Spatial Distribution of Microplastics and Synthetic Particulates in the Severn River and Annapolis Harbor

Midshipman 1/C Mary McClellen H. Hess, USNA Class of 2021

Advisors: Instructor Brianna M. Tracy, Mr. Benjamin Hickman, and Dr. Joseph P. Smith; Oceanography Department, U.S. Naval Academy, Annapolis, MD USA

ABSTRACT

The Chesapeake Bay is a large, partially-mixed estuary on the Mid-Atlantic Coast of the United States that is subject to numerous anthropogenic influences including the input of plastics and other synthetic materials. Standardized field sampling and laboratory analytical methods were used to quantify concentrations of microplastics and synthetic particulates in Annapolis Harbor and the Severn River, a tidal-tributary in the mesohaline region of the Bay, from September-December 2020. Results suggest the spatial distribution of these particulates is a function of local watershed land-cover/use and local scale circulation and mixing. This study aims to establish a baseline for follow-on research to identify sources and determine the transport, fate, and impacts of microplastics and synthetic particulates in the Severn River and other similar estuarine ecosystems.

METHODS & APPROACH

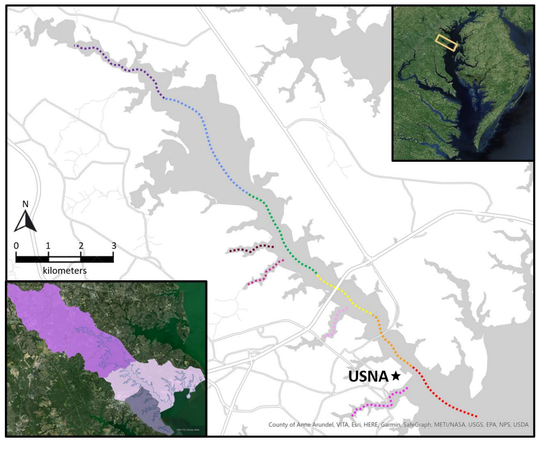

Figure 1. Map of sampling locations within the Severn River and surrounding creeks. Plankton or Manta net tows were conducted from a small boat along ten transects at approximately two knots speed. Upper right inset Chesapeake Bay with the Severn River study area highlighted. Lower right inset show the Severn River Watershed broken into three regions for the purpose of this study: North Severn River, South Severn River, and City of Annapolis.

Figure 2. (Top Left) Manta net with a 60 x 25 cm opening and a 2.5 m, 250 µm mesh net; (Top Right) Mechanical separation of large debris from net tow sample with a 500 µm mesh sieve; (Bottom Left) Sieved samples in a drying oven (125°C for 24 hours) and; (Bottom Right) Dried samples covered to limit exposure to plastic contamination until WPO digestions and gravimetric separation.

Surface waters were sampled for microplastics and synthetic particles along transects in the Severn River and Annapolis Harbor using either a 29 cm diameter plankton net (September - October) or a 60 x 25 cm Manta net (November – December) with a 250 µm net and cod end (**Fig. 1**). After each transect, the net was gently washed down with freshwater to ensure all solids were collected in the cod end. Contents of the cod end were sieved through a 500 µm stainless steel sieve to remove large debris. A freshwater control sample was also processed to account for potential contamination. After sieving, samples were placed in pre-weighed glass beakers in a drying oven for approximately 24 hours at 125°C (**Fig. 2**). Digestions were conducted on each sample using wet peroxide oxidation to remove soft organic materials (Masura et al., 2015). Gravimetric analysis was then conducted to isolate microplastics. Floating solids were collected on a pre-weighed, 11 µm Whatman filter, allowed to air-dry overnight in a clean-hood, and weighed again to attain the weight of microplastics found. Following drying and weighing, samples were analyzed under a microscope, pictures were taken and color, size, shape, and type of materials were recorded based on microscopic visuals (**Fig. 3**). For each transect, the area sampled was estimated using the length of the transect and the width of the net opening. For the plankton net tows, the effective width of the net opening was estimated using the chord length assuming 1/3 of the plankton net diameter was exposed. Total weight of plastic for each sample was divided by sampling area to solve for mass plastic per unit area (g/km^2) and results were compared to land cover and impervious surface coverage in the Severn River Watershed (as defined by USGS) using The Anne Arundel County GIS Feature Layers for Land Cover 2017 (https://gis.aacounty.org/arcgis/rest/services/OpenData/Environment_OpenData/MapServer/7) and Impervious Surfaces (https://gis.aacounty.org/arcgis/rest/services/OpenData/Environment_OpenData/MapServer/4).

Figure 3. (Left to Right) Samples undergoing wet peroxide oxidation (WPO) – contents were treated with 20 mL aqueous 0.05M Fe(II) solution and 20 mL of 30% hydrogen peroxide that were heated to 75°C; Six grams of sodium chloride were added per 20 mL of WPO sample solution to increase density and allowed to cool; WPO and salt solution were transferred to a density separator, loosely covered with aluminum foil, and allowed to settle overnight; Floating solids from density separation were collected on a pre-weighed Whatman filter and allowed to dry and; images of microplastic and synthetic particles were collected from processed samples.

RESULTS & DISCUSSION

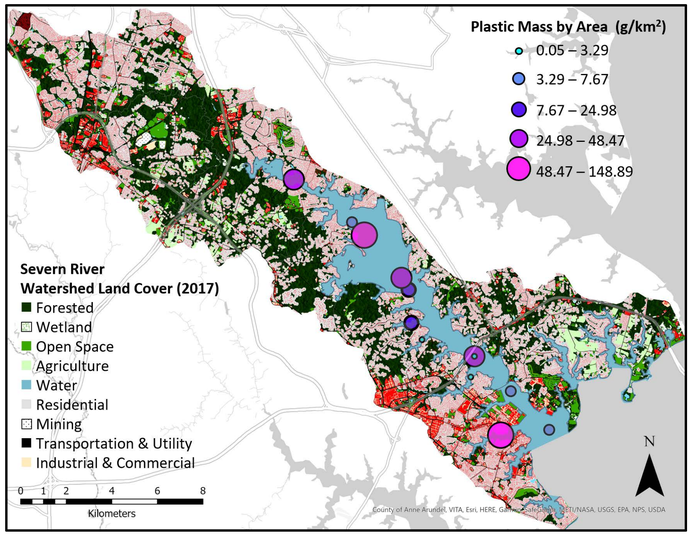

Figure 4. Map of plastic mass by area (g/km^2) collected, analyzed, and measured along transects conducted within the Severn Rive). Plastic mass was bound to the median intercept of transects and plotted. The associated Severn River watershed is overlaid with the Anne Arundel County GIS Feature Layers for Land Cover 2017 (e.g. forested, wetland, open space) using ArcGIS Pro v.25. Additionally, the Anne Arundel County GIS Feature Layers for Impervious Surfaces (red) was used better depict the type of surface represented within the three identified study regions: North Severn River, South Severn River, and City of Annapolis.

	Chesapeake Bay Tributary	Date Range	Plastic Mass by Area (g/km^2)
Yonkos et al. (2014)	Patapsco River	July – November 2011	10.6 - 238.1
	Magothy River	July – November 2011	5.2 - 245.7
	Rhode River	July – November 2011	3.2 - 56.1
	Corsica River	July – November 2011	2.7 – 19.2
This Study	Severn River	September – December 2020	0.04 - 148.9

Table 1. Reported microplastic concentrations values for Chesapeake Bay tributaries near the Severn River from Yonkos et al. (2014) and concentrations for the Severn River from this study using similar surface water microplastic sampling protocols. Results from Yonkos et al. (2014) represent the range of concentrations in samples collected over the course of six months.

Results from this study are consistent with those of others; microplastics are ubiquitous in coastal marine environments but concentrations vary considerably spatially, temporally, and in material composition. Microplastics were found during every sampling event. Of the transects sampled during this study, the locations with the greatest plastic mass by area (g/km^2) were Annapolis Harbor near the City of Annapolis and in the North Severn River region (**Fig. 4**). This could in large part be due to the greater percentage of impervious surfaces found in these areas. The percent impervious land cover of the City of Annapolis and North Severn River are 93.8% and 63.1%, respectively, with South Severn River impervious surface cover accounting for only 50.7% of total land cover. The bulk of land cover for all watershed regions sampled are classified as 'Transportation & Utility' or 'Residential' areas. Both North and South Severn River regions have sizeable areas designated as 'Forested' that could be acting as a natural buffer that is preventing some microplastic input into the river itself (**Fig. 5**). Despite the lack of uniformity in transect lengths, the range of values for plastic mass by area (g/km2) observed in the Severn River from August – November 2020 were comparable to those reported by Yonkos et al. (2014) in four nearby Chesapeake tributaries for July – November 2011 (**Table 1**). They also reported similar correlations between land usage and cover (i.e., impervious surface and urban/development) and microplastic concentration.

Most microplastic particles identified were classified as fragments or fibers which is also the reported results in multiple similar studies (Bikker et al. 2020; Yonkos et al. 2014). Green, orange, blue, pink, black, brown, gray, and white materials were all found during microscopic examination (Fig. 3). Green plastics, black threads, and white foam were the most common types of materials identified (**Fig. 6**).

Figure 6. Subset of microplastic samples collected in the Severn River.

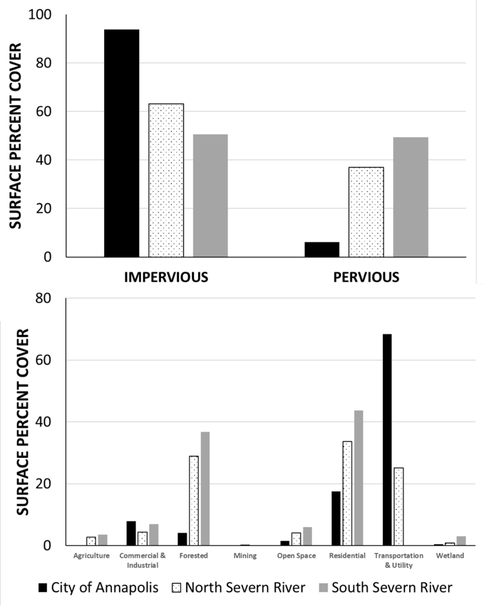

Figure 5. The percentage of impervious surface cover of the three sampled sub-watershed regions of the Severn River and the percentage of land cover associated with those regions (Anne Arundel County GIS, 2020).

CONCLUSIONS & FUTURE WORK

- ***Results indicate that microplastics and other synthetic materials exist in the Severn River in varying quantities that are comparable to concentrations found in previous studies of adjacent tributaries in the Chesapeake watershed***
- ***Results suggest a potential correlation between microplastic concentrations and surrounding land cover/land use, however more concrete conclusions can only be drawn by obtaining samples from a greater number of sites to gain more insight into potential sources and the transport, fate, and impacts of microplastics and synthetic particulates in the Severn River***
- ***Further research will include expansion of the sampling area and number of replicates. In future studies, the length of each transect will be standardized and individual particles will be counted in order to ensure consistency in analysis and comparison across studies. Quantification of microplastic by 'number of particles' in a sample will account for lower density microplastics – such as foams – that comprised a large portion of samples but are under-represented by mass***

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