly - air to breath, food to eat, livestock, buildings and nature as a whole. (The Environmental Protection Act – Finland.)

8.2.3 Information tools

Environmental information tools are presented in the form of online computer programs that provide information on atmospheric conditions locally, thus creating awareness amongst the population.

The Kokkola administration keeps the public up-to-date on information about air pollution levels, as well as on the plans and programs for management and improvement of the air quality. The pollutant concentration information is updated once an hour to an open website, where the AQM results are put from all Finland.

If the limit values have been exceeded then the public is made aware of:

- the date, hour and place of the occurrence and the reasons for the occurrence, where known;
- any forecasts of: changes in concentrations (improvement, stabilisation, or deterioration), together with the reasons for those changes;
- the geographical area concerned;
- the duration of the occurrence;
- the type of population potentially sensitive to the occurrence;
- the precautions to be taken by the sensitive population concerned;

(Wainaina 2007.)

8.2.4 The air pollution index (API)

The air pollution index (API), is a standardised colour-coded system designed to inform the general public about daily air quality levels in given locations. In the city centre of Kokkola, there is an information screen for informing about the current air quality.

TABLE 18. Finnish air pollution index (Koljonen 2008)

Index values	Quality Descriptor	Class	Health impacts
0-50	Green	Good	No health effects
51-75	Yellow	Satisfactory	Health effects are very unlikely
76-100	Orange	Fair	Health effects are unlikely
101-150	Red	Poor	Health effects are possible for sensitive individuals
151-	Pink	Very poor	Adverse health effects more possible for sensitive groups / subpopulation

9 DISCUSSION AND CONCLUSIONS

This section will discuss the results interpreted in this study. From the discussion, certain conclusions were drawn. Based on the conclusions drawn on this research, recommendations for future AQM are suggested.

9.1 Recapitulation of the study

How to maintain living standards and generating economic growth without causing irreversible environmental damage has become one of the greatest challenges for mankind. In industrialized cities, such as Kokkola and Fushun, power generation, transportation and industries all pose a great threat to the environment.

This research was motivated by the current problems that are faced due to air pollution. The work is based on information collected from Fushun and Kokkola cities over the last few years of the air quality monitoring. Along the urbanization and industrialization, air quality has improved in the cities of Kokkola and Fushun, but still there are some old and new air pollution problems.

In Fushun, urban air pollution is characterized by coal smoke. The major pollutants are particulate matter and sulfur dioxide, which come from coal combustion. Fushun has a vast number of large and small boilers, industrial furnaces and kilns, which usually locate in residential area for winter heating and this aggravates ground level air pollution. Due to five months' heating season and also due to the large temperature difference between day and night (average 15°C), urban air pollution is usually worse in winter than in other seasons. During recent years, demolition of old buildings has been common in Fushun, while construction sites can be seen everywhere. Therefore, re-suspended dust come from these sources make a large contribution to urban air pollution. Following the fast increase of vehicles, car exhaust gas emissions have increased progressively. NO_2 pollution is monitored in major traffic area.

In Kokkola, air quality in certain circumstances was poor in some places, which was caused by industries and traffic. The main air emission sources for sulphur dioxide, metal emissions and nitrogen oxides in Kokkola are the industries, energy production and the port activities in Ykspihlaja. The largest single emission source for nitrogen oxides is road traffic. PM_{10} is the main air quality problem faced in Kokkola. Use of road sand (grit material) and studded winter tyres is typical for Kokkola and Finland as a whole. Consequently, these traffic safety measures often lead to high particulate matter concentrations, especially during spring. (Koljonen 2007.)

Comparing the air quality conditions in Kokkola and Fushun, there are some similarities such as air emission sources and pollutants because these two cities are both industrial cities. But from the total emission levels in Fushun show significant differences in tonnage when compared with the emission levels in Kokkola. For example, in Fushun total SO_2 emissions were 53 times higher than in Kokkola in the year 2006 and the similar trends also applied to NO_X emissions. The concentration level of SO_2, NO_2, PM_{10} and CO in Fushun and Kokkola were also compared. There were big differences in the concentration levels of the pollutants. One should also note the differences in legislation. The limit values for the pollutants are different in Finland than in China. I.e. the PM10 yearly limit average value in Fushun is 100 $\mu g/m^3$ while in Kokkola is 40 $\mu g/m^3$. Facing the existing air quality problems, both cities have taken positive attitudes and activities make the air quality better.

9.2 Limitation of the study

The data used in this study shows that for the desired air quality objectives to be reached, the status of the present atmosphere conditions must be evaluated as compared to clean air standards and historical information. This is the only way to find out whether the direction we are heading in is the right one, and if so how to improve on the already current status.

Limitation exists during the course of this research study. All the latest data was not available. This may affect the accuracy of the research. A more extensive examination of the issues should be discussed in the future.

9.3 Suggestions for future AQM

Besides SO_2, NO_X and PM_{10}, which are the major three air pollutants monitored, there are also other pollutants that have an impact on the air quality. Ozone and fine particulate matters ($PM_{2.5}$) are pollutants what we should pay more attention to. They are among the dangerous pollutants to human health.

Normally ozone exists in the stratosphere 5-15 km above the ground. This Ozone layer can absorb UV radiation and is very important for protecting life on earth. However, ozone that exists close to the ground is extremely harmful to human. Ground level ozone is formed when vehicle exhaust and some other chemicals commonly used in industry mix in strong sunlight. The mix of hydrocarbons, nitrogen oxides, and ozone are the major components of smog that frequently occur in urban and suburban areas. When ozone concentrations get high enough, they can make breathing difficult, especially for people with asthma and other respiratory diseases. Ozone can be transported thousands of kilometres from its sources. Ozone monitoring is important to carry out in industrial cities such as Fushun and Kokkola. In order to get the highest ozone levels, the monitoring should be done in a background area because the NO emissions from traffic consume O_3.

$PM_{2,5}$ refers to particulate matter that is 2.5 µm or smaller. Particle diameter in size 10 µm or more will be blocked out in the human nasal cavity while the diameter between 2.5 to 10 microns can enter the upper respiratory. Particulate matter with diameter less than 2.5 micrometers can enter from the bronchial respiratory into blood. $PM_{2,\ 5}$ can cause health problems for humans, furthermore they can also become the carrier of viruses and bacteria. The sources of $PM_{2.5}$ include fuel combustion from automobiles, power plants, wood burning, industrial processes, and diesel-powered vehicles such as buses and trucks. $PM_{2.5}$ is also formed in the atmosphere when gases such as SO_2, NO_X, and VOCs are transformed in the air by chemical reactions. According to WHO's Air Quality Guidelines, the annual average concentration of fine particulate matter pollution limit is 10 $\mu g/m^3$. If the concentration reached 35 $\mu g/m^3$, the death risk rate for humans would increase at least 15%. $PM_{2,5}$ has not yet been monitored in Kokkola or Fushun but in the future it could be one important thing what should be done in AQM. New analyzers are not necessarily needed because $PM_{2,5}$ could be monitored by some already existing PM_{10} monitors by changing the air inlets.

9.4 Conclusions

This research compared and assessed air quality in Fushun and Kokkola. Along the urbanization and industrialization, air quality has improved in the cities of Kokkola and Fushun, but there are still some old and new air pollution problems. The overall results obtained from the study indicated that there are some similar characters such as air emission sources and main pollutants because Fushun and Kokkola are both industrial cities. But the total emission levels and concentration levels in Fushun show significant differences when compared with the ones in Kokkola. Since 1995 the emission trend for SO_2, NO_X, PM_{10} and metals has been declining, even if production has increased, which means the emission amount for each produced ton is decreasing. This is because of improvement of technology, better process control and strict limitation of emissions. Compared with Kokkola, Fushun city has a lot to do in the future for air quality monitoring. Fushun can learn from the experiences and expertise in the case of Kokkola, and help Fushun for cleaner and better environment.

Natural environment such as soil, water, and air are the basic materials that humanity relies on to survival and development. However, human activities influence environmental quality directly no matter with or without intention. If people cannot realize the importance to protect the environment, we will or already are punished by nature in different ways. To protect the environment is to protect ourselves. Economical development must not damage the environmental quality as a cost.

The research on the air quality comparison between Kokkola and Fushun is far from maturation; much more research can be done in this field. This thesis has attempted to give a helpful trial. It helps authorities take necessary actions improve the air quality and improve the AQM systems in these two cities.

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