International Journal of Energy and Sustainable Development
Vol. 1, No. 1, 2016, pp. 13-16
http://www.aiscience.org/journal/ijesd

Experimental Investigation of Vertical Purification Capacity of Different Lithologies in the Unsaturated Zone of Riverbed

Zhou Yuexian[1, *], Xing Shuo[1], Lv Liugen[2]

[1]Henan Jinyang Ecological Engineering Co., ltd, Zhengzhou, China
[2]School of Civil Engineering and Architecture, Jiaxing University, Jiaxing, China

Abstract

With test simulation of unsaturated zone under the condition of different lithologies such as sand, gravel, sandy soil, clay soil, the paper discusses the vertical purification capacity of unsaturated zone of riverbed of different pollutants, provides scientific experimental basis for delineating Water Source Protection Areas for Groundwater in Luoyang City.

Keywords

Different Lithologies, Vertical Purification, Unsaturated zone, Filtration, Experimental Investigation

Received: November 22, 2016 / Accepted: December 20, 2016 / Published online: January 21, 2017

1. Introduction

With the accelerating development of urbanization, the contradiction between the increasing emissions of water pollutants and limited sewage treatment capacity has become increasingly prominent [1-3]. For the protection of water resources, purification capacity of black box (Unsaturated zone) of atmospheric precipitation and surface water pollutedwas proposed through experimental investigation of vertical purification capacity of riverbed and floodplain of the Yihe River, Luohe River, Chanhe River and Jianhe River that flow through Luoyang City [4-5]

Studies suggest that the degree of contamination of groundwater depend on hydrogeological condtions of the area, the size and acuation time of pollution, the nature and concentration of contaminants [6]. There are 3 key elements of laboratory simulation: Raw water of local surface water polluted or simulated waste water with the same quality should be used as test water sample, Geological samples used should be representative of the local soil and geological structure, Leakage rate of filtrate should be appropriate [7-9]. The test is based on the unsaturated zone of riverbed in Luoyang City.

2. Vertical Purification Capacity Test of Different Lithologies

2.1 Sand and Gravel of Riverbed

2.1.1. Distribution of Lithology

The geological structure of the riverbed of Luohe River and Yihe River is mainly sand and gravel that contains uneven soil and thin layers of sediment, which plays an important role in the protection of groundwater from pollution as a layer of protective tape [10].

2.1.2. Meterials and Methods

Leachate: Raw water of Luohe River.

Lithology samples: Sand and gravel in the riverbed of Luohe River and Yihe River.

Black box simulation: Raw water was taken from Luohe River as the surface water sample. A vertical well with a depth of 8 meters was hit which was 30 meters away from the water point,

* Corresponding author
E-mail address: lvliugen83@163.com (Lv Liugen), jinyangshengtai@163.com (Zhou Yuexian)

and the groud water was taken as the water sample after purification [11]. 12 monitoring indexes of the water samples were analysised and the results are shown in *Table 1*.

2.1.3. Analysis

The water quality of surface water and ground water are respectively used as the water quality before and after purification. *Table 1* shows that purification capacity of various pollutants of sand and gravel is more than 90%. Under the condition that the pH value is greater than 7, the heavy metals would be deposited in unsaturated zone during infiltration, the removal efficiency is 100%. The removal efficiency of NH_4^+, NO_2^- is 97.6%, 95.4%. Meanwhile, the concentration of NO_3^- in goundwater rises through the vertical purification [12].

Table 1. Vertical purification capacity test of sand and gravel.

Testing items	surface water	ground water	efficiency of purification %
pH	7.95	7.69	-
COD_{Cr}	66.4	6.4	90.4
Permanganate index	21.86	0.89	96.0
BOD_5	11.44	1.11	90.3
Nitrite (as N)	0.789	0.036	95.4
Volatile phenol	0.055	0.002	96.4
Hg	Not detected	Not detected	/
Cu	0.11	Not detected	100
Petroleum	3.89	0.08	97.8
Nitrate (as N)	0.427	5.757	/
Total hardness [$CaCO_3$]	153.1	254.2	/
Ammonia nitrogen	20.565	0.505	97.6

The unit of data in *Table 1.* is mg/L except the pH, total hardness and ammonia nitrogen.

2.2. Sand

2.2.1. Distribution of Lithology

Sand is mainly distributed in the floodplain area of Yihe River and Luohe River. The upper part of the unsaturated zone is silt and silty soil with a thickness of about 2m, which mostly was reclaimed as farmland. The lower part is medium fine sand with a thickness of about 2m.

2.2.2. Meterials and Methods

Leachate: Raw water of Chanhe River in Luoyang.

Soil samples: 1# and 2#, which were taken from Shijiawan Village. 1# soil sample, with a total height of 3m, the upper part of which was 0.5m thick silty soil and the lower part was 2.5m thick medium fine sand. 2# soli sample, with a total height of 3m, the upper part of which was 0.75m thick loam and the lower part was 2.25m thick medium fine sand.

Black box simulation: The thickness of 1# and 2# soil sample reduced according to the ratio of 1/6 was loaded into the glass tube to carry out experiment, the height of soil sample in pipe was 0.5~0.55m.

2.2.3. Analysis

Afer 8h, the leakage began to flow out from the bottom of the glass tube of 1# sample, the amount of which was $0.493m^3/(d·m)$. After 12h, the leakage began to flow out from the bottom of the glass tube of 1# sample, the amount of which was $0.185m^3/(d·m)$. The results were shown in *Table 2*.

After standing for 125h, natural degradation rate of COD_{Cr} and BOD_5 in the raw water of Chanhe River is 25% and 21%, respectively. According to the results of 1# and 2# soil leakage test, polluted surface water that passed through the soil was changed from dark gray to colorless and transparent. The heavy metals, COD_{Cr} and BOD_5 decreased obviously [13].

As shown in *Table 2*, although the height of test soil sample is only 0.5m and the test time was less than 6d, the removal efficiency of pollutans listed in Table 2 were more than 87%. After the leakage of 142h, 1# and 2# soil samples had the same purification effect on polluted surface water.

Table 2. Vertical purification capacity test of sand.

Sample	Duration	Cu	Pb	Cr	COD_{Cr}	BOD_5	pH
Raw water	0	1.45	0.87	0.340	195.93	28.85	7.15
Raw water	125	1.43	1.27	0.384	145.50	22.85	7.16
	16	—	—	0.003	59.5	9.78	8.20
	47	—	—	0.002	65.01	9.30	8.12
	70	—	—	0.001	—	—	—
1#Sample	93	—	—	—	43.01	6.01	8.28
	119	—	—	0.000	—	—	—
	141	—	—	—	26.55	3.85	8.29
	Purification capacity%	100	100	100	87	87	—

Sample	Duration	Cu	Pb	Cr	COD_{Cr}	BOD_5	pH
	47	—	—	0.002	47.61	7.45	8.20
	95	—	—	0.002	34.70	4.05	8.24
2#Sample	135	—	—	—	—	—	—
	142	—	—	—	26.55	3.85	8.29
	Purification capacity%	100	100	100	87	87	—

The unit of data in *Table 2.* is mg/L except pH.

2.3. Sand SOIL

2.3.1. Distribution of Lithology

Sand soil (sand loam) is mainly distributed in the floodplain of Luohe River has a thickness of 1~3m and the lower part of sand siol layer is wet sand gravel.

2.3.2. Meterials and Methods

Leachate: Synthetic wastewater, the concentration of Ct^{6+}, Cl^- and Cu of which are equal to 10 times of the sandard concentration in "Standards for drinking water quality".

Lithology sample: Disturbed sand soil in the floodplain of Luohe River.

Black box simulation: Lithology sample with the thickness of 1m was loaded into a glass tube with the diameter of 75mm, as dense as the original sand oil.

2.3.3. Analysis

After 24h, the leakage began to flow out from the bottom of the glass tube, the amount of which was $0.158m^3/(d \cdot m)$, the results were shown in *Table 3*.

As shown in *Table 3*, after 48h, the removal efficiency of Cu of sand soil was 100%. Purification efficiency of Cr^{6+} achieve stability in 5d. However, sand soil filtration had little effect effect on the Cl^- removal [14].

Table 3. Vertical purification capacity test of sand soil.

Duration (h)	Cr^{6+}	Cl^-	Cu
0	0.509	2595	10.00
24	0.011	1175	0.02
48	0.060	2641	0.01
72	0.034	2737	0.00
96	0.043	2772	0.00
120	0.055	2762	0.00
720	0.051	2643	0.00
Purification capacity%%	90	0	100

The unit of data in *Table 3.* is mg/L.

2.4. Clay Soil

2.4.1. Distribution of Lithology

Clay soil is mainly distributed in the second terrace of Luohe River and the valley of Jianhe River, the hickness of which is 5~25m.

2.4.2. Meterials and Methods

Filtrate: Synthetic wastewater, the concentration of Ct^{6+}, Cl^- and Cu of which were equal to 10 times of the sandard concentration in "Standards for drinking water quality".

Lithology sample: Clay soil in the second terrace of Luohe River.

Black box simulation: Lithology sample with the thickness of 1m was loaded into a glass tube with the diameter of 75mm, as dense as the original sand oil.

2.4.3. Analysis

Afer 36h, the leakage began to flow out from the bottom of the glass tube, the amount of which was $0.113m^3/(d \cdot m)$, the results were shown in *Table 4* [16].

As shown in *Table 4*, clay soil had the strongest effect on the pirification of Cu, and the next is Cr^{6+}, which had almost no purification capacity of Cl^-.

Table 4. Vertical purification capacity test of clay soil.

Duration (h)	Cr^{6+}	Cl^-	Cu
0	0.404	2501	10.00
36	0.005	863	0.03
48	0.007	1271	0.01
72	0.011	2226	0.00
96	0.010	2532	0.06
120	0.023	2705	0.00
144	0.036	2709	0.03
168	0.039	2707	0.01
720	0.040	2711	0.00
Purification capacity%%	90	0	100

The unit of data in *Table 4.* is mg/L.

3. Conclusion

The 4 kinds of lithology mentioned in this research have a significant purification effect on the water pollutants, especially heavy metal [16]. (1) The purification efficiency from high to low: Heavy metals, organic matter, inorganic matter. (2) Purification ability of black box was limited, which had almost no purification capacity of Cl^-. (3) Nitrate in groundwater was increased in the surface water after the filtration of the unsaturated zone. In summary, the paper suggested that unsaturated zone had limitations in the purification capacity of pollutants. How to prevent the groudwater from being polluted effectively needs further study.

References

[1] R. W. McDowell, N. Cox, C. J. Daughney, D. Wheeler, and M. Moreau. 2015. A nitional assessment of the potential linkage between soil, and surface and groudwater concentrations of phosphorus. Journal of the American water resources association, Vol. 51, pp. 993-1002.

[2] Abbasi M. K., Hina M., Tahir M. M. 2011. Effect of Azadirachta indica (neem), sodium rhiosuphate and calcium chloride on changes in nitrogen transformations and inhibition of nitrification in soil incubated under laboratory conditions. Chemosphere, Vol. 82, pp. 1629-1635.

[3] Babatunde A. O., Zhao Y. Q., O' Neili M., O'Sullivan B. 2008. Constructed wetlands for environmental pollution control: A review of developments, research and practice in Ireland [J]. Environment International, Vol. 34, pp. 116-126.

[4] Benjanmin M., Sletten R., Bailey R., Bailey R. P., Bennett T. 1996. Sorption and filtration of metals using iron-oxide-coated sand. Water Research, pp. 2609-2620.

[5] Borin M., Passoni M., Thiene M., Tempesta T. Multiple functions of buffer strips in farming area. 2010. European Journal of Agronomy, 2010, Vol. 32, Issue 2, pp. 103-111.

[6] Borin M., Vianello M., Morari F., Zanin G. 2005. Effectiveness of buffer strips in removing pollutants in runoff from a cultivated field in North-East Italy. Soil Biology and Biochemistry, Vol. 102, Issue 1-2, pp. 101-114.

[7] Chang W. S., Hong S. W., Park J. 2002. Effect of zeolite media for the treatment of textile wastewater in a biological aerated filter. Process Biochenmistry, Vol. 37, Issue 7, pp. 693-398.

[8] Chung S. J., Ahn H. K., Oh J. M., Choi I. S., Chun S. H., Choung Y. K. 2010. Comparative analysis on reduction of agricultural non-point pollution by riparian buffer strips in the Paldang Watershed. Desalination and Water Treatment, Vol. 16, Issue 1-3, pp. 411-426.

[9] Kenneth E. Mc Connell. Valuing discrete improvements in drinking water quality through revealed preferences. 2000. Water Resources Research, Vol. 36, Issue 6, pp. 1575-1582

[10] Townsend A. R., Vitousek P. M., Trumbore S. E. 1995. Soil organic matter dynamics along gradients in temperature and land use on the island of Hawaii. Ecology, Vol. 76, pp. 721-733.

[11] Vassolo S. 1998. Determination of a well head protection zone by stochastic inverse modeling. Journal of Hydrology, Vol. 206, pp. 268-280.

[12] Hatt B. E., Fletcher T. D., Deletic A. 2009. Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale. Journal of Hydrology, Vol. 365, pp. 310-321.

[13] Hatt B. E., Fletcher T. D., Deletic A. 2008. Hydrologic and pollutant removal performance of fine media stormwater filtration systems. Environmental Science and Technology, Vol. 42, pp. 2535-2541.

[14] Hayakawa A., Nakata M., Kuramochi K. 2012. Spatial variation of denitrification potential of grassland, windbreak forest, and riparian forest soils in an agricultural catchment in eastern Hokkaido, Japan. Ecological Engineering, Vol. 47, pp. 92-100.

[15] Adekalu K., Olorunfemi I., Osunbitan J. 2007. Grass mulching effect on infiltation, surface runoff and soil loss of three agricultural soils in Nigeria. Bioresource Technology, Vol. 98, pp. 912-917.

[16] Adejuwon J. O., Ekanade O. 1988. A comparion of soil properties under different land use types in a part of Nigerian Cocoa Belt. Catena, Vol. 15, pp. 319-331.