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Fuel quality management versus vehicle emission control in China, status quo and future perspectives

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HIGHLIGHTS

- We summarize China's standards for vehicle emissions and fuel quality and the interaction.
- We outline the mechanism that China uses to establish its fuel quality standards.
- We illustrate the gaming of stakeholders in fuel standard formulation and fuel supply.
- Fuel quality data of 59 gasoline and 59 diesel samples across China are presented.
- Policy suggestions for China's fuel quality improvement in the future are provided.

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ABSTRACT

China's fuel quality standards and fuel supply management have long been an impediment to improved air quality by hindering the progress of vehicle emission control. This paper summarizes the status of China's fuel quality standards, fuel supply and vehicle emission standards focusing on the major problems of fuel quality management. The mechanism that China uses to establish its fuel quality standards is outlined. The gaming of stakeholders such as regulatory authorities, vehicle and engine manufacturers and the gigantic state-owned oil companies in the development of fuel quality standard formulation and fuel supply is illustrated. Results are presented from testing 59 gasoline samples for sulphur, olefins, aromatics, benzene, and manganese content and from testing 59 diesel samples for sulphur and poly-aromatic hydrocarbons collected across the country from 2010 to 2011. This paper also provides key policy suggestions to improve future fuel quality in China. China should improve fuel quality through the application of policy measures such as adjusting the fuel quality standard formulation process, introducing competition and enforcing the transition period for improved fuel introduction, unifying on-road diesel and non-road diesel fuel quality standards, and pay attention to issues like fuel detergent, methanol addition and evaporative emissions.

1. Introduction

1.1. Vehicle emission situations

The well-publicized serious haze pollution in central and eastern China each winter season since 2012 has put a spotlight on vehicle emissions and fuel quality problems. Oil giants like China Petroleum & Chemical Corporation (Sinopec) and PetroChina Company Limited (PetroChina) were criticized by the media (Xinhua News Agency, 2011; Caixin Online, 2011) and environmental protection sector (Yue et al., 2012a, 2013; Yue, 2012) for the stagnation of improving fuel quality around 2010 since they were seen as a monopoly and substantially control the formulation of fuel quality standards and fuel supply without being mindful of environmental protection needs associated with fuel quality improvement. As China has been leading the world's vehicle production and sales since 2009, vehicle emissions have been considered as one of the major contributors to such pollution. In 2013

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China produced and sold more than 20 million vehicles (Xinhua News Agency, 2014b). The population of motor vehicles was 250 million by the end of 2013, including motorcycles and low speed vehicles (like agricultural vehicles) (Xinhua News Agency, 2014a). In 2012, China consumed 476 million tons of oil, among which 56.4% was imported (NDRC, 2013b). The vehicle population explosion has resulted in substantial pollution. In 2012, China's on-road vehicles emitted 40.19 million tons of carbon monoxide (CO), 5.83 million tons of nitrogen oxides (NO_X), 4.82 million tons of hydrocarbons (HC) and 0.59 million tons of particulate matter (PM) (MEP, 2013). To cope with air pollution countrywide, China's Twelfth Five-Year Plan (i.e., 12th FYP) requires a mandatory NO_X emission reduction of 10% for the period of 2011–2015. Vehicular NO_X emissions are estimated to account for about 30% of national anthropogenic NO_X emissions (Wu et al., 2012). Given that China's Twelfth Five-Year Plan (i.e., 12th FYP) requires a mandatory NO_X emission reduction of 10% for the period of 2011–2015, further substantial emission reductions of vehicular NO_X emissions are therefore required (Zhang et al., 2014a, 2014b). Furthermore, early in 2012, the State Council approved the promulgation of China's new National Ambient Air Quality Standards (NAAQs), which set $PM_{2.5}$ as a new pollutant to be regulated, and tightened limits for PM_{10}, NO_2 and ozone (O_3) (Wu et al., 2012; Zhang et al., 2014a). Since vehicle emissions are closely related to all of these pollutants and as high vehicle emissions occur mostly in densely populated urban areas and economically well developed areas, they have become one of the most conspicuous and substantial problems for China's atmospheric environment.

1.2. Vehicle emission standards and fuel quality standards in China

In order to control vehicle emission pollution, China has implemented vehicle emission standards and fuel quality standards before year 2000 and afterwards tightened the standards every 3–5 years. In less than 13 years, vehicle emission standards in China have evolved from China 1/I to China 5/V. They are mostly equivalent to Euro 1/I to Euro 5/V, respectively (Euro1/I=Euro 1 light-duty vehicles/and Euro I heavy-duty vehicles). The China V standard was initially scheduled to be implemented about 2012–2013. However, the poor fuel quality, particularly high sulphur content of vehicle diesel, makes this impossible. Actually, fuel quality has been a major obstacle in the effort to reduce vehicle emissions for some time.

The worldwide "auto-oil" programs, regardless of their versions, conclude that vehicle and fuel shall be treated as a total system, i.e. in order to effectively reduce vehicle emissions, we have to improve fuel quality while upgrading the emission control technologies of the vehicle which are often sensitive to the fuels. In Europe, Japan and the United States, fuel quality standards correspond to vehicle emission standards at each control stage and the required fuel is usually supplied before the implementation of vehicle emission standards. For example, European regulations have required the supply of gasoline and diesel meeting regulatory requirements ahead of emission standard implementation since Euro I (The Council of the European Communities, 1993); Japanese law requires the supply of "Euro 5/V" fuels starting in 2008/2007 (METI, 2007) and its petrochemical industry advanced this date to 2005 by JIS standards (JISC, 2004a, 2004b), 1 year earlier than the deadline. Different from these practices, China's fuel quality standards and particularly the availability of required fuel supply have lagged behind vehicle emission standard requirements, especially for diesel fuel. Due to poor diesel fuel quality, emission standards for China IV diesel vehicles were postponed twice until July 2013, two years later than the initially scheduled date (i.e., July 2011) (MEP, 2010, 2011a). Even after the postponement, the diesel fuel quality is still at China III levels, with a maximum sulphur content of 350 ppm, except for very few cities (e.g., Beijing) (Zhang et al., 2014c).

1.2.1. Light-duty vehicle emission standards and gasoline fuel quality standards

China has implemented its vehicle emission standards in national wide since 2000. As shown in Table 1, the national standards series (i.e., GB18352) (SEPA and AQSIQ, 2001a, 2001b, 2005a) regulate light duty vehicle emissions. The GB18352 standards series require emission standards for light-duty vehicles from the China 1 to China 4 to be effective on July 1, of 2000, 2005, 2008 and 2011, respectively. Recently, after two rounds of public opinion solicitation, the China 5 emission standards (MEP and AQSIQ, 2013) for light duty vehicles were promulgated on September 17, 2013 and will take effect in 2018 nationwide, leaving the possibility of implementing the vehicle emissions standard ahead of the nationwide deadline for vehicles if conditions needed for implementation are met at local levels (e.g., Beijing, Shanghai).

The major national fuel quality standards started with the elimination of lead from gasoline about 1999 to 2000. A national environmental protection standard GWKB1-1999 hazardous materials control standard for motor vehicle gasoline (SEPA, 1999) led the phase out of lead in gasoline and regulated the environmental protection requirement for gasoline, such as requiring the addition of detergent additives. The national "China 1" gasoline standard (GB17930-1999 (AQSIQ and SAC, 2006)) for motor vehicles (NQTSB, 1999) promulgated later in 1999 followed most of the environmental requirements of the GWKB standards (see the footnote of Table 1). The national standard requires lead content to decrease from 0.013 g/L to 0.005 g/L and no lead should be intentionally added into the fuel. Sulphur content was required to decrease from 1500 ppm to 1000 ppm nationwide beginning in January 1, 2000. Gasoline with sulphur content below 800 ppm should be supplied to Beijing, Shanghai and Guangzhou from January 1, 2000 and countrywide from January 1, 2003. The actual supply of 800 ppm sulphur content gasoline countrywide took place from July 1, 2003, 6 months later than the required starting date. The time delay of 6 months is called "transition period" and is used to accommodate the change-over for the entire supply chain from fuel meeting previous standards to the new standards. The transition period is actually nominal, i.e. no required fuel is really supplied. Such transition periods exist throughout the whole gasoline and diesel fuel supply process up to now, only except for the China 2 gasoline standard requiring the sulphur content lower than 500 ppm that was implemented from July 1, 2005. The China 3 gasoline standard (GB17930-2006) was promulgated on December 6, 2006 and came into force on the same day. It requires the sulphur content to be lower than 150 ppm, with a transition period until December 31, 2009. The actual supply of China 3 gasoline countrywide took place from January 1, 2010, with 9 provinces or so further delayed for another 6 months. The China 3 emission standard for light duty gasoline vehicles was implemented on July 1, 2008. The fuel supply for it was provided about 1.5–2 years later.

In view of such delays of fuel quality standards and supply, the Ministry of Environmental Protection (MEP) promulgated environmental protection standards (i.e., the GWKB standards) for gasoline, regulating the implementation of China 4 and 5 stages (MEP, 2011b). It was promulgated on February 14 and came into force on May 1, 2011. It sets the limits for gasoline fuel constituents such as sulphur, lead, iron, manganese, phosphorus, copper, methanol, benzene, olefins, and aromatics. In view of the climate characteristics, it regulates that vapour pressure for tropical areas of Guangdong, Guangxi and Hainan requiring they use summer limit vapour pressure all year round while the remaining areas use summer and winter vapour pressure limits. It also requires adding