Study on Release and Pollution of Waste Pollutants under the Condition of Rainfall

Junzhen Di

College of Architecture Engineering, Liaoning Technical University

47 Zhong Hua Road, Fuxin 123000, China

Tel: 86-418-665-0721 E-mail: dijunzhen@126.com

Abstract

To study the release law of waste pollutant comprehensively and systematically, and analyze transporting law of pollutant and predict its distribution scientifically, the main pollutants of waste leachate were studies, including the release mechanism of COD, Cl^-, SO_4^{2-}, and total hardness, etc. by the dynamic dissolution experiment, according to the practical rainfall of Fuxin city. The results showed that Cl^- and COD have the most fast and slow transporting speed. The simulation was carried out by combining the COD decreasing curve fitting equations, which was considered as source sink term, and the established underground water dissolution transporting mathematical model. The result showed that, in the center of landfill, the simulated curve is accord with the COD experiment curve, and the result faithfully reflects the transporting law of pollutants. The model can provide the theoretical basis for the prediction of pollution of underground water by waste pollutant and its prevention and control.

Keywords: Landfill leachate, Dynamic dissolution, Underground water pollution, Rainfall

1. Introduction

As a potential pollutant source, the landfill site is very different from other underground water pollutant sources. After wastes being buried, there are a series of physical, chemical and biological reactions between wastes and its surrounding, because of leaching by rain or surface water. As a result, landfill leachate is produced, whose elements are complicated and pollution concentration is high. With the leaching of extraneous water on it, the concentration of elements of landfill leachate is changing. Moreover, the production of landfill leachate changes all the way. Therefore, it is very difficult to design the landfill site and control its pollution (Zhao, 2002, pp.83-88).Confirmation of landfill leachate water quality is the key point and basis of leachate treatment design, and it is also the basis of pollutant prediction and control.

2. Dynamic leaching experiment on simulating rainfall

The concentration of leachate elements changing with time, to predict the changing law of leachate pollutant concentration correctly, the experiment studied the organic pollutant elements and the process and law of its concentration change, using the waste of Fuxin Gong Guan Landfill Site, and taking tap water to simulate extraneous rainfall.

(1) Put into the Column: Put the clean quartz sand into the column and tamp it, making it as high as 4cm. Then, put the air-dried waste sample and tamp. When waste is as high as 60cm, its density is $1.0g/cm^3$. At last, put 4cm quartz sand on it.

(2) Leaching: To simulate practical rainfall, tap water is used to leache on the waste column evenly. At the beginning, the leaching speed is 180mL/h. Later, the speed becomes 40mL/h, when the waste is all immersed. Leaching lasts 24 hours every day and be watched. Sample is taken on 8 o'clock every morning and monitored for 10 days. Then, sample is taken and monitored every few days. All together, 23 samples are taken, and the leaching time is up to 1320h.

(3) Monitor index: Dynamic changing law of leachate pollutant elements is obtained with Cl^-, SO_4^{2-}, pH value, total hardness and density of COD.

3. Dissolution release law of waste pollutant

Production of landfill leachate is influenced by leaching. Because leaching is dynamic, chemical elements' concentration and production of landfill leachate is dynamic. Decay process is connected closely with simulation condition of leaching, including density of waste soil, disturbance of sample soil, the speed of infiltrating water and water injection method. According to the study of Zhao Yongsheng *et al* (Zhao, 2002, pp.83-88), if buried in the filed, the monitoring result is smaller than that of indoors. The practical decay process in the landfill is longer than that indoors. Therefore, when treating with experimental data, density changing curve is obtained taking W/S as a variable. As a result, influence of the random factors can be overcome, and the quantitative model is established. Then, the experimental result is used in fact, with W as quantity of leachate, S as quantity of filled waste in the column, W/S as infiltrating water quality per column.

3.1 Dissolution release law of chloridion, sulfate ion, pH value, and total hardness in the waste

In Fig. 1, concentration change Cl^- is high in the beginning of leaching. However, ionic concentration drops quickly. When W/S is 1, Cl^- concentration of leachate is 218.56mg/L. Its rate of removal can be up to 97.7%. When *W/S>1*, later, Cl^- concentration continues to drop, but the rate of removal is only 1.4%. It shows that the transporting speed of chloridion is faster during leaching. But once chloridion quantity in the pollutant is impermissibly high, the threaten is high to soil-ground water. In Fig. 2 sulfate ion is more active than chloridion during leaching time, because concentration rate of removal of sulfate ion is less than that of chloridion. The main reason is that, the microsoluble compound is produced by combination of sulfate ion, calcium ion and magnesian ion in water, which prevent the transport of sulfate ion. In Fig. 3, the changing tendency of total hardness also proves the result, the dissolution speed of the three materials is: Cl^->total hardness>SO_4^{2-}. Fig 4 is the changing curve of pH value. It drops at the very beginning, because of the acid production in the oxygen. Then, the curve begins to rise, because ammonia nitrogen is produced in the anaerobic processes denitrification.

3.2 Decay curve of dissolution of organic pollutant in the waste

Curve of COD concentration is as following figure.

Fit COD decay curve equation as follows,

$$S_c = 9.7927e^{-0.4448\left(W/S\right)},\quad R^2 = 0.9373 \tag{1}$$

Mean annual precipitation in Fuxin is 485.4mm, so water/soil in N year is

$$\frac{W}{S} = \frac{\rho_r A h_1 \alpha N}{\rho_s A h_2} = \frac{1000 \times A \times 485.4 \times 0.25 \times N}{1000 \times A \times 10000} = 0.012N \tag{2}$$

Put Equation (2) in Equation (1), then following equation is obtained,

$$S_c = 9.7927e^{-0.0054N}(g/L/a) = 0.027e^{-0.0054N}(g/L/d) \tag{3}$$

Where, ρ_r and ρ_s are density of rain and waste respectively, g/cm^3. A is the surface area of landfill. h_1 and h_2 are the rainfall and waste height, mm. N is the year of refusal.

3.3 Simulation of organic pollutant of waste under condition of rainfall

3.3.1 Establishment of model control equation

In ground water, there are physical, chemical and biological reactions during the transport of organic pollutant of waste. Therefore, equation of groundwater dynamics and pollutant dissolution transport are established as follows, based on adsorption-analysis, precipitation-dissolution, oxidation-reduction and biodegradation.

$$\begin{gathered} S\frac{\partial H}{\partial t} - \nabla \cdot \left[K\nabla\left(H + D\right)\right] = Q \\ [\theta + \rho_b k_P]\frac{\partial c}{\partial t} + c\frac{\partial c}{\partial t} + \nabla[-\theta D_L \nabla c + \vec{u}c] = \theta\phi_L c + \rho_b k_P \phi_P c + S_c \\ \theta D_{Lij} = \alpha\frac{u_i^2}{|\vec{u}|} + \theta D_m \tau_L \end{gathered} \tag{4}$$

Where, H is water head, m. K is permeability coefficient, m/d. $S = \gamma(\alpha + n\beta)$ is unit water coefficient, m^{-1}. Q is source sink term, kg/m^{3}d. D is coordinate basis vector, m. θ is water content. ρ_b is density of solid, kg/m^3. k_P is adsorption coefficient, m^3/ kg. c is concentration of pollutant, kg/m^3. ϕ_L and ϕ_P are coefficients of water dissolution item and adsorption decay, d^{-1}. $\vec{u}$ is Darcy flowing speed, m/s. S_c is pollutant source, kg/m^{3}d, which is the fitting value of the experiment. D_L is water dynamic dispersion coefficient,m^2/d. α is disparity of crosswise and lengthwise direction, m. D_m is molecular diffusivity, m^2/d. τ_L is tortuosity of porous medium.

3.3.2 Definite condition

Above equation is the control equation of pollutant in ground water. However, for the particular problem, the definite conditions are added on to establish complete coupled dynamics mathematical model. The definite conditions are as follows:

(1) Initial boundary condition of water transport:

$$\text{Initial condition: } H(x,y,z,t)\big|_{t=0} = H_0 \tag{5}$$

$$\text{boundary condition: } \begin{cases} H(x,y,z,t)\big|_{\Gamma_1} = H_1 \\ -K\nabla(H+D)\big|_{\Gamma_2} = 0 \end{cases} \tag{6}$$

(2) Initial boundary condition of pollutant transport

$$\text{Initial condition: } c(x,y,z,t)\big|_{t=0} = c_0 \tag{7}$$

$$\text{boundary condition: } \begin{cases} c(x,y,z,t)\big|_{\Gamma_1} = c_1 \\ -\theta D_L \nabla c + \vec{u}c\big|_{\Gamma_2} = 0 \end{cases} \tag{8}$$

3.3.3 Solution of coupled model and mathematical simulation

Parameters used in the mathematical simulation are obtained by experiment or reference (Liu, 2005, pp.4951-4955), in the simulation, equation of Van Genuchten (van Genuchten, 1980, pp, 892-898) is applied. Specific parameters are as follows:

Dynamic simulated computed result of organic pollutant concentration of waste in time and space shows that, at the point source (0m in Fig.6), concentration of organic pollutant drops with time, which shows that simulated result of concentration decay tendency fits with that of the experiment. At the point 2m and 4m distance to source center, concentration of pollutant gets to the peak at some moment and begins to drop until zero. It shows that concentration of pollutant drops till zero through water dynamic dispersion, adsorption-analysis and biodegradation in soil. The simulated result fits with the results in the reference (Jin, 2006, pp.98-99).

4. Conclusions

(1) Based on the experiment of waste column, dissolution law and influence factor of Cl^-, SO_4^{2-}, total hardness, and pH value in leachate are analyzed. Among them, Cl^- is fast in dissolution, followed by total hardness ($CaCO_3$).

(2) Dissolution and changing law of organic pollutant COD are analyzed, by waste column dynamic leaching experiment, predicting water quality of the landfill by making use of indoor experimental data fitted with model.

(3) Based on the established dynamics equation of organic pollutant transport in ground water, transport process of organic pollutant in ground water is simulated. The result shows that, after having the relevant practical parameter, pollution to the surrounding soil by leachate can be predicted, which supply some theoretical basis for controlling soil pollution and governing.

References

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Table 1. Model parameter

Name of parameter	value	Name of parameter	value	Name of parameter	value
K /(m/d) S /(m^{-1}) ρ_b /(kg/m^3)	1.1 0.3 1400	λ_1 /(d^{-1}) λ_2 /(d^{-1})	0.05 0.01	D_m /(m^2/d) k_b /(m^3/kg)	0.01 0.0001

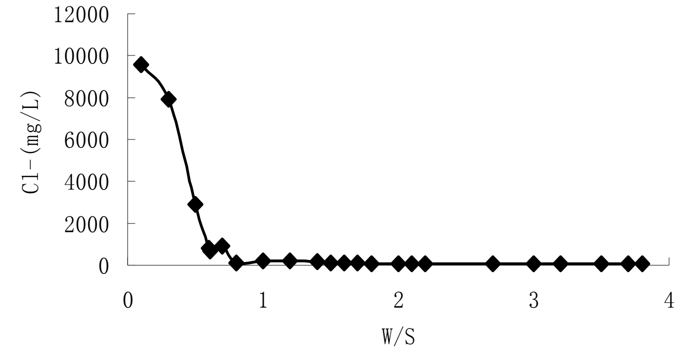

Figure 1. Change Curve of Cl^- Concentration

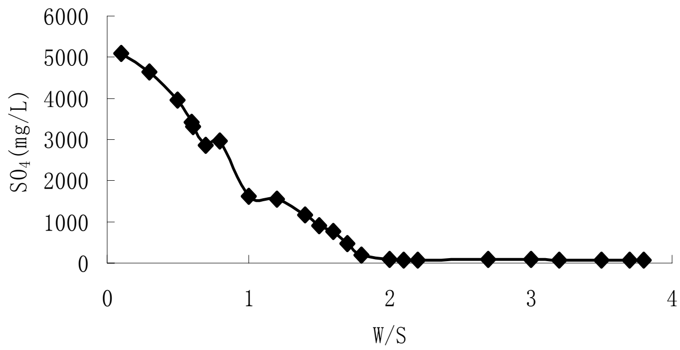

Figure 2. Change Curve of SO_4^{2-}Concentration

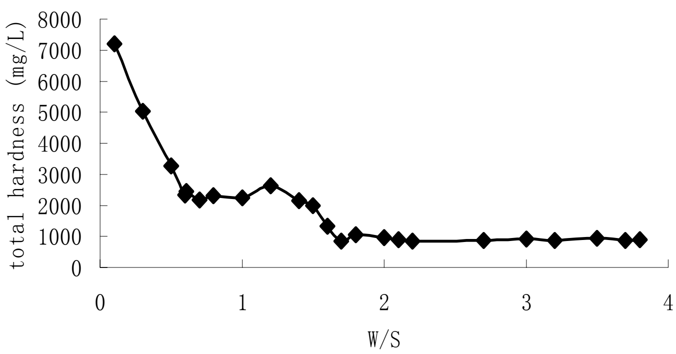

Figure 3. Change Curve of Total Hardness ($CaCO_3$)

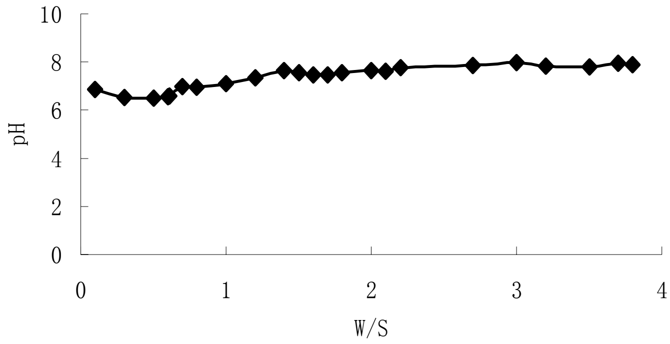

Figure 4. Change Curve of pH Value

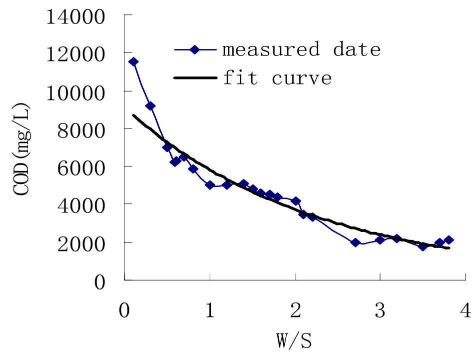

Figure 5. Measured and Fit Curve of Contaminant COD

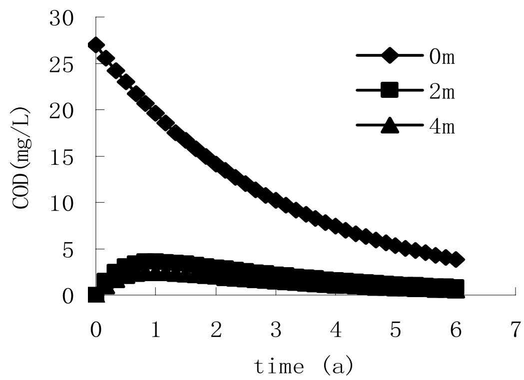

Figure 6. Space-time Variable Curve of Contaminant Concentration

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