How much plastic is discharged from our city to the sea via the urban river system?

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Abstract

A total of 34 hours and 33 minutes of river flow footage was analysed to reveal how much plastic debris, in no-rain and post-rain conditions, were discharged to the Tolo channel from Shing Mun River (Tai Wai Nullah). In no-rain conditions, conservatively speaking, there were over 48,000 plastic items per day, totalling 17 million plastic items per year (average plastic items discharge rate is 0.599 items/sec, average concentration is 0.180 items/m^2) discharged into the coastal water from the river. In post-rain conditions, the discharge rate rises to 562 plastic items in a time span of 10 minutes (average amount of plastic discharged is at a rate of 0.937 items/sec, average concentration is 0.426 items/m^2). The results suggest a positive correlation between rainfall and daily plastic debris concentration in the river. The most common plastic items in the 9 sampled rivers were plastic bottles, food wrappers, fast food utensils and containers (including straws, stirrers, lids and cups), plastic bags and polystyrene fragments.

Aim

The aim of this report is to investigate the extent and severity of local plastic pollution originating from Hong Kong, and to provide guidance for future research, the abundance and pattern of plastic leakage should be monitored. Hong Kong is a densely populated coastal city with a population of 7 million. The city is home to extremely diverse natural habitats, including vast seafood resources such as aquaculture zones for fish and oyster farms. However, local and external sources of plastic pollution threaten the marine environment of Hong Kong. There are a handful of local studies trying to uncover the scale of plastic pollution in Hong Kong coastal waters, yet those studies cannot answer the question of how much plastic actually originates from the city as the local source.

Background

Plastic pollution has become a global environmental crisis. Plastics are polymers designed to be light-weight, resistant and durable for packaging and single-use products. With the proliferation of single-use plastic (SUP) products, such as food wrappers, food containers and cutlery, since the 1950s, plastic fragments are found in almost every ecosystem and habitat, from the Arctic to the Antarctic. They also contribute to 61% of global beach litter. Large plastics continuously break down into smaller pieces (microplastics) and enter the food chain through animal ingestion. Animals are observed to be entangled by large plastic debris, and smaller plastic pieces clog the digestive systems of animals who mistake plastic debris for food.

Besides the physical threat, plastic releases hazardous chemicals into the environment during fragmentation. Toxic chemicals such as phthalates, bisphenol A, and PBDEs are used extensively in plastic as additives to enhance its physical properties and performance. Plastic also has the capacity to absorb persistent organic pollutants (POPs) from the surrounding environment, which can be passed on and accumulated in the food chain. How plastic impacts human health is still the subject of ongoing research, but studies on other animals have hinted at its potential damage.

Various international organizations and top academic institutions have conducted research on how much plastic has actually entered the (marine) environment, yet more attention is now directed to the source and how those plastics from urban cities leak to the ocean.

Objectives

The objectives of the research are:

- To quantify the amount of plastic debris from our city to the coastal areas of HK via the urban river system.
- To find the correlation between rainfall and plastic concentration in the river.
- To have a fuller understanding of what type of plastic items are commonly found along the major Hong Kong river systems.

Methodology

- The field investigation and all of the analyses were done in August 2018.
- Field visit and survey:
    - 9 major rivers located in the New territories, including Shing Mun River, Lam Tsuen River, Tai Po River, Tuen Mun River, Shek Sheung River, Sheung Yue River, Yuen Long Nullah, Shan Pui River and Kam Tin River were identified from Google Maps. Each selected waterway runs through densely populated urban areas[1] and connects to coastal areas with high ecological value such as Deep Bay and Tolo Channel.
    - At each river, plastic items were identified and counted with bare eyes as the researcher walked along the river for at least 30 mins. Photo records were also taken.
    - Plastic items were identified and categorized as plastic bottles, food wrappers, fast food utensils and containers, plastic bags, and other plastics pieces.
    - All the locations were visited at least once, while Shing Mun River and Kam Tin River were surveyed 5 times and 4 times respectively.
- Video record and analysis:
    - A time lapse camera (Brinno TimeLapse Camera BCC200) was fixed on a bridge above Shing Mun River (Tai Wai Nullah) and the footage of the river flow was recorded for 8 days. The footage was captured with 3 seconds per film, 30 films per second.
    - Sections of the footage were further selected and cut as the sampling footage with the following criteria: The sections with daylight and unidirectional river flow were selected; footage with and without rainfall (within 15 mins after an observable rainfall) were further identified and categorized.
    - Plastic items that were discharged along the river from upstream to downstream were identified from the collected footage and counted with bare eyes on computer screens by two researchers.

[1] Residential population and non-residential population along the river: Shing Mun River—Resident: 460,000 people, Non-resident: 280,000 people; Lam Tsuen River—Resident: 200,000 people, Non-resident: 70,000 people; Tuen Mun River—Resident: 380,000 people; Yuen Long Nullah—Resident: 240,000 people.

- In each session (both no-rain and post-rain)
  - The number of plastic pieces ($N^{\text{no-rain}}$ and $N^{\text{post-rain}}$) and the actual duration of counting (T) were recorded
  - The speed of river flow was calculated by recording the time of a piece of plastic travelling through a known distance ($V^{\text{no-rain}}$ and $V^{\text{post-rain}}$)
- Therefore,
  - Plastic discharge rate = N / T
  - No-rain plastic concentration = $N^{\text{no-rain}} / (T \times V^{\text{no-rain}} \times \textit{river width})$
  - Post-rain plastic concentration = $N^{\text{post-rain}} / (T \times V^{\text{post-rain}} \times \textit{river width})$
- The total time for no-rain plastic sampling footage is 15 hours 11 mins and the total time for post-rain plastic sampling footage is 19 hours 21 mins. The mean of all the sessions—no-rain and post-rain—is calculated separately for the plastic concentration and the plastic discharge rate

- Numeric adjustment, Calculation and Errors
  - Given that there might be a 20% human error on mistaken objects such as leaves, paper or other non-plastic objects to be plastic items and a 10% counting error on a computer screen; additionally, in the downstream area, there is a 20% chance that the plastic debris will be cleaned by FEHD[2] cleaning boats and a 10 % chance of other factors that the debris will not be flushed to the sea. The number of plastic that is counted visually was given a 60% reduction in total for all of the possibilities for error
  - Rainbow warrior microplastic research carried out by Greenpeace EastAsia and Prof. Lincoln Fok from HKEDU in early 2018 (unpublished report) found that the percentage of plastic items with a size of 4.76-200mm in Tolo Harbour is 10.9%, whereas from the present comparison of field observations and video analysis, the minimum size of plastic items identifiable on the computer screen is around 20-50mm in length. Therefore, the adjusted number of plastic items was multiplied by 10 to reflect the plastic items that cannot be seen on the computer screen but have been observed on-site with a size of <4.76mm
- Rainfall correlation
  - The August 2018 rainfall of Sha Tin district was acquired through the Hong Kong Observatory database.
  - The daily average plastic item concentration was correlated with the rainfall data

Result and Discussion

Field observations on all nine rivers revealed the similarity between debris composition and daily municipal waste, which is composed of plastic bottles, food wrappers, fast food utensils and containers (including straws, stirrers, lids and cups), plastic bags, polystyrene fragments, and aluminium cans. This suggests plastic pollutants in the river are from human activity in the neighbourhoods around the river. Stormwater drainage systems running beneath the streets are known to be one of the major pathways carrying plastic items from the city to the river during the rainy season.

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[2] Food and Environmental Hygiene Department of Hong Kong

The plastic concentrations and plastic discharge rates in Shing Mun River (Tai Wai Nullah) under no-rain and post-rain conditions are shown below:

No-rain condition			**Post-rain condition**		
Plastic concentration			Plastic concentration		
Average	0.180	items/m^2	Average	0.426	items/m^2
Max	0.497	items/m^2	Max	2.898	items/m^2
Min	0.008	items/m^2	Min	0.019	items/m^2
Plastic discharge rate			Plastic discharge rate		
Average	0.559	items/sec	Average	0.937	items/sec
Max	1.333	items/sec	Max	2.058	items/sec
Min	0.027	items/sec	Min	0.060	items/sec

Calculations based on the video analysis show that Shing Mun River alone carries at least 48,000 plastic items into the Tolo Channel on each no-rain day. In addition, the number of plastic items nearly doubles after rainfall. The graph below also indicates a positive correlation between rainfall and daily plastic item concentration. This further supports the conclusion that a majority of the plastic items originating from the city and flowing into the rivers through the stormwater drainage system were emitted during heavy rainstorm or typhoons during the wet season in Hong Kong (June to September).

Conclusion

Despite there being a level of uncertainty related to both measurements and projections of plastic emission through Shing Mun River, this study provides the first local quantitative research on river plastic emission of local sources in contrast to external pollution sources, i.e. marine debris carried to Hong Kong by waves and currents. Locally originating plastic pollution is heavily contaminating Hong Kong's coastline and is threatening marine life every minute. Although this is a short-term project, it gives insight into Hong Kong's urban plastic pollution. Moreover, it points to the direction of future investigations and monitoring on plastic sources, deposition and degradation processes. Extensive local river systems and coastal waters are important upon ceasing the plastic pollution in HK marine environment and protect the valuable and vulnerable nature. Action should be taken at the individual, local (corporate and government) and global level to tackle the problem by reducing single-use plastic products at the source.

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