Plastics on the move: Discharges to plastic transport in the Odaw river, Ghana

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Introduction

Marine plastic pollution is an increasing environmental threat (van Emmerik et al.,2018) which is of growing concern due to its direct and indirect negative effects to the ecosystem (Duncan et al., 2020). Several sources have been identified as pathways for these plastics to reach the marine environment. Rivers have recently been identified as the dominant source to marine environment plastic pollution contributing to 80% of the plastics. Though riverine litter input is estimated to be a major contributor to marine litter, there is little comprehensive information (González et al., 2016) about its temporal transport mechanisms (Meijer et al., 2021). Transport of riverine plastic debris vary at very small spatial and temporal scales (Browne et al., 2010). Patterns in the concentration of plastics suggest natural events related to climatic and meteorological conditions (strong winds, rain, floods, etc.) play an important role in the transport of plastics in rivers (Schirinzi et al., 2020). Observational studies have collectively examined the relative importance of river discharges, storms, heavy rainfall events and tidal effects (Honingh et al., 2020) on the transport patterns of riverine plastics however due to the short term variability of these hydrological and meteorological conditions particularly in urban areas, less is well understood on the temporal dynamics of riverine plastic concentrations. Our study focuses on the Odaw river in Accra, Ghana. Due to no field data on the quantification of macroplastics in this river, temporal dynamics of plastic transport are unknown. We aim to quantify the macroplastic transport through the Odaw and investigate the relation between discharge and plastic transport.

Methods

To quantify the floating macroplastics in the river, we conducted visual observations at 4 bridges closest to the river mouth. These bridges were sectioned into 2-3. At each section, plastic counts were done for 2 mins and repeated 4 times at each section of each bridge. This field observations were done over a period of 3 months (March-May) on 8 different sampling days between 20 March and 18 May 2021 (i.e., 20 March, 7, 12, 14 April, 13, 14, 17, 18 May. With this, the total plastic flux P_c [items/h] for each bridge was calculated using

$$P_c = \sum_{i=n} \mathrm{Pi} \bullet 30 \qquad (1)$$

where i = section of the bridge and P_i [items/2 mins] being the average plastic flux at each bridge section per hour.

Since there were no measured discharges for the river, rainfall data collected from TAHMO (Trans-African Hydro-Meteorological Observatory) were used in a hydrodynamic model to simulate discharge. Field observed data were first plotted against the simulated discharges for each sampling day. Later, the field data was combined with the discharge simulations to extrapolate plastic flux along the river for the sampling period. The extrapolation was done using the means [(1)] and linear equation methods [(2)]

$$\bar{C}_p = \frac{\bar{P}}{\bar{Q}} \qquad (2)$$

Where $\bar{P}$ = mean plastic transport per second [items/s] and Q as mean discharge per second Q [m^3/s].

$$p = \bar{C}_p \bullet Q + b \qquad (3)$$

With p = mean plastic transport per second p [items/s] and Q mean discharge per second Q [m3/s] and b as the intercept of the regression line plotted for the plastic flux and discharges.

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However, for this study, "b" was set to zero with the assumption that no discharge equals no plastic transport.

The above equations were first applied separately to the measured fluxes at each bridge (Separate Dataset) and then to the combined measured fluxes from all the bridges (Combined Dataset). With the above methods, macroplastic transport and plastic flux extrapolation over a period of time for the Odaw river were explored.

Results

Floating plastic flux

The instantaneous average plastic flux varied between 320 and 2400 items/hr with the highest observed at bridge B and the least at A. Bidirectional flow of plastics was observed at Bridge C and D. During the sampling days, simulated discharges were relatively low due to the limited rainfall events during the sampling days. Relating the simulated discharges to the plastic flux, there wasn't a consistent relation of plastic flux to the simulated discharges (Fig 1). For bridge B and C, plastic flux showed a clear follow pattern with the simulated discharges during sampling days in May. For bridge A on the other hand, though the simulated discharges were stable during the sampling days in May, the plastic flux showed a variation across the sampling days. Negative plastic fluxes related to negative discharges were observed at Bridge C and D. This indicates the influence of tides to the transport of plastics at these sections.

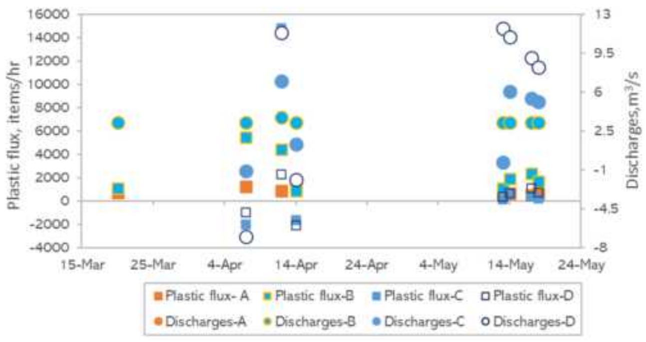

Figure 1. Measured plastics fluxes against simulated discharges at each bridge (A-D)

Extrapolated plastic fluxes

With the two equations (means and linear) applied on the two dataset approaches (separate and combined), the plastic flux extrapolation for the sampling period was estimated (Fig 2) A similar trend in extrapolated plastic fluxes across the sampling period was observed for each of the bridges except Bridge C and D that had fluctuations in their fluxes. Though the trend in temporal variation was similar, level of plastic fluxes for each of the extrapolation methods was different. Similar levels of extrapolated plastic fluxes were observed using the combined dataset approach as compared to the separate dataset. However, with relatively equal fluxes for the combined dataset, the means method resulted in higher peaks than the linear extrapolation method.

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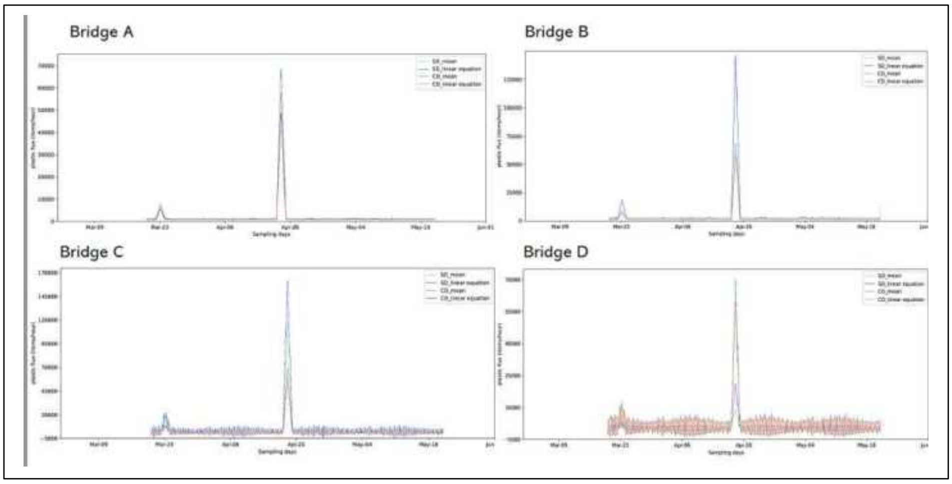

Figure 2. Extrapolated plastic fluxes during the sampling period at each bridge (A-D)