Hydrogeochemical Investigation and Numerical Simulation of Solute Transport into Surface and Groundwater , Case Studied: Jiaxing Landfill Leachate

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Abstract: Hangjiahu regions belong to the Yangtze River Delta region in Zhejiang Province in China. The vast majority of this region is flat, so surface and groundwater both have a low flow rate. With the rapid economic development of the area, a large number of industrial and domestic garbage are generated. These landfill or garbage are exposed and stacked. Because of mismanagement of environment, the atmosphere under the leaching rainfall, results in harmful gases and leachate. A serious pollution of the atmosphere surrounding the dump, soil, surface water and groundwater occurred. By studying the area under different hydro geological conditions this groundwater pollution due to the landfill can be stopped and prevented. This research can also provide a scientific basis. some samples were taken to some specific sampling points in order to do chemical analysis. A hydro geological investigation was done on the study area. By using all these data, groundwater pollution was evaluated and predicted through numerical simulation software: GMS (Groundwater Modeling System), from 1996 to 2011. it appeared that the level and the flow rate of the groundwater change according the dry or wet period. So, the pollution increases with there rising. In the Hexi Bang Village, the change in water level is about 0.5m:1.5m in wet period and 1m in dry period. Also water level is higher near the landfill (3.1m)than in other places. Groundwater flows very slowly and water level is law in some area because of poor permeability of the aquifer and groundwater exploitation, simulated water table was significantly lower than the region surrounding the central region. In July 2007 HexiBang demolition stopped the exploitation of groundwater in the area. The depression cones have disappeared in groundwater pumping areas on July 2009. The people of Hexi Bang village may have a negative impact on water quality. And surface and groundwater at the north and the south-east of landfill also can be harmful for people. Also from the simulation results, in January 2009 the chlorine ion (10mg / l) contour lines moved northward at about 220m. And in January 2011 they moved for about 235m. So from January 2009 to January 2011, during these two years, the 10mg / l contour moved to the north for about 15m. From the simulation results 0.01mg/l of BTEX contour line ,moved about 50m northward in 10 Years and about 84m northward in 20 Years. Experimental and simulation results were compared and showed that close agreement between these two values were obtained. The application of ecological methods to remove harmful substances such as the cultivation of suitable plants is also necessary.
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Keywords: Hydrogeochemical Investigation-Numerical simulation-Solute Transport-Jiaxing Landfill.

INTRODUCTION

Pollutants migration, transformation and accumulation in soil and groundwater are results of combined effects of a complex physical, chemical and biochemical actions. Research of pollutants migration and transformation in the groundwater has more than 50 years of history. Now we have a better theory and a wide variety of computing models, part of the models has been applied to solve practical engineering problems. Model solutions have also been in great progress, and we have some relatively sophisticated numerical simulation methods and softwares.

This work was done by combining both deterministic and stochastic models as defined by Addiscott (1985) [1].

The first to propose a similar model of advection-dispersion equation are Lapidus and Amundson (1952) [2], they opened a prelude to the study of solute transport, but they did not give the model parameters derivation ways and specific meaning.

In 1954, Scheidigg will use Lapidus to the three-dimensional expansion of the equation, bearing in mind at the time of the solute transport in the role of mechanical dispersion, so that the theoretical study of solute transport in a step forward.

In 1956, Rifai used Scheidigg on basic research results, but also takes into account the molecular diffusion of solute transport role and the introduction of the concept of dispersion (hydrodynamic dispersion coefficient and pore water velocity ratio $\alpha = D / V$), so that solute migration theory is used for more depth of groundwater.

Between 1961-1962 Nielson and Biggar [3,4] based on a series of experiments, made easy mixed replacement theory, consider the flux of solute by convection, diffusion and dispersion caused by the combined effects, and theoretically set up a convection dispersion equation.

According to the experimental results, Lapidus, Shceidegg and Nielson's model is a comparative analysis of the results and shows that the convection dispersion equation better describes the conservative substances in porous media.
Nielosn set up a one-dimensional convection-dispersion equation as follows:

$$R_d \frac{\partial C}{\partial t} = \frac{\partial}{\partial z}(D_{sh}\frac{\partial C}{\partial z}) - u\frac{\partial C}{\partial z}$$

Rd for the retardation factor, Dsh for hydrodynamic dispersion coefficient, (L2 / T); ц for the average pore water velocity, (L / T); C is solute concentration, (M/L3); z for vertical to the coordinates, (L).
Lindstrone et al [6], Cleary and Adrain [7], obtained the same results with different boundary conditions of the analytical solution[5].
With the popularization of computers, numerical methods are used to solve many solute transport problems [8].
In 1980, Dasgupta .. D [9], set up a chemical reaction groundwater solute transport model, and simulated a leachate migration and transformation of iron ions from a garbage in Miami in the United States. Morrison and Stan J (1995) [10], set up the value of uranium and iron six interaction reaction - migration model to analyze the reaction of iron hydroxides walls of hexavalent uranium in groundwater. Toride et al (1996) [11] set up for stable linear filter down and primary sport of the CDE(convection-diffusion Equation) model Absorption; Flury (1998) [12] the solute degradation and adsorption process and the relationship between soil depth using a generalized function, and experimental data authentication; Pachepsky (1999) [13] set up a description of the different soil moisture and reflect the fractal characteristics of medium convection - diffusion equation. In 1999 Stewart, Iris T, etc. [14] set up a TTFs (type transfer functions) model Fresno, California United States east of the regional DBCP (dibromo-chloropropane) on the impact of groundwater quality assessment of a simulation. Karapanagioti et al (2001) [15] taking into account evaporation, dispersion, adsorption and degradation established aquifer contaminant transport model of multi-component mixtures. Vanderborght (2007) [16] for pesticides and salt transmission prediction study will describe the material in the solid and liquid two states under the reaction function with convection -- combining the dispersion equation and application.

The study area Overview

Hangzhou-Jiaxing-Huzhou Taihu Lake Basin is located in the southeastern region of China in Zhejiang province(see Figure1and 2). The geographical coordinates are: longitude between 120° 00' and 121 °16' latitude between 30°13' and 31°02' , for an area of about 6490km2.

Figure 1 Location of the Study Area

Ground elevation is between 1 ~ 7m. In the Western Part, there is a sporadic distribution of residual hill with an average elevation of 100 meters.
The study area is located in subtropical monsoon climate zone with four seasons. The annual average temperature 15.7 ° C ~ 16.2 ° C. Average precipitation over the years is between 1140 ~ 1350mm.
The average surface evaporation is 910mm/year with an average of 80 percent of relative humidity.
The area occupied by surface water is of 679km2(10.5% of total area). The total river length is 24000km..
Jiaxing region is densely populated and economically developed.
The land known as the "land of fish and rice" is fertile and rich(9.31% of Zhejiang Province).
The study area's population is 19.35% of Zhejiang Province for a gross domestic product accounted of 30.64% (see the Table 1).

Table 1 Socio-economic profiles (by the end of 2004 statistical data)

Region	Population (million)	Land (km2)	Arable land (1000 hectares)	Gross domestic product (billion RMB)
Hangzhou City	4.0159	3068	98.327	1949.41
Huzhou City	1.5032	2502	72.734	388.45
Jiaxing City	3.3394	3915	210.84	1107.15
Province	45.7722	101800	1594.92	11243

Jiaxing City Landfill basic information

Jiaxing landfill is surrounded by rivers(see Figure 3).

Landfill rubbish dumps average altitude is about 25m and the elevation throughout the region is between 4.2m to 2.0m. The main aquifer layer is fine powder of sand. And there is no large-scale exploitation of water resources in the region.

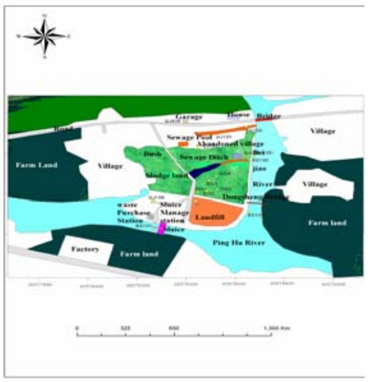

Figure 2 Jiaxing Landfills Overview map with the sampling points

MATERIALS AND METHODS

This work was done in two important phases: investigations and numerical simulation.

Investigations:

Landfill leachate is generated by water or other liquids passing through the trash [17]. Landfill leachate comes mainly from precipitation, surface water, groundwater intrusion into landfill and litter moisture [18-19].

Some soil and water samples were used for experimental analysis in November 2007 and September 2008. It was about: Absorption, adsoption, desorption,…,and to get the main organic and inorganic pollutants in the study area. The experiments were done at China University of Geosciences (Wuhan), School of Environmental Studies Laboratory of the solute transport. At the trial period, the indoor temperature was 23-25 degrees Celsius. The main experimental equipment are in Table 2.

Table 2 Main experiment Equipment

Name	Model	Remarks
Electronic Balance	BS210S Max210g d=0.1mg	Germany sartorious
Conductivity Meter	HI8733(With ATC function Sihuan HI76302 conductivity electrode)	Italy HANNA
Graduated cylinder	500ml,100ml,50ml,1050ml	
Ion chromatograph	DX120	Diana
Peristaltic pump		
Vacuum pump		

Landfill Leachate production forecasting methods are: empirical formula, water balance, statistical method and model.

Empirical formula:

$$Q = (C_1A_1 + C_2A_2) \times I \times 10^{-3}$$

Where:

Q —— average Leachate produced a day （m^3/d）；

I ——found by using the annual average rainfall to convert into daily average rainfall （mm/d）；

A1 ——Landfill area（m^2）；

A2 ——Landfill resting seepage or influence zone area（m^2）；

C1 and C2 are coefficients that are function of hydrogeological conditions (nature of soil, its porosity and slope, precipitation, evapotranspiration…) of respectively A1 and A2.they values vary from 0.2 to 0.8

For surface water we have [20]

$$Q_{max} = 0.25[1+(C-1)\lg(1.4R^{0.3})]W_{max} / R^{0.6}$$

(for high flow rate)

$Q_{max} = 0.25CW_{max} / R^{0.6}$ (for low flow rate)

Where: Q_{max} is the largest volume of leachate generated （mm/d）; W_{max} is the largest monthly precipitation（ mm/d）; C is the outflow coefficient(0.60-0.75); R is Filtrate leaching delay time（d）.

Water balance method:

$$P+W+Q_1+Q_2=L+E_1+E_2+Q_3+G+\Delta H$$

Where: L is Leachate production in a certain period （m^3）; P: precipitation in landfill site in the same period（m^3）; W: water generated by garbage degradation (m^3); Q_1: external infiltration of water（m^3）;Q2: inflow of water from the external surface（m^3）; Q_3: the loss of Landfill site from the water table（m^3）; E_1: Evaporation of water table landfill site（m^3）; E_2 Landfill plant leaf surface water evaporation(m^3）; G: the moisture away from landfill gas（m^3）; ΔH changes in the value of landfill pit water content(m^3）.

(3) statistical method

$$Q = q \times A \times 10^{-4}$$

Where: Q Leachate production (m^3/d);

A Landfill catchment area($m^{2)}$;

q Leachate production per unit area m^3/ha.d

The model: to predict the solute transport we need to solve simultaneously the groundwater flow in unconfined aquifer and the solute transport equations [21-22-23]:

$$\begin{cases} \mu\frac{\partial H}{\partial t} = \frac{\partial}{\partial x}\left[(H-B)K\frac{\partial H}{\partial x}\right] + \frac{\partial}{\partial y}\left[(H-B)K\frac{\partial H}{\partial y}\right] + W - P & (x,y \in D) \\ H(x_0,y_0,t)\big|_{t=t_0} = H_0(x_0,y_0,t_0) & (x,y) \in D \\ H(x,y,t)\big|_{\Gamma_1} = H_1(x,y,t) & (x,y) \in \Gamma_1, t>0 \\ (H-B)K\frac{\partial H}{\partial n}\big|_{\Gamma_2} = -q(x,y,t) & (x,y) \in \Gamma_2, t>0 \end{cases}$$

(Groundwater flow)

Where: K-permeability coefficient (m / d); - rock water aquifer degrees (dimensionless); H (x0, y0, t) - unconfined aquifer water level (m); B (x, y) - aquifer Bottom elevation (m); H0 (x0, y0, t0) - the initial flow field (m); H1 (x, y, t) - a class of the border on the water level (m); W-vertical aquifer system strength supply (m3 / (d.m2)); P-water supply and agricultural production intensity (m3 / (d.m2)); q (x0, y0, t) - II on the border of the flow (m3 / (dm)).

$$\begin{cases} R_d\frac{\partial C}{\partial t} = D_L\frac{\partial^2 C}{\partial x^2} + D_T\frac{\partial^2 C}{\partial y^2} - v_x\frac{\partial C}{\partial x} - v_y\frac{\partial C}{\partial y} & (x,y) \in D, t>0 \\ C(x,y,0) = C_0(x,y) & (x,y) \in D \\ C(x,y)\big|_{B1} = f_1(x,y) & (x,y) \in B1 \\ -D\frac{\partial C}{\partial x_j}n_i\big|_{B_2} = f_2(x,y,t) & (x,y) \in B1 \end{cases}$$

(Solute transport)

Where: C0 (x, y) - the initial concentration of pollutants (mg / l); f1 (x, y, t) to set the boundary concentration (mg / l); f2 (x, y, t) - gives the boundary diffusion flux (mg.m-2.t-1); D-hydrodynamic dispersion coefficient (m2 / d); Rd-pollutant retardation factor.

Numerical simulation

The results of these investigations have been used as input into a GMS(Groundwater Modeling System) to make simulation(by solving the model equations) in order to understand and to predict water pollution. Groundwater Modeling System (GMS) is a software made by Brigham Young University in the United States of America and US Army.

GIS (Geographic Information System) also has been used to output maps.

The study area covers 1.7km2, it is surrounded by three rivers and these rivers are cutting an unconfined aquifer. Landfill site is in south-east corner of the study area, it covers an area of 0.21853044 km2. The accumulation of ground above the average thickness is about 25m (Figure 4-5). According to the geological conditions and hydro-geological conditions, the thickness of the upper soil layer is about 0.2-3m; the lower fine powdered sandy layers thickness is 3-7m (Figure 6). They are two Anisotropic and homogeneous structures. The rivers can serve as a constant head boundary.

According to the characteristics of groundwater flow, the area can be summarized into a three-dimensional non-steady groundwater flow system.

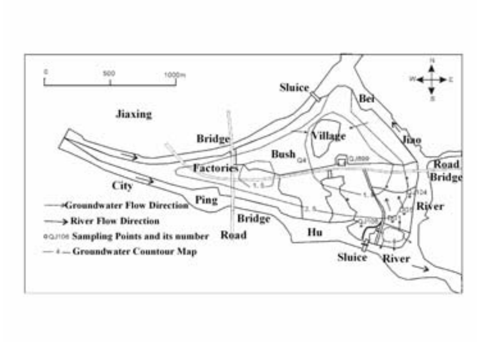

Figure 3 study area conceptual model.

Some sampling points have been set up to get initial water level (Figure 7).

There are two main periods: wet period and dry period taken as boundary condition. And the

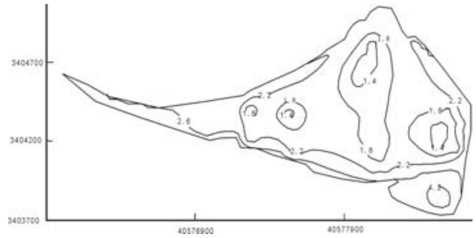

Figure 4 the initial water level map.

source/sink are: infiltration, precipitation, evapotranspiration irrigation, exploitation(water supply) etc. The main parameters are in table 3 and the rainfall distribution in Figure 8.

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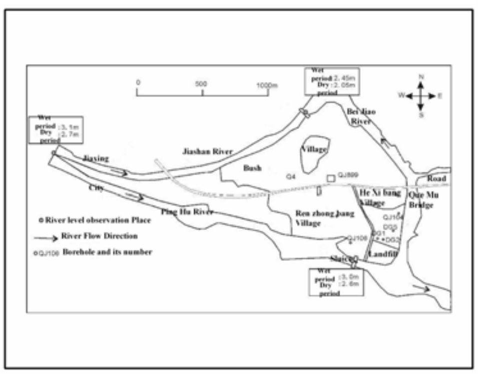


Figure 6 Change in the river water level

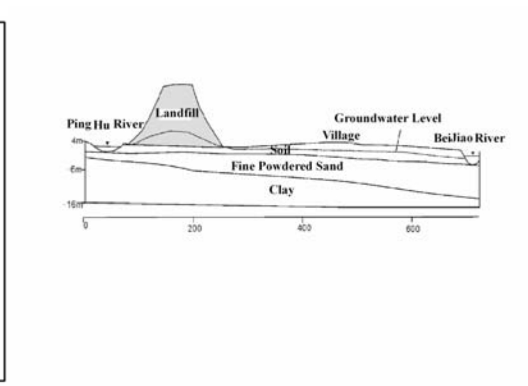


Figure 5 hydrogeological study area profiles

Table 3 Hydrogeological simulation parameter table

Parameters	The first Layer	The second Layer
The level permeability coefficient（m/d）	0.08	0.46
Degree of gravity water supply	0.1	0.3
Degree of flexibility in water supply（1/m）	0.0001	0.00003

*These data were get from Jiaxing Water Conservancy and Hydropower Survey and Design Institute

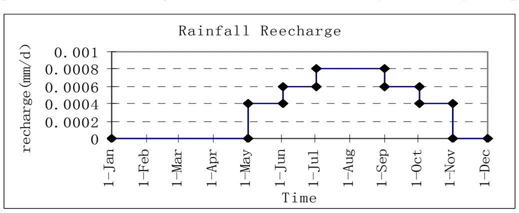
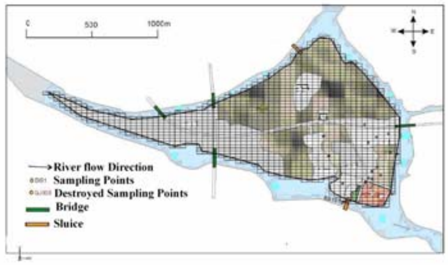


Figure 7 The average rainfall distribution on the study area

The simulation has used a discrete rectangular grid spacing. In the X direction the distance between two nodes is 43m while in the Y direction the grid spacing is 14m. In the Z direction, based on borehole data in this area, and the hydro-geological profiles, there are two layers(see Figure 9 and 10)

So there is at all 2892 cells (1446/layer)



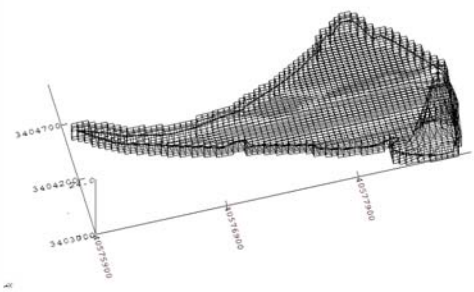


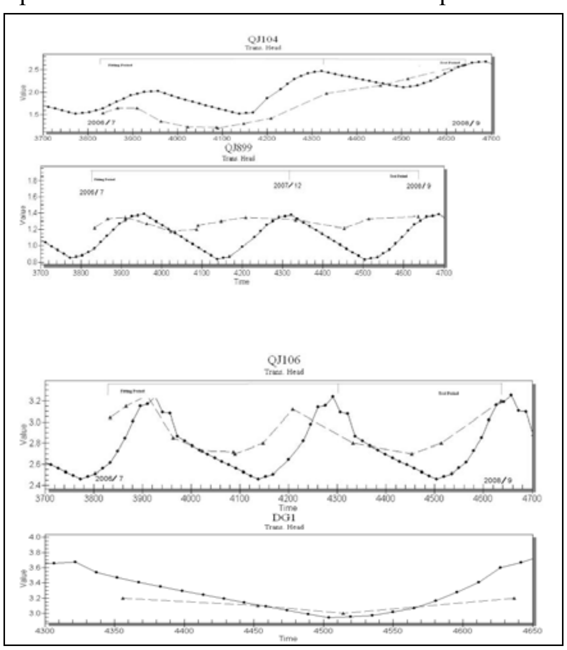
Figure 8 Mesh of study area map. Figure 9 Mesh of three-dimensional map (20 times vertical zoom).

The landfill was opened in 1996 and closed in 2007,but the simulation time is from January 1996 to February 2011. And time unit is one day. Seven observation wells: QJ104, QJ106 ,QJ899, DG1, DG2, DG3 and DG5 are chosen according to hydrogeological conditions and there data are used for the simulation(see Table 4).

Table 4 Fitting test observation time

Observation wells	Observation time	Fitting stage	The testing phase
DG1	2007.12-2008.9		2007.12-2008.9
DG2	2007.12-2008.9		2007.12-2008.9
DG3	2007.12-2008.9		2007.12-2008.9
DG5	2007.12-2008.9		2007.12-2008.9
QJ104	2006.7-2008.9	2006.7-2007.12	2007.12-2008.9
QJ106	2006.7-2008.9	2006.7-2007.12	2007.12-2008.9
QG899	2006.7-2008.9	2006.7-2007.12	2007.12-2008.9

This study used Calibration model based on previous hydro-geological conditions and the pumping test data to develop a set of initial parameter values. And the first time step values are got from these values, the second time step values from the first time step values etc. And simulation results reflected the observed data (Figure 11).



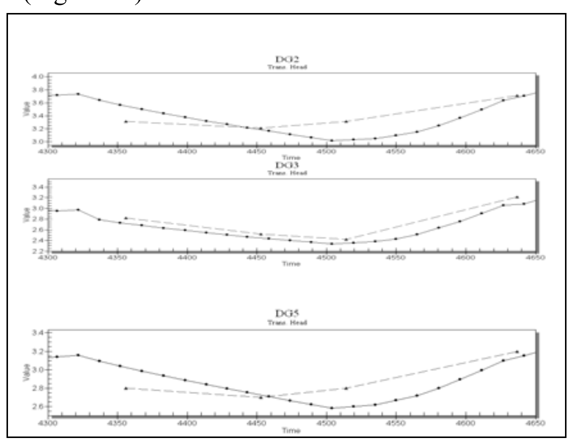


Figure 10 observation wells data set (*Triangle for the observed data **Dot for interpolated data)

RESULTS AND DISCUSSION

By comparing the results of investigations essentially for two years(2006and 2007), organic pollutants have been found in the entire study area. A total of six relatively high concentration pollutants were found: methylene chloride, chloroform, dichloromethane, benzene, two chloro-propane and toluene.

In November 2007, the landfills PH value was 7.9, its inorganic content are in table 5.

Table 5 Inorganic ions concentration

Element	Concentration (mg/l)	Element	Concentration(mg/l)
As	0.057	Ni	0.996
B	1.772	P	20.8
Ba	1.321	Pb	0.0715
Ca	60.981	S	60.6
Cd	0.002	Sb	0.0905
Co	0.0605	Se	0.0025
Cr	0.263	Si	24.38
Cu	0.033	Sr	0.7245
Fe	6.3045	V	0.441
K	2019.668	Zn	0.3555
Li	0.576	F^-	300.54
Mg	78.671	Cl^-	4445.958
Mn	0.265	NO_2^-	N
Mo	N	NO_3^-	N
Na	2023.313	SO_4^{2-}	172.904

*N means component note found or has a very low concentration.

The test found a high concentration of chloride ion in Jiaxing landfills leachate (4446mg / l). And experimental data showed different chloride ion concentrations in different layers. Absorption desorption phenomenon exists in pink sand layer while it is very weak in sand and loam layers(Figure 12 and table 6-7).

Table 6 Filtrate sample number and volume for leaching experiment.

Soil Samples	Filtrate Absorption No	Volume(ml)	Filtrate Desorption No	Volume
	CLJ1	300	CLJJ1	300
	CLJ2	300	CLJJ2	300
	CLJ3	300	CLJJ3	300
Sand	CLJ4	300	CLJJ4	300
	CLJ5	300	CLJJ5	300
	FLJ1	238	FLJJ1	185
	FLJ2	200	FLJJ2	200
	FLJ3	208	FLJJ3	240
	FLJ4	212	FLJJ4	200
	FLJ5	212	FLJJ5	200
	FLJ6	216	FLJJ6	228
Pink	FLJ7	232	FLJJ7	248
Sand	FLJ8	229	FLJJ8	248
	FLJ9	200	FLJJ9	278
	FLJ10	205	FLJJ9	287
	SLJ1	57	SLJJ1	65
	SLJ2	41		
	SLJ3	62		
	SLJ4	78		
Loam	SLJ5	58		
	SLJ6	42		
	SLJ7	40		
	SLJ8	43		
	SLJ9	46		
	SLJ10	25		

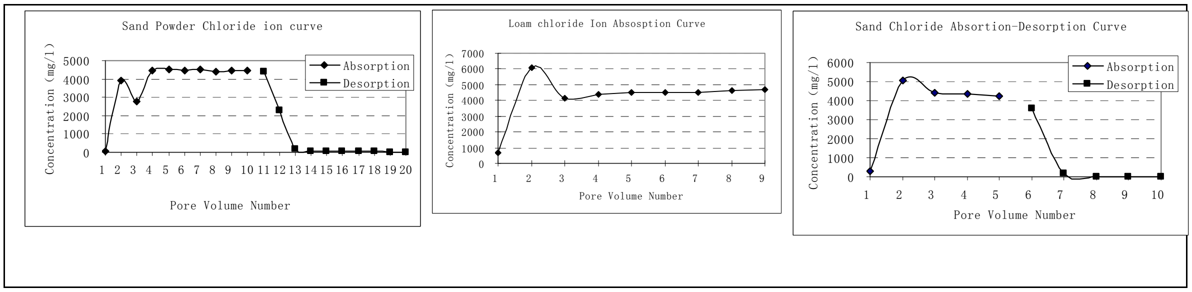


Figure 11 Absorption and desorption curves of chloride ions

Table 7 Cl-concentration changes in absorption and desorption experiments of powder sand

Sample No.	Filtrate volume（ml）	Filtrate concentration（mg/l）	Cl-content of filtrate（mg）	Sample Concentration	Cl-content (mg)
FLJ1	238	35.05	8.34	4445.96	1058.14
FLJ2X	200	3941.043	788.21	4445.96	889.19
FLJ3X	208	2796.18	581.60	4445.96	924.76
FLJ4X	212	4431.42	939.46	4445.96	942.54
FLJ5X	176	4497.72	791.6	4445.96	782.49
FLJ6X	216	4457.06	962.72	4445.96	960.33
FJL7X	232	4526.81	1050.22	4445.96	1031.46
FJL8X	229	4416.16	1011.30	4445.96	1018.12
FLJ9X	200	4436.87	887.37	4445.96	889.19
FLJ10	205	4463.90	915.10	4445.96	911.42
FLJJ1X	185	4373.87	809.17	14.00	2.59
FLJJ2X	200	2317.44	463.49	14.00	2.8
FLJJ3X	240	204.08	48.98	14.00	3.36
FLJJ4X	200	58.82	11.76	14.00	2.80
FLJJ5X	225	50.14	11.28	14.00	3.15
FLJJ6X	228	49.02	11.18	14.00	3.19
FLJJ7X	248	45.03	11.17	14.00	3.47
FLJJ8X	248	30.30	7.15	14.00	3.47
FLJJ9X	278	28.93	8.04	14.00	3.89
FLJJ10X	287	28.20	8.09	14.00	4.02

According to mass conservation law, the experimental adsorption of chloride ions is calculated as:

$$S = \frac{\sum_{i=1}^{k}(C_0 - C_i)V_i - V_0 \times C_0}{M} \quad (1)$$

S-unit mass of soil samples the amount of chloride ion adsorption (mg / kg); i-filtrate ID; C0-AS concentration (mg / l); Vi-section No. i filtrate volume (l); Ci-section No. i filtrate concentration (mg / l); V0-pore volume (l); M-soil quality (kg).

By the same way, we got a weak absorption-desortption in loam layer for sulfate and fluoride ions(table 8 and figure 13-14).

Table 8 Sulfate powder sand desorption-absorption test Record

Sample No.	Filtrate volume (ml）	Filtrate concentration（mg/l）	SO42-content of filtrate（mg）	Sample Concentration	SO42-content (mg)
FLJ1	238	29.56	7.02	172.90	41.15
FLJ2X	200	63.1995	12.64	172.90	34.58
FLJ3X	208	148.91	30.97	172.90	35.96
FLJ4X	212	150.86	31.98	172.90	36.66
FLJ5X	176	147.79	26.01	172.90	30.43
FLJ6X	216	150.83	32.58	172.90	37.35
FJL7X	232	144.15	33.44	172.90	40.11
FJL8X	229	145.02	33.21	172.90	39.60
FLJ9X	200	144.16	28.83	172.90	34.58
FLJ10	205	141.34	28.98	172.90	35.45
FLJJ1X	185	173.70	32.13	28.30	2.59
FLJJ2X	200	114.87	22.97	28.30	2.80
FLJJ3X	240	46.31	11.11	28.30	3.36
FLJJ4X	200	42.12	8.42	28.30	2.80
FLJJ5X	225	44.97	10.12	28.30	3.15
FLJJ6X	228	47.66	10.87	28.30	3.19
FLJJ7X	248	46.57	11.55	28.30	3.47
FLJJ8X	248	38.15	9.46	28.30	3.47
FLJJ9X	278	43.05	11.97	28.30	3.89
FLJJ10X	287	28.20	12.31	28.30	4.02

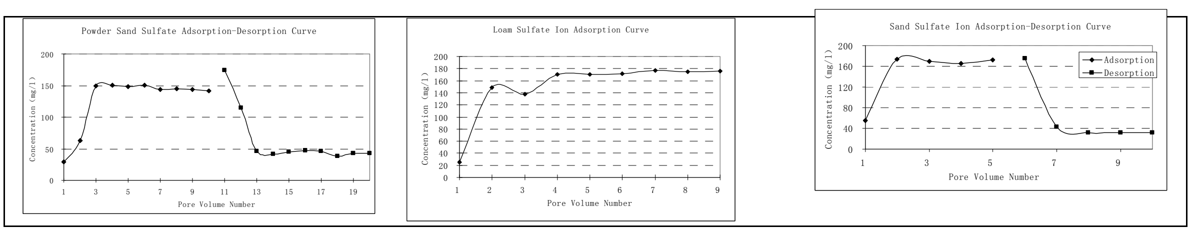


Figure 12 sulfate adsorption and desorption curves

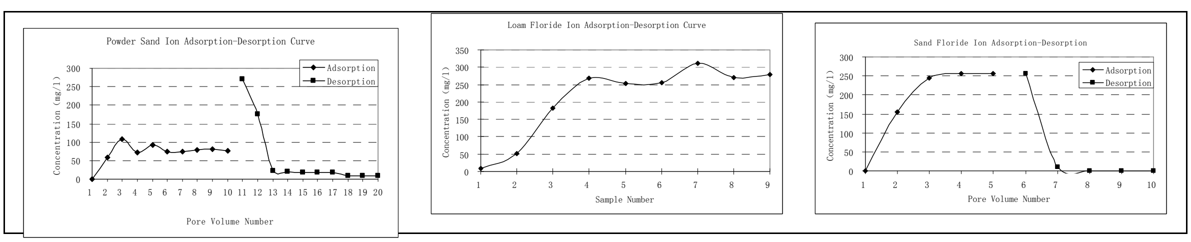
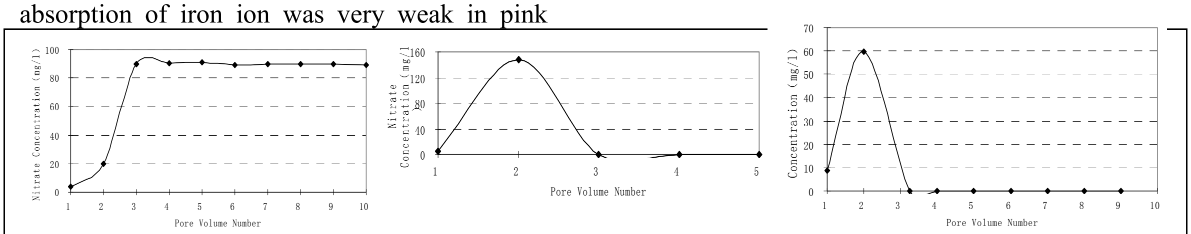


Figure 13 Absorption and desorption curves of fluoride ion.

No absorption for nitrate ion, and its most desorption was in pink sand(Figure 15). Also the absorption of iron ion was very weak in pink sand while its desorption is very weak in sand and loam(Figure 16).



Pink sand Sand loam

Figure 14 desorption curve of Nitrate ion

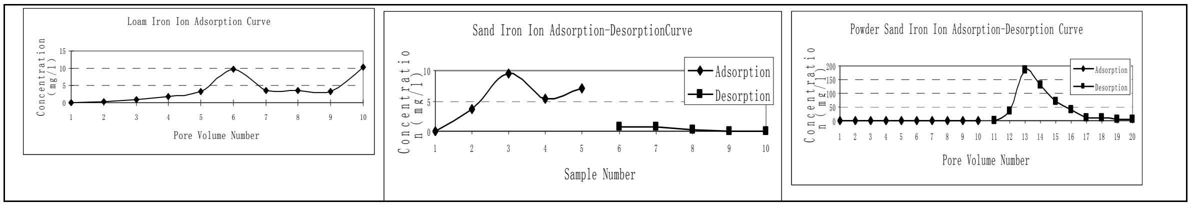


Figure 15 Absorption and desorption curves of iron ions

Simulation

Water level is always high near the landfill while it is often very low far from the landfill.(Figure 17-18-19). That affected seriously the solute transport from high level to low level.

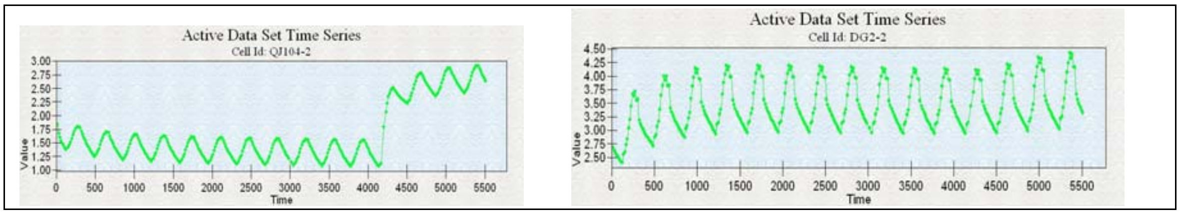


Figure 16 changes in water table in wells

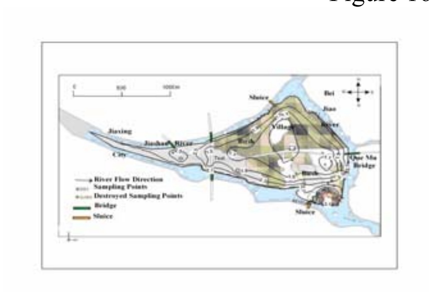


Figure 17 contour map in July 2007

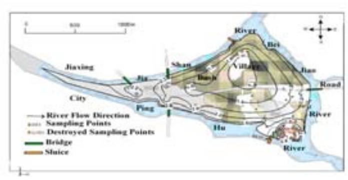


Figure 18 contour map in July 2009

From the simulation results, in January 2009 the chlorine ion (10mg / l) contour lines moved northward at about 220m. And in January 2011 they moved for about 235m. So from January 2009 to January 2011, during these two years, the 10mg / l contour moved to the north for about 15m(see table9 and Figure20-21-22).

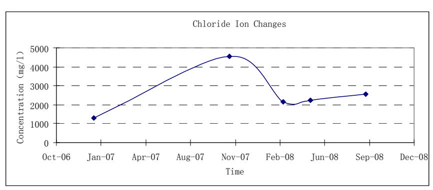
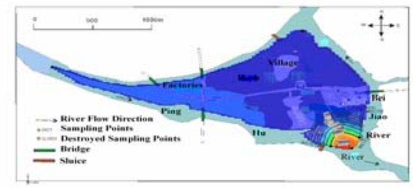


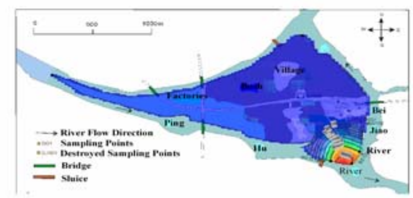
Figure 19 chloride ion concentration changes

Table 9 chloride ion (5mg / l) expansion in the second layer

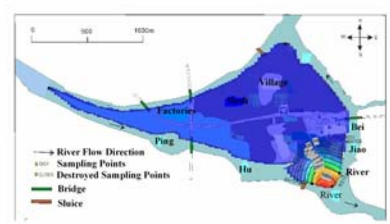
Time(period)	The expansion of distance(m)
2000.1.1	90
2002.1.1	142
2004.1.1	170
2006.1.1	196
2008.1.1	217
2010.1.1	238



(2009)

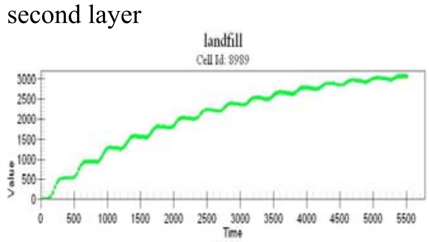


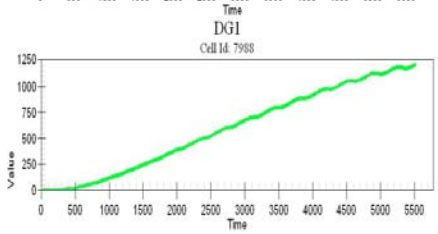
(2010)

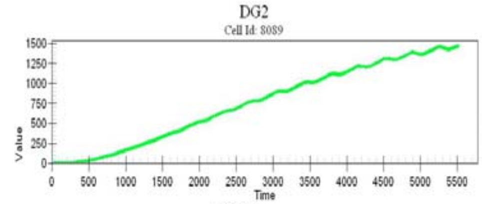


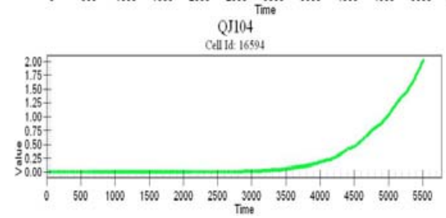
(2011)

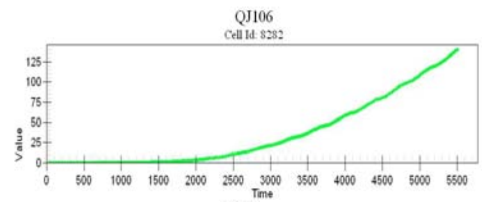
Figure 20 Chloride ion concentration in the second layer











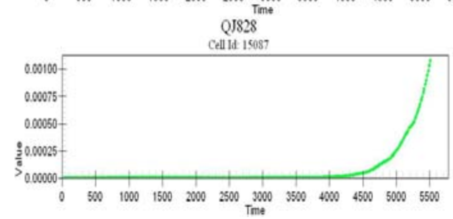


Figure 21 Change in chloride ion (mg / l)at some sampling points

From the simulation results 0.01mg/l of BTEX(benzene, toluene, ethylbenzene and xylene) contour line ,moved about 50m northward in 10 Years and about 84m northward in 20 years(figure 23-24-25). The main parameters of this simulation are in table 10 and the simulation times and migration distances are in table 11.

Table 10 the main parameters of the model

Parameter Name	Parameter values
F^{2+}	20.0mg/l
Methane	28mg/l
k_{HC,O_2}	0.08day^{-1}
k_{HC,NO_3}	0.009day^{-1}
$k_{HC,Fe^{3+}}$	0.0004day^{-1}
k_{HC,SO_4}	0.00019day^{-1}
k_{HC,CH_4}	0.0001day^{-1}
K_{i,O_2}	0.01[ML^{-3}]
K_{i,NO_3}	0.01[ML^{-3}]
$K_{i,Fe^{3+}}$	10[ML^{-3}]
K_{i,SO_4}	0.01[ML^{-3}]

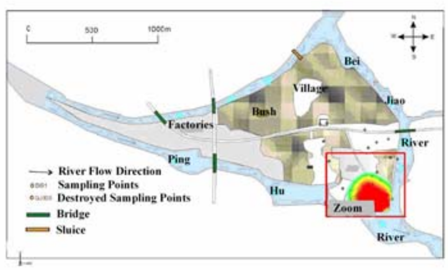
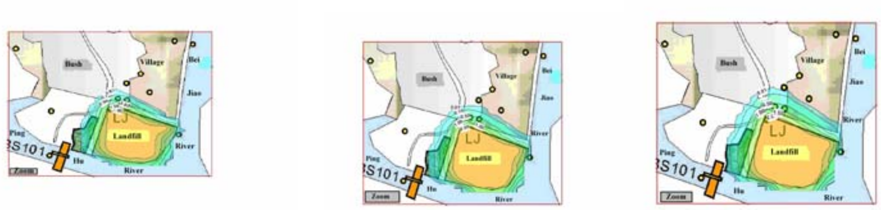


Figure 22 Landfill zone zoom after simulation

Table 11Simulation times and migration distances of BTEX(0.01mg / l)

time	Distance
2010/7	50m
2015/7	70m
2020/7	84m



July 2010 July 2015 July 2020

Figure 23 changes in BTEX concentration (mg / l) (enlarged simulation)

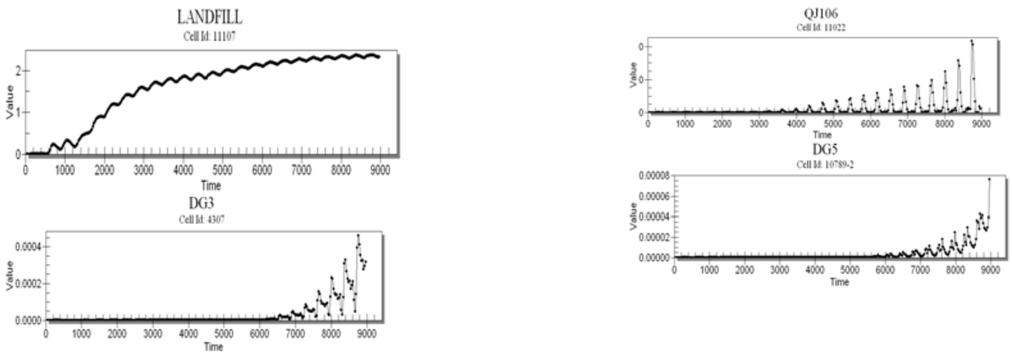
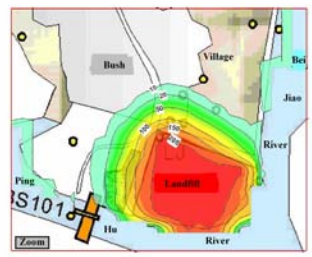


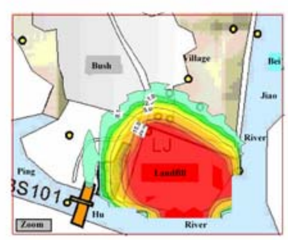
Figure 24 changes in BTEX (mg / l)

Dissolved oxygen and nitrate ion almost disappeared while sulfate and ferrous ions increased at the end of the simulation(Figure 26-27)

Dissolved oxygen

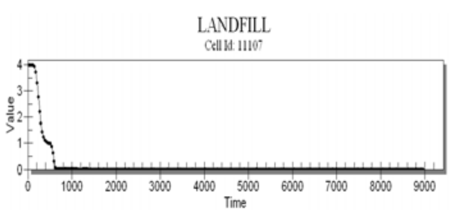


Sulfate

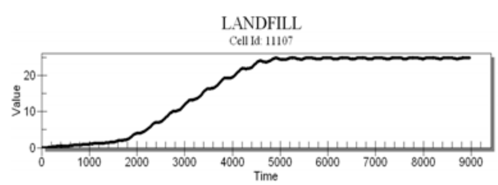


Ferrous ion

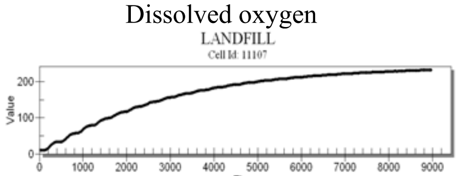
Figure25 concentration(mg / l) changes simulation for July 2010



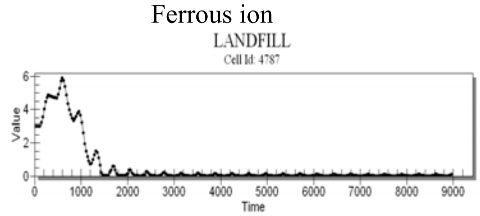
Dissolved oxygen



Ferrous ion



Sulfate ion



Nitrate ion

Figure 26 Changes in groundwater concentration (mg/l) on Landfill site

The exploitation of shallow groundwater is mainly from local residents. In recent years, because of groundwater pollution they can not continue to increase consumption.

This landfill was not a sanitary landfill because it did not have any protection system at the bottom and the top. There was no isolation from the entry of oxygen and rainfall infiltration; so that increased leachate production. The hydrogeological structure was not indicated for landfill therefore surface and groundwater are polluted.

CONCLUSION

Jiaxing landfill has been capped and transformed into a park, but its groundwater and surface water pollution will continue for many years. Anti-seepage curtain must be built to prevent the leakage of landfill leacheate. The application of ecological methods to remove harmful substances such as the cultivation of suitable plants is also necessary.

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