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On the management methods for regional air quality improvement

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Abstract: The air quality management in regional viewpoint was investigated for the improvement of national air pollution with various standard air pollutants. The focal region in this research is north-eastern region in asia where the many developing industries are located in neighboring countries. The major concerns were the trends of air quality in recent years and the state of environmental technologies and policies of air quality in each countries. The regional air quality management for the improvement of air pollution and the effective programs were suggested for the effective air quality management.

Key Words: Air Quality, Improvement, Management

I. Introductions

In general air quality means the con dition of air relative to the requirements of human needs or biotic species and we can check this condition from the measurement of pollutants in the air. The general air quality index (AQI) is generally used for estimating the healthiness of air condition as shown in Table 1(ME,2015). As shown AQI is classified as six stages from good condition to hazardous condition.

Table.1. Classification of air quality index

Air quality index levels of health concern values	
0～50	Good
51～100	Moderate
101～150	Unhealthy for sensitive groups
151～200	Unhealthy
201～300	Very unhealthy
301～500	Hazardous

In recent researches, region of Japan country has more better air quality than other regions in view of AQI in east asia. Urban air pollution is different from general air pollution because it comes mainly from vehicles and sources from citizen living regions with industrial complex neighboring urban area. Main pollutants to be solved are generally nitrogen dioxides, ozone, particulates and odors.

In this research, current states of air quality in east asian region are investigated, then many factors related with air pollution are discussed to know the main reasons of current states of air quality in this region. Finally the desirable air quality management plans are suggested to make more clean regions in east asian regions.

II. Consideration of Regional Air Quality

2.1. Air Quality in Korea

Our country is managing ambient air quality very carefully and the standard values are depicted in the Table.2(ME,2016). There are sulfur dioxides, carbon monoxide, nitrogen dioxide, particulates, ozone, lead and benzene. All standards are different time averaged values and methods of analysis are illustrated.

Table.2. Ambient air quality standard values in Korea

Air pollutants		Standards	Methods of analysis
Sulfur Dioxide (SO_2)		1 yr-avg 0.02 ppm 24 yr-avg 0.05 ppm 1 hr-avg 0.15 ppm	Pulse UV fluorescence
Carbon Monoxide (CO)		8 hr-avg 9 ppm 1 hr-avg 25 ppm	Non-dispersive IR
Nitrogen Dioxide (NO_2)		1 yr-avg 0.03 ppm 24 yr-avg 0.06 ppm 1 hr-avg 0.1 ppm	Chemiluminescent
Particulate	PM-10	1 yr-avg 50 ㎍/㎥ 24 yr-avg 100 ㎍/㎥	β-ray absorption
	PM-2.5	1 yr-avg 25 ㎍/㎥ 24 yr-avg 50 ㎍/㎥	Weight concentration
Ozone (O_3)		8 hr-avg 0.06 ppm 1 hr-avg 0.1 ppm	UV photometric
Lead (Pb)		1 yr-avg 0.5 ㎍/㎥	Atomic absorption spectrophotometry
Benzene		1 yr-avg 5 ㎍/㎥	Gas chromatography

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The recent trends of air quality in Korea are shown in Fig.2(ME, 2016). The concentration of PM-10 and lead have some fluctuations but gradually diminishes with the elapse of time. SO_2, NO_2 and ozone have nearly constant values with average values of all Korean regions. The monitoring stations in Korea check continuous air quality and concentration of air pollutants are automatically transmitted to server and finally shown in LED bulletin board which is shown to every citizens.

The distribution of yearly averaged SO_2 concentration in Korea is shown in Fig.3 (NIER,2016). In the period of 1989∼1994, the yearly averaged values and the range of concentration variation were relatively high but they gradually diminished until became almost constant in the period of 2001∼2015. This is mainly due to the clean energy policy after the air quality management regulation law for the urban regions in 1998.

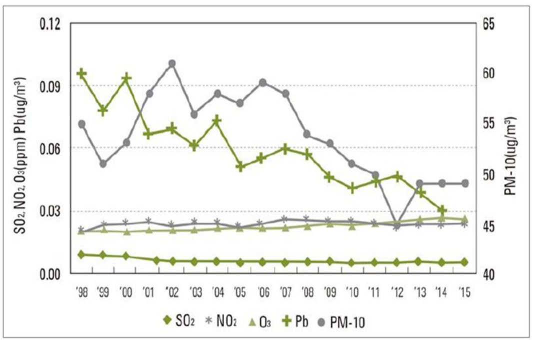

Fig.2. The recent trends of major air pollutants in Korea (ME, 2015)

The distribution of yearly averaged NO_2 concentration is very different from SO_2 shown in Fig.4 (NIER,2016). Almost all the concentrations have fluctuation values of NO_2 and do not decrease like the concentration of SO_2. This is mainly due to the largest population and energy consumption with vehicles and citizens therefore the effective methods of NO_2 regulations are needed but not completely prepared until recent years.

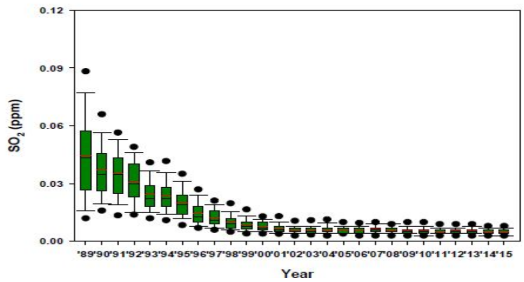

Fig.3. Distribution of yearly SO_2 concentration in Korea(NIER, 2016)

The problem of O_3 in major cities of Korea is serious as shown in Fig.5(NIER,2016). Distribution of yearly averaged O_3 concentrations are increasing continuously. And almost all the cities have rising values of O_3 and in case of Pusan city the value is relatively higher than any other cities in Korea. Values of Seoul city have decreased in the year of 2000 ∼ 2004 but increased gradually until the year 2015.

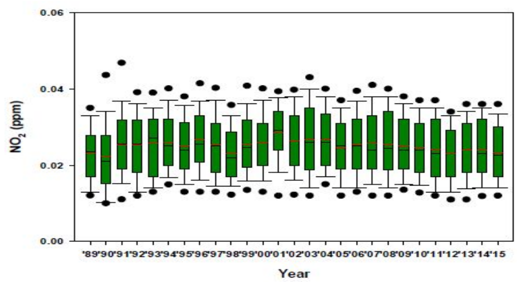

Fig.4. Distribution of yearly NO_2 concentration in Korea (NIER, 2016)

Fig.6 shows the distribution of yearly averaged PM-10 concentration in Korea(NIER,2016). Fortunately the averaged values and the range of fluctuations go down gradually with the lapse of years. The concentration of PM10 in major cities of Korea showed wide variation in the period of 1995 ∼ 2004 but all the cities have nearly constant values in the period of 2012 ∼ 2015.Incheon was the highest in PM-10 and PM-2.5 concentration among major cities as depicted in Fig.7(ME,2016).

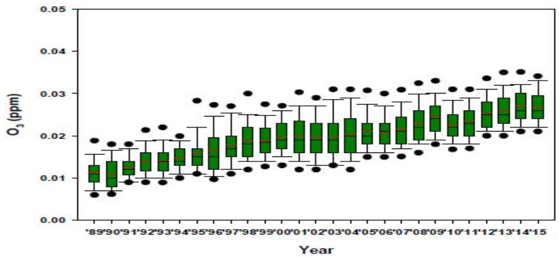

Fig.5. Distribution of yearly O_3 concentration in Korea (NIER, 2016)

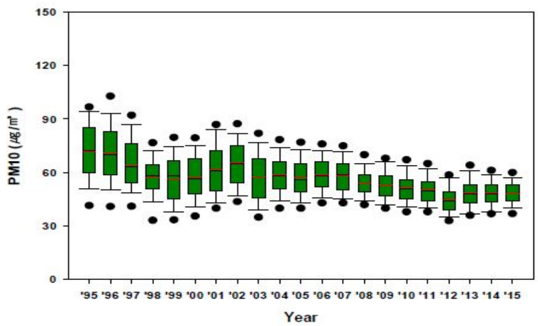

Fig.6. Distribution of yearly PM-10 concentration in Korea (NIER, 2016)

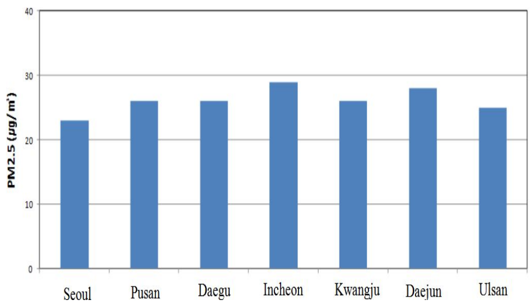

Fig.7. Tendency of PM-2.5 concentration in major cities (ME, 2016)

The number of car increase became larger in the year of 1985. And recently almost two thousands and nine hundred million cars were registered in 2014(ML, 2016). This is one of the main reasons of the increase of particulates, nitrous oxides and ozones in Korea.

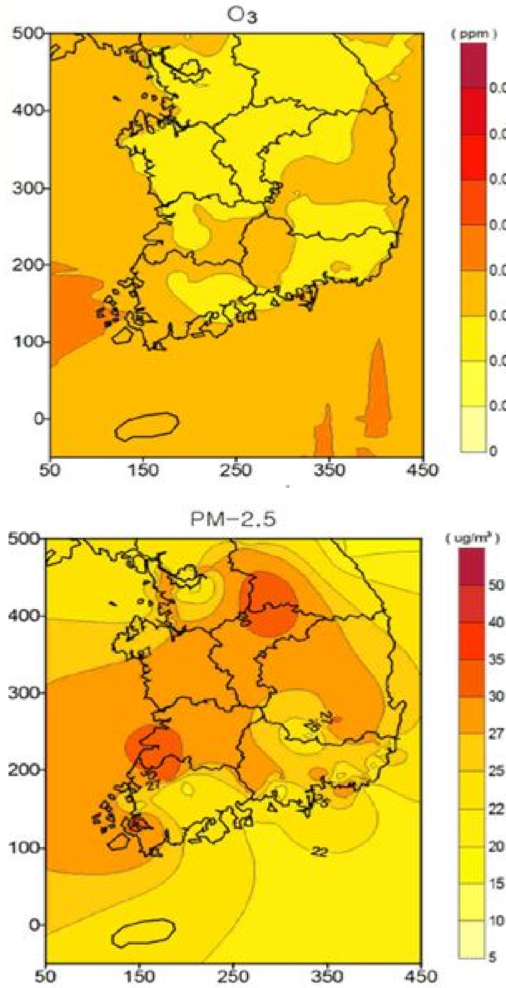

Fig.8. Distribution of O_3, PM-2.5 over standard concentration (NIER,2016)

From the distribution of major air pollutants in yearly averaged values in Korean region, SO_2 was high in southern industrial region, and NO_2 was high in urban region. And PM-10, PM-2.5 was relatively high in special regions.

Distribution of O_3 and PM-2.5 over standard concentration are summarized in Fig.8(NIER,2016). Two air pollutants showed somewhat different tendency as shown in the figure. Excess of O_3 over 8-hr standard was almost all regions and PM2.5 showed similar tendencies. Fig.9 is the states of SO_2 and NO_2 concentrations over standard values of air quality monitoring stations in Korea(NIER,2016). The major exceeded values are concentrated in urban regions of Seoul, Incheon metropolitan city than other regions.

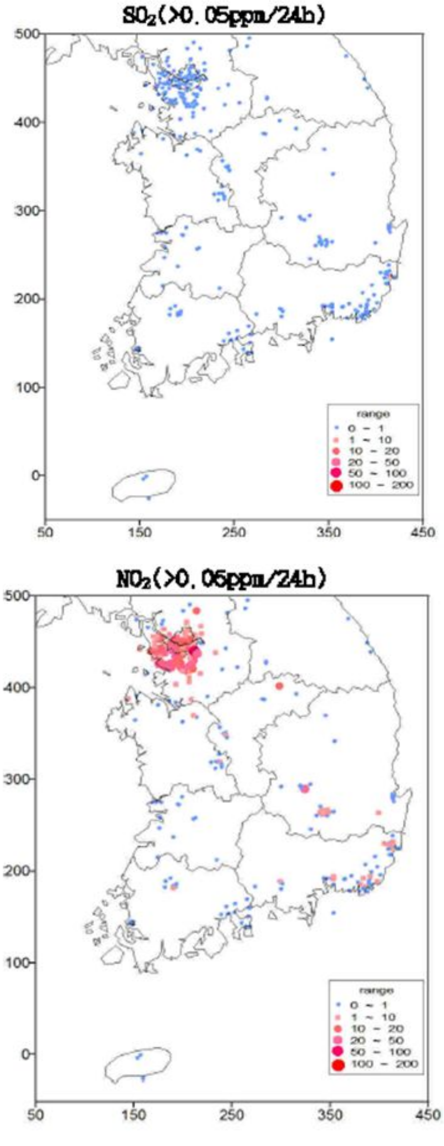

Fig.9. Over standard values of SO_2, NO_2 in monitoring stations (NIER,2016)

2.2. Air Quality in China

Air quality in major cities of China is shown in Table 3 (CSY,2016). For comparison of Beijing and Tianjin annual average concentrations of SO2, PM-10 were high in Tianjin, but NO_2, O_3 and PM-2.5 were higher in Beijing region. The geographical situation of Beijing and Tianjin city in Chian is very similar to Seoul and Incheon city in Korea. Therefore regional air quality management plans would be referred between two urban regions.

Table.3. Air quality in major cities of China (CSY, 2016)

City	Annual Average Concentration of SO_2 (μg/m³)	Annual Average Concentration of NO_2 (μg/m³)	Annual Average Concentration of PM_{10} (μg/m³)	95th Percentile Daily Average Concentration of CO (mg/m³)	90th Percentile Daily Maximum 8 Hours Average Concentration of O_3(μg/m³)	Annual Average Concentration of $PM_{2.5}$ (μg/m³)	Days of Air Quality Equal to or Above Grade II (day)
Beijing	14	50	102	3.6	203	81	186
Tianjin	29	42	117	3.1	142	70	216
Shijiazhuang	47	51	147	4.3	148	89	180
Tangshan	49	61	141	4.2	182	85	156
Qinhuangdao	38	45	99	3.6	107	48	259
Handan	45	47	166	3.8	141	91	149
Baoding	55	54	174	5.8	183	107	126
Taiyuan	71	38	114	3.1	131	62	230
Datong	44	27	87	2.8	139	40	292
Yangquan	60	41	113	2.8	132	54	265
Changzhi	50	37	106	3.6	161	65	242

Fig.10~11 is the SO_2, PM-10 concentration distributions in China for stepwise ranges (Kang T.G. et al, 2015, MEPPRC, 2013). We can see that almost all the regions are below standard concentrations in China. As shown in this figure, the regions of high range air pollutant concentrations are located near the industrial regions and urban cities of south and north eastern area. Therefore the government of China has been focused on the regulation of air qualities including Beijing and Shanghai city with the introductions of very strong regulations.

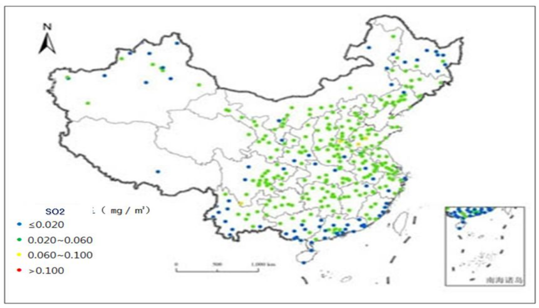

Fig.10. SO_2, concentration range in China (Kang T.G. et al, 2015, MEPPRC, 2013)

In China, the high acid rain was almost in southern regions of China and this may be due to the use of coal firing facilities in industrial regions neighboring southern regions. Steep increase of number of cars in China is another main reason of rain acidity and increase of nitrous oxides concentrations. Therefore the government of China has the plans of policies using liquefied natural gas and new and renewable energies in recent years.

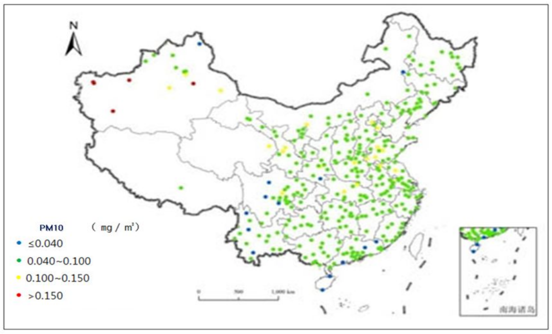

Fig.11. PM10 concentration range in China (Kang T.G. et al, 2015, MEPPRC, 2013)

The regions of high PM-10 concentration are very broad like north eastern and southern regions in China as can be seen in Fig.11. Recent particulate pollution sources are coal fired power plants as explained, vehicles using light oil and industrial utilities using fossil fuels in China. This situation is somewhat similar to the state of Korean air quality. Policy of transportation introducing large sized buses using clean energy such as compressed natural gas has contributed to maintain air quality as governmental policy in Korea. Comparison of air quality in urban area of Korea and China is depicted in Table 4 (Kang T.G., 2015).

2.3. Air Quality in Japan

The figure 12 depicts the trends of major air pollutants during the recent decades monitored in measuring stations in Japan (CESS, 2011). The concentration of SO_2, NO_2 and CO showed high values then decreased until showed stable values in low level. On the other hand, fine particulates and ozone showed similar trends until the middle period of 1980s, ozone increased but fine particulates decreased. Air quality monitoring stations, vehicle emission monitoring and acid rain monitoring stations are operated in Japan. Especially the qualitative analysis of PM-2.5 and hazardous air pollutants are proceeded with the data of Pollutant Release and Transfer Registers simulations of air pollution concentrations (Park,J.G., 2013).

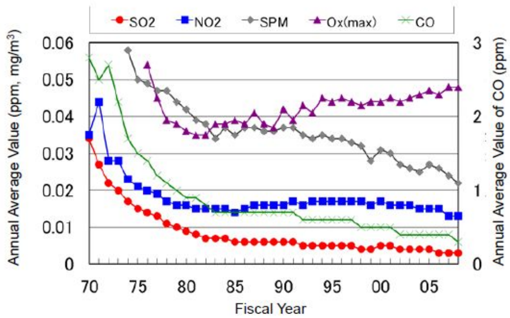

Fig.12. Tendency of air pollutants in Japan (CESS, 2011)

Table 4. Comparison of air quality in urban area of Korea and China (Kang T.G. et al, 2015)

Item		Urban area in Korea			Jing-Jin-Ji's region in China		
		Seoul	Incheon	Kyonggi	Beijing	Tianjin	Hebei
Air Quality	PM10	47 μg/㎥	54 μg/㎥	49 μg/㎥	82~126 μg/㎥	105 μg/㎥	55~98 μg/㎥
	SO_2	0.005 ppm	0.008 ppm	0.005 ppm	0.008~0.016 ppm	0.018 ppm	0.013~0.021 ppm
	NO_2	0.033 ppm	0.029 ppm	0.028 ppm	0.016~0.033 ppm	0.022 ppm	0.011~0.021 ppm
	CO	0.6 ppm	0.6 ppm	0.6 ppm			
	O3	0.132 ppm	0.111 ppm	0.123 ppm			
Major pollutant		PM10, NO_2, O_3	PM10, NO_2, O_3	PM10, NO_2, O_3	SO_2,NO_2,PM10 PM2.5, O_3	SO_2,NO_2,PM10 PM2.5, O_3	SO_2,NO_2,PM10 PM2.5, O_3
Main reasons		population increase mobile sources(urban area) increase of industrial region			* influence of adjacent city * car emission * combustion of coals * factory dust * decrease of forests	* combustion of fuels * centralization of emission sources * emission from vehicles	* emissions from industrial region * pollutant stagnation due to terrain

Especially Tokyo, Yokohama and Osaka cities have total amount regulation policy for nitrous oxides. By joining Acid Deposition Monitoring Network in East Asia, the acid rain monitoring is proceeded with the analysis, estimation and provisions of data. Policy of pollution prevention for yellow sands from China is co-operated with Korea, Japan and China in view of trans-boundary pollutants. Table 5 is the environmental standards and guidelines of major air pollutants in Japan(Wakamatsu S. et al, 2013).

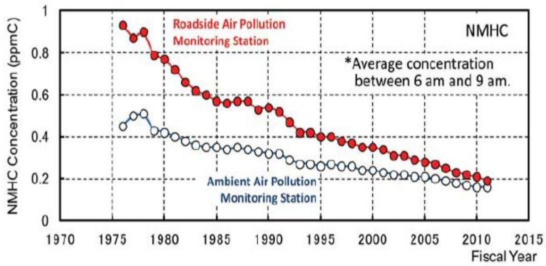

Fig.14. Annual average concentration of NMHC in Japan(Wakamatsu S. et al, 2013)

Table 5. Environmental standards and guidelines in Japan (Wakamatsu S. et al, 2013)

Environmental Standards	
CO	The daily average for hourly values shall not exceed 10 ppm (12 mg/m^3), and average of hourly values for any consecutive eight hour period shall not exceed 20 ppm (23 mg/m^3).
SO_2	The daily average for hourly values shall not exceed 0.04 ppm (105 μg/m^3), and hourly values shall not exceed 0.1 ppm (262 μg/m^3).
NO_2	The daily average for hourly values shall be within the 0.04-0.06 ppm (75-113 μg/m^3) zone or below that zone.
OX	Hourly value should not exceed 0.06 ppm (118 μg/m^3).
SPM	The daily average for hourly values shall not exceed 0.10 mg/m^3, and hourly values shall not exceed 0.20 mg/m^3.
$PM_{2.5}$	The annual standard for $PM_{2.5}$ is less than or equal to 15.0 μg/m^3. The 24 hour standard is less than or equal to 35 μg/m^3.
Environmental Guideline	
NMHC	Hydrocarbon levels should be determined by measuring the non-methane hydrocarbons. The 3 hour (6-9 a.m.) average concentration should be 0.20-0.31 ppmC or less (equivalent to the value in terms of ppm obtained by adding up the figures gained through the carbon molecules multiplied by the number of carbon atoms per molecule).

Fig 13 is the annual average concentration of SO_2(Wakamatsu S. et al, 2013). Roadside air pollution was higher than ambient air pollution station in 1970∼1995 period, but showed almost same tendency with the low values in recent years, this means that regulation of air pollution for vehicles showed effect of air quality improvement. The annual average concentration of non-methane hydrocarbon showed similar trend to SO_2 tendency in Japan with the same reason as in Fig.14(Wakamatsu S. et al, 2013).

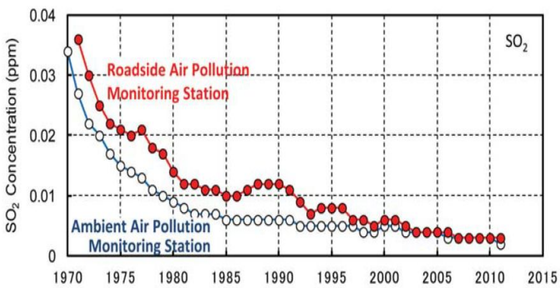

Fig.13. Annual average concentration of SO2 in Japan(Wakamatsu S. et al, 2013)

The annual average concentration of NO_2 in Japan is depicted in Fig15(Wakamatsu S. et al, 2013). Roadside air pollution and ambient air pollution station measuring data was very high in 1970∼1975 period, diminished gradually and showed similar tendency with the low values in recent years, but roadside air pollution is higher than ambient data as can be expected.

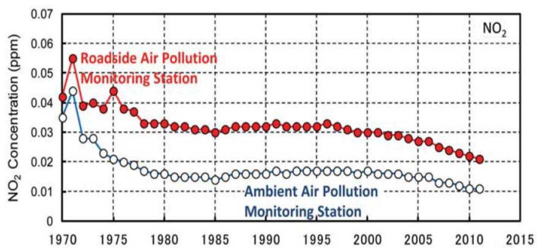

Fig.15. Annual average concentration of NO_2 in Japan (Wakamatsu S. et al, 2013)

III. Management method for air quality

This research has investigated current state of air pollution in Korea, China and Japan, international cooperation and finally Korea-China-Japan joint administration. Air pollution is not a isolated issue but trans-boundary problem for east asia therefore international cooperation is indispensable.

The main domestic sources of urban air pollution in Korea are heating systems and power plants (39%), vehicles (25%), fugitive dust (22%), construction equipment (12%) and the rest is biomass burning (2%). And contributions to total air pollution from foreign countries are about 55 % from the statistics (Shin C.S., et al., 2005).

The same air pollution sources in both countries are emission from manufacturing factories and moving vehicles. The state of air pollution in both countries is very similar in emission sources and generating regions. The difference of air pollutants in urban regions in Korea is small and the difference in China is considerably large. The air quality administration in both countries are common in managing special regions of air quality programs.

For the improvement of air quality, the development of environmental industry is important. Table 6 shows environmental industry expansion during recent ten years(Jo,S.H. and Tae Y.J., 2003). The most developed area was environmental service, and then soil pollution and air pollution during the year of 2005 ~ 2015. The area of water pollution was relatively high portions of budgets but that of air pollution was relatively low in Korea.

From the investment of air pollution control industry in China, flue gas desulfurization industry is almost equal for recent several years, but particulate matter removal showed clear increase. And flue gas denitrification industry has the tendency of gradual increase of financial investment(Shim, C.S., 2015). Both cities can share common concerns for the development of environmental industry in the near future especially in the scope of air pollution.

Korean air control technologies are about 60 ~70 % of more developed countries therefore government is proceeding environmental industries as national strategic ones. China is proceeding to import more developed countries' technologies and self developed technologies very actively. To improve air quality in east asian region systematic foundation of Korea-China cooperation will be made and durable operation should be done. Environmental industry expansion in Korea is illustrated in Table 6 (Jo S. H. et al, 2003).

Table 6. Environmental industry expansion in Korea (Jo S. H. et al, 2003).

(Unit : 100 Million Won,%)

Scope	1995	2005	2015	Annual growth rate	
				1995-2005	2005-2015
Air pollution	10803(18.2)	34595(16.6)	42450(15)	12.3	2.1
Water	28937(48.9)	82319(39.5)	84900(30)	11	0.3
Waste	17011(28.7)	50641(24.3)	56600(20)	11.5	1.1
Soil	2008(3.4)	15005(7.2)	31130(11)	22.3	7.6
Service	446(0.8)	25842(12.4)	67920(24)	50.1	10.1
Sum	59205(100)	208402(100)	283000(100)	13.4	3.1

The air quality improvement is very important for the health of human living from the statistics of possibilities of premature deaths from particulate, ozone show different estimate in many countries (WHO, 2016). The important factor for regional air quality is the demands of three countries for cooperation to make systematic foundation effective for the development of air quality control. The trans-boundary air pollutants are important factors that monitoring by two countries and the analysis will be important steps(Shim C.S. et al, 2015). Since the Convention on Long-Range Transboundary Air Pollution(CLRTAP), many efforts have been made between two countries. The cooperation must be proceeded more actively to build governance for the solution of trans-boundary air pollutants.

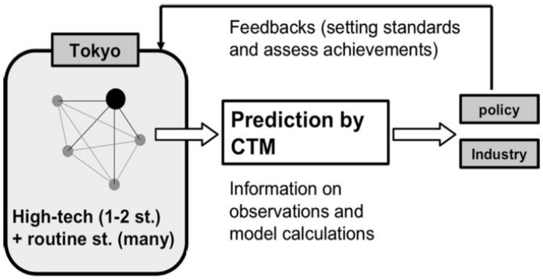

Fig.16. IMPACT Megacity air quality modelling simulation (WMO/IGAC, 2012)

As shown in Fig.16, IMPACT campaign was proceeded to understand air chemical characteristics in Tokyo metropolitan city region with the part of International Global Atmospheric Chemistry project(Shim C. S., 2013). The main purposes of this study are precursors of oxidizing materials, the physical characteristics of urban aerosols such as composition and mixing state and the estimation of emission inventories for trace gases such as NOx, SO_2, NH_3 and VOCs (Shim C. S. et al, 2015)

Another important factor is odor pollution in urban region. Odor is an important environmental issue and it can affect public amenity and quality of life. It is sensory pollution to human like noise pollution. Citizen needs for a clean environment makes odor pollution be solved completely.

Twenty two odor components are defined in Korean odor protection law such as Reduced sulfur compound, volatile organic compounds, aldehydes, nitrogen compounds and finally organic acids. In Incheon region, there are many odor generating sources such as landfill sites, sewage treatment plant, industrial facilities and food waste recycling plants. Therefore citizen's odor complaints in urban area goes up in recent years.

Methods of odor perceptions can be classified as sensory method and instrumental one. In Korea odor management of sewage water is important project which is not easy to prevent odor generation. Automatic odor sampler system is another Korean technology which is automatic sampling which exceed standard concentrations. This is remote control and on-site monitoring with 24 hours operations. And the system transmits SMS to related personnels with remote sampling odors.

National Environment Protection Bureau has paid much attention to the impact of odor pollution by manufacturing factories and investigations for odor qualities in China. EPB of China proceeded the research group actively for the odor investigations such as emission standards. These standards are for major odor pollutants such as hydrogen sulfides, ammonia, methyl mercaptan etc(Yoon Y.H.,2011: Lei S., 2004).

Odor monitoring system network has developed to have continuous instrumental analysis possible with weather monitoring in station server with wibro-telecom in Korea. Another effective one is smart monitoring system of odors which is real-time monitoring with high sensitivity module sensor. The system has alarms and data transmission with abnormal odor condition with automatic remote controls. Citizen can detect odor and just input data with monitoring report. This system may be effective methods for the solution of urban odor pollution problems.

Recent modified odor monitoring technology in Korea is GC and IC with odor sensor integrated system. In this system instrumental analysis is combined with odor sensor signal to make data acquisition very accurate. Smart odor monitoring system with citizens are actively developed in recent years in Korea.

Three countries must proceed effective regulation process for improving odor pollution, air environment, yellow sands. And the cooperation of environmental technologies and energy conservation with greenhouse reductions should be made gradually. The improvement program between three countries will be made to have active communication for urban air pollution improvement and greenhouse gas minimization. First of all, Korea must increase the development of renewable energy and

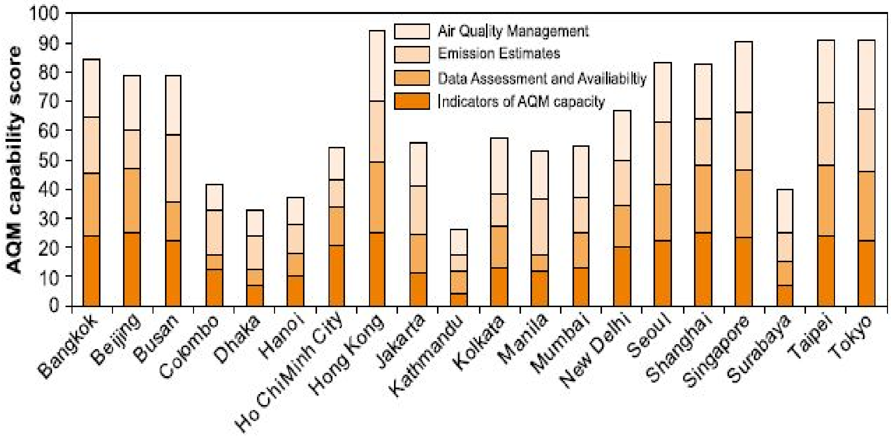

Fig.17. Air quality management capability in selected asian cities (Schwela et al, 2006)

clean energy utilization for stable air quality condition. Energy utilization policy with the focus of coal dependency should be changed between countries and active exchange and cooperation for clean energy increase must be proceeded.

Pollution emissions from manufacturing process are major reasons of air pollution therefore real-time monitoring system is important for preventing unexpected situations. The technologies between countries can be exchanged to make more efficient real-time monitoring system and this will decrease air pollution emission effectively. Fig.17 shows the air quality management capability in selected asian cities (Schwela et al, 2006). From the data the regional air quality improvement has high possibility in eastern asian areas.

Air pollution such as yellow sands and fine particulates from China make low visibility and respiratory troubles in Korea(Kang T.G., 2016). Pollutants emitted from industrial regions are accompanied by yellow sands and transferred to our country. Therefore cooperative researches for trans-boundary pollutants should be continued.

Regional air quality improvement researches in east asian region would have very fruitful and effective achievements like Seoul city of Korea and Beijing city of China with Tokyo city in Japan. Seoul-Beijing agreement contains exchanges about mutual cooperation for policy, technology, information and human and periodical air quality improvement forums.

Korean experiences for environmental engineering and industrial technologies can be owned with the related fields of China. Purification for emission utilities, water treatment, measurement and monitoring system are the typical cooperative projects for mutual developments(Lee.H.C. and Cheng L., 2015)

Future plans which can solve the problem of air pollution and urban sustainability simultaneously are suggested with local governments, specialists and citizen groups involved. Korea, China and Japan cities make these projects for common urban air pollution and will cooperate intimately. Development of greenhouse reduction policies such as producing new and renewable energy together can have more effective outcomes in the near future.

IV. Conclusions

Regional air quality management is a very important task for the health of all citizens especially living in urban regions neighboring various air pollution emission sources. In this study, state of air quality in korea, china and japan was investigated for major air pollutants and effective management methods were suggested to enhance the air qualities between three countries especially in urban regions.

Finally the effective management methods for regional air quality improvement were illustrated with the sustainable development of urban regions.

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