

Current situation and control measures of groundwater pollution in gas station

Qiong WU¹, Xiaofeng ZHANG^{1*} and Qianjin ZHANG¹

¹China Academy of Transportation Sciences, Beijing 100029, China

*E-mail: zhangxf422@126.com

Abstract. In recent years, pollution accidents caused by gas station leakage has occurred worldwide which can be persistent in groundwater. Numerous studies have demonstrated that the contaminated groundwater is threatening the ecological environment and human health. In this article, current status and sources of groundwater pollution by gas station are analyzed, and experience of how to prevent groundwater pollution from gas stations are summarized. It is demonstrated that installation of secondary containment measures for the oil storage of the oil tank system, such as installation of double-layer oil tanks or construction of impermeable ponds, is a preferable method to prevent gas stations from groundwater pollution. Regarding to the problems of groundwater pollution caused by gas station, it is proposed that it is urgent to investigate the leakage status of gas station. Relevant precise implementation regulations shall be issued and carried out, and supervision management of gas stations would need to be strengthened. Then single-layer steel oil tanks shall be replaced by double-layer tanks, and the impermeable ponds should be constructed according to the risk ranking. From the control methodology, the groundwater environment monitoring systems, supervision level, laws and regulations as well as pollution remediation should also be carried out and strengthened.

1. Introduction

Oil leakage could occur in the underground facilities (underground storage tank, oil pipeline, etc.) of gas station, caused by long-term use, lack of maintenance or material corrosion. Some toxic and hazardous substances such as methyl tert-butyl ether (MTBE), benzene series (BTEX), polycyclic aromatic hydrocarbons (PAHs) and other harmful substances in oil, which can gradually migrate into soil and aquifer, and become significant risk to groundwater[1]. BTEX and PAHs have been identified as human carcinogens. MTBE is also classified as suspected carcinogens, gathered in the human body through the food chain, could cause irreversible damage to the human health [2]. The soil and groundwater pollution caused by gas station leakage has strong concealment and high governance costs. The existence of large amount of contaminated sites with serious damage has attracted serious attention from governments to prevent and control gas station leakage.

2. Present situation of leakage and pollution of groundwater from gas stations at home and abroad

2.1. Present situation of leakage at gas stations at home and abroad

Gasoline field leaking is a common problem around the world. According to the data of US Federal Water Conservancy Bureau in 1995[3,4], 46% of the underground storage tank used more than 10 years in Pennsylvania leak; and this rate climbed to 71% as the service life raised to 15 years. In Nantes City of France, the 10 years old storage tank own a rate of 20% or more [5]. Till 2007, the



European Union has identified that about 24.2 million storage tanks existing leak pollution [6]. Czech Republic, Hungary and other countries had a similar situation [7]. Till 2014, The United States has confirmed that there are nearly 500,000 underground storage tanks existing leakage, accounting for 1/4 of total underground storage tank [8].

In China, a large number of gas stations were originally built in the 90th. At the end of 2011, the total number of gas stations reached more than 120,000[9], mainly in the commercial and residential areas, urban traffic arteries, highways, national roads, some gas stations even in the water source and nature reserves. In 2013, a research group collected the information of the location, construction time and environmental management status of more than 50,000 gas stations nationwide. It was found that the number of gas stations located within 1 km of the groundwater source was 1/100 of the total number. At present, the existing gas station number in Beijing has been more than 1081, and most of them locate in the city. Most of the underground storage tanks in China's gas station are utilizing a single-layer steel tank with a thickness of 5mm. The buried pipelines adopt a single-layer steel pipe with a thickness of 4mm. It is basically not equipped with double-layer oil leakage protection device (such as double oil tank, double buried pipeline) [7]. Once leak, groundwater pollution will occur easily. At present, the statistical data of gas station leakage has not been claimed yet. Over time, some of the earlier underground storage tanks at gas station, pipelines and other ancillary facilities have raced into the "aging period." According to the experience of developed countries, about 30% of the underground oil storage tanks and oil pipelines generally began to leak ran about 20 years due to corrosion. At the same time, because of China's oil quality and other issues, single tank average life expectancy is only 8 years around [10]. Following this trend, it can be inferred that China's gas field leakage situation is not so optimistically. The early survey data shows that some of gas stations constructed in the early time have begun to leak. In 2002, Xinjiang Karamay Oil Company investigated the corrosion and leakage of the 167 underground storage tanks. The public data revealed that there were 89 storage tanks had corrosion leakage in varying degrees, and 34 tanks had serious situation [11]. From 2006 to 2009, Zhou Xun et al. [12] estimated that 72.4% of the gas stations in 29 respondents had varying degrees of leakage by investigating the status and trends of leakage of gas stations in southern Jiangsu Province, and the typical accounted for 62.1%. Old gas station ran over 15 years had the leakage probability of about 60%. In 2013, Chen Xiaohua et al [10] made an analysis of the leakage potential of 119 gas stations in the upper reaches of the Huangpu River, Chongming Island and Changxing Island in Shanghai based on the Analytic Hierarchy Process, and the results of the actual sampling verification showed that more than 48% of the gas stations had higher leaking potential.

2.2. Present situation of polluted groundwater in gas station at home and abroad.

The oil leakage of underground oil storage tanks, oil pipelines and their facilities will directly lead to pollution in gas zone and groundwater. These leaks have become one of the largest sources of pollution at home and abroad [2,6,13]. Especially in the shallow groundwater area, where exists frequent groundwater fluctuation, is more vulnerable to oil leakage pollution [14]. According to the early data [3,4], the groundwater in United States had been polluted by petroleum hydrocarbon by 1 to 3% by now, and 50 States have thousands of wells were forced to disable; About 1/3 gas station owned by Shell in the UK has caused pollution to local soil and groundwater[15].

The gas station leakage also partially pollutes China's groundwater. A few years ago, Beijing Anjialou and Liulitun gas station had a serious oil spill, even forcing the nearby water plant failed to run for a while, affecting the water supply range of 36 km²[7]. In 2005, the gas station near Guangdong Maoming Shuangshan leaked. In 2006, the gas station in Jiangsu Nanjing Longpan Road leaked. Both accidents have brought serious pollution to the nearby groundwater. China Geological Survey makes a survey to part of the gas station in Tianjin. The results show that petroleum hydrocarbon of groundwater samples has the detection rate of 85%, and the exceeding sample accounted for 40% of the total number of groundwater samples [12]. In 2012, the research group analyzed groundwater samples from 16 gas stations ran over 10 years among four cities, and found

that the total petroleum hydrocarbons, benzene and other characteristic pollutants are generally detected, the total petroleum hydrocarbon exceeded the rate of 33.33 %, MTBE exceeded 4.8%, PAHs exceeded the standard rate of 19.05%. Pan Haiyan et al[16] made the investigation of MTBE content in surface water and groundwater in Huai'an City of Jiangsu Province and found that MTBE had different levels of pollution to groundwater in Huai'an city area, especially near the gas station, which was 6.41 $\mu\text{g/L}$, which exceeded the MTBE limits (5.2 $\mu\text{g/L}$) in EPA's recommended drinking water standard.

3. Reasons for groundwater pollution of gas station in China

3.1. Involving many departments and lack of supervision

Based on China's existing national conditions, although the gas station is part of the transportation system, but it belongs to oil system. Environmental protection department, as a regulatory authority, doesn't have reliable legal and supporting regulatory constraints. There is no uniform standard for the investigation, assessment and management of soil and groundwater pollution of gas station in China. And it lacks mandatory and guiding regulatory standards. In addition to the concealment of groundwater pollution, it leads to the era of social concern about the gas station groundwater pollution is late, which also leads to the lack of state regulation of gas station leakage risk.

China's State Council executive meeting in 2011 discussed and passed "national groundwater pollution control plan (2011-2020)". It requires underground tank of the running gas station update to double tank or set the seepage tank, and add the anti-leakage automatic monitoring equipment at the end of 2015. It means since 2011, which is behind the developed countries for nearly 10 years, China has asked gas station site pollution remediation work on the agenda [17]. Beijing developed "Technical Code for Prevent Leakage of Underground Storage Tank (DB11/588-2008)" in 2008, requiring underground storage tank outside the specially set anti-seepage tank, and set observation tube in the pool. In the underground drinking water source protection area within the storage tank area, it should be set up two observation wells. But the relevant technical specifications did not be carried out. In 2013, the introduction of the "Code for Design and Construction of Automobile Gasoline and Gas Filling Station (GB50156-2012)" requires new construction, alteration, and expansion of the gas station underground storage oil tank should take a single wall oil tank with seepage control pools or double-layer tank. However, no relevant provisions were set aiming at the already built gas stations. At the beginning of 2017, the Ministry of Environmental Protection issued "Technical Guide for Prevention and Control of Groundwater Pollution from Gas Stations (for Trial)". It set out the technical measures, testing methods, production operations and issues on environment supervision and management of anti-seepage leakage control for new and in use gas stations. The gas station groundwater pollution prevention and control management carried out the standard requirements. It also means that there is still a long way need to be explored from the technical guide to taking measures.

3.2. Oil tank with single wall has higher leakage risk

The results of the national groundwater basic environmental condition survey show that the proportion of double-layer tanks in China's gas stations is only 3.75%. The proportion of gas stations with seepage control pool is only 17.17%. Most gas stations still use single wall tanks with less seepage control pools. Issues of low standard technical standards and the poor quality of tanks exist in single wall tanks, which have become the biggest groundwater pollution source [18].

3.3. Less restoration technology and engineering applications

The US Environmental Protection Agency 2004 annual report on the remediation of soil and water pollution remediation technology shows that it has many successful cases of oil hydrocarbons contaminated groundwater restoration in the US. Especially in situ restoration engineering applications of contaminated sites, 60% projects aim to oil hydrocarbons pollution remediation. Oil pollution sites

and groundwater restoration currently still remain in the qualitative evaluation stage in China. The successful restoration cases are rarely reported.

4. Experience of pollution prevention and control of groundwater pollution at domestic and international gas station

Since 1980s, Europe and other developed countries have taken a series of measures to deal with the groundwater pollution of gas station, experience shows that, the strengthening of two barrier of oil storage system of underground storage gasoline tank system, the installation of double-layer oil tanks or construction of impermeable ponds are preferable means of prevention of groundwater pollution.

4.1. Systematic legal system

Europe, the United States, and other developed countries started earlier on the gas station pollution of groundwater. In the 1980s, a series of laws and regulations have been formulated and promulgated to strengthen the anti-leakage monitoring, leakage protection and pollution control of the groundwater pollution of the gas station and the supervision of groundwater environment, to deal with gas station groundwater pollution problems. Laws and regulations such as the United States Code (U.S. Code, Title 42, Chapter 82, Subchapter IX), LUST provision of the American Recovery and Reinvestment Act, UST provisions of the Energy Policy Act of 2005, Underground Storage Tank Compliance Act of 2005, management measures such as "Leaking Underground Storage Tank (LUST) Recovery Act Program Guidance" were implemented. This is also conducive to clear responsibilities. The international well-known large oil companies had set up special HSSE functional departments to develop the relevant HSSE management policy. The entire process of monitoring the oil company's commercial development transactions was set up to achieve control of corporate risk, to avoid the purpose of legal responsibility, which not only reflects the enterprise Social responsibility, but also to maintain the corporate reputation and image.

4.2. Precise prevention and control measures.

According to the domestic and international prevention and control experience, this indicated that installation of secondary containment measures for the oil storage of the oil tank system, such as installation of double-layer oil tanks or construction of impermeable ponds, is a preferable means for prevention of gas stations from groundwater pollution. This measure has played a positive role in the protection of the groundwater environment and the development of the gas station industry.

In 1984, the US Congress passed "the Hazardous and Solid Wastes Amendments Act", which for the first time stated the establishment of environmental management of underground storage tanks for the federal, aiming to reduce the corrosion and structural defects and to lower the risk of leakage. Then in the year 1988, the EPA put forward "the Technical Standards and Amendments for Underground Storage Tank Owners and Operators", which made requests on operation, maintenance, leak monitoring, disposal and shutting down of underground storage tanks. And in 2012, some important amending suggestions on Measures of 1988 were proposed by the EPA for the first time, converting the supervision of oil drain/leakage to the protection of it. Apart from further strength of the leaking provision of the underground storage tank system in gas station and personal training against leakage, it claimed that all underground storage tanks under EPA's supervision should install the secondary anti-leakage system. In addition to national regulations, the US states such as California and Florida have also developed the local laws and regulations according to their actual situation, requiring underground storage tanks are using double tank system[19]. This series of initiatives makes the US gas station accident since 1988, the annual rate of 50% decline[20].

Europe has a very stringent requirement for underground storage tanks. In 1988, Germany required the use of double tanks as underground storage facilities at the first time. Subsequently, the European Union in 2003 promulgated the "steel atmospheric oil storage tank the first part: the storage of water pollution of flammable and non-flammable liquid buried horizontal cylindrical single and double cans

(BSEN 12285-1: 2003) ". Based on the standard, Europe had basically completed the oil tank from the single to double the alternative work in 2006.

Taiwan required later the gas station underground storage tank. Until 2011, Taiwan promulgated the "underground storage tank system to prevent pollution of groundwater facilities and monitoring equipment installation management approach", which required the underground storage tank system to prevent groundwater pollution facilities. And the system should contain two barrier layer, underground storage tank and pipeline around the barrier Layer facilities and so on.

5. The prevention countermeasures and suggestions for groundwater pollution in gas station according to the risk classification

By analyzing the gas station at home and abroad on groundwater pollution status and experience, our country needs to strengthen the gas station pollution prevention and control of groundwater from the following aspects.

(1) Conduct a systematic investigation

China's gas station has entered a high incidence of leakage. It is urgent to conduct a systematic and thorough investigation on the leakage situation and pollution of the existing gas station in our country by using the non-destructive exploration technology such as geological radar according to the environmental sensitivity, construction period and the safety of the tank itself.

(2) Strengthen environmental supervision measures

The international rules of laws and regulations, pollution survey and control technology for gas station and pipeline management from developed countries has a lot of reference for China's oil and natural gas sales and related government supervision departments. To promote the reform of relevant laws and regulations, to carry out the life cycle assessment of gas stations, to control the existing gas station leakage and to repair the contaminated sites will require more attention. Programming environmental impact assessment (PEIA) and Environmental Admittance will help the new gas stations to reduce the risk of environmental pollution in the planning stage.

(3) Replace the underground storage tank and build the seepage tank

Strengthen the oil storage tank system of secondary blocking, replace single-layer tank to double-layer tank and build anti-seepage tank to enhance the service life of underground storage tank and reduce leakage.

(4) Using risk classification management

Different gas station oil leak into the groundwater cause different pollution degree and the level of risk is not the same. To manage the limited management resources efficiently and timely, it is important to highlight the management level of risk prevention. According to the risk, the groundwater function, and the receptor, different tank updates and work requirements shall be implemented for anti-seepage pond construction into implementation by stages and regions, and set a deadline for the construction period. For gas station in high risk zone, it's proposed to establish and perfect the water monitoring system, improve groundwater environment supervision level, increase the groundwater environmental protection law enforcement; those who do not meet the requirements of the specifications of the gas station should be ordered to suspend the deadline for rectification. At the same time to carry out the remediation of groundwater pollution in gas station. For gas station in central risk zone, it's proposed to establish and perfect the water monitoring system, improve groundwater environment supervision level, increase the groundwater environmental protection law enforcement; those who do not meet the requirements of the specifications of the gas station should be ordered to suspend the deadline for rectification. Control the deterioration of groundwater quality. For gas station in lower risk zone, it's proposed to establish and perfect the water monitoring system, improve groundwater environment supervision level, and regulate the daily behaviour of gas station.

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