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Motor vehicle diesel fuel quality compliance and enforcement in China: A look at the status quo and international best practices

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Background and objective

In response to a severe air pollution problem, China has implemented a series of comprehensive vehicle emission control policies. Among them are the China 6 light-duty vehicle (LDV) and China VI heavy-duty vehicle (HDV) emission standards, which take effect on July 1, 2020 and July 1, 2021, respectively. The China 6/VI standards combine best practices from both European and U.S. regulations and are considered among the most stringent emission standards in the world for the post-2020 timeframe.

The successful implementation of the China 6/VI emission standards will depend on several key factors, including the quality of motor vehicle fuels available. Better fuel quality reduces pollutants from fuel combustion directly and, more importantly, enables the use of effective exhaust aftertreatment technologies such as diesel particulate filters (DPF; Fung, 2011).

Following the path set by Europe, China's fuel quality standards have been gradually strengthened since 2000. The China V diesel quality standard has been in effect since 2017 and limits sulfur content to 10 parts per million (ppm). However, compliance with this standard remains a challenge in some regions. Some private fuel stations are still supplying non-compliant diesel fuel, especially in rural-urban continuum areas.

This working paper provides an overview of the current status of motor vehicle diesel fuel quality compliance in China. We also summarize international best practices and explore policy approaches that can improve China's diesel fuel quality compliance and enforcement programs.[1] To inform this work, we collected and summarized publicly available information regarding fuel quality from government agencies, research articles, and news reports.

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1 This paper only focuses on motor vehicle fuels. Marine fuels are outside of the scope.

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The rest of this paper is organized as follows. The next section summarizes sulfur's impact on emission control technologies, and then the current status of China's fuel quality compliance program is described. Following that, international best practices are detailed. The final section discusses findings and provides suggestions for improving policy.

The impact of sulfur on emission control technologies

Reducing the amount of sulfur in fuels can reduce vehicle emissions by directly reducing the sulfur dioxide (SO_2) and sulfate particulate matter (PM) that gets combusted. Less sulfur in the fuel also means better performance from vehicle aftertreatment systems and enables the use of new emission control technologies such as DPF. Indeed, using low-sulfur fuels can dramatically reduce emissions of all pollutants, and this greatly reduces the impact of vehicles on human health, the environment, and global climate (Blumberg, Walsh, & Pera, 2003).

Table 1 presents a summary of diesel emission control technologies that are impacted by the sulfur content of fuels. In summary, the sulfur content should be below 15 ppm to enable the effective use of these diesel emission control technologies.

Table 1. Diesel emission control technologies and the sulfur levels required for each technology

Technology	Pollutants targeted	Fuel sulfur levels	Benefits
Diesel oxidation catalyst (DOC)	PM, hydrocarbon (HC), carbon monoxide (CO)	Below 150 ppm required. Below 50 ppm recommended.	Reductions of 90%–100% for HC and 88%–99% for CO. Reductions of 15%–31% for PM with use of less than 50 ppm fuel.
Diesel particulate filter (DPF)	PM, HC, CO	Below 50 ppm required. Below 15 ppm highly recommended.	Reductions of 90%–99% for PM with use of less than 15 ppm. Efficiency drops to ~50% with 50 ppm. Reductions of 58%–82% for HC and 90%–99% for CO.
Nitrogen oxides (NO_x) absorber	NO_x	Below 15 ppm required.	Reductions of 78%–94% for NO_x
Selective catalytic reduction (SCR)	NO_x	Below 50 ppm required.	Reductions of 80%–90% for NO_x

Overview of the fuel quality control program in China

Laws

The New Clean Air Law, revised in 2015, gave the Ministry of Ecology and Environment (MEE) clear authority to formulate and implement ambient air quality standards and vehicle emission standards for air pollutants. Additionally, the Law states that "fuel quality standards shall comply with the national air pollutant control requirements and be linked to the national vehicle and non-road mobile machinery emission standards and implemented simultaneously."

Historically, the State Administration for Market Regulation (SAMR, formerly the General Administration of Quality Supervision, Inspection and Quarantine) and the Standardization Administration of China (SAC) have been in charge of formulating and implementing fuel quality standards. According to the New Clean Air Law, SAMR has the authority to enforce fuel quality standards. Refineries that produce non-compliant fuels and fuel stations that sell non-compliant fuels are subject to a fine of more than one time but no more than three times the value of the goods.

The MEE does not have the authority to create or enforce fuel quality standards, and it has repeatedly failed to coordinate with the SAMR and SAC to implement fuel quality standards in concert with vehicle emission standards (Yue et al., 2015). For example, the China IV emission standard was delayed for 30 months, from January 1, 2011 to July 1, 2013, because of an inadequate supply of qualified diesel fuel on the market.

Table 2 summarizes the agencies that are in charge of vehicle emission standards and fuel quality standards under the New Clean Air Law.

Table 2. Agencies and their authorities under the New Clean Air Law

Authority	Agency
Formulation and enforcement of emission standards of air pollutants	MEE
Formulation of fuel quality standards	Not clear
Enforcement of fuel quality standards	SAMR

Regulations

China's fuel quality standards follow the path created by Europe's standards. Since 2000, fuel quality standards in China have been gradually strengthened. Figure 1 gives an overview of the sulfur content limits and implementation timelines of fuel quality standards in China.

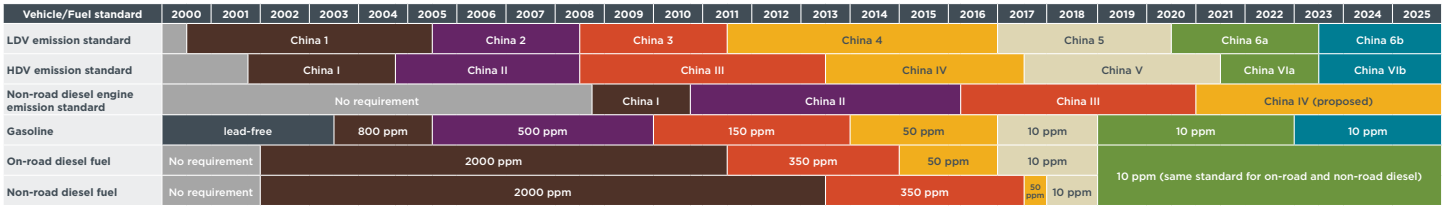

Figure 1. Sulfur content limits and implementation timelines of fuel quality standards in China

Leaded gasoline was banned nationwide in 2000. The limit on the sulfur content of gasoline was reduced from 1,500 ppm in 1999 to the current level of 10 ppm under the China VI standards. Other key properties regulated under the China VI gasoline standard include research octane, motor octane, anti-knock index, benzene, aromatics, olefins, T50, washed gum content, density, lead, manganese, oxygen, and Reid vapor pressure. For diesel, the limit on the sulfur content of on-road fuel was lowered from 2,000 ppm in the China I standards to the current level of 10 ppm in China VI. Key properties of diesel regulated under China VI include sulfur content, polyaromatics, cetane number, density, flash point, ash content, viscosity, polycyclic aromatic hydrocarbons, and total pollutant content.

For diesel fuel used for off-road machinery, sulfur levels were set in a separate national standard than the one for on-road vehicles. In the past, non-road diesel fuel quality lagged significantly behind the diesel quality for on-road vehicles. The non-road diesel or general diesel has higher sulfur content, lower cetane, and poorer lubricity than on-road diesel. Both types of diesel were available on the market at the same time, and this left room for the use of non-road diesel in on-road vehicles (Yue et al., 2015). In 2018, the China State Council released a National Plan of Blue-Sky Defense, and it required the abolition of the general diesel standard and the alignment on-road and non-road diesel standards (China State Council, 2018). Accordingly, on November 26, 2018, SAMR and SAC abolished the general diesel standard (SAMR & SAC, 2018). As of January 1, 2019, only diesels that are compliant with the China VI fuel quality standard are allowed to be sold in China.

Fuel quality compliance programs

Note that the fuel quality compliance program carried out by SAMR is a voluntary program. Additionally, regional AMR agencies typically conduct regular inspections in their provinces, but this is not mandatory, and some remote areas or inner provinces seldomly carry out supervision and inspection on fuel quality.

The central and local AMR agencies that carry out annual fuel quality inspections typically do so as part of product quality inspection programs. Fuel samples are collected from refineries or fuel stations, and compliance rates and the names and locations of fuel stations that supply non-compliant fuels are published in a summary report available to the public. However, detailed test results such as sulfur content levels are not revealed.[2] In the past, refineries that were found to have produced non-compliant fuels and fuel stations that were found to have sold non-compliant fuels were not heavily penalized because China lacked fuel quality compliance legislation. Violating refineries and fuel stations were simply ordered to stop producing and selling the non-compliant fuels.

National testing protocols for diesel and gasoline fuel are available for regional AMR agencies to follow when they conduct supervision and inspection (SAMR, 2011b; SAMR, 2015b). The test protocols specify the sampling method, handling method, items to be tested, whether testing of these items is mandatory or voluntary, testing method, rules regarding how results are determined, rules regarding how to handle contested results, and retest method.

According to the national protocol, the stations from which samples are taken should be selected randomly. When sampling from a refinery or fuel station, 6 liters of sample fuel should be collected. From that, 4 liters is used for testing, and the other 2 liters is sealed as a back-up sample. When sampling from a fuel station, samples should be collected directly from the oil gun. The sampling process should be witnessed by a representative from the refinery or fuel station. Then the associated documents detailing the test should be confirmed and signed by the representative of the refinery or fuel station and the sampler. Twenty fuel properties for gasoline and 19 properties for diesel are listed as items for testing. If any one of the properties is not compliant with national fuel quality standards, the sample is considered as a fail. If non-compliance is found, the fuel station or refinery has the right to request a retest of the second sample. Non-compliance will be investigated and penalized according to the law.

Other details such as when the testing should be done, how many fuel stations and refineries to test, and how many of the facilities tested should be private or state-owned, are not specified in the testing protocol. Each province or city may develop its own supervision and inspection plan based on the national rules. Some provinces and cities, such as Beijing and Guangdong, have released their own testing protocols and plans for motor vehicle fuel quality supervision (Beijing AMR, 2019a and 2019b; Guangdong AMR, 2019).

According to Guangdong's protocol, sampling should be conducted jointly by an AMR officer and a sampler from a certified laboratory. For each batch sampled at a fuel station, two samples should be collected. The first sample is used for testing, and the second sample is sealed and kept as a back-up for later testing, if needed. When sampling at a refinery, two sets of samples should be collected from the same batch of fuel product and both should be taken back to the laboratory. The first sample is used for testing and the second one is sealed as a back-up. Mandatory items to test include 12 properties for gasoline and 13 properties for diesel under China VI gasoline and diesel standards. If any one of the 12 or 13 properties is not compliant with China VI standards, the fuel sample is considered as a fail.

2 Compliance rate indicates the percentage of sampled products that are compliant with the standard.

The supervision and inspection plan in Beijing is similar, but there are some additional details about the sampling method. For example, all products from a refinery should be sampled. Additionally, the liquid level of the oil tank should be at least 1 meter high when sampled. The sampling process should be witnessed, and the associated documents should be signed by three parties—a representative from the refinery or fuel station, a sampler from the certification lab, and an officer from the AMR. In Beijing, 20 properties for diesel and 20 properties for gasoline are mandatory items to test for compliance.

These compliance programs do not appear to be working well in some regions in China. A random check conducted by the MEE showed that the diesel compliance rate of private fuel stations in Jing-Jin-Ji and surrounding areas was less than 50%, and the compliance rate of diesel extracted from truck tanks was even less than 10% ("Green Focus," 2018). Independent investigations by third parties and research organizations also showed that diesel quality was a serious problem, especially in private fuel stations (Yue et al., 2015).

In January 2019, 11 Chinese central agencies, led by the MEE, launched a Clean Diesel Action Plan to substantially clean up diesel-powered transportation fleets, including on-road diesel vehicles, off-road diesel equipment, and shipping engines (MEE, 2018). The plan is a critical component of the broader National Plan of Blue-Sky Defense. The Clean Diesel Fuel Program, as one of the four programs in the Clean Diesel Action Plan, calls for strengthening the supervision of fuel quality throughout the supply chain, including during refining, storage, distribution, retail, and usage. The Clean Diesel Fuel Program targets a compliance rate of 95% nationwide for diesel fuel quality and 98% for diesel emission fluid (urea) in key regions by 2020. To achieve this goal, China plans to establish a supply chain supervision program for diesel fuel and urea, strengthen random checks at retail stations and from the fuel tanks of vehicles, and carry out special campaigns against violating fuel stations. This work is led by SAMR, the National Development and Reform Commission, the Ministry of Commerce, the Ministry of Transport, and the MEE.

The Vehicle Emission Control Center (VECC) of MEE, which is in charge of vehicle emission control policies, occasionally hires third-party consultants to conduct fuel quality inspections for policymaking purposes. Research institutes such as the China Research Academy of Environment Science (CRAES) and Tsinghua University have been carrying out surveys of fuel quality in China, mainly for research purposes. Some vehicle manufacturers also hire third-party consultants to conduct fuel quality surveys as a way to understand the current fuel supply in China, but the results are usually kept confidential. This section summarizes publicly available information on the results of fuel quality compliance tests, and Table 3 summarizes the current fuel quality compliance programs and lead agencies, as well as the sampling and testing details.

Table 3. Summary of fuel quality compliance tests

Lead organization	Purpose	Frequency	Legal basis	Approach	Fuel specifications	Penalty for non-compliance
AMR	Enforcement	Periodic, at least once a year	By clean air law	Random check at refineries and fuel stations	All properties required by regulation	Stop producing and selling the products. Subject to a fine.
MEE	Policymaking	Random	By clean diesel action plan	Random check mainly at fuel stations or truck fuel tanks	Key properties, usually less than AMR	No authority for enforcement
Research institutes	Research	Random	No	Random check at fuel stations	Key properties, usually less than AMR	No authority for enforcement
Third-party consultants	Market research	Random	No	Random check at fuel stations	Key properties, usually less than AMR	No authority for enforcement

Results of compliance programs

Results of periodic tests by SAMR

Figure 2 summarizes the national average compliance rate of gasoline and diesel fuels from 2009 to 2017 in China. The average compliance rate of each was above 90% from 2009 to 2017. The only exception is that the compliance rate of gasoline was 88% in the year 2013. In the most recent four years covered in the chart, the compliance rates stayed at a stable level above 96%.

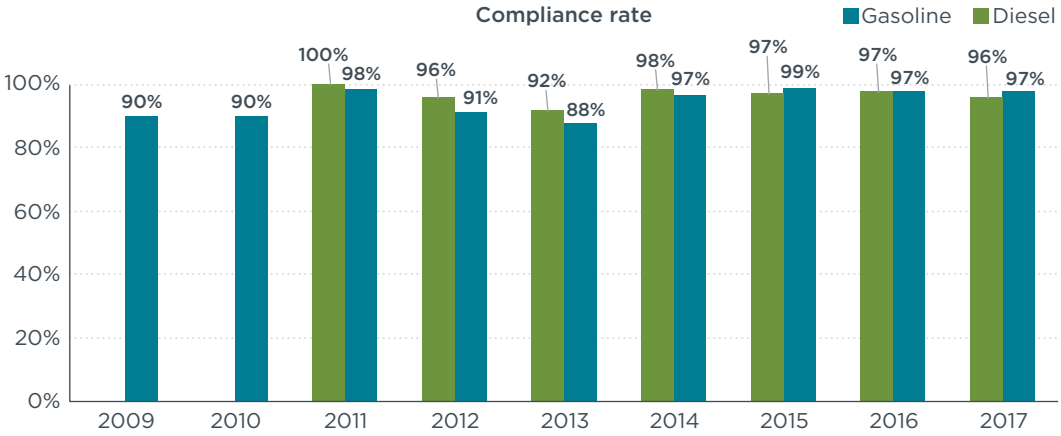

Figure 2. National compliance rate of gasoline and diesel from 2009 to 2017 in China. *Source:* SAMR

Figure 3 presents the compliance rate of gasoline and diesel by region. The data were collected from local AMR websites and most results are for 2017. For some provinces the data for 2017 was not available and results of the most recent year were used instead. For provinces where no compliance rate data was available, e.g., Heilongjiang province, the number of non-compliant fuel products is presented. The inner ring of the circle represents the compliance rate for gasoline and the outer ring represents the results for diesel. As shown, the compliance rates of the vast majority of the provinces was above 90%. Moreover, there were 12 provinces that had a 100% compliance rate for both gasoline and diesel. However, it should be noted that it is challenging to compare the fuel quality results by region since the number of samples varied widely. For example, only 18 fuel samples were collected in Shaanxi province, which had a 100% compliance rate; meanwhile, there were 1,440 samples tested in Jiangxi province, which had a compliance rate of 85%.

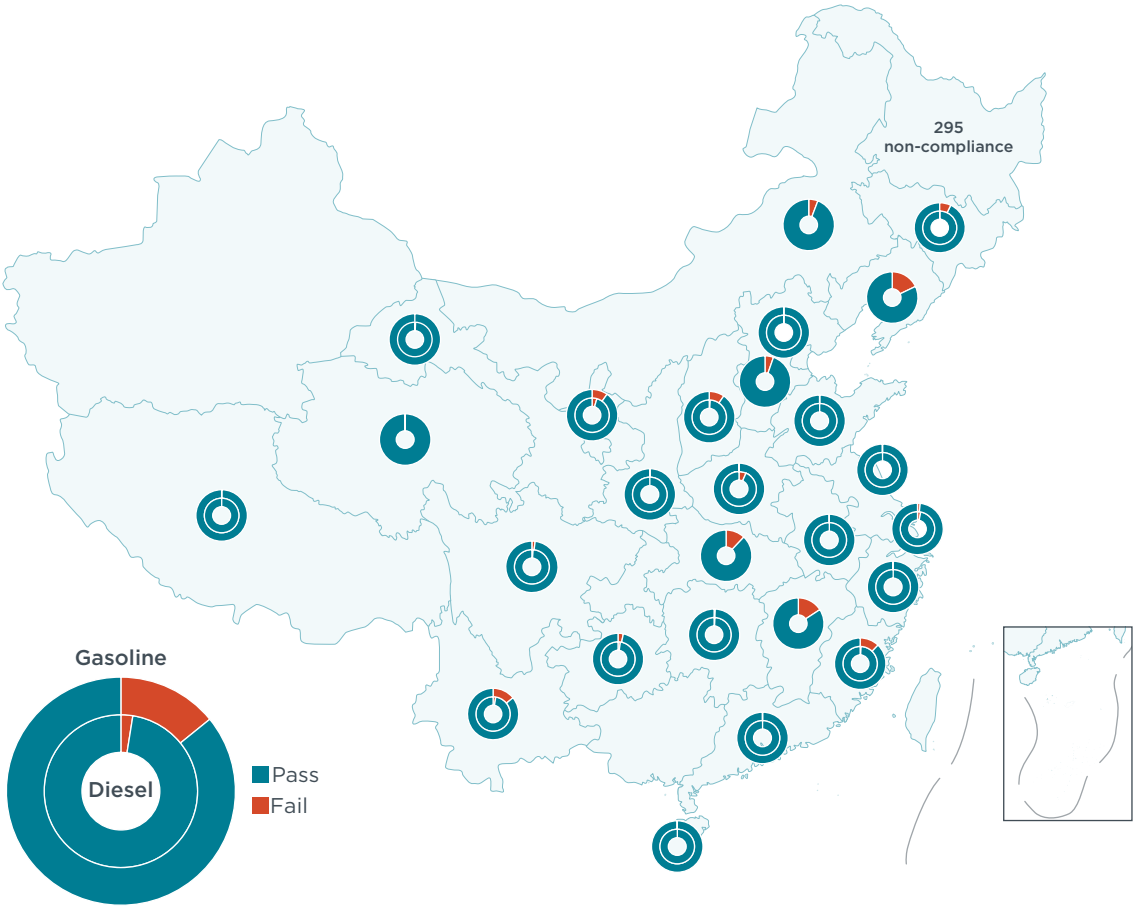

Figure 3. Regional compliance rate of gasoline and diesel in China, mostly for 2017. (*Source:* Regional AMR). The outer ring indicates the compliance rates for gasoline and the inner ring represents diesel. A single ring is used where separate compliance rates are not available, and where data for 2017 was not available, the most recent available year was used instead.

In the past, the violating refineries or fuel stations were not heavily penalized since China lacked fuel quality compliance and enforcement legislation. According to the summary report from the SAMR (2017), the non-compliant refineries and fuel stations were ordered to stop selling the non-compliant fuels; whether civil penalties were issued to violating companies was not disclosed.

Results of random tests by the MEE

In 2016 and 2017, VECC contracted with a third-party consultant company to conduct a fuel quality survey in three regions—Jing-Jin-Ji, the Yangtze River Delta, and 2+26 cities (i.e., Beijing, Tianjin, and surrounding cities). A random check was conducted at 216 fuel stations, including state-owned fuel stations and private fuel stations. Tables 4 to 6 present summaries of these three diesel fuel quality surveys (VECC, 2016a, 2016b, and 2017).

Table 4. Results of the fuel quality survey in 2+26 cities in winter of 2017

	Gasoline			Diesel							Urea
City	Private fuel station	Non-compliance	Compliance rate	Sino PEC	Non-compliance	Petro China	Non-compliance	Private fuel station	Non-compliance	Compliance rate	Compliance rate
Beijing	1	0	100%					3	0	100%	
Tianjin	1	0	100%					3	0	100%	
Langfang	1	0	100%					5	1	80%	
Shijiazhuang	1	0	100%	1	0	1	0	3	1	80%	
Cangzhou	1	0	100%					5	2	60%	
Baoding	1	0	100%					5	1	80%	
Tangshang	1	0	100%					5	2	60%	
Zhangjiakou	1	0	100%					4	4	0%	
Dezhou	1	0	100%					3	1	67%	31.25%
Jinan	1	0	100%	1	0	1	0	2	2	50%	
Zhengzhou	1	0	100%	1	0	1	0	2	1	75%	
Puyang	1	0	100%					3	2	33%	
Taiyuan	1	0	100%	1	0	1	0	2	2	50%	
Dtong	1	0	100%					3	1	67%	
Changzhi	1	0	100%					3	1	67%	
Erdos	1	1	0%					3	3	0%	
Total	16	1	94%	4	0	4	0	54	24	61%	

Table 5. Results of the fuel quality survey in the Jing-Jin-Ji region in winter of 2016

	Gasoline			Diesel		
City	Fuel station	Non-compliance	Compliance rate	Fuel station	Non-compliance	Compliance rate
Beijing	5	0	100%	10	0	100%
Tianjin	5	0	100%	10	2	80%
Baoding	4	0	100%	8	3	63%
Langfang	4	0	100%	8	3	63%
Cangzhou	4	0	100%	8	4	50%
Total	22	0	100%	44	12	73%

Table 6. Results of fuel quality survey in the Yangtze River Delta in summer of 2016

	Gasoline			Diesel		
City	Fuel station	Non-compliance	Compliance rate	Fuel station	Non-compliance	Compliance rate
Hangzhou	9	0	100%	3	0	100%
Jiaxing	7	0	100%	2	0	100%
Shaoxing	7	0	100%	4	1	75%
Huzhou	7	0	100%	3	0	100%
Ningbo	3	0	100%	1	0	100%
Jinhua	3	0	100%	1	0	100%
Quzhou	3	1	67%	1	0	100%
Shanghai	6	0	100%	3	0	100%
Suzhou	4	0	100%	1	0	100%
Wuxi	3	0	100%	1	0	100%
Wuhu	3	0	100%	1	1	0%
Xuancheng	3	0	100%	1	0	100%
Total	58	1	98%	22	2	91%

As shown in Tables 4 to 6, only 2 of 96 gasoline samples tested were not compliant. However, the quality of diesel fuels, especially from private fuel stations in the Jing-Jin-Ji area, was not good; the compliance rate was 61% in the 2+26 cities and 73% in the Jing-Jin-Ji area.

In 2018, the MEE carried out a fuel quality investigation program at 334 fuel stations in the Jing-Jin-Ji region and surrounding area. The overall compliance rate was 85.9%. On provincial roads and in country road areas, the compliance rate was lower, 70%. In three other provinces outside the Jing-Jin-Ji area, Shanxi, Shaanxi, and Inner Mongolia, 55 fuel stations were investigated, and the compliance rate was 67.3% (MEE, 2019a). Another random check by MEE showed that only 60% of the diesel fuel sampled from truck fuel tanks was compliant with the current fuel quality standards (MEE, 2019b). Since the MEE does not have the authority to enforce fuel quality standards, the investigations were used only for policymaking purposes and did not trigger follow-up enforcement actions against violating fuel stations.

Special enforcement campaigns against illegal fuel stations

Illegal fuel stations are fuel stations operating without any license, or with an incomplete or expired license. In most cases, the fuel sold at illegal fuel stations is not compliant with national fuel quality standards.[3] The non-compliant fuel may come from blenders who mix cheaper components such as heavy oil into normal motor vehicle diesel fuel, or from small and private refiners who produce poor quality fuels. The fuel sold at the illegal fuel stations is typically much cheaper than the market price for compliant fuels. Driven by the potential for large profits, illegal fuel stations have become widespread across China.

Beginning in 2017, national and local government agencies started carrying out special enforcement campaigns against illegal fuel stations. At the national level, the MEE together with SAMR, the Ministry of Public Security, and the Ministry of Commerce implemented a joint special campaign against illegal fuel stations in the Jing-Jin-Ji region and surrounding areas in 2019 (MEE, 2019b). The objectives included investigating fuel stations operating without a license, testing the sulfur content of diesel supplied at legal fuel stations, and tracking the source of the non-compliant fuels. In this special campaign, 1,466 fuel stations were found to be illegal. 40% of the illegal fuel stations were located in Hebei Province, 36% in Shandong Province, and 10% in Henan Province. In most cases, illegal fuel stations were located in residential areas, parking lots, or freight stations. Some illegal fuel tankers were disguised as rescue trucks, sprinklers, or moving trucks, and thus were difficult to discover. To achieve the second objective of testing diesel fuel quality from legal fuel stations, 19,552 samples of diesel fuel from 11,769 fuel stations were randomly taken and tested. The results showed that 4.5% of the samples had higher sulfur content than the regulatory limits. The sulfur content of the non-compliant diesel fuel was, on average, 25 times higher than the limit, and the worst diesel fuel exceeded the sulfur content limit by 902 times.

Local governments are also taking action against illegal fuel stations. Table 7 provides a summary of the provinces and municipalities that are conducting special campaigns against illegal fuel stations, the agencies that are in charge, and the number of illegal fuel stations that have been investigated and punished. For example, Shanghai launched a special investigation against illegal fuel stations in 2019. By July 27, 2019, 26 illegal fuel stations and fuel tanker trucks had been investigated and prosecuted. The sulfur content of the illegal diesel fuels was found to be as much as 120 times higher than the limit (Deng, 2019). In Henan province, a total of 2,056 violating fuel stations, 1,138 illegal fuel tanker trucks, and six illegal refineries were investigated and punished in 2018 (MEE, 2019a).

3 In some cases, illegal fuel stations may sell compliant fuels. They make profits by not paying the tax or not investing on safety facilities.

As shown in Table 7, different government agencies are in charge of fuel quality compliance and enforcement actions at the local level. In Henan, Shanxi, and Shandong, public security departments are taking the lead. In Fujian, Sichuan, and Guizhou, the local AMR is in charge. In some other provinces and cities, such as Shaanxi, Hunan, and Tianjin, the departments of commerce are taking enforcement actions against illegal fuel stations.

As discussed above, the New Clean Air Law does not specify which body of the national government has the authority to formulate fuel quality standards, but it gives SAMR the authority to issue civil penalties to refiners and fuel stations that produce or sell non-compliant fuels. The Clean Diesel Action Plan states that SAMR, the National Development and Reform Commission, the Ministry of Commerce, the Ministry of Transport, and the MEE are jointly in charge of the compliance and enforcement program of motor vehicle fuel quality. Historically, both the central SAMR and local AMR agencies have taken some responsibility for fuel quality inspections. But in practice, the division of responsibilities is not clear. Some local AMR agencies do not know that they are responsible for fuel quality compliance and enforcement. For example, the Shanghai Clean Air Action Plan (2018–2020) issued by the Shanghai municipal government explicitly specifies that Shanghai AMR is in charge of investigating illegal fuel stations. However, Shanghai AMR never carried out any special investigations against illegal fuel stations except for participating in one special action lead by the Department of Public Security. Moreover, Shanghai AMR received 44 complaint letters about illegal fuel stations in 2018, but it never undertook any investigations or enforcement actions (MEE, 2019c).

Table 7. A summary of provinces and municipalities conducting special campaigns against illegal fuel stations

Province/ Municipality	Department in charge	Number of illegal fuel stations found annually	Source
Tianjin	Department of Commerce	530 (in the first half of 2019)	Ministry of Commerce (2019)
Hebei	Joint enforcement by multiple departments	805 (as of October 2018) 4,474 (2017)	Zhang (2018) Liu (2018)
Shanxi	Department of Commerce	281 (as of October 2018)	Zhou (2018) Ren (2018)
Inner Mongolia	Administration for Market Regulation	2 in Huhhot (as August 2019)	Huhhot AMR (2019)
Liaoning	Joint enforcement by multiple departments. Lead by department of Public Security	10 in Shenyang (2019)	Su (2019)
Heilongjiang	Department of Commerce	26 (as of July 2017)	Liu (2017)
Shanghai	Administration for Market Regulation	26 (as of July 2019)	MEE (2019c)
Jiangsu	Joint enforcement by multiple departments	3,274 (as of November 2017)	Yao and Zhao (2017)
Zhejiang	Joint enforcement by multiple departments	45 in Hangzhou (as of July 2019) 200 in Ningbo (in the first half of 2019)	Zhu (2019) Li (2019)
Anhui	Joint enforcement by multiple departments	2,522 (from September 2017 to November 2017)	Bao (2017)
Fujian	Administration for Market Regulation	N/A	Fujian AMR (2019)
Jiangxi	Joint enforcement by multiple departments	N/A	Department of Commerce of Jiangxi Province (2019)
Shandong	Department of Public Security	N/A	Chai (2019)

Province/ Municipality	Department in charge	Number of illegal fuel stations found annually	Source
Henan	Department of Public Security	2,056 fuel stations 1,138 fuel tanker trucks 6 refineries (2018)	MEE (2019a)
Hubei	Department of Public Security	1,175 (as of September 2017)	Lei (2017)
Hunan	Department of Commerce	N/A	Department of Commerce of Hunan (2018)
Guangdong	Department of Industry and Technology Department of Public Security	N/A	Department of Industry and Technology of Guangdong (2018)
Guangxi	Joint enforcement by multiple departments	N/A	Guangxi Government (2017)
Hainan	Joint enforcement by multiple departments	N/A	Department of Commerce of Hainan Province (2017)
Sichuan	Administration for Market Regulation	N/A	Sichuan AMR (2019)
Guizhou	Administration for Market Regulation	N/A	Zhu (2019)
Shaanxi	Department of Commerce	34 (as of January 2019)	Cui (2019)
Gansu	Joint enforcement by multiple departments	N/A	Jiao (2017)
Qinghai	Administration for Market Regulation	34 (as of December 2018)	Peng (2018)

International experience and best practices

This section reviews the experience with fuel quality inspection programs in the United States, the U.S. state of California, Japan, and the European Union (EU). These countries and regions were selected because they have a high rate of compliance with fuel quality standards.

United States

The U.S. Environmental Protection Agency (EPA) manages a comprehensive fuel compliance program that combines fuel registration, fuel inspections, a fuel quality testing and reporting system, and stiff noncompliance penalties (Fung, 2011). The U.S. Clean Air Act gives the EPA the authority to regulate fuels and fuel additives for use in motor vehicles, motor vehicle engines, and non-road engine or non-road vehicles (EPA, 2019a). EPA's diesel standards require that after 2010, all highway diesel fuel supplied to the market be ultralow-sulfur diesel with a maximum sulfur content of 15 ppm.

EPA's fuel compliance program targets all parties in the distribution system, including refiners, importers, distributors, carriers, oxygenate blenders, retailers, and wholesale purchaser-consumers. Under the Clean Air Act, refiners and importers are required to register any motor vehicle fuel and fuel additive with EPA prior to marketing it. A list of registered motor vehicle fuel can be found on EPA's website (EPA, 2019b). Each batch of fuel must be tested by the refiner or the importer and all parties in the distribution system must conduct their own compliance checks. In addition, EPA randomly tests samples from refineries, truck loading terminals, retailers, and wholesale purchaser-consumers, and audits industry reports (Hart Energy, 2014).

Importantly, the compliance program places presumptive liability on refiners, importers, and other fuel handlers to demonstrate compliance through registration, fuel analysis,

and reporting. This means that when a violation occurs, the facility where the violation is found is deemed liable, as are all parties involved upstream.[4]

The Clean Air Act sets a maximum civil penalty of $37,500 per day per occurrence, and violators must also pay the amount of economic benefit or savings that resulted from the violation. The actual penalties are determined by EPA based on various considerations including economic benefits, business size, and the gravity of the violation (Fung, 2011). EPA's enforcement program has been successful and less than 1% of facilities are found in violation with fuel quality requirements.[5]

California

The California Air Resources Board (CARB) is in charge of the state's Motor Vehicle Fuels Enforcement program, which regulates the composition of motor vehicle fuels and ensures compliance with motor vehicle regulations (CARB, 2015). The Fuels Enforcement program is primarily responsible for enforcing reformulated gas and diesel programs and certification programs. Since 2006, the sulfur content limit for diesel is 15 ppm (CARB, 2014).

The core feature of California's enforcement program is comprehensive supervision throughout the supply chain. This includes the import, refinery, storage, distribution, retail, and usage stages. A key supervision method is the certification system. All parties involved in fuel distribution must be certified—including refiners, oxygenate blenders, distributors, and retailers—and these certified parties must report data to CARB for compliance purposes. There are three inspection points at which CARB inspectors obtain samples of gasoline and diesel fuel and they conduct frequent, unannounced inspections. The first is refining, which includes manufacturing and import. The second is at storage and terminal areas, in between refiners and service stations. The third is at consumer outlets, farms, commercial consumers, wholesale distributors, etc. In the sampling process, the inspectors collect two samples from the same batch, one for testing and the other for future re-testing if a violation is found from the first test. The samples are then analyzed in the Mobile Fuels Laboratory.

In 2017, CARB completed 481 inspections, analyzed 1,650 fuel samples, and evaluated 3,729 fuel formulation reports. The samples accounted for 14% of the total production in California in 2017. The results showed that 99% of the samples were compliant (CARB, 2018). Currently, CARB seldom collects fuel samples at the retail stage, since most of the fuels sampled at that stage have been compliant with the standards.

Japan

In Japan, the Ministry of Economy, Trade and Industry (METI) is in charge of enforcing the quality of gasoline and diesel sold. According to the Fuel Quality Control Law, diesel fuel has been limited to 10 ppm sulfur content since 2007 (METI, 2014). The Fuel Quality Control Law requires refineries and importers to test the quality of fuel prior to distribution and sale to ensure that the products meet all mandatory requirements. Refiners and importers share the responsibility if non-compliant fuel is found at any retail station they supply. This prompts the industry to regularly test fuel along the distribution chain (Fung, 2011).

In Japan, all retail stations selling gasoline must register with the METI. The Fuel Quality Control Law also requires that retail stations test the fuels they sell against the compulsory requirements once every 10 days. Retail stations may commission any one of the four laboratories accredited by the METI for fuel testing.

4 All parties have an opportunity to establish a defense.

5 EPA enforcement staff, personal communication, February 2010.

METI conducts massive fuel sampling and testing every year. It contracts the National Petroleum Association (NPA), an independent public corporation, to collect and test fuel samples at least once a year from each of the more than 45,000 retail stations in the country (NPA, 2019). Refineries, importers, and retailers selling fuels that fail to meet mandatory specifications are subject to a fine of up to ¥1,000,000 and/or up to 1 year of imprisonment. METI also has the authority to suspend any business for up to 6 months for distributing or selling non-conforming fuels, and then publicize the name of the non-compliant business.

In the second quarter of 2019, NPA collected and tested more than 10,800 samples of gasoline and 5,500 samples of diesel. Only four of the gasoline samples and 12 of the diesel samples tested exceeded the mandatory specifications (NPA, 2019). The historical monitoring of data from the auto industry also suggests that diesel and gasoline sold in Japan has met the 10 ppm sulfur limit since 2007 (Fung, 2011).

European Union

Since January 1, 2009, the European Union has prohibited the sale of motor vehicle fuel with more than 10 ppm sulfur content. Additionally, since 2001, the European Fuel Quality Directive 98/70/EC has required that each member state introduce a Fuel Quality Monitoring System that includes sampling and analyses of fuels to assess compliance with the fuel specifications set by the standard (European Commission, 2017).

Member states must sample fuels each year and report information relating to the quality of gasoline and diesel sold in their territories. By August 31 of each year, member states must submit a summary report of fuel quality monitoring data collected from January to December of the previous calendar year (Mellios & Kouridis, 2018). The minimum number of samples that need to be taken in each of the summer and winter periods is specified in European Standard EN14274. Countries can decide on their own national monitoring system, but the sampling must be done in accordance with requirements in European Standard EN14274 that ensure safety and precision. The standard specifies the number and location of samples to be taken and reported in their fuel quality reports (European Commission, 2015). The information submitted to the European Commission includes a compilation of the samples taken and an analysis of the results, details about quantities of each grade of gasoline and diesel sold in the country, and a description of the national fuel quality monitoring system (Hart Energy, 2014). In most cases, member states run the fuel quality monitoring system via government departments and their own laboratory. In some member states, for example in the United Kingdom, the Department of Transport uses industry quality analysis of batches of fuel produced domestically or imported and samples taken from distribution terminals and service stations (Mellios & Kouridis, 2018).

The EEA manages the annual fuel quality report process. This report is published on an annual basis and is publicly available. The latest annual report was published in 2018 for the data collected in 2016. In 2016, all EU member states plus Norway and Iceland submitted their individual fuel quality reports to EEA. The overall compliance rate of gasoline and diesel in the European Union was 98% in 2016. Member states reported 507 instances of non-compliance for gasoline and 101 instances of non-compliance for diesel. For gasoline, the most common violations concerned summer vapor pressure, research octane number, and motor octane number. For diesel, the most common violations involved sulfur content and fatty acid methyl ester content. The results indicate that the vast majority of fuels sampled were in line with the standards (Mellios & Kouridis, 2018).

The Fuel Quality Directive requires that effective, proportionate, and dissuasive penalties be applied by member states in cases of non-compliance, and such actions include informing the relevant authorities, initiating investigations, imposing penalties and fines,

and resamples (Mellios & Kouridis, 2018). No harmonized rules on penalties exist across member states in the European Union.

Summary of best practices from international experience

Experience in the United States, California, Japan, and the European Union has demonstrated that clear responsibility and authority, a stringent source control and certification program, presumptive liability, and heavy non-compliance penalties are the key components of an effective and successful fuel quality compliance program.

1. Clear responsibility and authority

In the United States, as the EPA and CARB both have the authority to regulate both vehicles and fuel, these agencies can adopt new limits for vehicle emission standards in tandem with increasingly stringent fuel quality requirements. In the EU, the Directorate-General for Environment (DG ENV) is responsible for setting the environment-related fuel standards and the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) sets vehicle standards; they work together on drafting new vehicle and fuel standards. In Japan, METI is in charge of enforcing the quality of gasoline and diesel sold on the market. In all countries reviewed, it is clear which agency has responsibility for fuel quality compliance and enforcement. International experience indicates that it is beneficial to have the same agency that set the standard also implement and enforce it, as this creates a robust, closed-loop control system in which issues found can feed back into the formation of new regulation and be used to improve stringency and robustness over time.

2. Stringent source control and certification programs

The United States, California, and Japan all have fuel registration and tracking systems that strictly control all upstream links before the fuel reaches the retail market. Key measures include establishing a certification system and a long-term random inspection program. Each party involved in the fuel market—including refiners, importers, distributors, carriers, oxygenate blenders, retailers, and wholesale-purchaser-consumers—needs to be registered and certified. At the refining and distribution stages, the authority checks the sales records and invoices of each party. Under such a system, the authority can accurately keep track of the flow of every barrel of fuel, and it is easy to find out if a refiner or distributor sells fuel to an uncertified party.

3. Presumptive liability

The countries and regions discussed above all hold refiners, importers, distributors, carriers, resellers, and retail and wholesale purchase-consumers responsible if they sell or use motor vehicle diesel fuel that does not meet fuel quality standards. When a violation is found, the party in possession of the non-conforming fuel, as well as all parties upstream in the fuel distribution system, are presumed liable unless they establish an affirmative defense. This presumptive liability encourages all parties along the distribution chain to undertake efforts to assure the quality of fuel received and deter the dropping of illegal fuel during fuel distribution (Fung, 2011).

4. Substantial non-compliance penalties, including fines and criminal penalties

In the countries and regions reviewed, fuel retailers and oil companies are subject to substantial penalties if they are found guilty. For example, in 2015, the EPA imposed a civil penalty of $900,000 against Equilon Enterprises LLC, doing business as Shell Oil Products US, Motiva Enterprises LLC, and Deer Park Refining Limited Partnership for Clean Air Act violations involving elevated levels of ethanol in gasoline, violations

of the gasoline and diesel sulfur standards, and numerous recordkeeping, reporting, sampling, and testing violations (EPA, 2015). In 2009, British Petroleum (BP) supplied approximately 64 million gallons of fuel that exceeded the reported total aromatics from a facility in California. CARB staff discovered the violation through routine inspections and sampling. In 2017, the court in Contra Costa County, California issued a judgment finding that BP was negligent and imposed a penalty of $2.5 million dollars. This was the largest penalty in the history of the fuels enforcement program (CARB, 2018). Heavy penalties have the potential to create a deterrent effect that encourages other parties to take more responsibility to ensure their compliance with fuel quality standards.

Table 8 presents a summary of fuel quality compliance and enforcement programs in the United States, California, Japan, the European Union, and China.

Table 8. Summary of fuel quality compliance and enforcement programs

	U.S.	California	Japan	EU	China
Authority	EPA	CARB	METI	DG ENV	Historically SAMR and SAC
Current sulfur limit	15 ppm	15 ppm	10 ppm	10 ppm	10 ppm
Fuel testing program	++	++	++	++	+
Presumptive liability	++	++	++	++	--
Fuel registration and tracking	++	++	++	+	--
Penalties	++	++	++	++	+
Overall noncompliance rates	<1% every year	1% in 2017	<0.1% in 2019	2% in 2016	3%–40% in 2019 Varying numbers from different sources and regions

++Strong, +Medium, --Weak

Conclusions and policy recommendations for China

Since 2019, China has implemented the China VI vehicle fuel quality standard, which is one of the most stringent national fuel quality standards in the world. But fuel standards on paper, no matter how stringent, do not guarantee good fuel quality at distribution points. A proper compliance and enforcement mechanism is key to ensuring the effective implementation of fuel quality standards.

Inspections have shown that the diesel fuel on the market in some regions in China is not meeting standards, especially the diesel from private fuel stations. This is a major obstacle to the use of advanced emission aftertreatment technologies such as DPF. At present, the primary methods of fuel quality supervision in China are random inspections at fuel stations and special campaigns against illegal fuel stations. However, it is still not clear which agency has the authority to implement vehicle fuel quality standards and initiate enforcement actions. Meanwhile, experience and best practices from the United States, Japan, and the European Union show the key components of a successful fuel quality compliance program, and it would be prudent for China to consider the following:

1. Define clear roles and responsibilities for regulatory agencies. Currently, the New Clean Air Law does not specify which governmental body has the authority to formulate and implement fuel quality standards, but it gives SAMR the authority to issue civil penalties to refiners and fuel stations that produce or sell non-compliant

fuels. The Clean Diesel Action Plan states that the SAMR, the National Development and Reform Commission, the Ministry of Commerce, the Ministry of Transport, and the MEE are jointly in charge of the compliance and enforcement program of motor vehicle fuel quality. But in practice, governmental roles and responsibilities on fuel quality compliance are ambiguous. China could instead consider defining clear roles and responsibilities for different governmental agencies with respect to fuel quality compliance programs.

2. Establish a fuel quality compliance certification system and require that each party involved in the fuel market, including refiners, importers, distributors, carriers, and retailers, be registered and certified. Such certification could help prevent non-compliant fuel from flowing into the market. Refineries and importers could be required to test every batch of fuels and report the results to the relevant authority to demonstrate compliance before the fuel is distributed. In addition, random testing could be carried out at distribution points, such as fuel stations, and also at upstream refineries and importers.

3. Presumptive liability. According to the New Clean Air Law, refineries and fuel stations that produce or sell non-compliant fuels are subject to civil penalties. In practice, inspections against illegal fuel stations are mainly carried out at the distributor level and, in most cases, penalties are imposed only on fuel stations. Without a certification and monitoring system throughout the supply chain, it is hard to identify the source of the non-compliant fuel. China could make all fuel handling parties responsible for fuel quality along the supply chain, including refiners, importers, distributors, carriers, resellers, and retailers. This would encourage refiners and importers to invest resources in ensuring fuel quality throughout the distribution chain.

4. Strengthen supervision and enforcement. In the past, non-compliant refineries and fuel stations were not heavily penalized in China. However, according the New Clean Air Law, refineries and fuel stations that produce or sell non-compliant fuels are subject to a fine of more than one time but not exceeding three times the value of the goods. For the regular fuel quality check program conducted by SAMR, the names and locations of non-compliant fuel stations are published for consumer awareness, but the details of fines are generally not available to the public. In the latest special campaign carried out by the MEE, the 1,466 illegal fuel stations and 644 non-compliant fuel stations were fined a total of 36 million RMB, which is roughly $5 million U.S. dollars (MEE, 2019b). The low fines imposed and high profit potential from breaking the law contribute to the prevalence of non-compliant fuels on the market. To improve, China could continue to strengthen supervision and increase enforcement of fuel quality compliance programs.

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