Evaluation of the Chinese New Air Quality Index (GB3095-2012)

Based on Comparison with the US AQI System and the WHO AQGs

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Abstract

The "PM2.5 issue" was the tipping point for China's clean air movement last year and the incentive for implementation of the new Air Quality Index (GB3095-2012). It is necessary to carry out an evaluation of the Chinese new AQI system based on comparison with developed countries and improve the system afterwards.

The study evaluates the Chinese new Air Quality Index through comparison with the EPA AQI system and with the WHO AQGs as reference. The six mutual indicators have been selected, transformed and categorized into homogeneous groups in order to compare different systems specifically. A review of the AQI system development history, methodology and general information about different indicators corresponding to its physical, chemical and health effects have been carried out. The Chinese new AQI system is evaluated comprehensively from different perspectives, which include its "reliability and scientificalness", "systematic disclosure", "health effects and suggestion", "timeliness" and "user-friendliness". The previous study of the AQI system has also been taken into consideration.

The result shows that the MEP AQI system has improved a lot in fact, but it still needs to be revised and upgraded in order to meet the international standards, including several means of measurement, unscientific breaking point, unmatchable monitoring means corresponding to health effects, missing contiguous plan, etc. The suggestion and future endeavors have been given as outcome of the study.

Language: English

Key words: Air quality, PM2.5, AQI, AQG, Indicator, Evaluation

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Abbreviation Explanation

AQI: Air Quality Index

API: Air Pollution Index

AQG: Air Quality Guideline

NAAQS：National Ambient Air Quality Standards

EPB: Environmental Protection Bureau

MEP: Ministry of Environmental Protection of the People's Republic of China

EPA: Environmental Protection Agency of United States of America

WHO: World Health Organization

IPE: Institute of Public & Environmental Affairs

NGO: Non-government Organization

IT_x: WHO Interim Target (x stand for the stage of the target, range from 1 to 3)

SO_2: Sulfur Dioxide

NO_2: Nitrogen Dioxide

CO: Carbon Monoxide

O_3: Ozone on Ground Level

PM10: Particular Matter between 2.5 and 10 micrometers in grain diameter

PM2.5: Particular Matter Smaller or Equals 2.5 micrometers in grain diameter（Fine Particle）

TSP: Total Suspended Particulates

VOCs: Volatile Organic Compounds

CEO: Chief Executive Officer

SOHO: Small Office/ Home Office

1 Introduction

1.1 Background

Peking, the capital of the People's Republic of China, which has the population of more than twenty million and is the fifth largest megacity in the world, is gathering the most talented people to pursue their Chinese dreams and leading China to embrace the future. People are satisfied with the remarkable improvement of the living standard, but when facing the most basic rights, breathing clean air, it seems a bubble dream that can never come true.

Everything came very suddenly. On 22nd October, 2011, the CEO of SOHO China, Siyi.Pan was sharing a Weibo (a Chinese version of Twitter) saying that the air quality in Peking was hazardous based on the monitoring data provided by the US Embassy of Peking (Zhao, C. 2013). This tweet was reposted very rapidly and widely through the Internet and caused a public panic about the air quality situation. At the same time, a new and unfamiliar word "PM2.5" was gradually known and realized by the public. PM2.5 is an indicator of measuring the air quality and which stands for the particle matter smaller than 2.5μm in grain diameter.

The "PM2.5 issue" was continuing to boom around China. On one hand, the US Embassy was continuing to share the air quality data using the account "Peking Air" on Twitter. On 4th December, 2011, the situation of the air quality in Peking caught public attention again due to the US Embassy saying the air quality was "beyond the index" (Wang & Cheng. 2013). On the other hand, the local people and NGOs got involved. A volunteer took 14 serial pictures from an apartment view of Peking with the specific time, date, location, and with the published air quality data provided by the Peking EPB of that day. This visualizing and direct way of showing the air quality situation spread the information from the social media to press media massively, and more than 100 newspapers and magazines have opened new columns to follow this hot issue (Huang, Y. 2013). Meanwhile, the public started to query about the air quality situation provided by the Peking EPB, which announced “Good” compared with the smog weather they were facing every day. Afterwards, the local NGOs started several programs to measure the PM2.5 in Peking by themselves. But due to lack of the national standard of PM2.5 and the accuracy of the monitoring equipment they had, it was hard to win the public trust and query the Peking EPB (Environmental Protection Bureau) with solid facts. At the same time, the local authority announced the PM2.5 data was only used as an exploratory data study and refused to share the details with the public. Finally, the lack of transparency of air quality standard led the public preferring to believe the data was provided by the US embassy rather than the Peking EPB. This phenomenon caused the local authority to face a lot of pressure and losing public trust at the same time.

In the beginning of March, 2012, the China’s Ministry of Environmental Protection (MEP) released the official (trial) revisions to the Ambient Air Quality Index (AQI, which is a notable shift from its previous form as the Air Pollution Index, API). The indicator of PM2.5 now was officially first added to the new AQI system (The Ministry of Environmental Protection (MEP). 2012. a).

1.2 Purpose

This thesis is focusing on explaining and comparing the AQI system of China and the US based on the World Health Organization (WHO) guidelines (WHO, Global update 2005) for air quality standard. Evaluation of MEP’s new AQI system and suggestions for the future monitoring means are the main purpose of this thesis. The parameters of different indicators, i.e. the concentration value of the pollutants, form and determine the final score of the AQI. Therefore, the relationship between the specific indicators and AQI will be explained. How will China and USA set their parameter for different indicators in order to reflect the air quality situation and inform the public with trust? How do their systems differ from WHO guidelines? How big is the gap between the different systems? Have they already fulfilled the WHO guideline or do they improve the targets to catch up with the WHO standards? All of these questions will be answered. The outcome of the thesis should explain the AQI system of USA and China in order to do further study on air quality monitoring to assist the decision makers to set achievable future targets concerning air quality improvement.

1.3 The situation of air quality monitoring in China, USA

Before the special date of 2nd March, 2012, China had its own air quality standard, which officially has been called the Air Pollution Index (API) and has been used for the past 20 years. While, with rapid urbanization and economy boom, the old air quality system is way behind the international standard. In order to keep the pace with the economy growing and achieve sustainable development, a more comprehensive, scientific and greater transparency air quality monitoring system needs to be implemented and introduced by the authority to society as soon as possible. Although, there are 34 air quality monitoring stations running now in Peking and a massive amount of stations are under construction in the capital of each province (The Ministry of Environmental Protection (MEP), 10.2012), the first step is to build a reliable air quality index in order to present the scientific data to the public reliably, and to move forward prepensely. Most importantly, a reliable and transparent air quality index will promote environmental performance from different perspectives.

- Promoting the government efficiency of enforcement of relative legislation.
- Promoting the public awareness of environmental risks and health effects.
- Involving the market, bank, stakeholder and consumer to supervise the enterprise’s environmental performance, further, increasing investment reversely.
- And driving the enterprise to promote their environmental performance and stimulating the reduction motives.

In 1982, China’s first Ambient Air Quality Standard was formulated and implemented. It was mainly aimed at managing atmospheric pollutants from coal smoke. The regulation was for the concentration value for total suspended particles (TSP). In 1996, the Ambient Air Quality Standard was revised, main changes include: the names of pollutants, analysis of monitoring and introducing PM10. In 2000, the MEP released the “Ambient

Air Quality Standard" (GB3095-1196), the major pollutant standard was tightened up, but it excluded the indicator of PM2.5. On February 29th, 2012, the third revision of the "Ambient Air Quality Standard" (GB3095- 2012) was released. The major changes in the standards are shown below.

- The Air Pollution Index (API) was changed to Air Quality Index (AQI) to be in line with international norms.
- "Special industrial zones" were merged with "residential zones, commercial and residential mixed zones, cultural zones, industrial zones and rural zones". At the same time requirements for ambient air quality areas were changed from a three-level standard to a two-level standard.
- Tightened up the PM10 and the pollutant lead concentration values, which lead only published yearly average.
- Included an average value for PM2.5 as well as an eight-hour average value for O_3.
- Revised the classification system for the index in order to better match the air quality level with the level of health effect.
- Changed the daily monitoring cycle from 12:00 – 12:00 to 00:00 – 00: 00 and decided to publish real time hourly concentrations for sulfur dioxide, nitrogen dioxide, carbon monoxide, PM2.5 and eight-hour concentrations for ozone.

(Ministry of Environmental Protection (MEP). 2012. b. P2-3)

Meanwhile, The MEP published the "Ambient Air Quality Monitoring Station Technology Regulation" (2.2013). This regulation details the model of monitoring device, the structure of monitoring network and the number of monitoring sites. Firstly, the monitoring network should consist of six types of monitoring sites based on different functions and purposes aiming to present the air quality situation systematically and scientifically. They are environmental evaluation site, transmission site, city wide comparison site, transportation pollution site, pollution monitoring and control site and information disclosure site. Secondly, the number of monitoring site should depend on the size and the population of the monitoring object (city). For those highly polluted areas, which the yearly air quality level is 20% higher than the national standard, should increase the number of monitoring site by 1.5 times more.

So, how is the real situation of air quality in China? Besides the horrifying data leaking out from the US embassy and the little chance of seeing the blue sky around China, we may check the situation of air quality from another angle. According to the data published by the Peking Health Bureau in 2010, the death rate of lung cancer in China has risen by 465% compared with 30 years ago (Greenpeace, 2012). The lung cancer has replaced the liver cancer and ranked the first of malignant tumors killing in China. Take Peking as an example, the number of people dying because of lung cancer accounts for 29% of the total malignant tumors killing in 2007. In 2011, more than 4,729 people in Peking died because of lung cancer. Most importantly, the smoking rate does not have a significant growth compared with 30 years ago (Global Times, 2012).

In United States of America, the air quality improvement was guided according to The Air Pollution Control Act. The first air pollution legislation was published in 1955, started to fund research for scope and sources of air pollution. In the year of 1963, "The Air Pollution Control Act" was replaced by "Clean Air Act' with development of a national program to address air pollution-related environmental problems and the development of techniques to minimize air pollution. In the year 1970, the first national Ambient Air Quality Standards was established with increasing enforcement authority. In the year 1977 and 1990, the EPA made a couple of amendments based on Clean Air Act 1970. Mainly changes including specific elaboration of toxic pollutants, establishment of permit program requirements and Acid Deposition Control. The indicator of particle matter, specifically the PM2.5, was first introduced into the AQI system in the year 1997. In 2006, the first comprehensive and fundamental AQI system was implemented, which many countries around the world copied and established their first AQI system on. The latest version of EPA AQI is updated to 2012. Compared with the 2006 version, several means of measurement of indicators have changed due to health effects concern (EPA, 2010).

1.4 Literature review

In December 2010, Amtonella Plaia & Mariantonietta Ruggieri published a study online called *Air Quality Indices: a Review*. In their article, they give an overview of the air quality indices proposed in literature and/or adopted by countries. They also tried to categorize the different AQI systems into homogeneous groups in order to compare them, but due to lack of common strategy, it is hard to compare the state of the air for cities that follow different directives. According to the article, they found that the major differences include: the number of index classes (associated color scheme), related descriptive terms, class bounds, averaging times and update frequency. They came to the conclusion, although the basic concepts are similar, that the AQIs show large differences in practical implementation. The local circumstances should be taken into consideration carefully, which makes comparison of values difficult and provides limited usefulness. They suggested that further work is required to achieve a harmonization, considering issues as averaging times, synergisms in air pollution indices and low level exposure.

Steven Q Andrews, who is an environmental consultant based in Peking, published a report on China Dialogue website (Andrews, S. 2011). His article precisely describes the air quality situation in Peking and analyzes the reason for big differences corresponding to the air quality result published by Peking EPB and US embassy. His studies show, firstly, that Peking EPB is suspected of lying to the public about the air quality situation by using means of relocating monitoring sites out from the worse air quality condition areas. Secondly, the new AQI standard of China is also not reflecting the facts of air quality when comparing with the Hong Kong authority and the European Union standard. “In the last two years, Peking reported that nearly 80% of the days had good or even excellent air quality. These same levels of PM10 pollution would have been classified as high or worse on over 80% of the days in the Hong Kong and the European Union.” (Andrews, S. 2010. paragraph 12).Thirdly, the reliability of the US Embassy’s data needs to be re-evaluated, due to the fact that one monitoring site cannot represent the real air quality situation of the whole city of Peking, even though, it is typical in most countries to use the worst monitoring station in the entire network to calculate attainment of standards, not a selective monitoring result as is done in Peking.

Angel Hus, who is completing her PhD at Yale School of Forestry and Environmental Studies, published one article on her blog to compare the new AQI systems of China and USA called "China's new Air Quality Index : How does it measure up?" (Hus, A. 2012). Although there are some mistakes relating to her conversion calculation (SO_2, NO_2, O_3) when comparing the breaking point between two different systems, the means of comparison contribute to this thesis a lot indeed. It suggested the monitoring of the PM2.5 is an important factor for implementing an AQI system without ignoring other important indicators, like SO_2, NO_2 and O_3. The evaluation of the AQI system should take the country's current situation into consideration instead of copying developed countries' AQI target directly.

2 Air Quality Indicators (AQI)

The air quality indicators mentioned in this thesis basically mean the six criteria of air pollutants. According to the EPA of USA, there are totally 187 air pollutants that can cause health problems to human beings (EPA, 2008. a). Those pollutants have different forms in the environment, some of them are solid, some of them are gas, and some of them are a mixture of those two. Those pollutants are not only functioning as an individual matter, but also have a reaction with each other afterwards and form new matters known as the secondary pollutants. The different temperature, humidity and air pressure can lead to different results. The different landscape, wind speed and wind direction will shape the different climate conditions or so to say the microclimate. Monitoring and analyzing all of those pollutants under such complicated conditions will be too hard and complex to achieve, and it is also hard to easily transform such a great deal of information about air quality conditions to the public easily (Amtonella P & Mariantonietta R. 2011). Therefore, the most dangerous, fundamental and typical pollutants need to be selected out from those massive pollutants in order to present the whole picture of the air quality condition. Apparently, this way of air quality monitoring has its limitation, but it is a relatively scientific, achievable and efficient method to be applied. The Chinese air quality index is based on USA's AQI system, which has been implemented for more than 40 years. Both systems have the same indicators and there are totally six key indicators: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particular matter (PM10, PM2.5). Those key indicators have been carefully monitored and transformed for the final AQI scores afterwards. Those six indicators will be introduced and explained individually, including their primary standard based on different systems, sources, harms and related health effects.

2.1 Sulfur Dioxide (SO_2)

Table 1: Primary Standard of SO_2 Concentrations Based on Different System (see Table 6)

Primary Standard of SO_2 Concentrations 24h Mean	
EPA AQI (1996)	89μg/m^3
MEP AQI (2012)	50μg/m^3
WHO AQG	20μg/m^3

Sulfur dioxide is one of a group of highly reactive gases known as "oxide of sulfur." SO_2 is a colorless gas with strong irritant smell. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulfur. The main anthropogenic source of SO_2 is burning of sulfur-containing fossil fuels for domestic heating, power generation and motor vehicles. In the US, 73% of the total SO_2 emissions are coming from combustion at power plants, and other industrial facilities account for another 20% of the total SO_2 emissions. In China, 91% of the total SO_2 emissions are coming from industrial production of which heating and power plants account for 47.5% of it. The remaining 9% of the total SO_2 emissions are coming from burning coal for daily use in remote areas of China (Li M S, Ren X X, et al. 2013, p1152). The annual 24 hour concentration value of SO_2 fluctuated between 42 and 57 (μg/m^3) from the year 2001 to 2008. (IPE, 2010)

SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Hospital admissions for cardiac disease and mortality increase on days with a higher SO_2 level. According to EPA, people with asthma are the group most at risk. When SO_2 combines with water, it forms sulfuric acid; this is the main component of acid rain which is a cause of deforestation. (WHO, 2009, p8).

2.2 Nitrogen Dioxide (NO_2)

Table 2: Primary Standard of NO_2 Concentrations Based on Different System (see Table 6)

Primary Standard of NO_2 Concentrations	
EPA AQI (1996)	null
MEP AQI (2012)	40μg/m^3 24h Mean
WHO AQG	200μg/m^3 1h Mean

Nitrogen dioxide is one of a group of highly reactive gases known as “nitrogen oxides”. The NO_2 is normally selected as the representative of the larger group of nitrogen oxide. The major sources of anthropogenic emissions of NO_2 are combustion processes (heating, power generation, and engines in vehicles and ships). Most importantly, it contributes to the formation of ground-level ozone and fine particle pollution.

Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at concentrations currently measured (or observed) in cities of Europe and North America (Burnett, et al. 2004).

The EPA set the standards for NO_2 firstly in 1971; they measured the concentrations of NO_2 annually and set both a primary standard (to protect health) and a secondary standard (to protect the public welfare). The 24-hours average concentration values are only measured when the AQI is beyond 200. In January 2010, EPA established an additional standard at 100ppb, averaged over one hour (EPA, 2013. a).

2.3 Carbon Monoxide (CO)

Table 3: Primary Standard of CO Concentrations Based on Different System (See Table 6)

Primary Standard of CO Concentrations 24h Mean	
EPA AQI (1996)	5mg/m^3
MEP AQI (2012)	2mg/m^3
WHO AQG	30mg/m^3 (1h mean)

Carbon monoxide is a colorless, odorless and toxic gas emitted from combustion processes. The major source is coming from mobile sources due to incomplete oxidation.

CO can cause harmful health effects by reducing oxygen delivery to the body organs, like the heart and brain. At low concentrations, fatigue is seen in healthy people and chest pain in people with heart disease. At higher concentration, impaired vision and coordination, headaches, dizziness, confusion and nausea can cause flu-like symptoms, even death. (WHO, 2009, p15).

2.4 Ozone (O_3)

Table 4: Primary Standard of O_3 Concentrations (see Table 6)

Primary Standard of O_3 Concentrations		
Measurements	1 hour mean	8 hours mean
EPA AQI (1996)	null	116μg/m^3
MEP AQI (2012)	160μg/m^3	100μg/m^3
AQG	null	100μg/m^3

The O_3 in this thesis means the ozone at ground level. It is not the ozone layer in the upper atmosphere, which protects human from ultraviolet rays. The O_3 is formed by the reaction with sunlight of pollutants, such as nitrogen oxides from vehicle and industry emissions and volatile organic compounds (VOCs) emitted by vehicles, solvents and industry. Normally, the highest levels of ozone pollution occur during periods of sunny weather.

The O_3 is measured both by 1 hour average and 8 hours' average. The 1 h standard focuses on short exposure at a high level. The 8 h standard provides greater protection against longer exposure at a moderate level. (EPA, 1996).

Several European studies have reported that with every 10 µg/m^3 increasing of O_3 concentrations, the daily mortality rises by 0.3% and that for heart diseases by 0.4 %. (WHO, 2002). The EPA suggests the people with lung disease, children, older adults, and people who are active outdoors as the sensitive groups. (WHO, 2009, p12).

2.5 Particular Matter

Table 5: Primary Standard of PM Concentrations Based on Different System (see Table 6)

Primary Standard of PM 24 Hour Mean		
Size of The Particles	PM10	PM2.5
EPA AQI (1996)	50µg/m^3	15µg/m^3
MEP AQI (2012)	50µg/m^3	35µg/m^3
AQG	50µg/m^3	25µg/m^3

PM, which is the short form of Particular Matter, PM10 means the size of the particles with an aerodynamic diameter smaller than 10 µm and PM2.5 with an aerodynamic diameter smaller than 2 µm. The size of the particle is how those kinds of pollutants have been identified.

Normally, there are three reasons for smog weather or low visibility. Naturally, when the moisture concentration of the atmosphere is about 90%, we call it fog. It is basically due to high concentration of evaporation of water (small water droplets' suspension in the air), which causes no harm to humans, they only cause inconvenience for life, like the delaying of airline and other means of transport. When the moisture concentration is less than 80%, and the visibility is still bad (less than 10 km), we call this weather condition haze, which is due to a high concentration value of particular matter in the air, especially the PM2.5. When the moisture level is somewhere between 80% and 90%, we identify the problems as a combined function for water drops and particular matters (MEP, 10.2012).

The PM affects more people and is more harmful than any other pollutant. Firstly, on a macro level, the PM is generally visible, which is different from other pollutants. This character gives the people a direct feeling about how bad the air quality is. It is also the major reason for preventing people from seeing the blue sky. Secondly, on a micro level, particle pollution contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Thirdly, the PM is a complex mixture of extremely small particles and liquid droplets of organic and inorganic toxic substances, including acid (mainly nitrates and sulfates), organic chemicals, metal and soil or dust particles. Those different and mixture particles do not only function separately, but also have “Cocktail Effects”. The damage to human is remaining unknown. (EPA, 2008, b)

PM10 is normally formed smoke, dirt and dust from factories, farming and roads through crushing and grinding rocks and soil. The PM2.5 is mainly a mixture of the toxic compounds and heavy metals that are coming from driving automobiles, burning organic material (brush fires and forest fires or yard waste) as well as smelting and processing metals. Others are formed in complicated reactions in the atmosphere of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from power plants, industries and automobiles. These particles, known as secondary particles, make up most of the fine particle pollution. In general, the monitoring of PM2.5 is more important than of PM10. Because, firstly, PM2.5 is considered to be more hazardous to human than PM10 (Kadri M & Christer J, 2012), and it penetrates more deeply into the lung. Secondly, the smaller the particle is, the longer they stay in the environment and the further they travel. Thirdly, PM2.5 originates more from man-made sources than PM10 and is, therefore, in principle more manageable.

In the new Chinese AQI system, the indicator PM2.5 was for the first time introduced into the system. This key indicator was regarded as the tipping point for last year’s clean air movement and pressure for pushing the government to upgrade the old air quality index from the API to the AQI system. Apparently, the importance of PM2.5 cannot be ignored. Xiaochuan.Pan (the professor of public health and environment department of Peking University) said on a TV show, according to his study, that the rise of the concentration value of PM2.5 with each 10ug/m^3 will raise the death rate about 0.5% to 1% and the rate of hospital admissions will rise by about 8%, especially for the sensitive group, who have hypertension problems. (ChinaDaily, PM2.5 the invisible killer, 2011).

The USA EPA started to monitor and control the PM2.5 in 1997 guided by the Clean Air Act (1990) based on the National Ambient Air Quality Standards (NAAQS). The MEP followed and set their new AQI system in 2012, which includes the PM2.5 as an indicator as well. According to the data, published by Peking EPB 2012, the major source of PM2.5 is coming from auto vehicles, which account for 22% of total emission; coal combustion accounts for another 17% of the total emission, the beyond region transfer is about 25% of the total emission (IPE, Chinese Atmospheric Pollution Source Positioning Report). In 2005, the WHO set a guideline value for particulate matter for the first time. The aim is to achieve the lowest concentrations possible. (WHO, AQG, 2005.p8).

3 Air Quality Index and Air Quality Guideline

The Air Quality Index (AQI) is a scale designed system or a platform to show the air quality situation in order to easily inform the public and the sensitive group. It is also a health protection alarming tool that is designed to help one make the decision to protect one's health by limiting short-term exposure to air pollution and adjusting one's activity levels during increased levels of air pollution. The AQI systems of China and USA both include six indicators. The six indicators are measured using different parameters, of which the indicators of SO_2, NO_2, CO, PM10 and PM2.5 are measured in daily average and indicator of O_3 is measured in 1 hour and 8 hours standard. Each indicator is measured individually and defined as "Individual Air Quality Index (IAQI)". The pollutant with the highest score of IAQI will be defined as the "Primary Pollutant". The final AQI score is represented by the exact IAQI of "Primary Pollutant". Among those six indicators, any IAQI that is beyond 100 will be defined as "non-attainment Pollutant".

The score of AQI ranges from 0 to 500 and is divided into six classes ("0-50", "51-100", "101-200", "201-300", "301-400", "401-500"). If the score is more than 500, it will be announced as "beyond the index". The way of calculation is explained below:

$$I_P = (I_{Hi} - I_{lo}) / (BP_{Hi} - BP_{Lo}) * (C_P - BP_{Lo}) + I_{Lo}$$

Where I_P = the index for pollutant p (IAQI)

C_P = the rounded concentration of pollutant p

BP_{Hi} = the breakpoint that is greater than or equal to C_P

BP_{Lo} = the breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

$$\text{The final AQI} = \text{Max}\ (I_{P1}, I_{P2}, I_{P3}, I_{P4} \ldots I_{Pn})$$

Where n = the number of pollutants

(Formula for determining the Final Air Quality Index,
Source: MEP, 2012. b)

The Air Quality Guideline (AQG) was implemented by the World Health Organization (WHO). In 1987, the WHO published the first air quality guideline, which is designed to offer guidance in reducing the health impact of air pollution. The AQGs are intended to inform policy-makers and to provide appropriate targets for a broad range of policy options for air quality management in different parts of the world. It is also designed to offer global guidance on reducing the health impacts of air pollution for both developed and developing countries. In 1997, the guidelines were updated based on expert evaluation of current scientific evidence. In the new version of "Air Quality Guidelines", four common air pollutants were related: particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). In addition to guideline values, interim targets are given for each indicator in order to suit the situation for developing countries. These targets aim to promote a shift from high air pollutant concentrations to lower air pollutant concentrations step by step. If these targets were to be achieved, one could expect significant reduction in risks for acute and chronic health from air pollution (WHO, 2005, p11-12). The interim targets (IT) are divided into three stages, stage 1 (IT-1) is the first target (the worst scenario) that needs to be achieved and stage 3 (IT-3) is the stage before reaching AQG level. (WHO, 2005. p2).

4 Methodology

In order to compare the AQI systems of the US and China, the most important thing to decide first is to set the right phase. Since China is still at the beginning stage of monitoring the air quality, the first comprehensive and relatively well developed AQI system of the US in 2006 was chosen as the comparison objective, which is not the latest version of the AQI system of the US. Secondly, due to the AQI system of MEP is basically based on the US system, it is possible to categorize the indicators into homogeneous groups and make the two different systems comparable and upgradeable. Meanwhile, the WHO AQG has been selected as the reference value aim to show from an international perspective as well.

The latest version of US EPA AQI (2012) has changed several means of measurements compared with the 2006 version, especially for the indicators of SO_2, NO_2 and O_3. The revised version of EPA AQI in a way gives suggestion about future air quality measurement and improvement, which will be discussed in the next section.

The final score of the AQI is reflected by each indicator's breaking point and the breaking point is set by the local authority. Therefore, comparison of each indicator's breaking point is the method to evaluate the AQI system from the perspective of reliability and scientificalness perspective view. The breaking point means when the concentration value of one indicator has reached some point when the AQI score turns to the next level. Take the indicator PM2.5 (based on EPA AQI system), for example, when the concentration value of PM2.5 is between 0 and 15(μg/m^3; 24h mean), the AQI score is 50 and means the air quality is "Good". While when the concentration value of PM2.5

is over 15(μg/m^3; 24h mean), the AQI is shifted to the next class (51-100) which means the air quality is "Moderate", the number 15 here being one of the breaking points for indicator PM2.5 (EPA AQI). The breaking point concentrations for the safe limit mean a good AQI. Therefore, the breaking point is the limit or critical value to determine the final score of AQI, which stands for the situation of air quality. The details of two AQI systems' breaking point tables are shown in the Appendices I and Appendices II.

The AQI system of USA measures the indicator of SO_2, NO_2, CO and O_3 with the unit of micro moles of pollutant per mole gas (ppm), whilst the Chinese AQI system bases the parameter of indicators on the unit of micro gram per cubic meter (μg/m^3). Therefore, the conversion factor from ppm to μg/m^3 is the first step. According to the US EPA standard, the conversion factor from ppm to μg/m^3 is: SO_2 2.62, NO_2 1.88, CO 1.15 and O_3 1.96 with a reference temperature of 25°C and a reference pressure of 1 atm.

After unifying the unit, all the data was imported into "Microsoft Office Excel" to generate a new sheet (*Figure 6*). In order to show the result of comparing each indicator more clearly and directly, four graphs (2-D bar) were produced and the vertical reference lines for the WHO AQGs were drawn based on the specific and comparable analysis subject.

5 Result

5.1 AQI

Even though the MEP AQI was originally based on the United States' AQI, there are differences in the corresponding of the breaking point set by the different authorities. The MEP new AQI system is upgraded from the old China API system, the indicator of PM2.5 and O_3 has been added into the new system. The comparison of the AQI systems of USA and China with WHO AQG as reference is shown in *Table 6.*

The MEP AQI color classification has been standardized, which is not set by local environment protection bureaus (EPB) anymore. With the same national color scheme, the travelers around China will not be confused again when they are passing different administration areas. Making the color classifications the same as the US will also provide more transparency and clarity for those familiar with the US AQI system. Both AQI systems have the same range of index with almost the same description of health effects. The summary of the health effects and suggestion of different system is showing in *Table 7.*

Table 6: China Air Quality Standard Comparison with USA and WHO

China Air Quality Standard (2012) Comparison With USA (1996) and WHO

AQI (China)	AQI (USA)	China & USA AQI	Pollutant Concentrations (µg/m³)													
			SO_2 (24h Average)		NO_2 (24h Average)		CO (24h Average ; mg/m3)		O_3 (1h)		O_3 (8h Average)		PM10 (24h Average)		PM2.5 (24h Average)	
Excellent	Good	0-50	50	89	40	-	2	5	160	-	100	116	50	50	35	15
Good	Moderate	51-100	150	377	80	-	4	11	200	-	160	147	150	150	75	35
Light Polluted	Unhealthy For Sensitive Groups	101-150	475	587	180	-	14	14	300	321	215	186	250	250	115	65
Moderately Polluted	Unhealthy	151-200	800	797	280	-	24	18	400	400	265	225	350	350	150	150
Heavily Polluted	Very Unhealthy	201-300	1600	1583	565	2260	36	35	800	792	800	733	420	420	250	250
Severely Polluted	Hazardous	301-500	2620	2631	940	3760	60	58	1200	1184	-	-	600	600	500	500
AQI (WHO)	AQG		20		200 (1h Average)		-		-		100		50		25	
	Interim Target-3		-		-		-		-		160		75		37.5	
	Interim Target-2		50		-		-		-		240		100		50	
	Interim Target-1		125		-		-		-		-		150		75	

1. Technical Regulation on Ambient Air Quality Index Daily Report, MEP, 2012
2. Guidelines for the Reporting of Daily Air Quality – The Air Quality Index (AQI), USEAP, 2006
3. Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide, WHO, Global Update 2005
4. Conversion factor from (ppb to µg/m³) provided by US EPA: O_3 1.96; NO_2 1.88; CO 1.15; SO_2 2.86
5. The symbol - in the table means the official data is not provided.

Table 7: The description of AQI Health Implications of China and USA

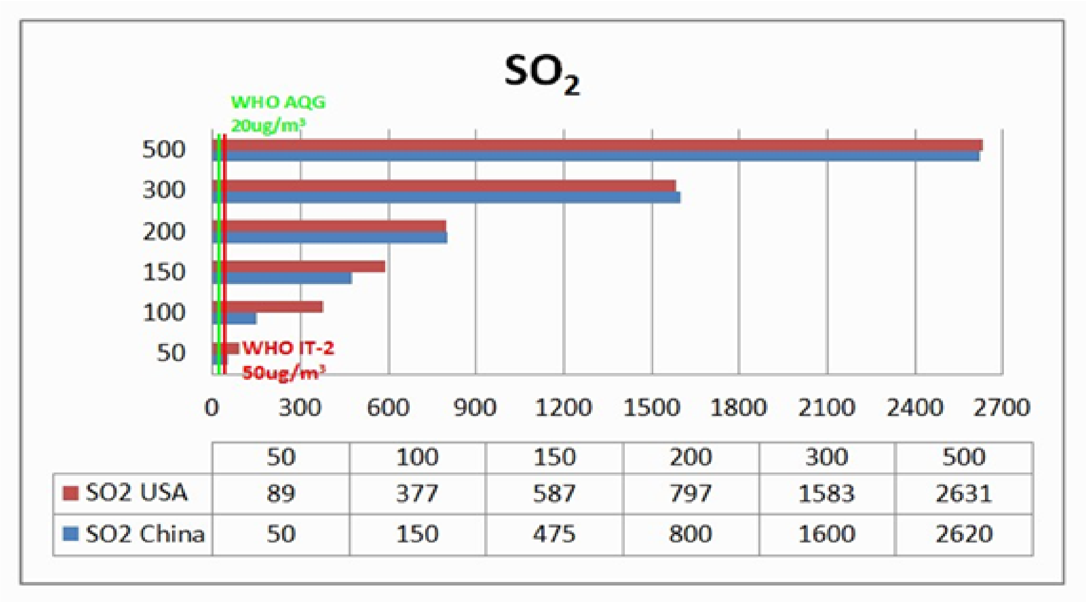
MEP and EPA Air Quality Index				
AQI (China)	AQI (USA)	China & USA AQI	Health Implications	
Excellent	Good	0-50	No health implications.	Satisfactory air quality, almost no air pollution.
Good	Moderate	51-100	Few hypersensitive individuals should reduce outdoor exercise.	Air quality is acceptable, but maybe unhealthy to a small number of sensitive groups.
Light Polluted	Unhealthy For Sensitive Groups	101-150	Slight irritations may occur, individuals with breathing or heart problems should reduce outdoor exercise.	Members of sensitive groups may experience health effects.
Moderately Polluted	Unhealthy	151-200	Slight irritations may occur, individuals with breathing or heart problems should reduce outdoor exercise.	Member of sensitive groups may experience more serious health effects, may impact the heart, respiratory system of healthy groups.
Heavily Polluted	Very Unhealthy	201-300	Healthy people will be noticeably affected. People with breathing or heart problems will experience reduced endurance in activities. These individuals and elders should remain indoors and restrict activities.	Exercise tolerance is reduced in people with heart and lung conditions; healthy people may exhibit symptoms.
Severely Polluted	Hazardous	301-500	Healthy people will experience reduced endurance in activities. There may be strong irritations and symptoms and may trigger other illnesses. Elders and the sick should remain indoors and avoid exercise. Healthy individuals should avoid outdoor activities.	Exercise tolerance of healthy people is decreased, strong symptoms and early appearance of certain diseases.

(Technical Regulation on Ambient Air Quality Index Daily Report, p8, MEP,2012 & Guidelines for the Reporting of Daily Air Quality,USEPA,2006)

5.2 Sulfur Dioxide (SO_2)

From *Figure 1, it shows that b*oth the MEP and the EPA's primary target of SO_2 are overpassing the standard of WHO AQGs with the concentration value of SO_2 is 20µg/m^3 per day, while, the MEP's primary target meets the WHO IT-2, which is 50µg/m^3 per day. This result is acceptable due to the fact that China is still a developing country and needs time to clean up the air. Before the index is reaching 200 (Unhealthy), the breaking point of SO_2 of EPA AQI is higher than MEP standard (lower target). When the AQI is beyond

200, the EPA standard is stricter or higher than the MEP, but their parameters are quite close to each other.



	50	100	150	200	300	500
SO2 USA	89	377	587	797	1583	2631
SO2 China	50	150	475	800	1600	2620

Figure 1: The SO2 Breaking Point Comparison, China & USA with WHO AQGs
The abscissa stands for the value of indicator concentration (μg/m^3) and the ordinate stands for the parameter of AQI.

5.3 Nitrogen Oxide (NO_2)

According to the comparison result from *table 6*, there is no short-term monitoring of NO_2 in the EPA AQI (2006). The data can only be generated when the AQI is above 200. The WHO sets AQG as 200μg/m^3 per hour, which is not comparable with MEP AQI, due to the difference of measurement means. When the index is beyond 200, the EPA sets the level of pollutants (the breaking point of concentration value of NO_2) much higher than MEP, which is about 4 times more.

5.4 Carbon Monoxide (CO)

The result of CO is quite interesting. From *Figure* 2, it shows that before the index reaches 150 (air quality unhealthy), the MEP sets the standard much stricter than EPA, which is during the phase when the health effects can be ignored relatively. Both countries set the same breakpoint when the AQI is at 150 (unhealthy for sensitive groups).

When the index is beyond 200 (unhealthy), the MEP sets the breaking point much higher than it should be compared with EPA standard. In other words, the EPA sets the standard stricter when the situation becomes harmful to humans. The WHO sets the AQG for CO with means of one hour average, which makes it not comparable with the MEP and the EPA AQI systems.

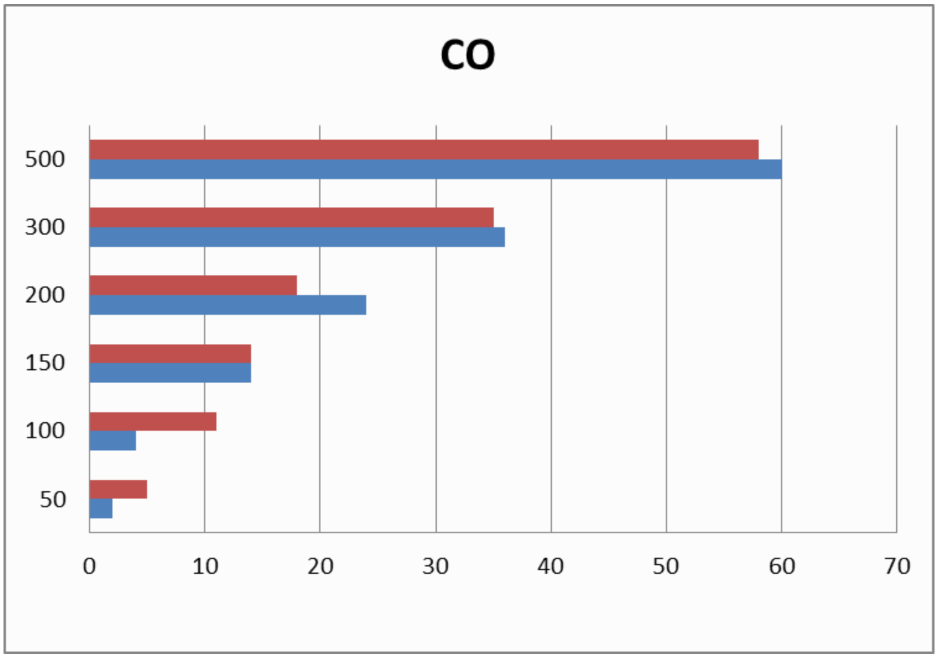


Figure 2: The CO Breaking Point Comparison, China & USA

The abscissa stands for the level of indicator concentration (mg/m^3) and the ordinate stands for the parameter of AQI.

5.5 Ozone (O_3)

Ozone is measured both with the parameter hourly and 8 hours' average. The WHO only published the O_3 concentrations of AQGs based on 8 hours mean (See *Table 6*).

The EPA started to measure the O_3 concentration (1 hour mean) when the AQI is directing to "Unhealthy" (beyond 100). The breaking points between the two systems are quite close to each other. The MEP sets the higher target at the beginning and lower target when the air pollution gets more serious, (See *Table 6*) while, since the year 1997, the EPA started to stop monitoring the O_3 with 1 hour standard. Several studies have shown that the new 8 h O_3 standard is more stringent than the 1 h standard. Velasco et al.

(2000) found that the 8 h O_3 standard provided a level of health protection that was similar to California's 1 h O_3 standard of 90 ppb, and five new non-attainment areas for 8 h standard were identified in California.

From *Figure 3,* it shows that, on one hand, the primary target (AQI=50) of O_3 concentrations (8 hour Mean) of MEP meet the WHO AQG and secondary target (AQI=100) meet the AQG IT-3. On the other hand, the EPA primary target is a little away from the AQG. With the index level increasing, the EPA AQI starts to become stricter than MEP AQI. The breaking point gap between the two systems becomes bigger and bigger as well.

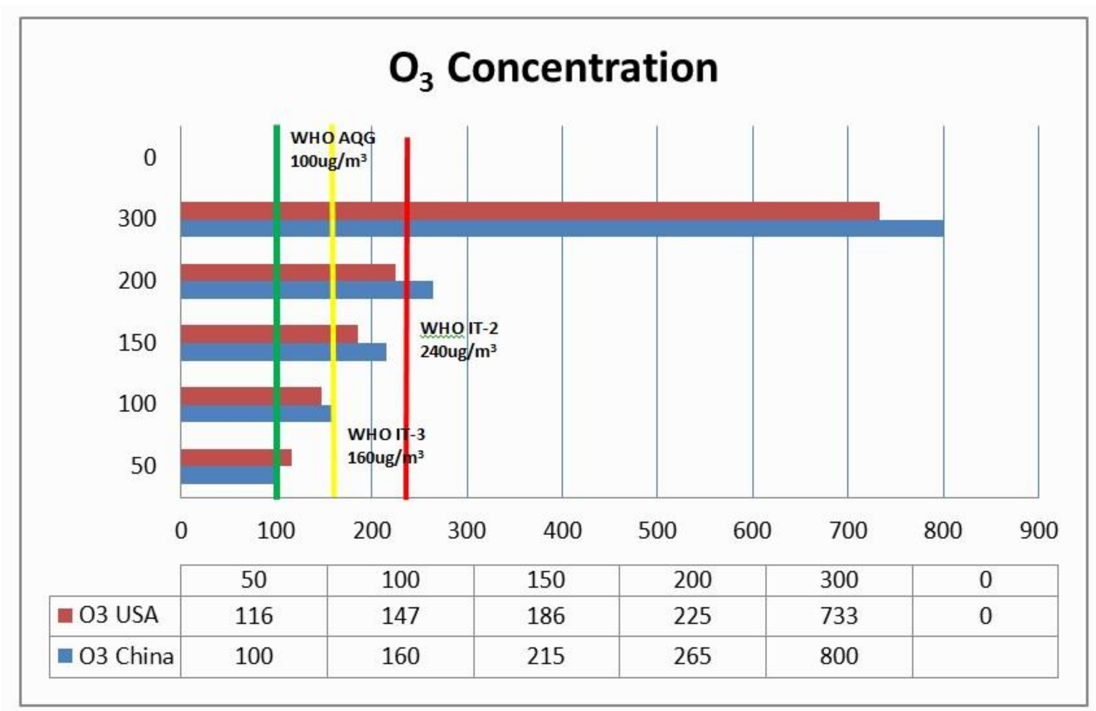


Figure 3: The O3 (8 hour Mean) Breaking Point Comparison, China & USA with WHO AQGs
The abscissa stands for the level of indicator concentration ($\mu g/m^3$) and the ordinate stands for the parameter of AQI.

5.6 Particular Matter (PM10 & PM2.5)

The breaking point of PM10 is totally the same in the two systems and both of them fulfill the WHO AQGs.

From the *Figure 4*, we can see the concentration value of PM2.5 of both AQI systems is not linearly growing with air quality index. But, the EPA AQI is more linear than the MEP AQI.

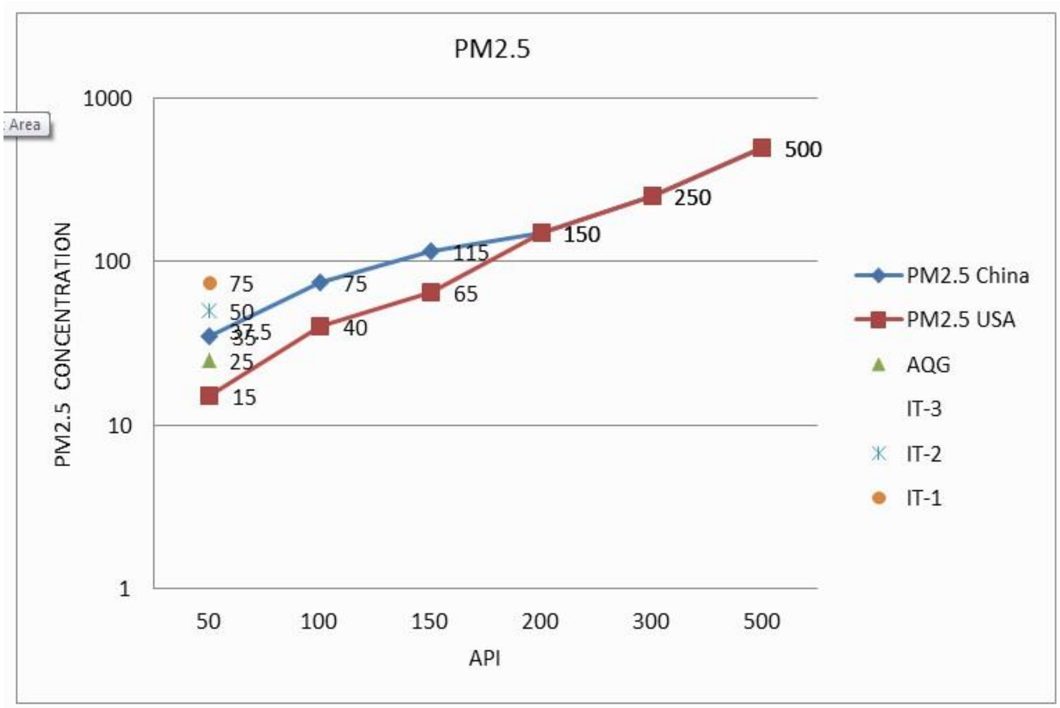
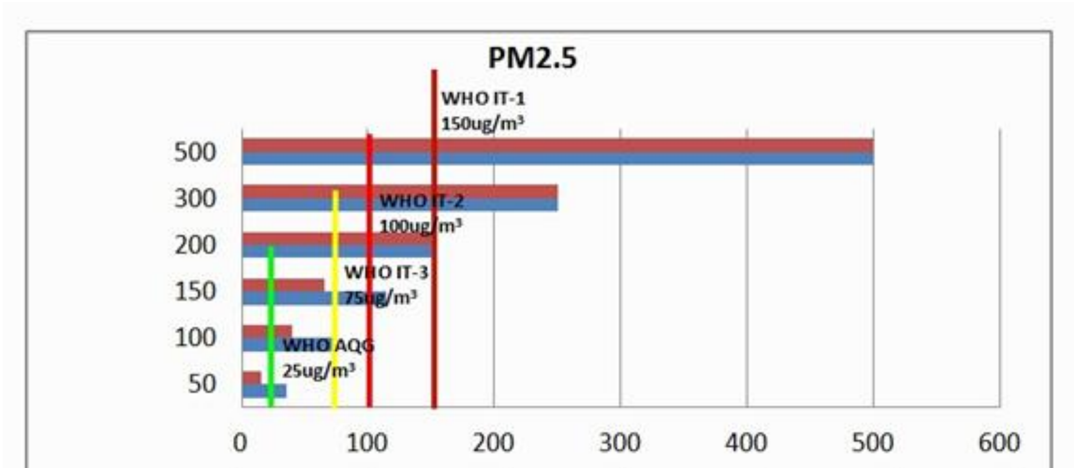


Figure 4: The Correlation between API and PM2.5 Concentration of China & USA AQI Breaking Point

From the *Figure 5*, we can see only the EPA AQI primary target fulfill the WHO AQG with MEP AQI catching up. The gap to each other is 10µg/m^3. The MEP AQI fulfills the WHO IT-3 when the AQI reaches 100. The EPA and MEP AQIs start to become the same when the air quality index reaches 200(unhealthy), which is the worst scenario of WHO IT-3. Before the AQI reaches 200, the two systems could have totally different results. For example, when the concentration value of PM2.5 is 75µg/m^3 per day, according to the MEP AQI, the air quality condition means “Good” compared to “Unhealthy for sensitive groups” based on the EPA AQI.



	50	100	150	200	300	500
PM2.5 USA	15	40	65	150	250	500
PM2.5 China	35	75	115	150	250	500

Figure 5: The PM2.5 Breaking Point Comparison, China & USA with WHO AQGs

The abscissa stands for the level of indicator concentration (µg/m^3) and the ordinate stands for the parameter of AQI.

6 Discussion and conclusion

The AQI systems of China and the US are quite the same or similar from the perspective of the structure. Both systems have the same AQI score range, the same color classification and similar health effects suggestion, but the individual indicator of the breaking point is the key factor behind this and they differ a lot from each other indeed. Although the EPA AQI system has changed a lot compared to the 2006 version, for example, the indicators of SO_2 and NO_2 are not measured with 24 hour means anymore, it still makes the two systems comparable as well. In order to compare different systems and give suggestions about future improvement, it is important to narrow down the study field and focus on specific and similar systems. The Amtonella Plaia & Mariantonietta Ruggieri "Air Quality Indices: a Review" has come to the same conclusion. The reason behind this will be discussed in this section. Other indicators maintain the same means of measurements. On one hand, the breaking point of them maybe be tightened afterwards to fulfill the WHO AQGs, On the other hand, China, which is the developing country as a fact, is the target set suitable compared to the WHO "Interim Target" and what the phase is will be discussed as well. Based on the data comparison, the reliability and scientificalness of the system will be evaluated and a conclusion will be drawn. Meanwhile, the systematic disclosure, the timeliness and the user-friendliness of the MEP AQI system will be evaluated as well.

6.1 Reliability and scientificalness

From the table 8, it shows that both China MEP and US EPA set their primary target of SO_2 concentrations lower than the WHO AQGs, while the MEP primary target fulfills the "WHO Interim Target 2". It shows that China has the endeavor and ambitions to catch up with the international standard. The EPA AQI (2006) has a much lower standard compared to MEP AQI, but when the index level rises, the parameters of the indicator SO_2 become quite close to each other. It illustrates that the standard of EPA AQI rises (more concerning health effects), when the situation of air quality becomes worse. Current scientific evidence shows that the short-term exposures to SO_2 ranging from 5 minutes to 24 hours, with an array of adverse respiratory effects, including bronchoconstriction and increased asthma symptoms. Therefore, after the year 2006, The US EPA revoked the old 24-hour standards and established the new 1-hour standard at 75 ppb for the EPA AQI 2012. Due to lack of the international 1-hour standard of SO_2, it is hard to say how the health effects correspond to the new index. The 1-hour standard is however more scientifically reliable and reasonable, since the SO_2 concentration value with 24-hour standards is calculated by summing up each hour pollutant concentration value, and divided by 24. The update of EPA AQI (2012) is shown in *figure 13*.

Table 8: The Comparison of the EPA AQI (SO_2) 1966 and 2012 with MEP and AQG

SO_2	EPA 1996	EPA 2012	MEP 2012	AQG
24 Hours Mean	30 ppb = 89µg/m^3	revoked	50µg/m^3	20µg/m^3
1 Hour Mean		75ppb = 196µg/m^3		50µg/m^3(IT-2)
3 Hour Mean	500ppb=1310µg/m^3	revoked		125µg/m^3(IT-1)

Conversion factor from ppb to µg/m^3 provided by US EPA: SO2 2.62

On one hand, the WHO established the AQGs of NO_2 based on 1 hour standard and EPA revised their AQI system of NO_2 (NAAQS. 2012) to 1 hour standard as well. On the other hand, the MEP set their standard based on 24 hour mean, which is the same as the EPA AQI 1996. Regarding those two systems, the MEP set the breaking point of NO_2 more scientifically reliable than the EPA standard when the parameter of AQI is beyond 200. Although this fact does not make much sense after the EPA applied the new AQI standard for NO_2. It is reasonable to revise the measure means of NO_2 from 24 hour standard to 1 hour standard, not only because the short exposure of NO_2 can cause serious health effects, but also the NO_2 is the contributor to form ground level ozone and PM2.5 (Jeffrey S Peterson, MD, Nitrous Dioxide Toxicity, 2006). According to the EPA's report, the level of NO_2 has decreased by more than 40% since 1980 at 18-37$\mu g/m^3$ annually (Environment Performance Report, EPA, 2012). The situation in China is that the annual NO_2 concentration value is fluctuating between 2-77$\mu g/m^3$ compared to AQGs 40$\mu g/m^3$ (IPE, AQTI report, 2010). In some regions of China the NO_2 concentration value is rapidly increasing, especially in the Yangtze River delta and the Pearl River delta where the industry area is. The monitoring of those areas needs to be evaluated and dealt with separately. (MEP, 2008, P54).

The indicators of O_3 and CO are both showing, before the AQI reaches to 200(unhealthy), that China MEP sets higher target (lower breaking point) than US EPA, which the health effects can be ignored at this stage. The result becomes totally opposite when the index is beyond 200. This phenomenon suggests China is trying to minimize the negative situation of the air quality with expanding the limits when the index is beyond the healthy category. We cannot say this is cheating the public, due to the fact that primary targets of those two pollutants are quite high compared to the EPA standard, and even the primary target for O_3 fulfills the WHO AQG. But it shows the real situation of those pollutants has been underestimated when concerning public health, specially, when China is still a developing country and the concentration values of those two pollutants remain high now.

From the discussion above, it shows the tendency of the EPA and the WHO implemented their AQI systems towards the real time reporting. The measurement for both indicators SO_2 and NO_2 is based on the 1-hour standard instead of the old 24-hour average in EPA

AQI 2012. The measurement for indicator CO is also based on the 1-hour standard according to the WHO AQGs. The Chinese new AQI system is only based on daily reporting, even though they have the real-time monitoring system.

The result shows the MEP AQI for PM2.5 is reliable compared to the EPA AQI, although China has higher limits (breaking point) of PM2.5 as primary target and it has not achieved the WHO AQG standard, but the primary target is between the WHO AQG and IT-3. Both systems have the same parameter of PM2.5 when the AQI is beyond 200(unhealthy). However, it should be noticed that the EPA AQI of PM2.5 is more scientifically reliable than the MEP one.

6.2 Systematic disclosure

Systematic disclosure means the monitoring site of one city should be built into a systematic network in order to reflect the air quality situation of the whole city.

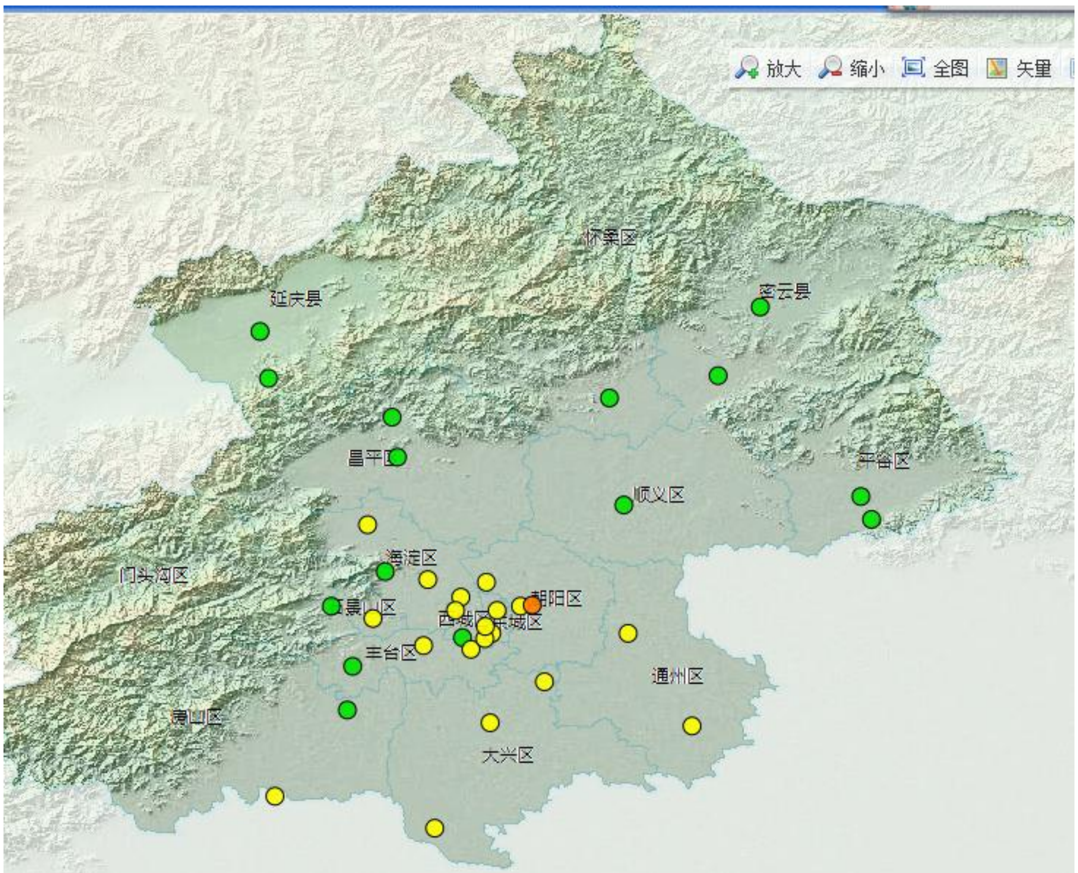
This thesis is only focused on the evaluation of the AQI system, while somehow the scientific AQI score is quite dependent on the systematic infrastructure of the monitoring site. Therefore, the completeness of the monitoring network will be discussed here in general as well.

According to Steven Q Andrews' study (Steven, 2011), the Peking EPB is suspected to cover the real air quality situation by the means of relocating the monitoring site. The fact that China has just started to upgrade their monitoring sites to meet the new AQI standard cannot be ignored. It shows that the authorities have a great ambition to consummate their target in a relatively short agenda.

According to the MEP "First Stage Monitoring Implementation Plan for the New Air Quality Standards", by the end of year 2013, the key areas such as Peking, Tianjin and Heibei, the Yellow River Delta and the Pearl River Delta as well as municipalities and provincial capitals should finish the first stage of implementation of air quality monitoring facilities and start test operation. While several cities have a relatively integrated monitoring network, many other cities have several monitoring sites which cannot represent the whole city air quality situation. (MEP, 2013)

Peking is the capital of China as well as the pilot project to start the air quality monitoring; it has a relatively good and comprehensive network. There are totally 34 monitoring sites, including 3 environmental evaluation sites, 1 city wide comparison site, 5 transportation pollution monitoring and control sites, 3 area background transmitter sites (MEP, 2012, c). The monitoring site of Peking is shown below:

Figure 6: Monitoring site in Peking. (Source: http://zx.bjmemc.com.cn/)



In other cities, like Chengdu, Wuhan, etc., the original monitoring sites and new sites are either under upgrading or construction in order to meet the new AQI standard.

6.3 Health effects and suggestion

Since the majority of cities in China still experience a high level of air pollution and it takes a long time to clean up the air (Environment Performance Report, MEP, 2009), having a contiguous plan for the polluted days is very important for the interim period. In the new AQI system, corresponding to the level of index, the health effects and a suggestion have been given, but a contiguous plan is still missing, especially for the sensitive groups, like children, the elderly and sick people with heart disease or respiratory illness. Information on how to inform the school to cancel the sports class, how to inform the hospitals to keep patients indoors, how to inform the elderly to stay at home and keep windows closed, is missing. It is necessary to ask the Education Commission and the MEP to work together and immediately launch related policy measures to ensure that primary school and middle school students are able to limit their exposure to pollution from outdoor activities on smoggy days. It is also necessary to build the communication or information channel to reach the public.

6.4 Timeliness

Timeliness is primarily evaluated by how promptly local air quality information is released, whether in daily, monthly or annual reports.

According to the regulation of the new MEP AQI, the six indicators should be published and monitored in real time. It means that the concentrations of all six indicators should be monitored and published with certain time intervals. Normally, the data will be published hourly and the trends graph will be drawn with time passing. Peking as the pilot-city to start the air quality monitoring does follow the guideline of real time monitoring, but the corresponding health effects and the suggestion are still missing. Due to the fact that the AQI system gives the health effect suggestion based on daily reports instead of real time composure will lead to public misunderstanding and overrating the air quality situation.

6.5 User-friendliness

The MEP AQI system (2012) promotes user-friendliness a lot compared to years ago. After the AQI was implemented in 2012, the MPA started to provide the real air quality situation based on digital map presentation. This clear and direct way of reporting makes the information easily pass to the public. The MEP “The Key Cities’ Air Quality Announcement System” is shown below. The system will publish six monitoring indicators: SO_2, NO_2, CO, O_3, PM10 and PM2.5 with real-time hourly concentration values, daily average concentration values, AQI, the past 24-hours history values and the area covered by the monitoring site. (MEP, 2012, a).

Figure 7: National Air Quality Announcement System. (http://113.108.142.147:20035/emcpublish/)

Mobile phone applications have also been developed to inform the public. Those apps allow users to download and compile data. It is crucial that air quality information is provided in real time and mobile phone applications provide the most up to date real-time information. By accessing the 3G network and Wi-Fi connection, the smart phone user can check the air quality situation before the exposure in polluted air without any protection. The mobile apps do not only provide a good user experience, but information can be spread very quickly. Compared with the traditional media, like television, the information of air quality can be checked anytime and anywhere you want. Even with the help of “location services” the users can check air quality information from the exact location where you are. That enterprising and interactive way of using experience is just simple, effective and updated to the real time. But it has its limitation as well; the smart phone users are mainly the young generations, which the elderly people and children are not part of and who are targeted as the sensitive group mostly.

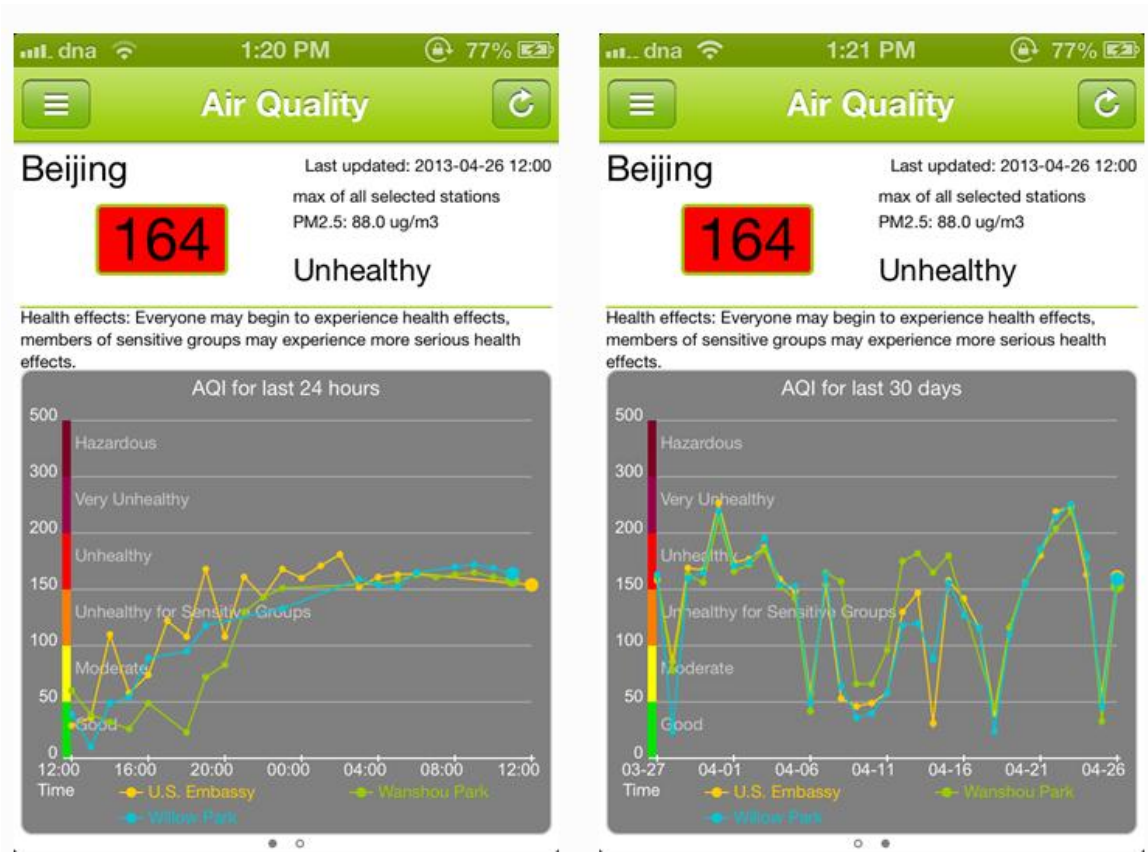


Figure 8: example of "Air Quality" apps. (http://air.castudio.org/)

The local municipality has also opened the social media account to publish the air quality index hourly. If the situation of air quality gets really seriously bad, the tweets can be reposted by followers and spread the information largely as well. This official way of publishing air quality does show the government's strength to enhance the air quality situation.

From the above discussions, we can draw the conclusion as below:

- It is necessary to shift the means for monitoring the indicator of SO_2 from 24-hour average measurement to 1-hour average standard.

- The means for monitoring the indicator of NO_2 must follow the WHO AQGs and the latest version of NAAQS, and it is necessary to shift form 24-hour average standard to 1-hour average, especially in some industrial areas of China.
- In the means for monitoring the indicator of O_3, it is necessary to revoke the 1hour standard and maintain the 8 hour standard.
- The breaking point for O_3 and CO concentration values need to be adjusted when the index is beyond 200.
- The means for monitoring the indicator of PM2.5 is reliable, but there is still a gap to meet WHO AQG.
- The corresponding health effects as a result of real-time hourly pollutant concentrations need to be drawn up and revised.
- A contiguous plan for the polluted days is still missing.
- The user-friendliness of the AQI system has improved a lot, but experienced system breakdown and updates are not in time.
- In general, the Chinese new AQI system has been promoted a lot, but it is not impeccable compared to international standards.

7 Future Endeavors

It took Europe and USA about half of a century to clean up the air (MEP, The History of Air Pollution). If that is possible, China is able to learn from the experience of developed countries to shorten the time to reach the WHO AQGs.

According to the “MEP Timetable for the Implementation of the New Standard”, until the year 2016, the new standards are able to be implemented nationwide. Before this date, only the key cities can have a relatively systematic monitoring network. Therefore, revising the breaking point of different indicators, changing several means of measurements, implementing the contiguous plan for the sensitive group and coming up with the action plans for reducing the air pollution is the major direction to work on. The suggestions are given below based on AQI system enhancement.

1. Levels of air pollution information disclosure should be further increased.

    - The upgrading and construction of monitoring sites should meet the standard of systematicness and completeness.
    - The stability of "a national Air Quality Announcement System" should be enhanced.
    - The digital map system with visualization of AQI color classification layer should be upgraded.
    - The AQI should consist of a National Weather Broadcasting system.
    - Improving the historical data publishing and carrying out more research afterwards.

2. The means of several indicators' measurements of the AQI system should be revised.

    - SO_2 and NO_2 measurement is necessary to revise into 1 hour standard.
    - O_3 measurement is necessary to revise into 8 hour standard and revoke the 1 hour standard.
    - The breaking point of O_3 and CO is necessary to tighten when the index is greater than 200.
    - The AQI system should be adjusted to match the real-time monitoring system.

3. Practical contingency plans for heavily polluted days should be urgently formulated and implemented.

    - Based on their own situation, different cities should draw up unique plans for an information transmission channel.

- The plan should give suggestions for different sensitive groups for protecting them from composure.

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9 Appendices

9.1 Appendix I Breaking Point of MEP AQI

空气质量分指数（IAQI）	污染物浓度值（单位：毫克/立方米）						
	二氧化硫（SO_2）日均浓度值	二氧化氮（NO_2）日均浓度值	颗粒物（PM_{10}）日均浓度值	一氧化碳（CO）日均浓度值	臭氧（O_3）日1小时浓度最大值	臭氧（O_3）日8小时浓度最大值	颗粒物（$PM_{2.5}$）日均浓度值
50	0.050	0.040	0.050	2.0	0.160	0.100	0.035
100	0.150	0.080	0.150	4.0	0.200	0.160	0.075
150	0.475	0.180	0.250	14.0	0.300	0.215	0.115
200	0.800	0.280	0.350	24.0	0.400	0.265	0.150
300	1.600	0.565	0.420	36.0	0.800	0.800	0.250
400	2.100	0.750	0.500	48.0	1.000	(1)	0.350
500	2.620	0.940	0.600	60.0	1.200	(1)	0.500
说明：	(1) 臭氧（O_3）日8小时浓度最大值高于0.800mg/m^{3}的，不进行其空气质量分指数计算。						

9.2 Appendix II Breaking Point of EPA AQI

This Breakpoint...						...equal this AQI		...and this category
O_3 (ppm) 8-hour	O_3 (ppm) 1-hour[1]	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)	AQI	
0.000 - 0.064	-	0 - 54	0.0 - 15.4	0.0 - 4.4	0.000 - 0.034	([2])	0 - 50	Good
0.065 - 0.084	-	55 - 154	15.5 -40.4	4.5 - 9.4	0.035 - 0.144	([2])	51 - 100	Moderate
0.085 - 0.104	0.125 - 0.164	155 - 254	40.5 - 65.4	9.5 - 12.4	0.145 - 0.224	([2])	101 - 150	Unhealthy for Sensitive Groups
0.105 - 0.124	0.165 - 0.204	255 - 354	65.5 - 150.4	12.5 - 15.4	0.225 - 0.304	([2])	151 - 200	Unhealthy
0.125 - 0.374 (0.155 - 0.404)[4]	0.205 - 0.404	355 - 424	150.5 - 250.4	15.5 - 30.4	0.305 - 0.604	0.65 - 1.24	201 - 300	Very unhealthy
([3])	0.405 - 0.504	425 - 504	250.5 - 350.4	30.5 - 40.4	0.605 - 0.804	1.25 - 1.64	301 - 400	Hazardous
([3])	0.505 - 0.604	505 - 604	350.5 - 500.4	40.5 - 50.4	0.805 - 1.004	1.65 - 2.04	401 - 500	Hazardous

[1] Areas are required to report the AQI based on 8-hour ozone values. However, there are areas where an AQI based on 1-hour ozone values would be more protective. In these cases the index for both the 8-hour and the 1-hour ozone values may be calculated and the maximum AQI reported.

[2] NO_2 has no short-term NAAQS and can generate an AQI only above a value of 200.

[3] 8-hour O_3 values do not define higher AQI values ($\geq$ 301). AQI values of 301 or higher are calculated with 1-hour O_3 concentrations.

[4] The numbers in parentheses are associated 1-hour values to be used in this overlapping category only.