J. Appl. Environ. Biol. Sci., 9(10)17-20, 2019

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

The Challenges of Implementing Phytodrainage for Urban Areas

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Received: May 29, 2019
Accepted: August 23, *2019*

ABSTRACT

Drainage is the drying of rainwater precipitation on the surface of the earth. Natural drainage technology infects rainwater into the ground and drains rainwater on surface water bodies. The physical form of natural drainage technology by infiltration is permeable soil cover, which is in the form of green open spaces of plants the so called phytodrainage. The physical means of natural drainage technology in the drainage of the land surface are rivers, lakes and the like. Drainage technology based on practical methods of changing quality loads proves that reducing green space for the expansion of living infrastructure (including settlements) results in an excess of quality burden for water bodies. Attenuation of the impact of drainage channels on water bodies requires a study of the placement of ponds or the like to reduce fluctuations in the quality of the water body.
KEYWORDS: rainwater, infiltration, permeable soil cover, phytodrainage

1. INTRODUCTION

Changes in land cover due to various activities of human life (construction of buildings, roads and other infrastructure) result in changes in the hydrological response [1]. Quantitatively, the hydrological response in question is, among others, a decrease in the infiltration of rainwater into the soil and an increase in runoff of rainwater at the ground surface. Qualitatively, an increase in runoff causes increased soil erosion, and with the addition of human life activities, it continues with an increase in contaminants in runoff to the level of rainwater pollution. Coverage of various pollutant sources on a regional scale characterizes polluted rainwater as a carrier medium for non-point pollution, which ends up leading to a centralized disposal point in a body of water (rivers, lakes, estuaries).

Potential rainwater runoff pollution is expressed as an area load, which is formulated as follows: *Load area (Ba) = Qr * A * C*. Qr is rainwater runoff discharge, obtained from the hydrograph unit (mm $year^{-1}$), C is the quality of contaminants (mg L^{-1}) and A is the area of rainwater runoff (km^2).

The area load changes to a water quality load in the drainage channel: *Load (B) = Qd * Cd*. Qd is the rainwater discharge in the drainage channel (m^3 sec^{-1}) which drains the rainwater Qr for area A, and Cd is the quality of rainwater in the drainage channel (mg L^{-1}) whose number and amount are the same as C.

Some of the challenges of applying phytodrainage are described below. This is intended to be the preparation of a rainwater drying program during the rainy season. Its application is mainly for the tropics.

2. Drainage channel

Drainage channel is made to drain rainwater runoff. Some of the contaminants that did not undergo gas transformation carried in the drainage channel with a load of Qd * Cd. The discharge of drainage runoff into water bodies adds to the quality burden of existing water bodies (Qb * Cb). Water bodies before getting input of drainage runoff (dry season) have a quality burden [2], which comes from deep ground water sources and surface water. During the rainy season and the water body gets input of drainage water, the quality of the water body becomes the following mixed quality load: *Qc*Cc = Qb*Cb + Qd*Cd.* Notation c is a body of water mixed with drainage water, d is drainage water, and b is a body of water without drainage water.

3. Drainage and material channels made permeables

Drainage problems in developed countries, especially the USA are solved by the choice of using permeable materials, namely paving stones. The development of drainage technology to reduce impacts on water bodies is known as low impact development (LID). Drains that drain rainwater runoff coupled with the construction of artificial permeable materials translate into an interrelation of environmental impacts. In the rainy season, rain water falls over the contaminants that are present in the soil surface and from the results of human activities. The process that occurs is that some of the contaminants in the runoff are transformed into carbon dioxide which is released into the air.

Some of the contaminants that did not undergo gas transformation carried in the drainage channel with a load of Qd * Cd. During rainwater runoff in contact with permeable artificial material, part of the load is released

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into the soil infiltration (Qi * Ci). Drainage discharge into the water body adds to the quality burden [3] of the existing water body (Qb * Cb). Water bodies before getting input of drainage runoff (dry season) have a quality burden, which comes from deep ground water sources and surface water. During the rainy season and the water body receives input of drainage water that has been reduced by infiltration through permeable material, the water quality load becomes the following mixed quality load: $Qc*Cc = Qb*Cb + Qd*Cd - Qi*Ci$.

4. Phytodrainage concept

In the rainy season, rainwater drops over the contaminants that are on the surface of the soil and the result of human activities. The process that occurs is that some of the contaminants [4] in the runoff are transformed into carbon dioxide that is absorbed by plants.

Some contaminants that do not undergo gas transformation are carried away in phytodrainage with a Qd * Cd load. During rainwater runoff in contact with plants, part of the load is released into soil infiltration (Qi * Ci) and plant uptake (Qt * Ct). Disposal of phytodrainage runoff to water bodies reduces the quality burden of existing water bodies (Qb * Cb). The application of phytodrainage results in a mixed quality body water load, which is smaller than that of the drainage channel, due to the reduction in the quality burden by infiltration (Qi * Ci) and the following plant uptake (Qt * Ct) quality load: $Qc*Cc = Qb*Cb + Qd*Cd - Qi*Ci - Qt*Ct$.

Qualitatively demonstrated the superiority of phytodrainage over drainage channels in suppressing environmental impacts. But realistically, phytodrainage may not be able to replace the drainage channels because the capacity of plant processes is a certain natural nature which is not as flexible as developed drainage channels. Therefore it is necessary to study the optimization of the feasibility of phytodrainage in the urban drainage system as a whole. An example is the intensification of plant retention ponds (phytoretention ponds), which are placed in each building and certain road network segments; the remaining rainwater runoff is completed by the drainage channel.

5. Drying stagnant water

Application of plant retention ponds requires indicators of the ability of plants to drain water developed plant pump indexes in the field of evapotranspiration. Plant pump index is defined as the ability of plants to absorb water through the roots and release it through the surface of plants, which are driven by sunlight energy. Water flow through roots (transpiration flow) plus evaporation flow (E) is evapotranspiration flow (Et). The pumping rate of plants is measured as a transpiration factor and expressed as an Et / E ratio greater than 1. The pumping ability must be balanced with the continuity of plants to carry out the evapotranspiration process. Guaranteed continuity of plants is technically expressed as a relative growth rate (RGR). The Et and RGR parameters are obtained through laboratory or field experiments. Plants are declared capable of natural pumps if the plant pump index has a high Et / E ratio accompanied by a low RGR.

6. Atenuation of impact of drainage for water bodies

Drainage water disposal can be carried out into the environment:

1) Surface water bodies, which can be:

a) River, potential for high and low altitude areas.

b) Coastal lakes and wetlands (natural stagnant water bodies) and reservoirs / artificial stagnant water bodies, which are potential for lowland and coastal areas.

c) Sea, potential for coastal areas.

2) Injection into deep groundwater bodies, which are potential for drought prone areas and prone to sea water intrusion.

Of the various drainage impacts on water bodies, two types of impacts that require important attention are impacts on:

1) Water body assimilation capacity (KAb). KAb is the ability of a water body to accommodate quantity (Q) and process quality (C). Q is inert (the structure of the object does not change, for example H_2O remains H_2O even though it is cooled or heated); the effect of adding Q results in the accumulation of Q. While C is inert (= conservative, for example NaCl remains NaCl even though it is cooled or heated) and some is non-conservative (the structure of the body changes, eg BOD dissolves into CO_2 gas); the effect of adding C can be synergistic, antagonistic, additive, accumulative, multiplicative. If the accumulation of Q can still process additional C (change the form of substances), then the body of water has an assimilation capacity (KAb) to its input. As per the water body's assimilation capacity definition, KA is a measure of the impact event. Drainage impacts occur if the quality load is mixed with water bodies (Qc * Cc)> KAb.

2) Fluctuations in water body loads. Both quantity (Q) and quality (C) occur naturally in each drainage channel and water body. Fluctuations in the maximum load need to be the focus of attention, because it is likely to exceed the assimilation capacity of water bodies. The maximum load fluctuation factor becomes a measure to determine the occurrence of the impact of drainage on a body of water, formulated as follows: Fbm = Q * C (max) / Q * C (average).

1) The determination of KAb and Fbm is by monitoring the Q and C of water bodies and drainage channels that exist in the rainy season. Table 6.4 presents the results of monitoring Q and C of a river and upstream city drainage channel accompanied by a calculation of the quality load for both the water body and the upstream city drainage channel. While Table 6.5 presents the results of monitoring Q and C of the city downstream drainage channel accompanied by a calculation of the quality load for both the same river and the downstream drainage channel of the city.
2) Based on this monitoring it was determined that KA was 2.5 kg sec^{-1}. River Fbm without downstream city drainage is 2,160 / 1,331 = 1,623, Fbm downstream city drainage is 0,612 / 0,143 = 4,279, and River Fbm is mixed with downstream city drainage is 2,412 / 1,475 = 1,635. In these conditions it is known that:
    a. No drainage effect on river KAb (mixed quality load = 2,412 kg det-1 <KA = 2.5 kg det-1).
    b. There was a time shift in the Fbm river occurrence from the 10th week (river without drainage downstream of the city) to 12th week (river with downstream drainage of the city).
    c. The impact of an increase in river Fbm from 1,623 (river without drainage downstream of the city) to 1,635 (river mixed with downstream drainage of the city).

7. Infrastructure of load fluctuation

The two examples above give a description of drainage that can give effect to KAb while not affecting the Fbm of the river. Likewise the impact occurs on river Fbm but does not affect KAb. Of course drainage water disposal is not expected to have an impact on both KAb and Fbm water bodies. For this reason, the impact attenuation method is needed to reduce the fluctuation of the maximum drainage load [5].

The technological approach adopted is the addition of new water bodies that can reduce load fluctuations. Practical experience is the addition of stagnant water bodies, for example ponds / reservoirs. The system faced is to reduce the fluctuating load (QC, or VC) to less volatile loads and set the pool volume (Vk). The problem faced is which drainage canals should enter the additional pool to produce fluctuations in the output load lower than fluctuation in drainage loads.

8. Applied phytodrainage

In a phytotechnology perspective, man-made drainage infrastructure is the last work or the rest of the work after nature completes it. Therefore, it is important to provide natural infrastructure as much as possible, so that man-made infrastructure becomes small, small and cheap and has little impact on the environment. The available natural infrastructure is the body of river water, lakes, wetlands, and land. The capacity of the soil to dry rainwater by infiltration can be increased by expanding the area of land permeability using plants (phytodrainage).

Phytodrainage (origin term: biodrainage) has been developed in developed countries since the 1970s, especially in the USA. Phytodrainage starts from the roof of the house (vegetated roof) and continues to drainage the road using a combination of paving and grass. The use of vegetated roofs in Indonesia has not yet been found, but in some places small and partial scales have used phytodrainage.

Plant pump index research in the field of evapotranspiration reveals the ability of plants to absorb water through roots and release it through the surface of plants, which are driven by solar energy. Water flow through roots (transpiration flow) plus evaporation flow (E) is evapotranspiration flow (Et). The quantitative plant pump index is expressed as a transpiration factor (Tr) and expressed as an Et / E ratio greater than 1. The meaning of Et / E> 1 in drainage is that phyodrainage dries rainwater more often than in the drainage channels without plants.

The research also states that the use of plants can improve water quality [6]. In this case phytodrainage can improve the quality of rainwater runoff, in addition to providing the availability of ground water and minimize standing water. Going forward, phytodrainage can be effective and efficient in the use of resources as well as minimizing the impact of rainwater runoff, by means of an integrated regional system approach. Namely, phytodrainage starts from housing and continues in residential areas and continues on the road network. Old residential areas and new development should start to rearrange road construction. At the same time improving the drainage system using paving, and in some asphalt intersections provided facilities parks.

CONCLUSION

Man-made drainage technology to increase infiltration is to increase the permeability of land cover by using paving stones or the like. Man-made drainage technology for flowing runoff is a drainage channel using various types of construction. Phytodrainage and / or paving stone placement in the drainage channel makes drainage technology effective both in solving quantity problems and improving runoff water quality.

REFERENCES

1. Horsley Witten Group, 2004. Model Stormwater Management Bylaw. Prepared for the Towns of Duxbury, Marshfield, & Plymouth, MA, USA.

2. Winer, R. 2000. National Pollutant Removal Database - Revised Edition. Center for Watershed Protection, Ellicott City, Maryland.

3. Waschbusch. 2000. Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994-1995. In: National Conference on Tools for Urban Water Resource Management and Protection. US EPA February 2000: pp. 15-55.

4. Schueler, T. 1999. Microbes and Urban Watersheds. Watershed Protection Techniques. 3(1): 551-596.

5. Steuer, J., W. Selbig, N. Hornewer, and J. Prey. 1997. Sources of Contamination in an Urban Basin in Marquette, Michigan and an Analysis of Concentrations, Loads, and Data Quality. U.S. Geological Survey, Water-Resources Investigations Report 97-4242.

6. Bannerman, R., D. Owens, R. Dodds and N. Hornewer. 1993. Sources of Pollutants in Wisconsin Stormwater. Water Science and Technology. 28(3-5): 241-259.