The Character of Plastic Pollution in Urban Stormwater Runoff

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Highlights

- We present an analysis of litter at a catchment scale and identify litter hotspots in existing urban drainage networks.
- A methodology is proposed for the identification of litter hotspots.
- We present a means of capturing and estimating the quantity of plastic pellets which is a micro-plastic of concern, particularly in manufacturing, transportation, and recycling facilities.

Introduction

Plastic litter pollution entering stormwater drains, stream, rivers, and oceans is a global challenge. According to current estimates, between 24 and 34 million metric tonnes of plastic pollution are emitted into our oceans annually. If we continue with current practices this trend is expected to increase. Even with ambitious reductions in single-use plastics manufacturing this trend is expected to increase to 20 to 50 million metric tonnes by 2030 (Borrelle *et al.*, 2020). Most plastic pollution is generated and transported from land sources into receiving waters through efficient stormwater reticulation networks (Burton & Pitt, 2002; Jambeck *et al.*, 2015). This includes microplastics – as Zhu *et al.* (2020) recently demonstrated through an extensive monitoring programme, the volume of microdebris (plastics and other anthropogenic debris) entering San Francisco Bay from stormwater outfalls was 140 times greater than from wastewater effluent sources.

The effects and characteristics of plastic pollution entering the environment is complicated and rapidly developing field internationally, both in scientific understanding, public awareness, and legislative regulations. Together these factors create a need for research to facilitate science-based and data-driven decision-making processes. A recent local government review in Aotearoa New Zealand highlights significant knowledge gaps in our understanding of the sources, mechanisms and impacts of plastic pollution on the environment (PMCSA, 2019). To fill these gaps, we need clear and standardised methods to identify, monitor and quantify the amount and types of plastic littered to the environment.

Here we present the results of two case studies undertaken in Aotearoa New Zealand (in Auckland and Wellington) using similar methods to measure and quantify plastic litter from two urban drainage networks. We use the combined findings to critically evaluate the methods used, demonstrate the variability in plastic litter loads and identify remaining knowledge gaps. We then present a case study from Ontario, Canada where micro plastic pellets from a manufacturing facility were monitored. We also present methodologies for the collection and characterisation of macro- and micro-plastics captured in stormwater catchpits.

Methodology

Macro-Plastic Pollution in Existing Urban Watersheds

The first urban litter study is from Auckland where 34 catchpits were monitored using the LittaTrap technology. This study started in June 2019 and ran for one-year on the island of Waiheke to determine the average number of plastic litter items per drain across a variety of land uses. We also seek to measure the variability and determine the types and quantity of plastic litter items and then determine the influencing factors around plastic litter loads in high and low loading drains. From this data we seek to determine a metric for identification of litter hotspots.

The second study area is the Kaiwharawhara Stream in Wellington. This is a 7 km stream in the central suburbs of the city. As part of a larger research project investigating plastic sources and transformation within this stream, we monitored litter (including plastic) by installing LittaTraps in 30+ stormwater catchpits, located at random throughout the catchment – including near residential land, schools, parks and commercial and industrial land, near the mouth at the Wellington Harbour. Trapped debris was collected every month by scientists and community group participants, carefully sorted, categorised, and weighed.

We also propose a methodology for measuring litter loads in individual catchpits to determine the factors that influence variability based on land use, rainfall, catchment area, social aspects, and temporal-based variables such as events and tourism.

Micro-Plastic Pollution in Industrial and Manufacturing Applications

Using the LittaTrap insert with a 1000µm liner we capture plastic pellets (often referred to as nurdles) which come in a variety of size and composition. Generally, pellets are 3-5mm in diameter and are captured by the liner which has ~1 mm square openings.

This study is from a manufacturing facility in Ontario, Canada, where five catchpits had LittaTraps installed and monitored from March to November 2020. In this study we present the full capture of plastic pellets that are washed or blown around the facility. We also present a sampling methodology that has been used to measure the pellet loss across a site to determine the source.

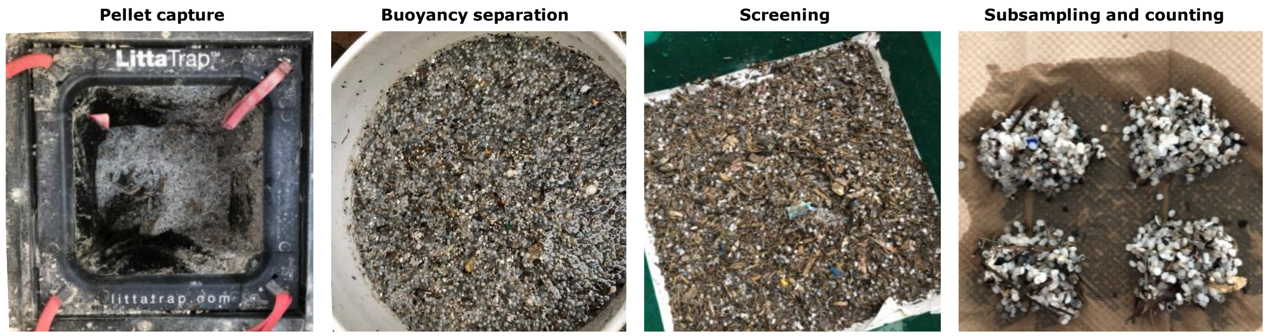

Figure 1. Plastic pellet capture and sampling, specific example from a manufacturing facility in Ontario, Canada. This work was conducted in collaboration with the University of Toronto as part of Operation Clean Sweep.

Results and discussion

Macro-Plastic Pollution in Existing Urban Watersheds

The study in Auckland captured 25,162 pieces of litter, of which 18,097 pieces were plastic in composition. The most numerous items were cigarette butts at 8,103 in total. The average number of plastic litter items per drain is 834 pieces per year, however this was highly variable based on land use. Capture rates were highest in autumn and summer which corresponds with an increase in rainfall and an increase in tourism respectively. We present this variability try to determine the influencing factors around plastic litter loads in high and low loading drains. Use the dataset to determine a metric for identification of hotspots, group drains in similar land uses, determine a targeted removal rate (i.e. 80% of the plastic litter from 40% of the drains?).

The Wellington study shows that plastic was the most common non-organic debris collected in the traps (45-98 %) however other material classes were also collected (e.g., rubber, cloth, paper, glass). Plastic litter loads were significantly higher in commercial areas compared to residential areas (~25 times greater). The most common litter items in commercial area included packaging material (e.g., polystyrene packaging, strapping bands and palette wrapping), cigarette butts, and food packaging. Capture rates were highest in the winter and spring when rainfall was highest. In residential areas, capture rates were highly variable in the autumn when leaf fall would block the drain cover. The types of plastic (and litter in general) collected represented only a subset of the litter profile in the streams draining the catchment (as determined by stream-side litter surveys) highlighting the role of other mechanisms (e.g., wind, littering) in transferring litter into stream networks.

Micro-Plastic Pollution in Industrial and Manufacturing Applications

A total of 34,766 plastic pellets were captured across the five catchpits over 289 days. There was high variability in pellet loads across the five catchpits which can be linked to specific activity within the catchment area. A double drain in a truck loading area captured 21,890 pellets in 289 days. In this catchment there are logistics and material handling activities in and out of trucks. A single drain in a train to truck loading zone captured 11,950 pellets over 289 days. Here pellets are offloaded from trains using vacuum hoses. Lastly, a double drain in the truck parking area captured 926 pellets in 151 days. Even across five drains there is a clear hotspot loading effect present.

Conclusions and future work

Determining the input variables that influence litter and plastic pollution is complicated. Their primary influences are land use, rainfall, and human activity. Despite these variables we believe it is possible to characterise urban drainage networks based on measurable features to determine litter hotspots. One study of an urban drainage network shows that more than 50 % of the influent litter is received by 25 % of the catchpits. Measuring and understanding these influencing variables can guide both scientific and regulatory developments around litter. The overwhelming influence tends to be around human activities, particularly loading zones and bus stops.

We show that the management of plastic pellet pollution can be controlled using a structural solution in the catchpit. The targeted drains should be those where operations including loading/unloading areas. For this reason, we propose that plastic pellets are treated as a point-source pollutant. The methodology developed allows for quick and easy monitoring. This methodology can be used to quantify pollution reduction strategies on such a facility, those being both structural (i.e. using the LittaTrap to capture plastic pellets) or non-structural controls, such as awareness and education drives. Such a study is currently underway in Auckland.

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