Discussion of the problems of municipal rubbish dumping and burial on the geological environment in China

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Abstract: The way rubbish is handled is often restricted by the development level of a country and the urban economy. Before the 1980's, rubbish was mostly dumped and buried on the outskirts of cities in China. There was no sanitation control in the municipal rubbish dumping and burial site. Since there is neither capping on the top of the site nor means to prevent the leakage at the base of the dumping and burial site, the rubbish is in contact with the earth's surface and the leachate infiltrates through soil. At present, the Chinese government is constructing modern landfill in accordance with the international standards for sanitation landfill. Municipal rubbish dumping and burial sites will be closed and remediated.

The geological environment problems of municipal rubbish dumping and burial must be studied in order to close and remediate them successfully. The rubbish dumping and burial sites and the combined relevant rubbish materials were investigated in China. The impact of leachate from rubbish dumping and burial sites on surface water, soil and rock, and groundwater water was analysed, together with gas movement and enrichment in the geological environmental. As a result, the geological environmental problems of municipal rubbish dumping and burial were understood. The study provides a basis for municipal rubbish dumping and burial site remediation in the cities of China.

Résumé: De voie les ordures sont traitées est souvent limité par le niveau de développement d'un pays et l'économie urbaine. Avant les années 1980, les ordures ont été surtout déposées et enterrées aux faubourgs de villes en Chine. Il n'y avait aucun contrôle d'assainissement dans le parc d'ordures municipal et le site d'enterrement. En raison du manque de n'importe quel panneau de recouvrement au sommet du site et ou l'établissement de n'importe quels moyens pour empêcher la fuite à la base du parc et le site d'enterrement, les ordures sont en contact avec la surface de la terre et le leachate s'infiltre par le sol. À présent, le gouvernement chinois construit l'enfouissement des déchets moderne conformément aux standards internationaux pour l'enfouissement des déchets d'assainissement. Le parc d'ordures municipal et des sites d'enterrement seront fermés et reobtenus par médiation.

Les problèmes de parc d'ordures municipal et l'enterrement sur l'environnement géologique doivent être étudiés pour fermer et les reobtenir par médiation avec succès. Le parc d'ordures et les sites d'enterrement et les matériels d'ordures appropriés combinés ont été examinés en Chine. L'impact de leachate du parc d'ordures et des sites d'enterrement sur l'eau superficielle, le sol et la roche et l'eau d'eau souterraine a été analysé et ensemble avec le mouvement du gaz et l'enrichissement dans le géologique environnemental. En conséquence, les problèmes environnementaux géologiques de parc d'ordures municipal et l'enterrement ont été compris. L'étude fournit une base pour le parc d'ordures municipal et le site d'enterrement remédiat dans les villes de la Chine.

Keywords: waste disposal, environmental geology, landfill, leachate, pollution, rock mechanics

INTRODUCTION

With a large number of populations, the amount of rubbish in China increases quickly. The way rubbish is handled is often restricted by the development level of cities' economy and urbanization. Before the 1980's, most of the rubbish was simply dumped and buried on the outskirts of cities in China. With cities' rapid development, people's residences are becoming nearer and nearer to the sites of municipal rubbish dumping and burial, and the site of dumping and burial is not consistent with international standard. What's more, the site of municipal rubbish dumping and burials are no longer adapted to current needs. At present, the Chinese government is constructing sanitary landfills according to international standard, and is to solve the problem of sites of rubbish dumping burial left over by history. The site of municipal rubbish dumping and burials will be closed and remediated. However, only the top and periphery of the site can be sealed. The bottom can not be sealed. The contaminations and leachate are still stored in the sites. In order to close up and remediate the sites successfully, it is urgent to understand the problems of municipal rubbish dumping and burial on the geological environment, and then we will have a definite target to solve it. So it is important that we study on the geological environmental problems of municipal rubbish dumping and burial in time.

THE PRESENT SITUATION OF SITES MUNICIPAL RUBBISH DUMPING AND BURIAL

Before the 1980's, the rubbish had simply dumped and buried on the outskirts of cities. The sites of rubbish dumped and buried were lack of any capping at the top of the site, and of any the establishment to prevent the leakage at the base of site (Fig.1) (Hou, 2004. The rubbish was contacted with the earth's surface. The leachate infiltrates into soil, contaminating the soil and groundwater. The environment around the sites of rubbish dumping was contaminated. There are many sites in every city of China. For example, there are about 215 sites of rubbish dumping and burial in Pudong of Shanghai city of China (Zhang, Fei, Zhao, et al. 1996). Most of the rubbish was dumped in ravine, billabong and mountain valley. The sites of rubbish dumping and burial are unregulated in China.

(a) The panorama of the landfill. (b) The part of landfill (it is 6 m in height).

Figure 1. A circumstance of rubbish dumping site and burial in Sichuan province (Hou, 2004).

The composition of municipal rubbish is affected by the level of living standard. For the most, the compositions of municipal rubbish are the food rubbish and ash 10 years ago. The percentage of food rubbish and ash is higher than that of the other compositions. They make up of about forty-five percent of the municipal rubbish, respectively. The recyclable rubbish (such as paper, glass, plastic and so on) is little (table.1) (Chen 1999). The characteristic of municipal rubbish compositions make the rubbish dumping apt to produce a lot of the leachate and gas, serious polluting the environment.

Table 1. There are compositions of municipal rubbish in some large cities of China (Chen, 1999)

Component	Content in Shanghai (%)	Content in Beijing (%)	Content in Chengdu (%)	Content in Wuhan (%)
foods	40.2	48.48	55.68	36.53
ashes	40.61	32.44	36.70	54.82
paper	2.9	4.17	3.02	2.36
metal	0.9	0.8	1.17	0.17
grass	0.5	0.92	1.50	0.85
plastic	0.5	0.61	0.31	0.31
other rubbish	14.39	10.98	1.62	3.92

THE GEOLOGICAL ENVIRONMENT PROBLEMS OF LEACHATE

The degree which the leachate pollutes the environment is related to the leachate's chemical composition. The chemical composition statistics of municipal rubbish shows that the chemical component is complex, and the density of chemical composition is high (table.2). Such as, the density of COD is higher than 105 mg/l, and is 100 times more than the standard of the waste water drained in industry. The average density of NH4-N is higher than 700 mg/l, it is as 3~4 times as that of excrement (Zhang, 1999). The other compositions densities are high too, and their pollutions are serious.

The leachate pollutes the geological environment harming humans

The leachate compositions are analyzed. There are many chemical compositions which do harm to people in the leachate(Feng & Li, 2001). The chemical compositions do. Once the leachate flows into water and soil, it will pollute them (Liu, Sun & Jing et al .2002). Zhang, Fei & Zhao et al (1996), they analysed the chemistry of rubbish burial leachate and the fish-pond waters which are about 300 m, 400 m, and 600 m away from a site of rubbish burial(table.3). It shows that water quality of leachate is bad. The densities of Cd, Cr, Pb, and Zn in leacahte are higher than that of drinking water standard. The densities of Cd, Cr, Pb, and Zn in fish-pond are lower than that of leachate. The most densities of contaminations of fish-pond waters which were 300 m away from a site of rubbish burial were higher than that of fish-pond waters which were 400 m and 600 m from a site of rubbish burial. The

densities of COD and NO2- were high. The densities of COD were ranged from 24 mg/L to 36.4 mg/L. The densities of NO2- were ranged from 0.02 mg/L to 0.04 mg/L. It shows the fish-pond water was polluted by the leachate of rubbish burial.

Once the leachate pollutes environment, it may be harmful of human. In order to protect the environment from pollution, the leachate moving is must be controlled. If there is not any measure which prevents seepage in site of rubbish dumping and burial, the leachate would pollute water from site of rubbish burial to soil, to groundwater, or to surface water, even directly pollute water. If people drink the polluted water, the health will be directly harmed. The leachate also flows into nearby field. If the heavy metal and other contaminations of leachate are absorbed by soil, and enrichmented by crop, vegetable and livestock, in the end they will go into body by human diet. People's heath will be harmed. When the harmful substances exceed certain restriction in the water or the human body, it will bring great danger to people's health and 6geological environment. Heavy metal (such as Hg , Cd , Cr , Pb and so on) will endanger human's nervous system, heart, kidney, stomach , intestine etc., and will cause "ostealgia disease", gastritis, multiple neuritis, skin and nail pathological change etc. The NO^{2-} may cause the cancer. The NO^{3-} do not endanger the human body directly, but it can turn into NO^{2-} which endanger human body directly. And such organic matter as the carbohydrate, protein, grease, etc. , they can create conditions for the propagation of bacterium, disease germ, virus and helminthes. They will worsen water quality further•and endanger the health seriously.

Table 2. There is statistics of chemical composition of municipal rubbish leachates (zhang, 1999).

Component	Content in America (mg/l)		Content in the mostly larger city of China (mg/l)	
	range	average	range	average
PH	3.7~8.5	5.8	8.28~9.34	8.69
COD	40~89520	8100	793~12027	4346
BOD	81~33360	5700	47.21~892.93	258.71
TOS	584~44900	8955	2006~13826	9238
Cl	47~2500	1700	30.91~4726.11	2743
NH^4-N	0~1106	218	320.77~1423.6	773.9
Pb	0.1~2.0	0.75	0.1~0.2	0.15
Cd	0.3~1.7	0.5	0.05~0.1	0.107
Cu	0~9.9	0.5	0.04~0.24	0.11
Fe	0~2820	94	1.33~13.2	7.26
Zn	0~370	3.5	0.075~1.06	0.48
Ca^{2+}	60~7200	438	110~5420	672
Mg^{2+}	17~15600	230	1803~6540	337
Rigidity ($CaCO_3$)	0~22800	2750	90.72~12670.4	3401
SO_4^{2-}	1~1558	47	6.82~2904	385

The rubbish is simply dumped and buried. There is not sanitary equipment in most sites of rubbish dumping and burial. The leachate directly polluted geological environment, endangered people's health near the sites, where those pollutions had happened several times. They have been draw attention by Chinese government.

Because the leachate of rubbish dumping and burial had polluted geological environment in Heping section of Tianjing, the government had paid ¥ 300 000 for local farmers, in December 1996 (Sun, Wen & Zhang, 2000).

Table 3. The chemical analysis of water from different rubbish disposal site (Zhang, Fei & Zhao et al, 1996).

Component	Content in leachate of rubbish burial (mg/L)	Content in first fish-pond water * (mg/L)	Content in second fish-pond water † (mg/L)	Content in third fish-pond water ‡ (mg/L)
PH	6.9	5.80	6.37	7.0
COD	680	36.4	24.0	28.4
NO_2^-	0.04	0.02	0.02	0.04
Fe	1.98	1.66	0.37	0.52
Mn	0.055	0.13	0.88	0.22
Sr	2.35	0.87	0.51	0.51
Zn	0.21	0.17	0.11	0.013
Al	1.40	0.28	0.43	0.36
P	10.5	0.30	0.06	0.64
As	0.10	<0.05	<0.05	<0.05
Pb	0.21	<0.025	<0.025	<0.025
Cd	0.01	<0.002	<0.002	<0.002
Cr	0.36	<0.005	<0.005	<0.005

* The fish-pond from away site of rubbish is 300 m.
† The fish-pond from away site of rubbish is 400 m.
‡ The fish-pond from away site of rubbish is 600 m.

It happened twice that the leachate polluted environment in Mudanjiang city in 1996. One is the leachate of a rubbish burial flew into a nearby fish-pond, polluting fish-pond, and a lot of fish died because were shortage of oxygen. The other is the leachate of other rubbish burial polluted the underground deep well of a nearby factory, and

the bacilli content exceeded restriction of the drink water 1000 times, which affected people's living and the factory's producing. The environment sanitation department of Mudanjiang city had paid for the owner of fish-pond and factory because of the two incidents, and had to seek a new water source for the factory (Sun, Wen & Zhang, 2000).

The leachate pollutes geological environment affecting the stability of rock and soil engineering

The leachate pollutes soil and rock in two ways: first, the contaminations of leachate permeate in the rock and soil; second, the contaminations of leachate have chemical reaction with soil and rock, corroding soil and rock, and reducing the capability of rock mechanics (Smith, Rowe & Booker, 1993).

The shear strength of rock is related to cohesive strength among rocks granule, normal stress, fracture or pore water pressure and internal friction angle. The shear strength express as follows as equation (1):

$$\tau = \mathrm{c} + (\sigma - \mu)\tan\varphi \tag{1}$$

where, τ is the shear strength in Kpa, c is the cohesion in Kpa, σ is the total normal stress, μ is the pore water pressure in Kpa, φ is the friction angle in degrees.

The leachate has chemical reaction with soil, corroding surface of rock, and reducing cohesive strength of rock. At the same time, the leachate of rubbish will influence the friction angle of rock. The size of rock internal angle depends on the form and size of granule. The friction angle of corner angle granule is bigger than that of slick granule. The corrosion of leachate is obvious to the corner angle, which will make the corner angle granule turn into the slick granule, reducing the internal friction angle. Besides, the leachate contains many organic compounds which are similar to the anti-friction material. The organic compounds can change frictional property and affect interface among granules, and reduce the friction angle of rock. The leachate can increase the pore water pressure. In a word, the leachate reduces the cohesion, the pore water pressure of rock and friction angle. However, the normal stress don't change, the shear strength of rock is reduced for the leacahate influence. In addition, since the leachate has been submerging the rock for long time, the rock becomes soft. The shear strength of rock is reduced. The slope of rubbish dumping and burial would become instability. The slope of landfill would have landside and landslip. The site of rubbish dumping and burial had slid several landsides for recent years in China, the scene of recourse in a landside of rubbish dumping in Chongqing city (Fig. 2) (Chongqing medium, 2002).

Figure 2. The succor scene on a rubbish dumping and burial landslide in Chongqing city (Chongqing medium, 2002).

THE PROBLEMS OF LANDFILL GAS ON THE GEOLOGICAL ENVIRONMENT

The percentage of rubbish organic compound is high in China. So the percentage of CH4 and CO2 is high in the gas of rubbish dumping and burial (table.3) (Wang, Wang & Wang, 2001).

Table 4. There are compositions of gases of rubbish dumping and burial in China (Wang, Wang & Wang, 2001)

Component	The content percentage of volume (%)
CH_4	45~60
CO_2	41~60
N_2	2~5
O_2	0.1~1.0
H_2	0~0.2
H_2S	0~1.0
NH_3	0.1~1.0
CO	0~0.2
Micro gas	0.01~0.05

The geological environment problems of CH_4

The percentage of CH_4 is the highest among those gases. People will stifle if the density of CH_4 is higher and the density of O_2 is lower than that of normal density. If the percentage of CH_4 is 5~10% in air, the CH_4 will explode.

Besides, if the CH_4 is largely stored up in the sites of rubbish dumping and burial, forming mighty pressure which is higher than that of overburden; and if the pressure in the sites of rubbish dumping and burial suddenly is decompressed; the gas will explode in the sites of rubbish dumping and burial. The landfill gas moves out of rubbish dumping and burial site to surface through crannies. Or the landfill gas goes into inside of building through drain and or other pipeline. It will explode if the density of CH4 gas attains a certain degree. Because the CH4 had been massed largely, the CH4 had exploded several times in 1990's in China.

In August 1994,a site of rubbish dumping and burial where bulk was 20 000 m3 exploded, casting 15 0 000 000 kg rubbish to the sky, and destroying a pump room out of the site in Yueyang city of Hunan province (Sun, Wen & Zhang, 2000).

In 1995, due to a larger number of landfill gases horizontally moving, the landfill gas went into nearby building. Then the gas exploded in the nearby building which it had occurred in a site of rubbish dumping and burial of Beijing (Sun, Wen & Zhang, 2000).

In addition, if the density of CH4 is high over field around the sites of rubbish dumping and burial; the CH4 would replace the air, and prevent the air from getting into the soil, which causes the crop which is short of oxygen and die. So the high density of CH4 will be harmful to the nearby crops.

The geological environment problems of CO_2

The percentage of CO2 is the second maximum among those gases. It is achromatic, tasteless, and avirulent. Its heat stability is high. Only if the environment temperature is high, the CO2 will be decomposed to CO and O2. People can not breathe if the percentage of CO2 is equal to or bigger than 3% in air. People will lose consciousness, cease breath and die. The density of CO2 is 1.5 times as much as air. The CO2 dissolve into water to carbonic acid. The CO2 moves into the site of dumping and burial, dissolves into groundwater, and causes the rigidity of water quality become high.

The stratum is limestone mostly in Chongqing city, Guizhou, Guangxi and Yunnan province in westward of China. The CO2 and H2O come from organic compound degradation. The CO2 and H2O can corrode limestone. Once the CO2 dissolves in water, it will turn into H2CO3, then the H2CO3 dissociates for H+ and (HCO3) - in water. The H+ and (HCO3) - can dissolve the insoluble carbonate (such as CaCO3) into the soluble carbonate (such as Ca (HCO3)2). The courses of corrosion are expressed as follows chemical equitation (2) to (4).

$$CO_2 + H_2O = H_2CO_3 \tag{2}$$

$$H_2CO_3 \xrightarrow{\text{hydrolyze}} (HCO_3)^- + H^+ \tag{3}$$

$$(HCO_3)^- + H^+ + CaCO_3 = Ca(HCO_3)_2 \tag{4}$$

The high calorific value and moisture physical property of the Chinese rubbish determined that the rubbish will produce large amount of heat and leachate, when the organic compound of rubbish degrades. The heat and leachate can greatly accelerate the corrosion course, increasing the slope instability of rubbish dumping and burial.

The geological environment problems of the other landfill gases

The H_2S is one kind of fetid gas. If the percentage of H_2S reaches 0.1 % in the air, people will have a headache and dizzy. If people breathe a lot of H_2S, they will be unconscious or dead. The H_2S can oxidize to S, SO_2 and H_2SO_4, increasing the yield of acid rain, polluting the grounder water and corroding the rock and soil. The NH_3 is achromatic, fetid gas and alkalescence. The NH_3 has chemical reaction with acid of rock and soil to produce salt, changing the chemical characteristic rock and soil.. The NH_3 is easy to dissolve in water. The CO is the toxic gas. If people absorb a lot of CO, they will be poisoned even to death. The density of micro gas is low. But it has large toxicity and do harm to people (Lawson, 1989). The law of micro gas distribute over sites of rubbish dumping and burial as following the density of micro gas in new sites is higher than that of old sites; the density in sites is higher than that of out of sites; the density in low topography is higher than that of high topography; the density at downwind of sites is higher than that of windward. The volatilization organic compound pollute environment around among 2 km^2 of sites.

In order that the sites of rubbish dumping and burial are closed up and remediate successfully, decreasing environment pollution, it is importance that the landfill gasses be collected and handled.

CONCLUSIONS

There are neither capping at the top of the rubbish dumping and burial site, nor establishment to prevent the leakage at the base of site, or nor drainage to drain water around the site of rubbish dumping and burial. The rubbish dumping and burial produce many leachates and gases, polluting the environment. The leachates permeate into the ground and pollute groundwater, surface water, rock and soil, harming lives of mankind. The leachate corrodes rocks and soils, decreases friction of rocks and soils. The leachate soaks rocks and soils, reducing compressive strength and increasing hydraulic pressure. In short, the leachate reduces the shear strength, increasing the slope instability of site rubbish dumping and burial.

There is no establishment to discharge gases. The landfill gases build up in the site of rubbish dumping and burial. Then the landfill gases move in the rock and soil or discharge into the air. The gases will explode when the

percentage of gases is 5%~15% in the air. The CO_2 moves in the base of site of rubbish and burial and has chemical reaction with rock and soil, corroding rock and soil, decreasing the slope stability of site of rubbish dumping and burial. Other gases are few, but their toxicity is big.

In short, the sites of rubbish dumping and burial left over by history have a lot of geological environment problems. In order to decrease the pollution, the top of sites should be sealed, the waters should be drianed around the sites, the leachate of sites should be collected and handled, and the landfill gas should be orderly exhausted. On the basis of analyses on the geological environment problems of rubbish dumping and burial site, some measures are put forward to remediate these sites.

There are the clay and film on top of sites of rubbish dumping and burial to prevent the rainwater from seeping into sites. The drain and ditch are built around the site of rubbish dumping and burial, preventing the surface water from flowing into site. The cistern is built to hold up leachate to be pumped out of cistern. The exhaust pipe is built in rubbish and dumping burial site. The landfill gases are piped out of site, and then the gases are collected and utilized. After close up of the site, the vegetations would be planted in the site to absorb the landfill gas and to purify the leachate. As a result, geological and ecological environment may recover as soon as possible.

Acknowledgements: The work presented in this paper was carried out with funding from Natural Science Foundation of Chongqing grant number 102075120040022, and from the Apllied and Fundamental Foundation of municipal manage committee of Chongqing city grant number 200511.

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