Does clogging of stormwater Infiltration systems only depend on TSS inputs?

Le colmatage des ouvrages d'infiltration dépendent-ils seulement des M.E.S. apportées par les eaux pluviales ?

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RÉSUMÉ

Le colmatage est un processus qui a été beaucoup étudié et caractérisé aussi bien en laboratoire qu'*in situ*. Les études antérieures font souvent l'hypothèse que le colmatage physique dû aux matières en suspension (MES) apportées par les eaux pluviales est dominant et que les autres facteurs sont négligeables. Dans ce contexte, un bassin d'infiltration des eaux pluviales représentatif des bassins de la région Rhône Alpes (France) a été suivi pendant plus de 6 ans. Le but du travail a été plus particulièrement d'investiguer la part du colmatage liée aux apports de MES par rapport aux autres sources exprimée en termes d'épaisseurs.

Le travail a montré que les apports de MES constitue la part principale (entre 63 % to 74 %) mais que les autres facteurs (externes et/ou biologiques) étaient loin d'être négligeables.

L'étude a permis également de donner des ordres de grandeur de progression annuelle moyenne de l'épaisseur d'accumulation dans le bassin (de 6.5 à 10 mm/an).

ABSTRACT

Clogging of infiltration basin is a process that has been widely studied and characterized both with laboratory experiments and field studies. Previous works often made the assumption that physical processes due to total suspended solids (TSS) brought by stormwater was dominant and other factors negligible. In this context, an infiltration basin representative of the majority of infiltration systems of Rhone Region (France) was monitored for more than 6 years. The aim of the work was more particularly to investigate the part of the clogged layer due to TSS inputs compared to other sources expressed in terms of thickness.

This work highlights that TSS inputs remained the main source of clogging (between 63 % to 74 %) but put forward the importance of other factors (external and/or biological) far from being negligible.

The study also allows giving an indicator of the mean annual progression of sediment accumulation thickness associated to TSS and other factors (resp. 6.5 to 10 mm/year).

KEYWORDS

Clogging, Infiltration basin, Sediment, Stormwater, TSS

1 INTRODUCTION

Infiltration is widely used to manage stormwater in cities for many reasons: it tends to reduce flood risks by limiting water volumes and runoff peak flows in downstream networks or water courses, contributes to aquifer recharge, limits pollution discharges to surface waters and can easily be integrated to urban landscape design.

However, questions remain about their longevity in particular because of their potential for clogging.

Clogging has been largely attested and evolution over the time studied (e.g. Schuh 1990; Lindsey *et al.* 1992; Warnaars *et al.* 1999; Dechesne *et al.* 2005; Le Coustumer & Barraud 2007; Emerson & Traver & 2008, Gonzalez-Merchan & Barraud, 2011). However very few researches have addressed the problem of the source of clogging with long series of data acquired from field measurements.

The clogged layer results from a combination of physical, chemical and biological processes (Baveye *et al.* 1992; Rinck-Pfeiffer *et al.* 2000). Previous studies suggested that physical process dominates chemical and biological ones (Bouwer 2002; Siriwardene *et al.* 2007) and put forward the probable role of Total Suspended Solid (TSS) contained in stormwater (Browne *et al.* 2008; Wang *et al.* 2012), but biological phenomenon was also suspected (e.g. Gautier *et al.*, 1999). Therefore, evolution over time, composition and dominant factors of its development have to be better analysed, especially for large infiltration systems.

In this context, a stormwater infiltration basin representative of the majority of infiltration systems of Rhone Region (France) has been monitored for more than 6 years. The aim of the work is to investigate the part of the clogged layer due to solids brought by stormwater to infiltration systems and the part attributable to other sources which is a combination of atmospheric deposits, particles brought by the wind, parts of vegetation, exudates from the root systems, biofilm mineralised, erosion of banks…

For that purpose, the spatial characteristics of the accumulated sediments in the basin in 6 years were analysed and total thickness of sediments compared to the thickness due to TSS inflow on the same periods of time.

2 MATERIALS AND METHODS

2.1 Experimental site description

The infiltration basin monitored in this study is located at Chassieu, in the eastern suburbs of Lyon, France (www.othu.org). It is situated at the outlet of an urban and industrialized catchment of 185 ha, with a flat topography (mean slope 0.4%) and an imperviousness coefficient of about 75 %. The total area of the basin is about 8,000 m² with a capacity of 61,000 m^3. Stormwater from the catchment flows successively through: i) a detention and settling basin, ii) a flow control device allowing a maximum flow rate of 350 L/s, iii) a 60 cm circular connection pipe and iv) the infiltration basin.

Figure 1 shows the configuration of the retention and the infiltration basins.

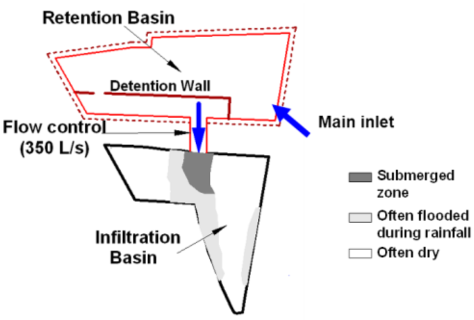

Figure 1. Configuration of the Django Reinhardt retention – infiltration basin and the wet zones distribution in the infiltration basin.

The bottom of the basin was designed to be bare. The underground substratum of the infiltration basin is composed of quaternary fluvial and glacial deposits and the groundwater table is around 13 meters below the bottom of the basin.

The basin has been functioning for more than thirty years, has been rehabilitated in 2002 and totally scrapped in April 2004 (sediments and the topsoil completely removed). The retention compartment was also scrapped but in 2006.

According to previous work the basin has been submitted to regular and rapid clogging until 2006. The clogging evolution being monitored by the evolution of the hydraulic resistance of the basin (see Gonzalez-Merchan *et al.,* 2012) for the procedure.

From the end of 2006 to the beginning of 2007, the basin has been progressively overgrown with spontaneous native vegetation currently found in wet areas in particular in the submerged and often flooded zones as shown in Figure 1. During this period, clogging has grown but with at a lower rate. In this site, stormwater flow quantity and quality were monitored continuously with a 2 minute time step and in particular the turbidity transformed into TSS by means of a specific methodology reported in (Bertrand-Krajewski, 2004) taking uncertainties of both TSS concentration and turbidity into account. Climatic factors (air and water temperatures, solar energy & rainfall) were also monitored but not used in the work presented in this paper. More details of the site and the monitoring system can be found in Barraud *et al.* (2002) and Bertrand-Krajewski *et al.* (2008).

2.2 Methodology

The methodology is based on the assessment of the difference between (i) the mean thickness of the accumulated sediments in the basin and (ii) the mean thickness of sediments due to TSS inputs.

Previous work has shown that thickness was very heterogeneous over the basin (Gonzalez-Merchan & Barraud 2011). However the mean thickness will be considered here as an indicator easy to interpret which does not mean any homogeneity or representativeness of its spatial distribution.

2.2.1 Evaluation of the thickness of sediment accumulation (eTotal)

Considering that the bottom of the basin was totally scrapped in April 2004 when the infiltration basin was renovated, the sediment thickness was determined as the difference between basin topsoil made of sediments and the underlying soil made of fluvio-glacial deposits. This has been done by visual inspection, the two layers being indeed very contrasted in terms of colour and structure and therefore very easy to distinguish.

The mean thickness (e_{Total}) was determined as the ratio of the total sediment volume accumulated during the period to the product of the total basin area with its bulk density.

This thickness was measured during two campaigns (one in May 2008 and one in April 2010) with about 100 points spatially distributed according to a regular 10 by 10 meter grid. It was also possible to evaluate the thickness of sediments during 3 periods: from 2004 to 2008, from 2008 to 2010 or on the total period (i.e. from 2004 to 2010).

2.2.2 Evaluation of the thickness due to TSS inputs (eTSS)

The thickness due to TSS inputs was calculated from the TSS mass, the bulk density, the porosity and the basin area. The mass of sediment brought to the system was assessed using the continuous measurement of turbidity and the relationships between TSS concentration and turbidity calibrated for wet and dry weather periods (see Gonzalez-Merchan, 2012 for more details). The TSS inputs includes particles coming from the catchment and the deposits in the retention basin situated upstream (both from atmospheric and run-off sources). They do not integrate the direct atmospheric deposits of particles in the infiltration basin which are indirectly estimated within the difference between e_{Total} and e_{TSS}. Even if a rigorous data verification methodology was carried out to validate the flow and turbidity series, there were gaps in the data series whether because of monitoring equipment failure or maintenance. In that case, a methodology to fill them using both expert algorithms and modeling were applied (see Gonzalez-Merchan, 2012 for details).

In order to estimate this thickness (e_{TSS}), the bulk density was evaluated according to the calibrated cylinder method (ISO NF X31-501, 1992), the particle density was assessed with the NF P94-054 standards (AFNOR, 1991) and the soil porosity (ε) calculated with the dry bulk density (ρ_d) and particle density (ρ_s) according to the following equation: $\varepsilon = 1 - \rho_d / \rho_s$.

Uncertainties of the two different thicknesses were calculated using the uncertainty propagation law and the uncertainty of the different parameters estimated by their standard deviation (triplicates).

3 RESULTS

In order to identify the part of TSS inputs relatively to other sources (biological and external factors (e.g. wind-driven particles brought to the infiltration basin)) in the clogged layer, e_{Total} and e_{TSS} values were compared. For example between April 2004 and April 2010, TSS load was found to be 140 t ± 32 t. Using an average sediment density of 0.688 t/m^3 ± 0.019 t/m^3, a porosity of 0.62 m^3/m^3 ± 0.04 m^3/m^3 homogenously distributed over the 8,000 m² of the basin, the thickness (e_{TSS}) of the accumulated sediment within 6 years was about 41 mm ± 6 mm, i.e. about 6.5 mm/year. (Gonzalez-Merchan & Barraud, 2011).

On the same period the thickness (e_{Total}) was estimated. Considering the clogged layer uniform on the surface of the basin, the mean sediment thickness accumulated from April 2004 (basin totally scraped) to April 2010 was estimated at 59.3 ± 15.4 mm with a bulk density of 0.688 t/m^3 ± 0.019 t/m^3 (i.e. 31.5 mm ± 11 mm from April 2004 to May 2008 and 59.3 ± 15.4 mm from May 2008 to April 2010). The accumulation is therefore about 10 mm /year.

The same methodology was applied on the 3 periods. Results are plotted in Figure 2.

If clogging of stormwater infiltration systems was mainly due to TSS inputs, e_{Total} and e_{TSS} should be about the same. However the last results show that from 26% to 37% came from other sources.

The clogged layer can be considered as a microcosm related to external factors and biological activities which are far from being negligible.

We can also notice that, as time passes, the percentage of these factors seems to increase. Between 2008 and 2010 the percentage is 38% *vs* 26% at the first period. After 2008 the infiltration basin showed an important growth of vegetation, which can be suspected to modify the physical and bio-chemical characteristics of soil (in the last period zones frequently submerged show a peaty soil type).

To corroborate the order of magnitude of the results obtained on the infiltration basin, the same methodology was applied to the retention compartment placed upstream (see figure 1) from 2006 to 2010. The TSS mass trapped was estimated from the difference between TSS mass at inlet (299 t) and at outlet (122 t). The total mass of TSS was then estimated at 177 t with 60% of efficiency of the basin. The mean dry bulk density of sediment being 0.736 t/m^3, the porosity of 0.73 m^3/ m^3 and the surface 11,000 m², the thickness resulting from TSS was 29 mm.

The total volume of accumulated sediments in the retention basin was about 401 m^3 giving a thickness (e_{Total}) of 36 mm and a difference with e_{TSS} value of 22 %. The percentage of sediments thickness resulting from external and/or biological factors is less important than the one found in the infiltration basin but globally in the same range. This reason might be that the vegetation in retention basin is less dense than in the infiltration system.

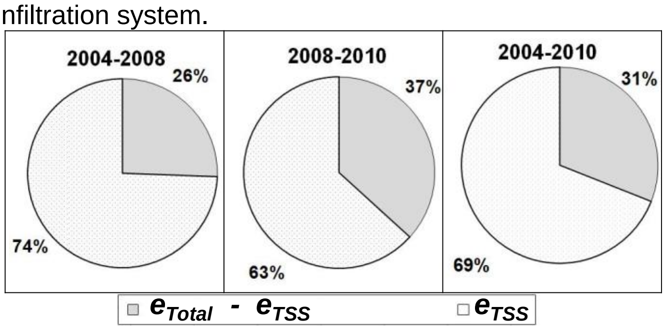

Figure 2. Part of sediment thickness due to TSS inputs and other sources for each period analyzed.

4 CONCLUSIONS

This work highlights that TSS inputs remain the main source of clogging (between 63 % to 74 %) but put forward the role of other factors (external and/or biological) far from being negligible. If probable sources are known (see introduction), each one cannot be identified precisely in the study. However the vegetation life could be a significant factor on the accumulation of sediments over time. The study on retention and infiltration basin allows to give an indicator of the progression of sediments thickness accumulated per year, associated to TSS and others different factors (from 6.5 to 10 mm). The study of clogging in real conditions turns out to be an interesting work demonstrating the importance the parameters neglected in laboratory experiments.

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