Tracking down China's Haze Pollution

By XIN Ling (Staff Reporter)

An interdisciplinary research consortium led by Prof. HE Hong from the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences has been tracing the culprits of the toxic haze above China. In about ten years' time, they will strive to identify the hazardous particulates in the air, figure out where they come from and how they evolve, and help policymakers develop targeted and cost-effective measures to curb the pollution.

As Prof. HE told BCAS reporter XIN Ling in an interview, "China's haze problem is very sophisticated, involving multiple pollution sources including coal burning, car emission and sandstorm". There are plenty of challenges in understanding and managing the situation. Primary research results showed that NO_x plays a key role in haze formation, so the control over vehicle exhaust, especially diesel exhaust, should become a policy priority in the future.

Haze above China: "cocktail with a complicated recipe"

When an unexpected heavy haze started to engulf large part of China in January 2013, Prof. HE Hong's office at the Research Center for Eco-Environmental Sciences was filled with colleagues and journalists. As chief scientist of a haze research program initiated by CAS, he worked around the clock with his group and responded to the exploding public concern.

"China's air quality is becoming more and more worrying in recent years, and haze is now our No.1 air

"The dreadful smog", a schoolchild's painting shown at a low carbon exhibition at the Capital Museum from June to July, 2013. (Photo: BCAS)

Prof. HE Hong, an expert in environmental catalysis at the Research Center for Eco-environmental Sciences, has been working as chief scientist of the Academy's strategic priority research program on "Formation Mechanism and Control Strategies of Haze in China". (Photo: BCAS)

pollution problem to be solved. It regularly hits about one third of the nation in area and affects the lives of 800 million people," the professor's voice was anxious.

Indeed, haze not only delays traffic but can induce serious health problems from respiratory illnesses to heart disease, premature death and cancer. In Beijing, the terrible weather has reportedly led to record high hospital visits in a decade.

Easy as it may seem to tell a haze from the color of the sky, "Identifying its composition and mechanism is by no means easy, especially for a country like China," he said.

According to Prof. HE, although most air pollutions in the world are combined pollutions, the Chinese case is particularly complicated. When the famous London fog was blamed on coal burning, and the photochemical smog in Los Angeles largely resulted from vehicle exhaust, each of these pollutions was related to a particular development phase with one major pollution source. But these different types of pollution prevail simultaneously in today's China due to its dramatic economic development in the past thirty years.

Prof. HE and his colleagues are approaching the problem from the perspective of environmental catalysis. As a distinguished expert in environmental catalysis, Prof.

"The air above China is like a cocktail with an extremely complicated recipe. The complexity is unprecedented. Given this unique situation, we do not have any ready-made experiences to learn from. We have to work on our own to develop a comprehensive understanding about the whole situation and find a way out."

HE has worked with catalysts for many years: the catalysts for indoor formaldehyde elimination, vehicle exhaust purification and industrial denitrification. As he suggested, naked natural surfaces like that of particulate matter may also catalyze physicochemical processes in the atmosphere.

"Taking the atmosphere as a huge photo-thermal reactor, we'll find out how the haze forms and how particulate matter contributes to the process," he explained.

The idea was first proposed five years ago. After that, his lab received a grant from the National Natural Science Foundation of China and support from CAS for related research. Gradually, experts in field observation, lab simulation and modeling from within and outside the lab gathered together to constitute a team dedicated to haze study. In September 2012, their study on the "Formation Mechanism and Control Strategies of Haze in China" was officially launched as a strategic priority research program under CAS' Innovation 2020 framework.

According to Prof. HE, the ten-year-long program is going to focus on fine particulate matter (PM2.5) — the prime culprit of haze in China — to investigate how it emerges, evolves and can be reduced. Via controlled experiments, field observations and numerical simulations, scientists will identify the types and sources of key pollutants, unravel the different formation mechanisms of haze in different parts of China, and develop a suite of source-control based technologies for the monitoring, forecasting and management of haze. The study will cover three major economic centers in China: the Beijing-Tianjin-Hebei region in the north, the Yangtze River Delta in mid-east, and the Pearl River Delta in the south.

The choked capital city: some primary results

For the first half of the program, the scientists will focus on Beijing and surrounding cities because the haze in this area is among the worst in the country.

According to their study, throughout January, the region suffered from a series of strong haze pollution with air quality index hiking to exceed 500 mg/m^3 from time to time, which was far above the "heavily polluted" line. For May, government statistics showed that only for eight days had Beijingers breathed in safe-quality air, compared to an 18-day national average.

Talking about Beijing's plight, Prof. HE considered its situation "rather tough" due to a number of natural disadvantages. In terms of landform, Beijing is surrounded by mountains on three sides, making it difficult for pollutants to be blown away quickly. It also has to suffer from sand and dust storms coming from northwestern deserts.

(Left) CAS Vice President DING Zhongli (second from left) paid a visit to the Longtanhu observation station in southeast Beijing in April 2013. Also present were (from left) Prof. HE Hong, Prof. WANG Xiaoke (the station's director) and Prof. WANG Yuesi. **(Right)** Air sampling devices are installed on the roof of the cabin. (Photo courtesy Prof. HE Hong)

Study showed that the rare meteorological condition around January was a decisive trigger of the event. "The haze was induced by a sudden warming of stratosphere in northern hemisphere high latitudes, a rare phenomenon that happens for no more than five times in thirty years," Prof. HE quoted a report of his colleagues as saying.

In a calm weather, the weak air flow and atmospheric temperature inversion will remarkably reduce air circulation, which is unfavorable for the dispersion of pollutants, he explained. The pollutants are then trapped in between to go through a series of complicated reactions and transform from gas state to particulate matter.

Of course, the region's energy structure is first and foremost to blame for the choking air. As Prof. HE noticed, each of the neighboring provinces including Hebei, Shandong, Shanxi and Inner Mongolia are burning hundreds of millions of tons of coal every year.

Meanwhile, vehicle emission has become a big source of fine particulate matter. With the rapid development of the auto industry in the area, the number of cars registered in Beijing has surpassed five million and is still in quick increase.

"As far as Beijing is concerned, our analysis showed that vehicles are the biggest source of PM2.5, accounting for about 25% of the pollution. Then it's coal combustion and cross-regional transfer, each accounting for 20%. Besides, the contribution of oil volatilization and commercial cooking have grown notably", according to Prof. WANG Yuesi, a researcher from the CAS Institute of Atmospheric Physics who chairs the field observation group of the haze program.

Based on air sampling and component test, scientists detected not only a host of major pollutants such as PM2.5, PM10, O_3, SO_2, NO_x and CO, but also other pollutants like ammonia, which was "much higher than expected, which we speculated to have something to do with stock raising," Prof. HE revealed.

"If Beijing and the surrounding region cannot take effective actions to cut anthropogenic emissions, they are bound to suffer from more serious hazes in the near future", he warned.

Working together for innovation

Five work groups have been established under the program to help achieve its overall goals.

Among the five, the laboratory simulation group will mimic the processes of atmospheric pollution in smog chambers to observe how gaseous pollutants evolve into haze-causing particulate matter and how atmospheric oxidability affects the process. The field observation group will collect and analyze air samples to trace the haze to its sources. These two groups are mutually complementary and their results are supposed to match up with each other toward a final conclusion. Based on lab simulation and field observation, researchers of the numerical simulation group are responsible for modeling the haze through mathematical calculation.

Lab simulation will be headed by Prof. HE together with Prof. WANG Xinming from the Guangzhou Institute of Geochemistry, while field observation and numerical simulation will be carried out under the leadership of Prof. WANG Yuesi and Prof. WANG Zifa from the Institute of Atmospheric Physics.

At the same time, Prof. LIU Jianguo from the Anhui Institute of Optics and Fine Mechanics will conduct a team to develop homemade facilities to support lab simulation and field observation.

Last but not least, a group led by Prof. CHEN Yunfa from the Institute of Process Engineering will be dedicated to exploring cutting-edge technologies for source-based pollution reduction, highlighting coordinated control of multiple pollutants, such as an integrated solution to desulfurization, denitrification and dust removal for power plants.

As chief commander of such an ambitious program, Prof. HE was well aware of the challenges ahead. To him, the biggest difficulty is innovation, both methodologically and technologically, since there are no ready-made experiences or practices to learn from.

"How can we achieve effective simulation in the lab? How to screen massive observation data and achieve source apportionment? How to obtain a reliable source inventory and source spectrum? I mean, there are so many questions we've got to think about before we start," the professor obviously had a sea of questions on his mind.

"We've set out to tackle fine particulates in car exhaust. We also want to use photo-catalysis to manage the pollutants that are already spread out wide in the atmosphere."

Prof. HE's lab at the CAS Research Center for Eco-Environmental Sciences simulates how haze is formed and can be controlled through catalysis. (Photo: BCAS)

The program's success largely rests with whether the "modeled" (from lab simulation) and the "measured" (from field observation) eventually agree with each other and point to a common convincing conclusion, telling what is actually happening in China's sky, he said.

Another big challenge for Prof. HE is how to make such a big consortium work. There will be over 300 scientists and engineers participating in the program. They come from different disciplines and institutions, including 16 CAS institutes and more from outside the Academy.

"It will certainly take some efforts to coordinate, but it's also very exciting and inspiring to have people from different backgrounds working together and learning from one another. I believe collaboration is not only the key to our program but helpful for all scientists involved. I'm really looking forward to it," he smiled confidently.

Curbing NO_x emission from diesel exhaust: a policy priority

In Prof. HE's eye, the Chinese government has paid great attention to the study and control of air pollution, all the way from the acid rain in the 1960s and photochemical smog in Lanzhou in the 1970s to today's haze problem. Although the haze has brought about much debate, China's achievement is still "quite remarkable".

"Despite China's massive coal consumption, we can now observe some emission curves at their inflection point toward a downward shift."

For instance, the emission of sulfur dioxide reached its peak in 2010 and has been steadily declining ever since. "It's outstanding, especially when you realize the use of coal is still going up rapidly. To achieve this, China has demanded all new power plants to install desulfurization facilities and helped existing ones with their reconstruction or upgrading."

PM10 is also under control through extensive forestation and reforestation. Although desertification and sandstorms are still big concerns for north China, things are taking a good turn in the rest of the country.

Unfortunately, in contrast to the reduction of sulfur dioxide and PM10, nitrogen oxides (NO_x) have been adding up fast by a 30% rise over the past decade.

According to Prof. HE's latest research results, the accumulation of NO_x can remarkably increase the oxidability of the atmosphere. This in turn gears up the conversion of sulfur dioxide to particulate sulfates and

thereby facilitates the formation of PM2.5 and the haze.

"In some sense, the increase of NO_x has offset the government efforts in improving China's air quality," he acknowledged.

As he pointed out, the NO_x problem in fact arose from one of China's pollution control policies, which has long prioritized desulfurization before denitrification. Now that the government has come to realize the importance of denitrification, new power plants and factories are required to equip denitrification facilities before they start operation.

But unlike desulfurization, upgrading existing power plants for denitrification purpose is very costly and impractical due to technical reasons. "It may take years to see a distinct drop in NO_x emission from heavy industry," he noted.

Eventually, the control of vehicle exhaust, which is the second largest emission source of NO_x and biggest source of PM2.5, emerged as an immediate and promising answer to the problem.

According to Prof. HE, among all types of vehicles, diesel cars have the highest potential for pollution reduction, because "the current China-III emission standard for diesel exhaust has a high tolerance for NO_x release. Compared with a gasoline car, a diesel car in China is chucking out much more NO_x."

Although the Chinese government has adopted a conservative attitude toward the development of diesel-engined passenger cars, the country's need for high burning efficiency diesel trucks never diminishes. For China, the purification of diesel exhaust is a must.

What upset Prof. HE was that their NO_x reduction techniques wouldn't be applied to diesel vehicles until the China-IV emission standard comes into effect, and the introduction of the new standard has been postponed twice because "some big energy enterprises have been making up reasons to postpone improving their fuel quality to corresponding level. It's really disappointing," the professor seemed frustrated.

"Developing state-of-the-art treatment devices for NO_x and particulate matters in diesel exhaust is on the top of our agenda for the next few years."

Vehicle exhaust control could have been the most immediate solution to China's air pollution problem. China aims to reduce its NO_x emission by 10% by 2015 compared with 2010, but with such strong obstacles the goal seems very challenging. It may also undermine the enforcement of the country's new anti-pollution measures, which was announced in mid June by the State Council to cut air pollution by 30% in heavy-polluting industries by 2017.

Exhaust control alone is not enough, of course. For Beijing, more coordinated action with the neighborhoods is essential if it is to win the battle against air pollution.

"Since 30-40% of Beijing's PM2.5 came from cross-regional transfer, its success in the anti-haze campaign is much dependent on the performance of its neighbors like Tianjin, a big industrial polluter and Hebei, one of the nation's largest coal consumers. It's vital that local governments break administrative barriers to work hand in hand," Prof. HE hoped.

Breathing is our one common constant. Therefore, it is urgent to improve the nation's air quality. But like the old saying goes, Rome wasn't built in a day. The pollution that has been accumulated from over 30 years of rapid economic growth will not be cleaned up overnight. In the long run, by gradually cutting fossil fuel consumption and boosting industrial restructuring, China will find a healthy and sustainable way to carry on, and fulfill its responsibility to the world. Let's keep our fingers crossed and eyes open wide to see.

The capital city of Beijing was blanketed by hazardous haze throughout January 2013, as a result of special air conditions, regional industrial development and a soaring number of cars — five million and rising — running in Beijing's streets. (Photo: Internet)