Journal of Environmental Sciences Vol. 18, No. 1, pp. 115—119, 2006

ISSN 1001 0742
CN 11 2629/X

Article ID: 1001-0742(2006)01-0115-05 **CLC number**: X703 **Document code**: A

Reducing non-point source pollution with enhancing infiltration

MU Huan-zhen*, ZHENG Tao, HUANG Yan-chu, ZHANG Chun-ping, LIU Chen

(Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. E-mail: mhzh@ rcees. ac. cn.)

Abstract: The rainfall system was set up on a slope land, which was used with some materials to enhance soil infiltration. The results showed that it was effective to enhance the infiltration of rainwater in soil and reduce the pollutants of surface runoff. After the soil meliorated by the lignin polymer and zeolite, runoff was delayed about 10 min and reduced by 44.40%—50.00%, synchronously, the pollutant loads, such as total suspended solids (TSS), chemical oxygen demand by ditromate (COD_{Cr}), total nitroger (TN) and total phosphorus (TP), were reduced on averages by 44.58%, 37.80%, 51.62% and 44.11%, respectively. It is an available technique to control the pollution of non-point source from sources.

Keywords: runoff; enhancing infiltration; lignin polymer; non-point source pollution

Introduction

Natural summaries, such as urbanization, population growth, construction sites and impervious surfaces, are useful in providing an overview of the magnitude of problems associated with urban runoff. Unfortunately, the aquatic environmental condition has not been improved commensurately with these industrial point source controls in the South China. Non-point source contributions remain and have increased as a share of the problem. It has been reported that aquatic environmental problem in some water body became more and more serious.

In Wuhan City, degradation of water quality often results from rainfall runoff with many contaminations, and eutrophication affects the ecological balance of water body seriously. At the same time, the problem aggravates the water resource situation. All of these showed, the non-point source pollution has become a main problem of sustainable development.

Surface runoff that can have a harmful effect on water body, is a primary cause of non-point source pollution. Therefore, an important tache to control non-point source pollution is that deal with runoff from source. Soil, which is a natural system interface and environmental container, not only can purify pollutant, but also has low cost and big capacity (Li *et al.*, 1999). With penetrative surface soil, the effective means, which include enhancing soil infiltration, reducing rainfall runoff and decreasing deferent pollutant concentration, can reduce non-point source pollution that lead by storm water. It is a effective way to reduce surface runoff, that meliorating soil with polymers which function is the same to organic matter, strengthening the soil ability of resisting outside force, and enhancing soil infiltration (Long *et al.*, 2000).

The present experimental research was aimed to use the lignin polymer and zeolite as a soil conditioner to increase rainfall infiltration, enhance soil capacity, reduce rainfall runoff, and dispel pollutant loads.

1 Materials and methods

1.1 Materials

The zeolite mineral sample was from natural zeolite mine in Jinyun of Zhejiang Province. The fundamental property is as follows: specific gravity 2.16, aperture 3.5—4.0 $\times 10^{-10}$ m, specific surface area 230—320 m^2/g, water content 12 g/100 g, and exchangeability of ammonium 150—170 meg/100 g.

The lignin in the laboratory that appears as solid powder, was produced by a papermaking company in Shandong Province, retrieved from black papermaking liquid of alkali system with acidifying.

The lignin and starch were dissolved into the solution of NaOH, and then acrylamide, calcium chloride and the initiator were added to the reactor in proportion. The polymerization react was accomplished in the range of 60—70℃ with the protection of N_2. The resultant was named LAS.

The research place was located at the slope field in Wuhan Zoo. Because of the influence of visitors and poor property in the soil, there were sparse plant, bare surface and low permeability. The soil pH was measured as 5.58, the soil organic matter 3.38% by weight, TP (P_2O_5) 0.277%, TN 0.093%, the permeability coefficient(K_{10}) 0.12 mm/min.

1.2 System design and treatment

1.2.1 Experimental design

The experimental system was a 16 (16 m$\times$1 m) m^2 block with three replications, which gradient 5%.

Foundation item: The Hi-Tech Research and Development Program(863) of China(No. 2002AA601022); *Corresponding author

There were some small areas around them to separate from outside environment. The surface 40 cm soil was dug, and the sundries, such as stones and remnant plant body, were eliminated. To separate every district, there are some low soil banks, which high 20 cm, thick 15 cm. In addition, to avoid the mix of the runoff and infiltration between both blocks, there were partition films, which stretched up 30 cm and down 10 cm from the ground, and embedded in the banks. The surface flow collector was set up in downstream and surface runoff could be collected to the container through pipes.

1.2.2 District build

The appropriate amount of soil from the research place was air-dry and sifted through 20 screen mesh. According to 1 t/ha lignin and 4 t/hm^2 zeolite, lignin and zeolite were mixed with the soil in order. The admixture was bestrewed equably on the surface of each treated units and the same quantity soil was spread on the contrast, and then the soil of each units was dug and mixed. The LSA was sprayed as 3 kg/ha over the treated units and the same water to the contrast, and then Oxalis corymbosa was planted in every units.

1.3 Surface runoff sample and pollutant load analyze

The experimental system of the district has been accomplished before the rainy season. As shown in Fig.1, the main rainfall distributed from May to August in 2004. During this period, there were eight middling intensities or heavy rain that resulted in surface runoff. We accomplished a successful observation of the rainfall on the research palace in July 11 which measured 62.5 mm in step. Once the runoff in each unit appeared, it has been collected and noted by every 10 min. The surface runoff pollutants, which included TN, TP, COD_{Cr}, TSS, NH_4^+ and NO_3^-, were analyzed. The original samples of runoff were filtrated through 0.45 μm aperture membrane and then the DN (dissolved nitrogen) and DP (dissolved phosphorus) were analyzed.

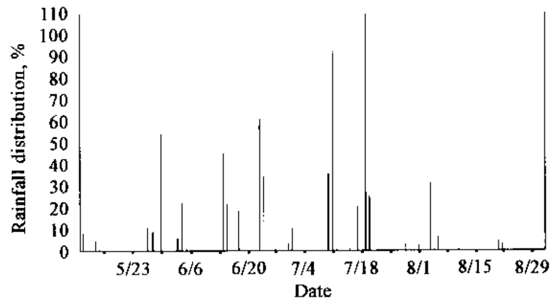

Fig.1 Primary precipitation and distribution

2 Results and discussion

2.1 Effect on rainfall runoff

The observation results of the runoff in the rainy season of 2004 from May 29 to August 14 are presented in the Table 1. It can be seen that the difference between the CK (contrast) and the T (treated).

Table 1 Effect on rainfall runoff in the rainy season

No.	1	2	3	4	5	6	7	8	9	10	11
Rainfall, mm	39.5	24.0	46.8	88.1	142.2	37.5	12.5	62.5	160.0	47.7	121.5
Runoff, CK	1.73	4.42	12.67	163.04	56.33	78.43	8.13	96.50	37.67	83.33	297.65
Runoff, T	0.78	2.09	3.33	36.23	18.00	23.00	1.35	45.23	9.67	61.67	135.23
Decrease, %	54.91	52.71	73.72	77.78	68.05	70.67	83.39	53.13	74.33	25.99	54.57

Some polymers can play the role of soil organic matter in soil to promote the formation of soil aggregates and strengthen soil particles reuniting each other. The soil spread by LSA was changed into loose and porous with the increase of aggregates, which affected the time that runoff appeared and runoff quantity directly. This resulted in the difference of runoff quantity between the CK and the T. As shown in Table 1, comparing with the CK, the runoff quantity of the T was reduced by 25.99%—83.39%.

2.2 Effect on runoff pollutant loads

The whole process of the storm water in July 11 was studied. When the runoff appeared in the rainfall, the runoff samples of the CK and the T have been collected eight times in order and noted the sample serial number respectively. Then the runoff samples were analyzed for the pollutant loads in order to study the effects of the LSA accelerant on reducing the runoff pollution.

2.2.1 Effects on runoff quantity and TSS

The delay of the runoff and the decrease of runoff quantity was the primo index to appraise the accelerant effect on enhancing rainfall infiltration. The results on the locale was observed, that the time which runoff appeared in the T lagged 10 min behind the CK approximately. The surface runoff averaged 12.50—33.30 ml/s in the Ck and 6.30—16.70 ml/s in the T, which reduced by 44.40%—50.00% with LSA.

Soil loss is mainly lead by rain force and soil erosion in rainfall. Soil loss can contribute many pollutants to water body and many pollutants are highly associated with particles. The associated pollutants include phosphorus, nitrogen, and oxygen-demanding substances.

TSS (total suspended solids) is a measure of the concentrations of sediment and other solid particles suspended and is also an indirect measure of other pollutants carried by runoff, because nutrients, metals, and organic compounds are typically attached to sediment particles (Vieux and Moreda, 2003). TSS is influenced by surface runoff directly. The results showed that it was remarkable to reduce the runoff TSS with enhancing the infiltration of rainfall. As Fig. 2 shown, during the observation, the TSS loads have achieved the value 0.037—0.322 g/s in the CK and 0.022—0.159 g/s in the T. In the whole event, the mean TSS loads in the CK were 0.161 g/s and 0.086 g/s in the T, respectively. With LSA, it was seen that the average TSS loads were reduced by 44.58%.

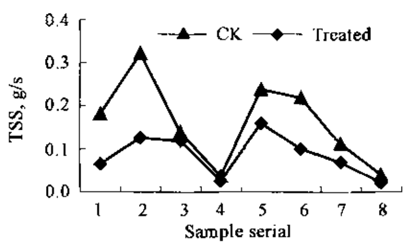

Fig.2 Effect on runoff TSS with enhancing infiltration

2.2.2 Effect on COD_{Cr} loads in runoff

The chemical oxygen demand determined by K_2CrO_7 is one of the important indexes to indicate water quality. Many pollutants were washed out by rainfall and moved with runoff, and could cause the rising of COD_{Cr} loads. As Fig.3 shown, the COD_{Cr} loads were reduced clearly with enhancing infiltration and the COD_{Cr} was related with runoff quantities nearly. During the process of rainfall, the way with enhancing infiltration by LSA was effective to reduce surface runoff and made the runoff COD_{Cr} in the T reduce by 11.1%—58.4%, on averaged by 37.80% comparing with the CK.

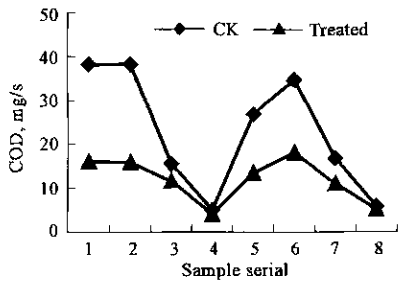

Fig.3 Effect on runoff COD_{Cr} with enhancing infiltration

2.2.3 Relationship of TN, TP and TSS in runoff

The results (Fig.4) showed that TN and TP load were correlated with TSS closely in runoff. The correlation coefficient of them on square in the T was 0.8728 and 0.8696 separately, 0.7156 and 0.7136 in the CK. Therefore, we could control runoff TSS to reduce water pollution that resulted from nitrogen and phosphorus from non-point source.

Through treated with LSA runoff decrease leaded TN, TP amount to reduce. As Fig.5 shown, the peak value from the part in TN density load of the controlled and the treated have appeared when the runoff peaked.

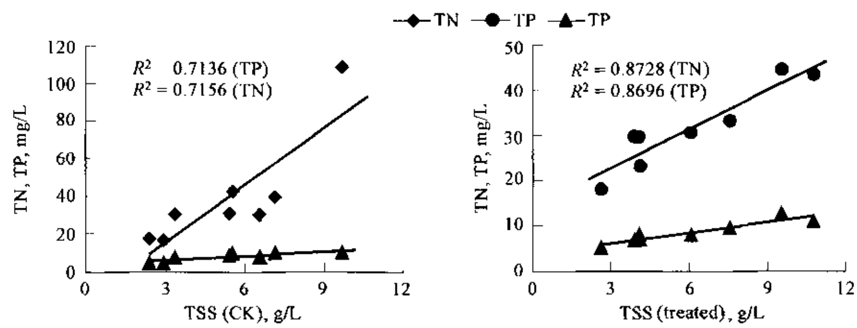

Fig.4 Relationship of TN, TP and TSS in runoff

Fig.5 shows that the runoff in the T was reduced with enhancing the soil infiltration and the TN and TP loads also were decreased at the same time. After 20 min of runoff, the peak value of TN in the CK appeared, achieving the value 103.28 mg/L. Comparing with the CK, the peak value of TN in the T lagged 10 min and the value reached 43.42 mg/L, reducing by about 58%. The second TN peak value in the CK appeared at the 30 min of the surface runoff, the close value at the 60 min in the T. In the

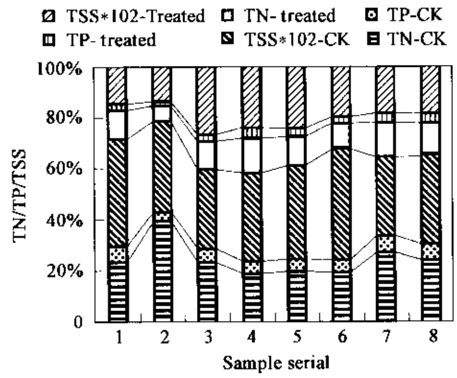

Fig.5 Relation between TN, TP and TSS
TSS was 1% real value

observation process of surface runoff, the TN values in the CK attributed from 0.205 mg/s to 3.611 mg/s, from 0.145 to 0.741 mg/s in the T, their average values were 1.588 mg/s and 0.445 mg/s respectively, and with enhancing infiltration the TN loads was reduced on average by 51.62%.

Most natural phosphorus exists in non-dissolved form and the transfer of phosphorus is mostly related with suspended substances or sediment particles that carry phosphorus away. The phosphorus that causes non-point source pollution mainly comes from organic or colloid forms carried by runoff particles (He and Huang, 2001; Healthwaite *et al.*, 2000). As the observation shown, there were closely interconnect between particles and runoff, so with enhancing infiltration, we could reduce runoff and TSS to achieve the decrease of the TP loads. The results showed that the TP loads of surface runoff achieved 0.042—0.209 mg/s in the T and 0.052—0.335 mg/s in the CK, and the mean values were 0.118 and 0.224 mg/s, respectively. During the process of runoff, the TP loads in the T were reduced by 44.11% on average. The use of lignin in the T took an effect to absorb and fix the phosphorus in the soil.

The strength of surface runoff in rainfall was the most important factor influencing the output of TSS. The observations showed that the peak value of the surface runoff in the CK appeared at 20 min when the runoff began and the peak values of TSS or TN or TP appeared, too. On the contrary, the curve of runoff quantities trended to decline and reached the minimum at 40 min of the runoff process. At the same time, the trends of TSS or TN or TP loads were quite similar to runoff quantities. All of these results proved that the water pollution from non-point source, such as suspended substance, nitrogen and phosphorus and so on, could be controlled by the means that reducing and delaying rainfall runoff with enhancing infiltration.

2.3 Effect on runoff NH_4^+, NO_3^-, DN and DP

As Fig.6 shown, the NO_3^- curve was trend to downward and a little rose in the later during the runoff. The NH_4^+ concentration had no big change before 20 min and the peak value in the CK appeared at 30 min when the runoff peak value presented and turned stabilization in the CK. The NH_4^+ concentration in the T rose with the surface runoff peak and then descended. The soil erosion that leaded by runoff affected the nitrogen of soil to dissolve and move. The more the exchangeable nitrogen dissolved with the addition of the erosion, the more the concentration rose. However, there was a balance between the amount of NH_4^+ dissolved and the exchange after a stretch of runoff.

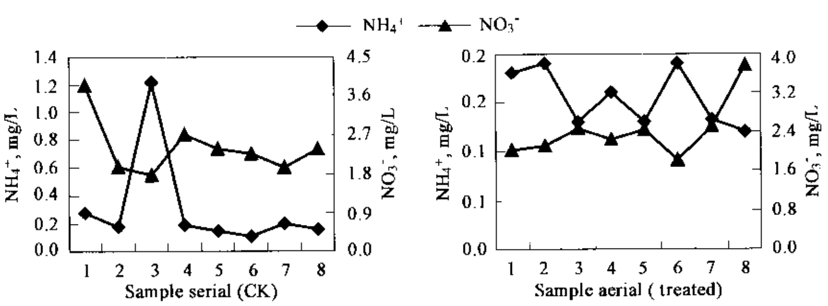

Fig.6 The Changing curve of NH_4^+ and NO_3^- in the runoff

The NH_4^+ loads in the T were lower than in the CK because of the decrease of runoff and the material treated with lignin and zeolite. Zeolite has lacunose structure and strong adsorption, and lignin has the macromolecule organic character, so they can improve soil and accelerate rain infiltration. With them the active ions were adsorbed in soil, and the exchangeable dissolved and washed away by surface runoff. In addition, all of these accelerated the nitrogen movement to the inner soil and reduced the nitrogen loss with runoff.

The results showed that the DN and DP in the runoff accounted for a little proportion of the TN and TP concentrations during the rainfall runoff. On average, the proportion values of them achieved 8.8% and 3.9% in the CK, and 8.1% and 3.5% in the T. During the observation, the DN concentrations in the runoff achieved the value 2.193—2.824 mg/L in the CK and 2.026—2.884 mg/L in the T. In the whole event, the mean values were 2.499 mg/L in the CK and 2.322 mg/L in the T. Corresponding, the DP concentrations value were 0.184—0.317 mg/L in the CK and 0.200—0.367 mg/L in the T, and the mean values were 0.267 mg/L and 0.257 mg/L. This was confirmed further that the nitrogen and phosphorus of non-point source pollution mainly came from the suspended substance in the runoff and so the key for reducing the nitrogen and phosphorus pollutant of receiving water was to decrease the surface runoff and the suspended substance carried by runoff in rainfall.

2.4 Comprehensive benefit analysis

The performance and environmental effect of the polymer could influence its extensive use of lignin, which has abundant resource and ecological friendship, can be degraded naturally. The LSA could not only enhance soil infiltration, but also meliorate soil and decrease the pollution from non-point source. The value of the LSA primary materials which have resource in abundance and low cost, such as starch and lignin, were 1800 RMB Yuan/t and 1500—2000 RMB Yuan/t in market, respectively. In the range, the performance of the LSA was the same with polyacrylamide (PAM), which was used in soil improvement extensively(James *et al.*, 2002). And the cost of LSA was reduced in a certain degree. Comparing with PAM, each ton LSA with lignin and starch instead of 20% acrylamide which value 14000 RMB Yuan/t, could reduce 15%—20% cost. Therefore, to enhance soil infiltration with LSA, which was used to reduce the pollution from non-point source, could obtain more environmental and economic benefits.

3 Conclusions

Enhancing the rainwater infiltrating of the soil with the polymer of lignin and zeolite can be used to delay and reduce the surface runoff in rainfall. The runoff quantities were decreased by 44.40%—50.00% and the loads of TSS, COD_{Cr}, TN and TP were reduced by 44.58%, 37.80%, 51.62% and 44.11% on average, respectively.

The surface runoff in rainfall was the primary source of pollutants from non-point sources, such as TSS, COD_{Cr}, TN, TP and so on. TN and TP loads were correlated with TSS loads closely in surface runoff, the correlation coefficients on square in the T achieved 0.8728, 0.8696 and 0.7156, 0.7136 mg/L in the CK. The DN was 8.8% and 8.1% of TN in the CK and in the T, and the DP was 3.9% and 3.5% of TP on average in the rainfall runoff. Reducing surface runoff in rainfall is one of the most important to control non-point source pollution to water body.

Lignin and zeolite can be used to meliorate soil, which affect the nitrogen movement and delay and weaken the peak value.

To accelerate the osmosis of rainwater into soil with the polymer of lignin and zeolite is an effective and practical technique to decrease the pollution from non-point source.

References:

Heathwaite A L, Dils R M, 2000. Characterising phosphorus loss in surface and subsurface hydrological pathways[J]. The Science of the Total Environment, 251/252: 523—538.

He X B, Huang Z B, 2001. Zeolite application for enhancing water infiltration and retention in loess soil[J]. Resources Conservation and Recycling, 34: 45—52.

James A E, Sojka R E, Watwood M *et al.*, 2002. Polyacrylamide preparations for protection of water quality threatened by agricultural runoff contaminants [J]. Environmental Pollution, 120: 191—200.

Li Q H, Li C Z, Sun B P *et al.*, 1999. Prediction and control of soil erosion and non-point sources pollution [J]. Bulletin of Soil and Water Conservation, 19(4): 54—57.

Long M J, Zhang H W, Zeng F S *et al.*, 2000. Applications of polymers in soil and water conservation [J]. Bulletin of Soil and Water Conservation, 20(3): 5—9; 14.

Vieux B E, Moreda F G, 2003. Nutrient loading assessment in Illionis River using a synthetic approach [J]. Journal of the American Water Resources Assiocation, 39(4): 757—769.

(Received for review April 8, 2005. Accepted May 24, 2005)