CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762258

Risk Evaluation and Repair of the Sites Polluted by Nitrobenzene Chemical Plant

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In order to study the potential soil pollution risk of polluted sites with changed purposes in intensive industrial and commercial areas, this paper has determined the distribution points sampling and monitoring scheme for the polluted sites by analyzing the production history and future planning of a nitrobenzene chemical plant. The concentrations of benzene, toluene, chlorobenzene and nitrobenzene in different depths and locations are tested for single-factor analysis, according to which a risk evaluation is conducted and a current soil repair method is discussed. According to the result, various organic pollutants especially benzene have polluted the soil, which is more severe in the upper soil. The pollution degree decreases with depth and only the deepest soil is not polluted. Therefore, the soil repair technology is to be determined comprehensively according to the pollution condition with environmental, technical and economic evaluations.

1. Introduction

As a new environmental problem emerging in industrialization and urbanization of China, polluted sites are resulted from the conflict between rapid urban population and economic growth and scarce land resources. Sites used to serve factories, warehouses, refuse landfills, gas stations, refuse dumps are required to be repaired and developed to be residences, public entertainment venues, commercial lands and other construction lands which are highly demanding in environmental quality (Jiang et al., 2014).

The soil pollution of nitrobenzene chemical plants is more serve (Aghasian et al. , 2017), the pollutants of which include nitrobenzene, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), both highly toxic and difficult to degrade with mutagenesis, carcinogenesis teratogenesis effects (Bianconi, 2012). Existing in environment for a long time, these substances are transmitted by air or water to earth, geosphere and stratum cycles all over the world to accumulate in soil, ground water, living beings and other media, causing severe pollution (Charalampidis et al., 2014) which endangers ecosystems and human health. At present, the current soil pollution concentration of PAHs in China has risen from μg/kg level to mg/kg level (Zhu et al., 2012) with the detection rate from less than 20% to more than 80% (Fuhr and Aschwanden, 2017). In recent years, PCBs are even detected in the soil of Namcha Barwa in Qinghai-Tibet Plateau. These organic pollutants not only degrade soils, but also affect the safety of agricultural products, thus affecting human health (Gonzalez-Longatt, 2015).

2. Condition of the polluted site and monitoring point

2.1 Condition of the polluted site

The site once was a nitrobenzene chemical plant established in 1992, which stopped production in 2012 with the production installations on the site dismantled. The dismantled area is a rectangular area of 80 meters long and 61 meters wide to be used as a logistics and warehousing center (Hari et al., 2013). In operating the nitrobenzene chemical plant, there might be toxic material leakage and uncontrolled pollutant emissions. Meanwhile, toxic substances had been flushed into the soil under the plant during the plant and ground cleaning to cause certain pollution to the soil (Li et al., 2015). Therefore, the site is listed as a suspected polluted site by the enterprise to conduct sampling and monitoring (Liu et al., 2016).

Please cite this article as: Jiulin Zhang, Mei Hong, 2017, Risk evaluation and repair of the sites polluted by nitrobenzene chemical plant, Chemical Engineering Transactions, 62, 1543-1548 DOI:10.3303/CET1762258

Since the site is situated at the upper reaches of the Yellow river with a continental climate in the mid-temperate zone, there is neither severe heat in summer nor severe cold and winter in the city. The annual average temperature is 9.1°C, the annual average precipitation 324.8m, the annual average wind speed 0.9m/s, the annual average sunshine duration 2446 hours and the average altitude in the city 1520m. The geologic structure of the area is the east extension part of the fold system of Qilian Mountain with the upper part covered with a thick layer of quaternary loess and the lower part with tertiary gravel layer. The base is the muddy sand of cretaceous system in Hekou formation with stable geologic structure.

2.2 Monitoring point selection and pollutant detection

Since the area of the nitrobenzene chemical plant is small and flat, quincunx is adopted in arranging 6 monitoring points with the sampling depths of 0.5m, 1.0m, 1.5m and 2.0m respectively (Lorin et al., 2014). The detection and analysis methods for the pollutants are pursuant to the Technical Regulations for analyzing and Testing National Soil Pollution Survey Samples.
Four organic pollutants, including benzene, methylbenzene, chlorobenzene and nitrobenzene are detected in the petrochemical plant. See Table 1 for the details of the pollutants.

Table 1: The results of each pollutant test (mg/kg)

Pollutant		Benzene	Toluene	Chlorobenzene	Nitrobenzene
0.5m	1#	14.5	50.44	22.74	11.31
	2#	16.7	54.86	24.96	11.7
	3#	18.1	57.46	27.66	11.817
	4#	20.89	61.62	31.68	11.505
1.0m	1#	3.6	37.44	10.44	7.683
	2#	3.1	34.06	10.14	7.488
	3#	3.8	38.22	11.94	6.201
	4#	2.1	39.78	9.66	5.109
1.5m	1#	0.44	29.68	7.28	4.4
	2#	0.49	27.36	7.76	4.4
	3#	1.02	36.86	10.37	5.8
	4#	0.71	37.15	10.75	5.7
2.0m	1#	0.06	6.34	2.1	1.4
	2#	0.07	6.73	2.07	1.4
	3#	0.07	7.37	2.31	1.3
	4#	0.15	15.3	2.21	2.3

3. Pollution analysis and risk evaluation

Table 2: The results of single factor evaluation on pollutants

Pollutant		Benzene	Toluene	Chlorobenzene	Nitrobenzene
Standard value		0.2	26	6	3.9
0.5m	1#	72.50	1.94	3.79	2.90
	2#	83.50	2.11	4.16	3.00
	3#	90.50	2.21	4.61	3.03
	4#	104.45	2.37	5.28	2.95
1.0m	1#	18.00	1.44	1.74	1.97
	2#	15.50	1.31	1.69	1.92
	3#	19.00	1.47	1.99	1.59
	4#	10.50	1.53	1.61	1.31
1.5m	1#	2.20	1.14	1.21	1.13
	2#	2.45	1.05	1.29	1.13
	3#	5.10	1.42	1.73	1.49
	4#	3.55	1.43	1.79	1.46
2.0m	1#	0.30	0.24	0.35	0.36
	2#	0.35	0.26	0.35	0.36
	3#	0.35	0.28	0.39	0.33
	4#	0.75	0.59	0.37	0.59

3.1 Site pollution analysis

The standard value of the Soil Environmental Quality Evaluation Standard for Exhibition Purpose is selected as the standard evaluation value. The evaluation result is as shown in Table 2 by the pollution evaluation standard according to the single-factor pollution index method (McMillan, 2011).
It can be seen from the table that the pollutant distribution is related to depth.
3.1.1 At the depth of 0.5m, the pollution indexes of all the pollutants are more than 1, which means the pollutants have polluted the soil. Among them, the maximum pollution index of methylbenzene is 104.45 far more than 1, which means the soil pollution by methylbenzene is extraordinarily severe, while other pollutant indexes are lower than 5.28.
3.1.2 At the depth of 1.0m, the pollution indexes of all the pollutants decrease to some extent, which means the pollutant concentrations are lower. Yet all the pollutant indexes are still more than 1, which means the pollutants have also resulted in soil pollution. Among them, the maximum pollution index of benzene is 19 far more than 1, which means benzene pollution is very severe. But a great decrease compared to that of 0.5m suggests benzene migrates and degrades fast between in the depth range between 0.5m-1.0m.
3.1.3 At the depth of 1.5m, the pollution index range of all the pollutants decreases to 1.05-5.1, which means there is still extensive pollution which is alleviated compare to that of 1.0m. Among them, the maximum pollution index is 5.1, also from benzene, which is lower compared to that of 1.0m. It suggests the migration and degradation speed of benzene is lowered while the pollution indexes of other organic pollutants are below 2.0.
3.1.4 At the depth of 2.0m, the pollution index range of all the organic pollutants decreases to below 1, which means none of the pollutants have polluted the soil.
The average of the indexes at the 4 different depths is obtained to draw the graph below for the benzene with the highest pollution concentration, as Figure 1, which suggests the pollutant content decreases with the increasing soil depth.

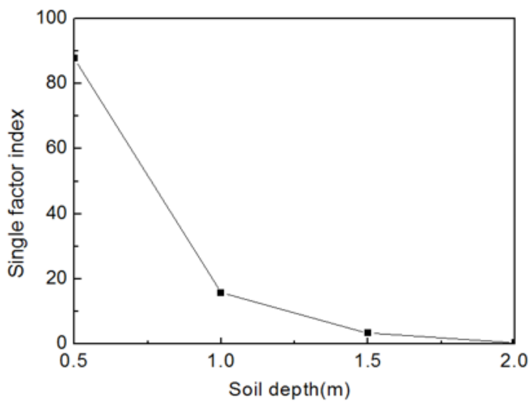

Figure 1: Changes of Benzene Content with Soil Depth

3.2 Health risk evaluation for pollution sources

See Figure 2 for risk evaluation procedure for pollution sources. It includes (1) analysis of pollution sources: to identify pollutants concerned and their discharge rates; (2) exposure analysis: to identify potential population exposed to, exposure route and exposure degree; (3) toxicity analysis: to identify the relationship between pollutant concentration level and health reaction; (4) risk evaluation: to identify the environmental and health risks of the site (Pino et al., 2015). This paper conducts health risk evaluation for residential lands according to the population exposure under the residential land condition of the Technical Guidelines of Risk Evaluation for Polluted Sites (for approval).

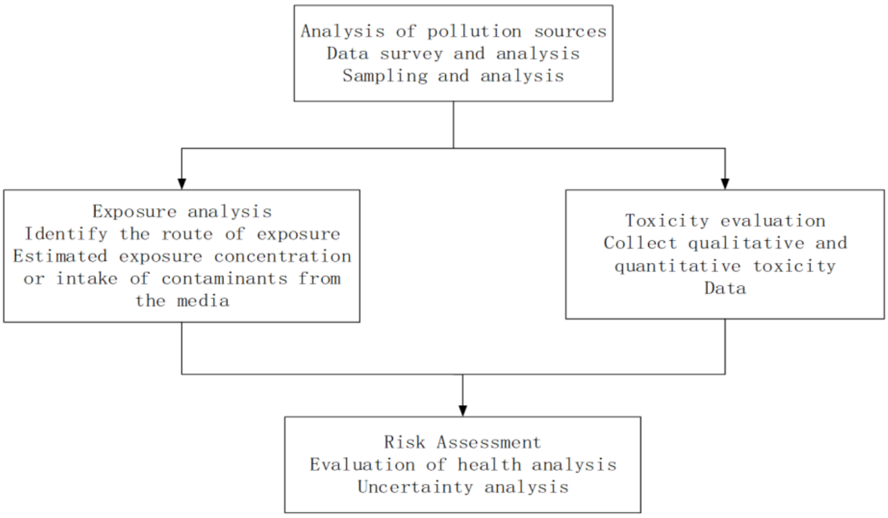

Figure 2: Risk Assessment Procedure for Soil Contamination

Exposure route means the procedure for pollutants in site soil migrate in a certain manner to reach and enter sensitive receptors (Rudin et al., 2012). Areas to be planned as residential lands in future planning shall be considered in risks and harms caused by the soil as a source of pollution respectively. Analyzed from a human health perspective with soil as a source of pollution, children and adults are sensitive receptors who are mainly exposed to the pollution by oral intake of polluted surface soil, skin contact with polluted surface soil, breath intake of the indoor and outdoor particles diffused from polluted surface soil, breath intake of outdoor vapor volatilized from polluted surface soil. Breath intake of indoor and outdoor vapor volatilized from polluted lower soil, etc. (Sahani et al., 2016). The concept model for residential lands is shown in Figure 3.

As for the site, aniline and nitrobenzene are toxic substances with moderate toxicity and volatility (Wagner et al., 2016). They may migrate or run off from soils to water, and then volatilize to the atmosphere by which means it enters human body by breath to jeopardize their health. On the site, there once was an intoxication accident of a scavenger, who was rescued in time with a near miss from death. The underground water level of the site is high according to on-site geological survey (1.50-2.50m below the surface). The pollution from the chemical plant has not yet polluted the underground water for domestic water for the time interval between the dismantling of the plant and the survey is short. Aniline and other pollutants will pollute surrounding farmlands along with flowing underground water and volatilize to the atmosphere to jeopardize the heath of nearby residents.

4. Site environment repair technology

Repair for polluted sites is divided into in-situ repair technology and ex-situ repair technology according to treatment location (Zhu et al., 2017). Being more economical than ex-situ repair, in-situ repair is relatively simple in operation and maintenance without costly engineering treatment facilities and long-distance transportation of pollutants. The disadvantage of in-situ repair is that it is not suitable for sites with low permeability and complex geologic structure. With long repair time, the repair effect is generally not as satisfied (DeRouin et al., 2016). In contrast, ex-situ repair is costlier in usage and equipment maintenance. However, it takes shorter time to repair with satisfying repair effect (Getto and Labriola, 2016).

Figure 4 shows the statistics of polluted site repair project cases in recent years in China (Naeem et al, 2015). The top four are in-situ soil stripping technology, biodegradation technology, immobilization technology and soil leaching technology.

It is worth noting that the following factors are to be considered in selecting soil repair schemes: overall protection requirements, environmental standards or legal requirements for human health and environment, effectiveness, durability, and short-term effectiveness of treatment, operability, cost and acceptance of treatment schemes by the government and community residents.

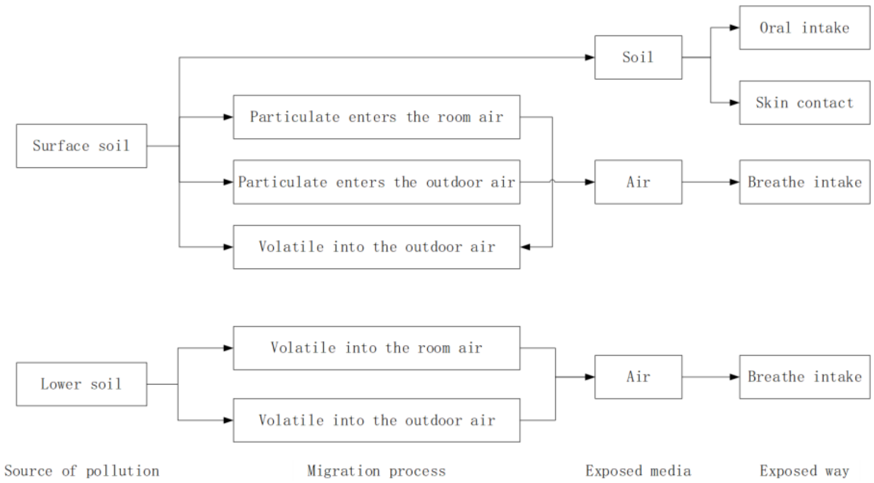

Figure 3: Assessment model of health risk

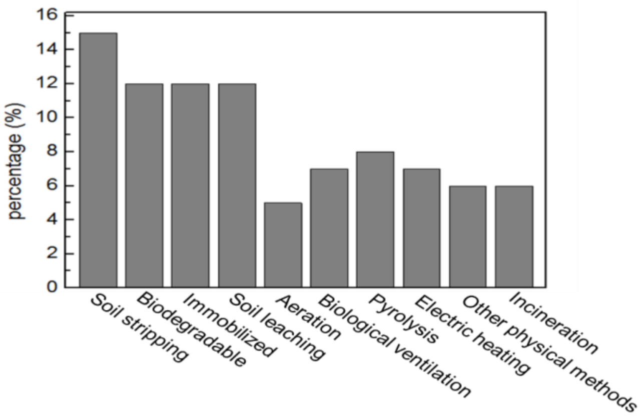

Figure 4: Statistics of contaminated repair project case

5. Conclusion

Soil environment in cites is closed related to production and life of the residents by directly influencing people's physical health. The polluted sites in China are characterized by extensive pollution range, large area, large depth, complex pollution content, heavy pollution and high risk. This is because of long production history and great changes in polluting enterprises move from the sites, complex land use and information loss, poor enterprise management resulting in leakage during production causing severe soil pollution. Ignorance in the demolition process after these enterprises closed results in pollutant diffusion in soil. The fact that polluted sites in China are generally used for residential development intensifies the harm to human health. The risk evaluation of land pollution and polluted land repair are to be further enhanced.

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