Potential use of sediments retained in stormwater harvesting systems

Utilisation potentielle des sédiments retenus dans des systèmes de réutilisation d'eaux de ruissellement

María A. Pimiento*, Jaime A. Lara-Borrero*, Andrés Torres*

*Facultad de Ingeniería, Pontificia Universidad Javeriana, Bogotá, Colombia. (email mpimiento@javeriana.edu.co)

RÉSUMÉ

L'objectif de ce travail est d'établir les conditions liées à la qualité des sédiments retenus dans des systèmes de réutilisation d'eaux de ruissellement pour être utilisés comme matériaux productifs et d'identifier des relations entre les caractéristiques des pluies et celles des sédiments. Les sédiments se sont avérés utiles pour leur utilisation en activités d'amélioration des sols non agricoles, comme la dépollution et la végétalisation et comme matériau pour des surfaces destinées à des usages décoratifs ou de loisir. L'utilisation dans des activités de construction est limitée dû à la fine taille des sédiments (D50 <150 µm). Cependant, il est possible de les utiliser comme matériau de fourrage pour la fondation de structures en béton ou des tuyaux d'assainissement. Des relations entre les caractéristiques de la pluie et des sédiments ont été établies: plus les périodes sèches sont courtes, plus la taille des sédiments augmente ainsi que les concentrations en Carbone Organique Total, et plus les concentrations en métaux lourds diminuent.

ABSTRACT

The objective of this work was to establish the quality conditions of the sediments retained in a stormwater harvesting system to be used as productive material and found the relationship between rainfall and sediment characteristics. Sediments are suitable for use as productive material in activities such as remediation and vegetation of soils that are not for agricultural use and as materials for ornamental and recreational areas. Considering that these are thin particles (D50 <150 µm), the uses in the construction area are restricted. However, it is possible to use the sediments as filling material of concrete structures and sewers in the core area or foundation. Interesting relationships between rainfall and sediment characteristics were found: in shorter dry seasons, higher the particle diameter, lower the concentrations of heavy metals (HM) and higher the concentrations of total organic carbon (TOC).

KEYWORDS

Productive material, Rainfall characteristics, Sediments characteristics, Stormwater harvesting systems.

INTRODUCTION

The environmental policies that are being developed around the world seek to create systems for reusing of resources. One of the most exploited of them is rainwater (Lara Borrero et al. 2007). Nevertheless, rainwater has a sediment load that can also be used according to its characteristics for purposes such as construction, soil restoration (Akcil et al. 2015), gardening or road construction (Wang et al. 2015). Commonly the sediments extracted from different water systems are rejected in sanitary landfills, confined for aquatic disposal or discharged into the sea. These practices are considered the most applied management strategies in the world (Akcil et al. 2015).

Sediments extracted from different water sources have been analyzed to determine their characteristics. With t this, it is sought to establish the degree of contamination of the sediment and in which cases it is possible to use. In some countries, there are regulations for the pollutant loads contained in sediments. However, these standards are not always met (Simpson 2015). Research has shown that concentrations of pollutants in sediments vary significantly according to the size of the sediment particles (Vaze and Chiew 2004), according to the type of land use, or the surface (Charters, Cochrane and O'Sullivan 2015). There is a need to know the behavior of sediments in stormwater systems since the management of these involves costs. For this reason, it is necessary to find alternatives for sediment management, such as productive use. The objective of this work was to establish the quality conditions of the sediments retained in a stormwater harvesting systems to be used as productive material and found the relationship between precipitation and sediment characteristics.

1 METHODS

In order to study the sediments retained in stormwater systems, experimentation was conducted in the constructed-wetland/storage-tank (CWST) system of the Pontificia Universidad Javeriana (PUJ). This system has two sand traps, one on the eastern side which receives the runoff water from the parking lot building (0.81 ha) and the second one located on the western side which receives the runoff water from the soccer field and the surroundings (2.73 ha) (Galarza-Molina et al. 2015). Samples were taken every fortnight in each of them for six months.

The sediment traps necessary for the experiment at the site must meet the following characteristics: not to alter the water flow, they must be easy to submerge and extract, and they must be stable. After reviewing different types of traps available in the market, and according to the characteristics stated, we concluded that they had to be specially constructed for the study case.

In order to determine the particle size distribution (PSD) of the sediments, a laser diffraction analysis was carried out in a range of 0.1 µm to 1000 µm. ICP was used to heavy metal concentrations in sediments (HM), especially those that create a health risk as Cd, Cr, Cu, Ni, Pb and Zn (IDEAM 2006). Also, the TOC was used as an indicator of the presence of the chemical components of organic matter. The rainfall data were collected from the El Granizo (PA - 036) rainfall station and a rainfall station located inside the PUJ campus. The analysis of the data obtained was done by Multiple Correspondence Analysis (MCA) to determine the most important variables influencing the variability between samples and to find the relationships between the variables.

2 RESULTS AND DISCUSSION

From the analysis of MCA concerning the PSD results, we obtained that the most of the sediments collected at the eastern sand trap have diameters <100 µm, while the most of the sediments collected at the western sand trap has diameters between 100 µm and 450 µm. This result indicates that the particles of the western sand trap can be considered thicker.

We compared the variance of HM concentrations in sediments obtained from the qualitative analysis by ICP with thresholds of HM concentrations for sediments defined for some countries. For Cr, the measured concentrations vary between 3.93 mg/kg and 110.80 mg/kg, with a median value of 35.84 mg/kg. This value is lower than the safety limit concentration; however, according to (Norwegian Environment Agency, 2018) this concentration represents a human health risk. The Cu lowest and highest concentrations measured were 24.94 mg/kg and 263.25 mg/kg respectively, with a median value of 115.5 mg/kg, which is higher than the low-risk level but lower than the probable effect level. The Pb concentrations, in general, exceed the established limits with a minimum of 106.83 mg/kg, a maximum of 798.85 mg/kg and a median of 331.45 mg/kg. Zn concentrations are higher than the probable effect concentrations, in a range of 623.3mg/kg to 3067mg/kg (Wisonsin Dept. of Natural Resources 2003; Canadian Council of Monisters of the Environment 2001; Norwegian Environment Agency, 2018;

Australian and New Zealand Environment and Conservation Council 2000).. Regarding the concentrations, the eastern sand trap presents higher concentrations for Pb and Cu and are also related to the fine particles of the sample. This result may be because the sediments come from the parking lot. In the same way, it occurs with TOC, for which high concentrations are associated with smaller particles

Additionally, we obtained an inverse relationship between the total rainfall height or the rainfall intensity and the sediment diameters collected in the sand traps: the higher the total rainfall height or, the greater the rainfall intensity, the smaller the diameters of the particles that will reach the sand traps. Sediments with diameters <100 µm are related to high and medium rainfall intensities, to low and medium antecedent dry weather periods (ADWP) and high rainfall mean intensities.

Similarly, an analysis was carried out to determine the relationship between the quality of the sediments and the rainfall characteristics: for higher antecedent dry weather periods and rainfall intensities, higher HM concentrations and lower TOC concentrations were obtained. This result indicates that the HM concentrations in sediments increase with higher periods of accumulation during dry weather, especially those that have contact with vehicular traffic, mainly due to the wear of the tires.

The chemical and physical analysis showed that the eastern sand trap is the one with the highest amount of fine particles and these sediments have higher Pb and Cu concentrations, related to diameters smaller than 75 µm. The relationship between rainfall and physical characteristics of the sediments showed that the higher the intensity of the rainfall and the total height of the rain, the smaller the particles of coarse grains that reach the sand traps. In the same way, we found that a smaller number of dry days the higher the sediment diameters retained in the sand traps. ADWP was also found to be related to HM concentrations, being higher for higher ADWP, contrary to what happens with TOC concentrations, which tend to decrease. From the above it is necessary to emphasize that when there are summer seasons, HM concentrations in sediments will increase, while those of TOC will be lower, limiting the possibility of using the sediments in activities such as gardening.

2.1 Possible Uses

In Colombia, the Technical Regulation of the Drinking Water and Basic Sanitation Sector (RAS) in Title F specifies the physical and chemical characteristics that a material must have to be reused, defined the permissible values for two categories of reuse: Category A/Agriculture as organic fertilizer; Category A/Other as land remediation of contaminated soils; Category B forestry, for the stabilization of slopes on roads, rehabilitation of lands for recreation, gardens, parks and green areas (Ministerio de Vivienda, Ciudad y Territorio, 2012).

We compared the HM concentrations with the limits for each use defined. It is not possible to reuse the sediments for agriculture purposes due to the high HM concentrations ; it is possible to reuse them in land remediation, based on RAS Category A/Other; and use the sediments in gardens and urban landscaping (RAS Category B). According to the PSD of the samples, the sediment is too thin to be used as a material for most of the activities related to the construction. However, the material may be suitable for filling concrete structures and culverts in the core or foundation area (INVIAS, 2012). However, the organic matter content limits this use. The sediments can be used for non-agricultural soil restoration, besides being able to be used as an ornament in recreational or gardening areas.

3 CONCLUSIONS

According to the Colombian legislation, the sediments collected from the CWST sand traps are considered suitable to be used in activities such as the remediation and revegetation of soils that are not for agricultural use. However, it is necessary to consider that the receiving soil has lower or worst characteristics than the sediments. Likewise, according to the high TOC concentrations obtained, the use should be limited as a filling material for concrete structures and culverts in the core or foundation area. Finally, it is not possible to use the sampled sediments in activities related to agriculture because of the high levels of HM obtained.

From the analysis of the results of the physical and chemical characteristics of the sediments, the latter are the most influential in the possible use of sediments as a productive material, due to the high concentrations of Pb an Zn. These concentrations come mostly from the wear of the vehicle tires, the brakes and the oils and lubricants that are used in the automotive industry (Trujillo-González 2014) .

The relationship between the hydrology and the physical characteristics of the sediments showed that the higher rainfall intensity, and the higher number of days in dry weather, higher HM concentrations, contrary to what happens with TOC concentrations, which tend to decrease. These last results open the possibility of proposing sediment management systems based on the hydrological behaviour in the study area. This implies lower costs associated with the management of sediments and more timely response times. Further studies will deepen these relationships to estimate critical characteristics of the sediments that provide elements for making decisions regarding their use without the need for systematic or frequent sediment characterizations.

LIST OF REFERENCES

Akcil A, Erust C, Ozdemiroglu S, Fonti V, Beolchini F., (2015). *A review of approaches and techniques used in aquatic contaminated sediments: metal removal and stabilization by chemical and biotechnological processes.* Journal of Cleaner Production; 86(Supplement C), 24–36.

Australian and New Zealand Environment and Conservation Council. 2000. 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality', October.

Canadian Council of Monisters of the Environment. 2001. 'Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.'

Charters FJ, Cochrane TA, O'Sullivan AD. (2015) *Particle size distribution variance in untreated urban runoff and its implication on treatment selection*. Water Research., 85(Supplement C):337–45.

Faram MG, Iwugo KO, Andoh RYG. (2007) *Characteristics of urban run-off derived sediments captured by proprietary flow-through stormwater interceptors*. Water Science and Technology., 56(12):21–7.

Galarza-Molina SL, Torres A, Moura P, Lara-Borrero J., (2015) *CRIDE: A Case Study in Multi-Criteria Analysis for Decision-Making Support in Rainwater Harvesting*. International Journal of Information Technology & Decision Making 14(01):43–67.

IDEAM. (2006) *Metales en agua por Plasma Acoplado por Inducción (Cd, Cr, Cu, Ni, Pb, Zn)*. [Metals in water by Plasma Coupled by Induction (Cd, Cr, Cu, Ni, Pb, Zn)] Subdirección De Hidrología - Grupo Laboratorio De Calidad Ambiental;.

INVIAS (2012). *Rellenos para Estructuras* [Fillers for Structures] ARTÍCULO 610 -13.

Lara, J.A., Torres, A.E., Campos, M.C., Duarte L., Echeverry, J.I., Villegas, P.A., (2010). *Aprovechamiento del agua lluvia para riego y para el lavado de zonas duras y fachadas en el campus de la Pontificia Universidad Javeriana (Bogotá) [Use of rainwater for irrigation and for washing hard areas and facades on the campus of the Pontificia Universidad Javeriana (Bogota)]*. Ingenieria y Universidad: Engineering for Development, 11(2).

Ministerio de Vivienda, Ciudad y Territorio. (2012) *Reglamento Técnico del Sector de Agua Potable y Saneamiento Básico - RAS. TÍTULO F Sistemas de Aseo Urbano*. [Technical Regulation of the Potable Water and Basic Sanitation Sector - RAS. TITLE F Urban Cleaning Systems.]

Norwegian Environment Agency,. 2018. 'Risk Assessment of Contaminated Sediments'. In , M-1132:115.

Simpson S, Batley G. (2016). *Sediment Quality Assessment*

Trujillo-González JM. (2014) *Evaluacion de tres zonas de la ciudad de villavicencio a partir de las concentraciones de metales pesados presentes en el polvo vial*.[Evaluation of three zones of the city of Villavicencio from the concentrations of heavy metals present in road dust.], Universidad De Bogotá Jorge Tadeo Lozano.

Vaze J, Chiew FHS. (2004). *Nutrient Loads Associated with Different Sediment Sizes in Urban Stormwater and Surface Pollutants*., Journal of Environmental Engineering,130(4):391–6.

Wang L, Kwok JSH, Tsang DCW, Poon C-S. (2015). *Mixture design and treatment methods for recycling contaminated sediment*. Journal of Hazardous Materials. 283(Supplement C):623–32.

Wisonsin Dept. of Natural Resources. 2003. 'Consensus-Based Sediment Quality Guidelines Recommendations for Use & Application'. In , 40.