Discussion about the Health Effects, Causes, and Probable Solutions to the Air Pollutions Caused by Vehicle Exhaust Emissions

Lai Wang

1Harbin No.9 High School, Harbin, Heilongjiang, 150028, P.R. China
chunchenxiao@cas-harbour.org

Abstract. After the Chinese economic reform, the number of vehicles in cities increases sharply. Serious air pollution is caused which also results in a lot of health problems. In this article, the author discusses the causes of pollution, the categories of pollution, the evaluation systems, as well as the health problems. In the end, the author gives suggestions to improve such situation from different aspects.

1. Introduction
After the Chinese economic reform, the number of vehicles in the populated cities (e.g., Beijing, Shanghai) increases sharply. The fact that increasing mortality from cardiopulmonary disease is associated with the living location (e.g. the distance from the road) has previously been found in the Netherlands. 1 Also, the adverse health effects and increasing mortality that are caused by air pollution have been observed in many cohort studies worldwide. 2 The main force behind these circumstances is the exhaust gas of vehicles. Similar problems also occur in China, but the impact of traffic emission is often ignored by the public. Although the air pollution from land traffic owns only 3% mortality out of entire air pollution sources in China, the extremely large basement of total deaths rises the deaths share of land traffic approach to the whole deaths caused by air pollution in the USA (Table 1). 3 Reasons that cause high exhaust gas pollution are the relatively low level of the technique of the vehicle industry, loose standards for the emission of exhaust gas, and the over-serve old cars. Till now, most citizens in China are in the stage of just knowing that exhaust gas from vehicles is harmful to both human health and environment, but they are not familiar with the actual meanings and causes behind the increasing seriousness of air matters. A test in American six cities in 1993 had already revealed that increasing fine particle concentration would cause an increasing mortality. 4 And a study in China for indoor heating policy and the reason behind decreasing citizen’s life expediency in North China shows that different particle concentration could cause the difference of life expectancy. 5 The cause and effect are of major importance, but at the same time the ways to regulate emission and to decrease the harm to people should come to the first. Improving engine design, recommending new energy cars, reinforcing the regulation of emission, developing public transportation, improving the gasoline quality, and setting an improved model of three-way catalyst will have a positive effect. The source, health effect of exhaust gas and the approaches to governing it will be discussed in this paper.
2. Pollutant categories

The exhaust gas emitted by vehicles contains carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), hydrocarbons (CnHm), volatile organic compounds (VOCs), respirable particulate matter (PM), and some non-toxic compounds (e.g., Water (H2O), Carbon dioxide (CO2), Nitrogen (N2), Oxygen (O2), and Hydrogen (H2)). In the following sections, “Pollutant” refers to these toxic compounds. The contents that are exhausted from vehicles can be divided in three ways. (I) According to the percentile share of the exhaust compounds, the exhaust gas from vehicles can be divided into the major ones (take up more than 1 percent) and the minor ones (take up less than 1 percent). The major ones contain H2O, CO2, N2, O2, Carbon monoxide (CO), H2, while the minor ones contain Oxides of sulfur (SO2, SO3), Oxides of nitrogen (NO, NO2), Aldehydes (HCHO, etc.), Organic acids (HCOOH, etc.), Alcohols (CH3OH, etc.), Hydrocarbons (CnHm), Carbon monoxide (CO), Hydrogen (H2), and smoke as it lists in Table 2. (II) Different exhaust gas emissions can be grouped by their toxin. H2O, CO2, N2, O2, and H2 can be incorporated in the non-toxic group. On the other hand, CO, SO2, NOx, hydrocarbons, VOCs, and PM are listed as noxious compounds. (III) According to the physical matters and chemical matters, these pollutants can be divided into gaseous pollutants which contain CO, SO2, NOx, Hydrocarbons, VOCs, and PM. It is notable that PM does contain particles like dust; heavy metals (e.g., lead, mercury, cadmium silver nickel, vanadium, chromium and manganese), organic compounds, material of biologic origin, ions, reactive gases, and the particle carbon core also contribute to the toxin of PM. The detail will be discussed in the next part.

3. Health effects

The majority of these pollutants have adverse health effects on human health after being inhaled and ingested by human. It is due to the fact that pollutants may dissolve in water and deposit on both the leaves of vegetables and the organs of livestock (e.g., cows, pigs), and drinking water and eating foods are two daily actions of people. 8 Because most pollutants could enter the circulatory system and deposit...
in different tissues, adverse effects could occur in every area of the human body. Although most of those harmful compositions (CO, SO2, NOx, etc.) take up less than 1 percent of all of the exhaust gas, the consequent effect cannot be neglected. NOx can have a photochemical reaction with O2 to form O3, which do harm to people’s eyes and may even finally affects the function of the lung and trochee, causing the change in airway permeability if they were inhaled by people. 9 Without reaction, NOx can solely affect human health. Some recent studies show, except for respiratory system disease, NOx can also cause cardiac diseases, vascular diseases, circulatory shock, local inflammation, and even cancer. 10 Oxides of sulfur (SO2, SO3) can directly affect human health by doing harm to nose and throat irritation, finally causing bronchoconstriction and dyspnea, especially in asthmatic individuals. 11 CO can bond with hemoglobin (HGB) and reduce its ability to carry O2. 12 As a result, human’s organ cannot get the adequate supply of O2, eventually resulting in dizzy and cardiovascular disease. VOCs can increase rates of chronic respiratory symptoms characteristic of reactive airways. 13 PM can absorb a bunch of pollutants, such as heavy metals, organic compounds, and 2,3,7,8-Tetrachlorodibenzodioxin (TCDD, or dioxin), which would cause secondary harm to human health. Heavy metals such as lead and mercury will penetrate humans’ respiratory system and weaken lung function. 14 Ions of these heavy metals could also affect nervous system; it will finally cause memory disturbances, sleep disorders, anger, fatigue, hand tremors, blurred vision, and slurred speech. 15 Especially, lead will cause injury in some systems (e.g., dopamine system, glutamate system, and N-methyl-D-Aspartate (NMDA) receptor complex) that play an important role in memory function. 16-17 Mercury is linked to some categories of neurological cancer. These heavy metals would also do harm to human’s urinary system including kidney injury and increase the risk of both stone formation and renal cancer. 18-19Heavy metals have adverse impact even on the new-born infants if their mothers are exposed to these heavy metals during pregnancy. Increasing rate of abortion, low infant weight, and restriction in nervous system development of infants are parts of the consequences of lead exposure. 20-21 Exposure to TCDD has similar adverse consequences to those caused by heavy metals. TCDD has the function of reducing the velocity of the nerve signal conduction in children. And TCDD would increase the concentration of certain enzymes in blood; thus, it will induce the damage of liver cells, which increases the risk of liver cancer. TCDD would transfer to infants through the placenta during parents’ pregnancy, which could cause disruption of fetus’ growth, especially in the central nervous system. 22 People are affected by these pollutants through changing the DNA bond, limiting the enzyme activities, impacting the ions balance, and producing free radicals oxidizing organic molecules. 7 If these changes happen, there is no way to reduce these damages. Thus, protection and regulation of pollutants are of major importance. Before regulation, the cause of high-level exhaust gas emission in China will be discussed in the next section.

4. Reason discussion
There are several factors that cause the terrible vehicle emission in China, (I) the sharp increase of the vehicles’ number, (II) the late and loose regulation of vehicle emission, (III) the coarse quality of gasoline. These factors will be discussed orderly in this divide. The first factor is the sharp increase of car numbers, or car parc. Car parc means the total number of vehicles that have already been registered in a certain region. After the Chinese economic reform, Chinese people’s fiscal condition has greatly improved. Population along with car Parc increased significantly at that time. The rate of population increasing was exceeding 10% during 1984 – 1997; however, the growth rate of Parc did not as sharp as the growing rate of the population at that time. (Figure 1, Figure 2) The curve of population growth is a line with the decreasing slope, which would probably due to the wide spread of the low willing of procreation in a new century.
However, the curve of Parc growth is more similar to an exponential function that has an increasing slope. The most-increasing reign of the population and the most-increasing reign of car parc are not overlapped, which means, the fastest growing population did not contribute to the fastest growing of car parc. This phenomenon is probably because the population grew rapidly at that time (1984 – 1997); however, the economic condition was not so good that only a few Chinese citizens could afford a car. And when in the 21st century, the economic condition allowed much more citizens to buy a private car, and the immense population basement that accumulated in the 1990s provided millions of potential consumers; thus, the car parc exploded after 2005. The car Parc tripled during 2005 – 2017, which caused the rapid increase of air pollutant. The second reason is the late and lax regulation of car emission. The emission standard in China is intended to follow the European emission standard; however, the revising of emission policy has its backwardness compared to the Euro emission standard. In 1983 Chinese government published the first edition of the emission regulation, and in 1993, the government revised the 1983 regulation. But in the 1993 policy, China used the ECE R15—03 standard,
which had already been used in Europe in 1979. In 1999, Chinese government published the GB18352.1-2001 standard, which was equivalent to the Euro I standard (93/59/EC, published in 1993). In 2004, the GB18352.2-2001 standard began to apply in China; this standard was equivalent to the Euro II standard (96/69/EC, published in 1996). In 2007, China utilized GB18352.3-2005 standard, which was equivalent to the Euro III standard (published in 2005). Till 2010, the emission standard in China had caught up with the Euro latest standard at the same period; the time line of the emission standard in China compared to that in Europe are listed in Table 3.

Table 3. State Environmental Protection Administration of China

| Years | Europe | China |
|-------|--------|-------|
| 1995  | Euro I | -     |
| 1996  | Euro II| -     |
| 1997  | Euro II| -     |
| 1998  | Euro II| -     |
| 1999  | Euro II| -     |
| 2000  | Euro III| - |
| 2001  | Euro III| GB-1 |
| 2002  | Euro III| GB-1 |
| 2003  | Euro III| GB-1 |
| 2004  | Euro III| GB-2 |
| 2005  | Euro IV| GB-3 |
| 2006  | Euro IV| GB-3 |
| 2007  | Euro IV| GB-3 |
| 2008  | Euro IV| GB-3 |
| 2009  | Euro IV| GB-3 |
| 2010  | Euro IV| GB-4 |

It is easy to find a 15-year blank period in China’s emission standard. In this period, nearly half of the entire car parc had already formed; over 50 million cars flowed into the market. Till now, some cities in China still use cars that registered before 2005 as taxi, bus, or cargo carrier. These cars occupy less than half of the entire car parc, but contribute to over half of total emission. And the effect of the late-pace emission standard will be accumulated over time until all the cars that use fall-behind emission policy have been taken place. Third, the gasoline quality is uneven. China’s vehicle gasoline standard and diesel standard are also falling behind of the Euro standard as shown in Table 4 and Table 5. It can easily be found that although the Chinese standards narrowly met the Euro standard in about 2010, the Sulfur concentration in Chinese standards was still much higher (15 times) than that in Euro standard. 23 Thus, the sulfur concentration of gasoline and diesel are higher in China compared to the developed countries.

Table 4. Zhang et al. (2010)

| China ethane | China vehicle gaso- | China vehicle gasoline | Euro V gaso- |
|--------------|---------------------|------------------------|-------------|
| Effective date | 2004.5.1 | 2006.12.6 | 2010.1.1 | 2009 |
Sulfur/(%) | ≤0.08 | ≤0.05 | ≤0.015 | ≤0.001
Benzene % | ≤2.5 | ≤2.5 | ≤1.0 | ≤1.0
Aro- | ≤40 | ≤40 | ≤40 | ≤35
Olefin %(v/v) | ≤35 | ≤35 | ≤30 | ≤18

Table 5. Zhang et al. (2010)

| Effective date     | China light | China vehicle diesel | China vehicle diesel III | Euro V diesel |
|--------------------|-------------|----------------------|--------------------------|--------------|
| Sulfur/(%)         | ≤0.02       | ≤0.05                | ≤0.035                   | ≤0.001       |
| Type               | Mandatory   | Recommendatory       | Mandatory                | -            |

In fact, more than half of gasoline in China has a sulfur concentration over 150 ppm, and most of the diesel in China has a sulfur concentration over 500 ppm, even some diesel has a sulfur concentration over 2000 ppm (Figure 3). The higher concentration of sulfur would directly cause the increase of SO2 emission. And there is an evidence that increasing sulfur concentration in gasoline would cause the efficiency of three-way catalyst decrease, which will cause extra emission of NOx, Hydrocarbons, and CO. 24 The octane number of gasolines is also a factor that would affect emission. Superior single emission and huge numbers of vehicles are the root points of the exhaust gas problems.

Figure 3. Zhang et al.

5. Ways to govern emission
There are several ways to govern emission (I) improving engine design, (II) recommending new energy vehicles, (III) reinforcing the regulation of emission, (IV) developing public transportation, (V) improving the efficiency of the three-way catalyst, and (VI) polishing up the quality of gasoline. Improving engine design is an effective but time-costing strategy to govern the emission. Higher efficiency of fuel burning and heat recycling often come along with the new design of engine. Low burning efficiency is the reason for CO production; increasing the idle speed of engine would have the effect of decreasing CO emission. Using multiple-injection in diesel engine is tested to be an effective way to reduce the emission of NOx. 25 Recommending new energy (CNG, electricity, biodiesel) of cars is exactly a more effective way to regulate exhaust gas emission. Using CNG as the fuel of vehicles would bring higher brake thermal efficiency and lower Hydrocarbons, CO, and O2 emission than
that of gasoline as shown in Figure 4. CNG is also more economical than gasoline when used as fuel. Trucks used biodiesel could emit lower PM, CO, and hydrocarbon, than the identical trucks fuelled by normal diesel. In some cities in China, public transportation vehicles have already applied new model that uses natural gas or electricity as energy sources. Actually, Chinese government has already enacted policies to encourage people to purchase new energy cars. Till 2018, the Parc of electric cars in China has already reached 1.6 million, taking up half of the world share. More and more benefits would appear after decades of using new energy. Reinforcing regulation standard is essential as well. China just falls behind in 2 generations of standards than Europe, and it actually shows a wide gap between the pollution in China and Europe. Although the standard is revised to be equivalent to the latest Euro standard these days, the impact of the delayed standard over past 15 years cannot be negligible. If Chinese government directly uses the same generations of Euro standard from the 1990s, the emission problem could not be as severe as it is today. The USA is not only the first country that published the standard of vehicle emission but also the country with the strictest regulation policy. The effects of strong regulation have floated in the USA. Developing public transportation is a wide-use way in many countries. The traffic condition in downtown is always disgusting, causing frequent break and start-up of engine. It is known that when the driving condition changes frequently (frequent acceleration, break), the amount of emission would remarkably increase. Public transportation like bus or subway can carry many passengers and only occupies less space on the road compared to a group of cars. The recent popular station-free bicycles sharing is an effective way to reduce emission. In fact, there are 1.9 million shared bicycles in Beijing; if most citizens choose to ride shared bicycles for short-ranged commute, the reduction of exhaust gas emission would be noticeable. Three-way catalysts are exhaust control devices that convert toxic gas such as NO, NO2, CO, and hydrocarbons into less-toxic pollutants through catalyzing and redox reaction. Thus, increasing efficiency of three-way catalysts would significantly decrease the pollution emission from vehicles. There are two aspects of the quality of gasoline, the sulfur concentration and the octane number. The higher sulfur concentration in China gasoline and diesel has already been analyzed in the former part. If the content of sulfur is regulated, both the direct exhaust emission of SO2 and the indirect emission of NOx, CO would be reduced. The octane number is a universal measure of the performance of an engine or aviation fuel. Over all, the higher the octane number is, the more compression the fuel can withstand before detonating, and high-octane number means better performance in a gasoline engine. Burning fuel with a lower octane number in gasoline engine may lead to the risk of engine knocking, which would induce the decreasing lifespan of the engine and the incomplete combustion of fuel and finally cause increasing emission of hydrocarbons and CO. If high-octane-number gasoline could be widely used in China, CO and hydrocarbon emission from the vehicle would probably decrease.
6 Conclusion
In this paper, the categories, the health effects, probable reasons, and the probable ways to govern the exhaust emission from the vehicles are discussed.

1) There are three ways to divide these exhaust emission gas:
   a. The percentage share of the compounds to divide.
   b. The toxin of the compounds to divide.
   c. The physical matters and chemical matters of the compounds to divide.

2) Adverse health effects of the pollutants in exhaust emission are concluded in the paper:
   a. Harming cardiovascular system.
   b. Ruining respiratory system.
   c. Injuring nervous system, especially memories.
   d. Damaging urinary system, increasing the risk of stone formation.
   e. Blemishing liver function, even causing cancer.
   f. Impacting fetal development.

3) The discussion of reasons for the high-level exhaust pollution in China is presented:
   a. The meeting of the significant economic development and the accumulation of the immense base of potential car buyers cause the immense increase in car parc.
   b. The delayed standard causes an over-10-year vacuum time from of emission regulation.
   c. The low quality of gasoline and diesel further increase the exhaust pollutant emission.

4) Probable approaches to improve the circumstances are analyzed in the paper:
   a. Improving engine design.
   b. Using new energy cars.
   c. Reinforcing the regulation of emission.
   d. Developing public transportation.
   e. Enhancing the efficiency of the three-way catalyst.
   f. Strengthening the quality of gasoline.

References
[1] Hoek, Gerard, et al. "Association between mortality and indicators of traffic-related air pollution in
the Netherlands: a cohort study." The lancet 360.9341 (2002): 1203-1209.
[2] Loomis, Dana, et al. "The carcinogenicity of outdoor air pollution." The lancet oncology 14.13 (2013): 1262-1263.
[3] Lelieveld, Jos, et al. "The contribution of outdoor air pollution sources to premature mortality on a global scale." Nature 525.7569 (2015): 367.
[4] Dockery, Douglas W., et al. "An association between air pollution and mortality in six US cities." New England journal of medicine 329.24 (1993): 1753-1759.
[5] Chen, Yuyu, et al. "Evidence on the impact of sustained exposure to air pollution on life expectancy from China’s Huai River policy." Proceedings of the National Academy of Sciences 110.32 (2013): 12936-12941.
[6] Elliott, Martin A., Gerge J. Nebel, and Fred G. Rounds. "The composition of exhaust gases from diesel, gasoline and propane powered motor coaches." Journal of the Air Pollution Control Association 5.2 (1955): 103-108.
[7] Kampa, Marilena, and Elias Castanas. "Human health effects of air pollution." Environmental pollution 151.2 (2008): 362-367.
[8] Thron, Raymond W. "Direct and indirect exposure to air pollution." Otolaryngology--Head and Neck Surgery 114.2 (1996): 281-285.
[9] Lippmann, Morton. "Health effects of ozone a critical review." Japca 39.5 (1989): 672-695.
[10] Pacher, Pál, Joseph S. Beckman, and Lucas Liaudet. "Nitric oxide and peroxynitrite in health and disease." Physiological reviews 87.1 (2007): 315-424.
[11] Balmes, John R., Jonathan M. Fine, and Dean Sheppard. "Symptomatic Bronchoconstriction after Short-Term Inhalation of Sulfur Dioxide,2." Am Rev Respir Dis 136 (1987): 1117-1121.
[12] Badman, David G., and Ernst R. Jaffé. "Blood and Air Pollution; State of Knowledge and Research Needs." Otolaryngology--Head and Neck Surgery 114.2 (1996): 205-208.
[13] Ware, James H., et al. "Respiratory and irritant health effects of ambient volatile organic compounds: the Kanawha County Health Study." American Journal of Epidemiology 137.12 (1993): 1287-1301.
[14] Rastogi, Subodh K., et al. "A cross-sectional study of pulmonary function among workers exposed to multimetals in the glass bangle industry." American journal of industrial medicine 20.3 (1991): 391-399.
[15] Ewan, K. B., and Roger Pamphlett. "Increased inorganic mercury in spinal motor neurons following chelating agents." Neurotoxicology 17.2 (1996): 343-349.
[16] Lasley, Stephen M., and Mary E. Gilbert. "Glutamatergic components underlying lead-induced impairments in hippocampal synaptic plasticity." Neurotoxicology 21.6 (2000): 1057-1068.
[17] Lasley, Stephen M., Mary C. Green, and Mary E. Gilbert. "Rat hippocampal NMDA receptor binding as a function of chronic lead exposure level." Neurotoxicology and teratology 23.2 (2001): 185-189.
[18] Damek-Poprawa, Monika, and Katarzyna Sawicka-Kapusta. "Damage to the liver, kidney, and testis with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland." Toxicology 186.1-2 (2003): 1-10.
[19] Boffetta, Paolo, Enzo Merler, and Harri Vainio. "Carcinogenicity of mercury and mercury compounds." Scandinavian journal of work, environment & health (1993): 1-7.
[20] Bellinger, David C. "Teratogen update: lead and pregnancy." Birth Defects Research Part A: Clinical and Molecular Teratology 73.6 (2005): 409-420.
[21] Garza, Aníbal, Rosario Vega, and Enrique Soto. "Cellular mechanisms of lead neurotoxicity." Medical science monitor 12.3 (2006): RA57-RA65.
[22] Wang, Shu-Li, et al. "Infant exposure to polychlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls (PCDD/Fs, PCBs) —correlation between prenatal and postnatal exposure." Chemosphere 54.10 (2004): 1459-1473.
[23] Zhang, Kesong, et al. "Sulfur content of gasoline and diesel fuels in northern China." Energy Policy 38.6 (2010): 2934-2940.
[24] Furey, Robert L., and David R. Monroe. Fuel sulfur effects on the performance of automotive three-way catalysts during vehicle emissions tests. No. 811228. SAE Technical Paper, 1981.
[25] Han, Zhiyu, et al. "Mechanism of soot and NOx emission reduction using multiple-injection in a diesel engine." SAE transactions 105 (1996): 837-852.
[26] Jahirul, Mohammad I., et al. "Comparative engine performance and emission analysis of CNG and gasoline in a retrofitted car engine." Applied Thermal Engineering 30.14-15 (2010): 2219-2226.
[27] Wang, Wei-Guang, et al. "Emissions from nine heavy trucks fueled by diesel and biodiesel blend without engine modification." Environmental science & technology 34.6 (2000): 933-939.
[28] Ministry of Public Security of the People's Republic of China
[29] Anderson, J. E., et al. "High octane number ethanol–gasoline blends: Quantifying the potential benefits in the United States." Fuel 97 (2012): 585-594.