Effect of roadside vegetation management on the quantity and quality of highway stormwater in cold climate conditions: a pilot study

Effet de la gestion de la végétation en bordure de route sur la quantité et la qualité des eaux pluviales des autoroutes dans des conditions climatiques froides : une étude pilote

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RÉSUMÉ

L'objectif principal de notre projet est d'étudier l'impact de la gestion de la végétation en bordure de route sur la quantité et la qualité des eaux de ruissellement et d'établir des pratiques de gestion respectueuses de l'environnement en climat froid. Le but de notre étude pilote était d'effectuer le suivi d'un système de collecte des eaux de ruissellement en bordure de route et d'optimiser la conception expérimentale qui sera utilisée sur 11 sites à partir du printemps 2019. La quantité et la qualité des eaux de ruissellement recueillie à 0 m (bord de la route), 3 et 6 m dans une pente avec gestion de la végétation, a été déterminée. Une réduction de volume médiane de 96% et un bon enlèvement de la matière organique (DCO 60%) et des solides (MES 85%) accompagnés d'une diminution de la concentration en métaux lourds ont été observés. En conclusion, cette étude pilote à l'aide d'un système de collecte des eaux de ruissellement en bordure de route a montré des résultats prometteurs et nous a fourni les connaissances nécessaires à la poursuite du projet.

ABSTRACT

The main purpose of our project is to study the impact of roadside vegetation management on highway runoff quantity and quality, and to establish environmentally-friendly management practices in cold climate conditions. The purpose of our pilot study was to monitor one roadside runoff collection system and to optimize the experimental design that will be used on a total of 11 sites from spring 2019. The quantity and quality of runoff 0 m (highway edge), 3 m, and 6 m down the slope with managed vegetation, was determined. Median 96% of volume reduction and good removal of organic matter (COD 60%) and solids (TSS 85%) accompanied with decrease in heavy metals concentration was achieved. In conclusion, this pilot study using a roadside runoff collection system showed promising results and has provided us with necessary knowledge for successful continuation of the project.

KEYWORDS

green infrastructures, highway runoff, low impact development practices, vegetated filter strips

1 INTRODUCTION

The increase in urbanization has led to a surge in number of roads and vehicles. In Canada, vehicles registration has increased by 1.6% just from 2016 to 2017 (Statistics Canada, 2018). Therefore, a concern about the impact of the road runoff on the surrounding environment has raised. To overcome the water crisis in urban areas, water conservation and treatment through usage of green infrastructures and low impact development (LID) practices is recommended (Higgins et al., 2016; Matlock and Morgan, 2011). The LID methods like bioswales, vegetated filter strips and vegetated buffers – otherwise called phytotechnologies – are used for treatment and management of the highway runoff (Higgins et al., 2016; Stagge et al., 2012). These phytotechnologies utilize special design in combination with media and selected vegetation for runoff capture and pollutants removal (Higgins et al., 2016; Leroy et al., 2016; Stagge et al., 2012). According to the study by Henderson et al. (2016), in the humid subtropical climate, the unmanaged roadside vegetation has better efficiency in peak flow reduction and pollutant removal than the managed vegetation. Un-managed vegetation therefore can be considered a phytotechnology. However, more evidence is needed about the impact of roadside vegetation management on runoff quantity and quality in cold climatic conditions to change the general management of roadside vegetation and therefore adopt this phytotechnology (Storey et al., 2009).

The current project aims to: a) study the impact of highway roadside vegetation management on runoff quantity and quality in cold climate conditions; b) to establish environmentally-friendly management practices. The purpose of the pilot study was to: a) monitor one roadside runoff collection system and b) optimize the experimental design, that will be used on a total of 11 sites from spring 2019.

2 MATERIALS AND METHODS

2.1 Experimental Set-up

The project “Impact de la végétation en abords de route comme pratique de gestion optimale à la source végétalisée (PGOSV) des eaux pluviales” was initiated by Ministère des Transports, Quebec (MTQ), in collaboration with the Institut de Recherche en Biologie Végétale (IRBV) and Chaire en paysage et environnement, Université de Montréal, Québec, Canada.
On year 2019, a total of 11 highway runoff collection sites will be established. The 11 sites will be placed randomly on the chosen part of the same highway slope. The experimental plan consists of a) 5 replicates with minimal vegetation management (cutting only near highway edge according to road safety rules); b) 5 replicates with maximal vegetation management (cutting 3 times per season on all the slope and ditch); c) one additional site with current management practice (once a season, cutting all the roadside and twice a season, cutting only the edge of the road).

The pilot runoff collection system, monitored from August – November 2018, was located on the vegetated side slope (South facing) of the Autoroute Jean-Lesage (45.582º -73.309º) near Sainte-Julie town, Quebec, Canada (Fig. 1). The vegetation was managed according to current management practices (cutting at 100-150 mm height from ground level) and plants were re-growing during monitoring period from August to November 2018. The average annual daily flow on this highway section is 91 000 vehicles.

Figure 1. Pilot highway runoff collection system with gutters and collection tanks, and view of 3-meter gutter.

For designing and sizing the runoff collection system according to on-site conditions and precipitation data, first, the runoff calculations were performed. The runoff volumes from the different parts of the

highway, i.e., the paved roadway and the vegetated slopes, were estimated using the rainfall calculations in Huffman et al. (2013).

The pilot site included three collection systems with gutters (made from 3 m long Ø10 cm PVC pipes) intended to collect the runoff into three 1000 L tanks that had overflows to avoid back-flow of runoff to the gutters (Fig. 1). The gutters were positioned one meter apart at three different heights on the vegetated highway slopes: 0 meters (on the edge of the roadway), 3 meters (distance of the first and last cutting events) and 6 meters from the highway edge (middle of the slope). Each gutter was staggered from the previous one to ensure that they do not interfere with each other. Furthermore, after collecting preliminary runoff volume data from 5 rain events, additional work was done for avoiding interference between gutters and for capturing the runoff from the specific 3 m wide area of the highway: a) small bunds on the gravel strip next to the highway asphalt were constructed; b) the runoff from the other areas of the roadway was redirected with small trenches on the slope outside the gutter sections. As the main purpose of the pilot study was to optimize the experimental design according to the simulations and data collected, and without any previous onsite data about the runoff quantity (only calculated estimates), during the pilot study, the collection tanks were each calibrated to receive the same maximum volume of 390 L. This volume was chosen according to the onsite elevation differences between the lowest 6m gutter and the tank.

2.2 Sampling and analyses

From year 2019, the runoff volume data of specific rain events will be compared with precipitation data from onsite weather station. During year 2018, precipitation data from the closest public weather station in the Saint Hubert Airport (45.310º -73.250º) was used. The runoff volume of 10 rain events was measured in autumn 2018. Total four events out of ten had enough volume for water analyses (min 5 L). The representative samples from each tank were collected after throughout mixing of the content of the tank by proportional grab sampling of the runoff that was flushed from the tanks into 30 L tote. Following water analyses were carried out at the EnvironeX Group laboratories: pH, electrical conductivity (EC), total suspended solids (TSS), chemical oxygen demand (COD), total organic carbon (TOC), nitrates (NO_3-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ortho-phosphates (PO_4-P), total and mineral oil and grease, hydrocarbons (C10-C50), chlorides, and Zn, Ni, Cr, Cd.

3 RESULTS AND DISCUSSION

After the modifications in the initial collection system design, the pilot system performed according to plan and collected the runoff from the corresponding length and width of the slope. The volume measurements from pilot collection system showed that the 3m and 6m gutters receive significantly less runoff then the 0m gutter (Fig. 2). The reduction in volume was 81% just 3 m down the slope and an additional 15% at the 6 m down the slope (total reduction 96%). Therefore, our first volume reduction results already showed some similarities to the calculated results (i.e. 10 times less surface runoff than impervious asphalt). The tank volumes of the 11 collection sites from spring 2019 will be constructed according to the data collected with the pilot system. The tanks will be designed and sized to receive 90% of the runoff volumes of monitored rain events and the overflow systems will prevent back-flow to the gutters during rain events with extreme runoff volume. The representative samples will be collected from mixed and homogenized tank contents by grab sampling the necessary volume straight from the tanks.

When comparing our preliminary volume reduction results with a similar study conducted by Henderson et al. (2016), we can see that our pilot site with managed vegetation reduced the runoff volume more than the managed slopes in Virginia, US (e.g., volume reduction 76% compared with our 96%). Further large-scale study with 11 collection sites and different management practices with more rain events will provide us with extra information about the role of the vegetation management, e.g. impact of vegetation height and cutting frequency, on the runoff quantity.

Our preliminary results show that the road runoff collected with 0-meter gutter has on average lower pollutant concentrations (Fig. 2) than road runoff from statistical review done by Duncan (1999). When comparing our results with study on grassy swales on a highway side (Stagge et al., 2012), then the TSS and TP removal is lower on our site (85.9% and 46% compared with 90.9% and 64.6% in Stagge et al. (2012), respectively). The heavy metal concentrations in our first samples are on average much lower than those in Duncan (1999) review and Stagge et al. (2012) study or even under detection limit.

When comparing the results obtained in our pilot study from 0-meter, 3-meter and 6-meter gutter we can see a clear reduction in organic matter and hydrocarbons concentrations (Fig. 2). The pollutant concentrations decreased 6 meters down the slope by 64%, 85%, 2%, 50%, 38%, and 93% for COD, TSS, TKN, NO_3-N, TP and hydrocarbons, respectively. The change in TP and TKN concentration was modest and we will see if this result is an exception or will be obtained also on 5 runoff collection sites

with managed vegetation from spring 2019. The runoff sampling from many rain events on our 11 parallel sites from spring 2019 will give us better overview of the pollutant concentrations from the highway of our study area.

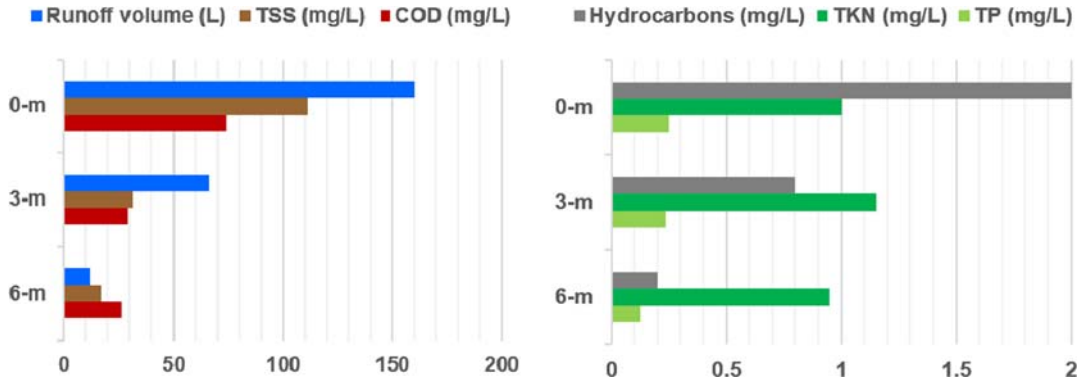

Figure 2. Comparison of the median runoff volumes and pollutant concentrations in runoff collected 0 m, 3 m and6 m from the highway edge on the vegetated slope.

Similar study performed by Henderson et al. (2016) in Virginia, U.S. shows that the unmanaged vegetated strip gave statistically lower peak flows and mass loads of TN, TP, Cu and Zn compared with those of the managed vegetated strip. Our further research will determine if vegetated highway slopes of current study in cold climate conditions will perform similarly to the U.S. study which was conducted in a humid sub tropical climate and whether we will have the same removal patterns when comparing unmanaged and managed slopes.

CONCLUSION

The pilot study done during summer and autumn 2018 provided us with necessary information for further modifications in the collection system design and extra knowledge for successful continuation of the project. The pilot results showed that runoff volume reduction and pollutants removal can be achieved already with the applied management practice. Further study on the runoff quantity and quality, comparing managed and unmanaged vegetation will determine the effect of vegetation management. In addition, research on the hydraulic performance of the vegetated highway slopes and simulations of flow-paths will be performed.

Furthermore, all this will allow us to evaluate if the vegetated highway slopes and ditches in cold climate could be considered by their performance as phytotechnologies and low impact development practices.

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