Extreme rainfall, high water, and elevated microplastic concentration in the Hans Groot Kill: implications for the Mohawk River

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Introduction

Microplastic particles are widely recognized as an environmental threat in the oceans (Avio et al., 2016) and, increasingly, in fresh-water and terrestrial ecosystems (Baldwin et al., 2016; Chae and An, 2018). Microplastic particles (typically defined as having a grain size <5 mm) may be manufactured (primary particles) or result from the breakdown of larger plastic items (secondary particles) over time (Avio et al., 2016). While large enough to be seen with the eye or a microscope, microplastic particles are also small enough to be mistaken for food and consumed by organisms (Barnes et al., 2009), allowing them to enter the food chain. Plastics are potential sites for adhesion by hydrophobic organic chemicals such as PCBs and dioxin (Koelmans et al., 2016).

Our interest lies in determining 1) the extent to which microplastic pollution is present in a river system, 2) where and by which pathways microplastic particles enter the river system, and 3) what factors result in variability in abundance and concentration of microplastic particles in the tributaries and along the main channel of the river. The study area is the Mohawk River watershed in New York State (Figure 1). The Mohawk River flows generally eastward and is the largest tributary of the Hudson River. The Mohawk River has three major tributaries: West Canada Creek, East Canada Creek, and Schoharie Creek. Numerous smaller tributaries also flow directly into the main channel of the Mohawk River.

Previous work: Microplastic particles in the main channel of the Mohawk River

In 2016 we collected 63 planktonic samples and 64 sediment samples from the main channel of the Mohawk River between Cohoes and Rome, NY (Smith et al., 2017a, 2018). Microplastic particles were found in all of the planktonic and sediment samples. Abundance varied over two orders of magnitude in the planktonic samples, from a high of >500 particles in samples collected downstream from Utica to a low of 3 particles in a sample collected between Sprakers and Fonda. Abundance did not increase systematically downstream but instead was generally higher near urban areas and lower in rural areas. The proportion of various types of particle (e.g., fragment, fiber) also varied from sample to sample. Abundance was generally lower in sediment samples (1-75 particles) and fibers were the dominant type of particle found. The non-systematic variability in the abundance of microplastic particles in the planktonic samples prompted further study of the role of tributaries in delivering microplastic particles to the main channel.

Microplastic particles in tributaries of the Mohawk River

We sampled surface and near-surface water in 21 tributaries and the main channel of the Mohawk River upstream of the Erie Barge Canal in Rome, NY, for microplastic particles over eight consecutive days in June 2018 (Figure 1). The first five days of sampling were mostly sunny and dry, followed by two days of intermittent rain, then a final day of sun. An additional day of fair-weather sampling occurred in July.

The 21 tributaries included the three major tributaries to the Mohawk River (West Canada Creek, East Canada Creek, and Schoharie Creek) and 18 smaller tributaries (Table 1). All but one of the streams (the Hans Groot Kill) were under relatively low-flow conditions during sampling; we re-sampled the Hans Groot Kill in early July during low-flow conditions.

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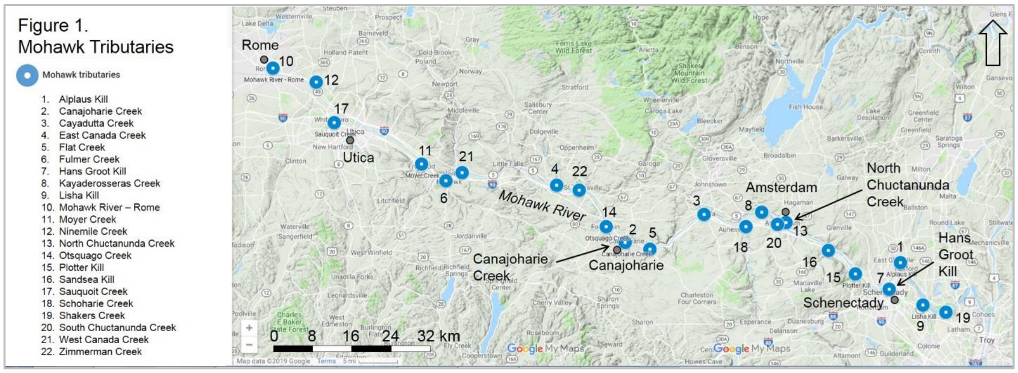

Figure 1. Sampling locations in 21 Mohawk tributaries and the Mohawk River main channel in Rome.

Sampling methods. We used a 3-m neuston net with 335-µm mesh attached to a 1-m x 0.5-m aluminum frame with interior dimensions of 0.91-m x 0.41-m (Sea-Gear Corporation). The net has a detachable 335-µm mesh cod end. The net was held in place manually during sample collection and positioned so that the water surface lay within the net opening.

TABLE 1. Sampling data for Mohawk tributaries

Tributary	Latitude	Longitude	Bank	Sampling date	Time (min)	Flow rate (m/sec)	Submerged depth (m)	Volume of water (m^3)	Stream depth (m)	Stream width (m)	Particle abundance (total # particles)
Alplaus Kill, Glenville (at Rt 146)	42.866585°	-73.902845°	N	6/18/18	22	0.17	0.25	54.38	0.33	13.72	131
Canajoharie Creek, Canajoharie	42.902993°	-74.573514°	S	6/20/18	25	0.18	0.19	52.44	0.37	9.91	470
Cayadutta Creek, Fonda	42.953656°	-74.380986°	N	6/20/18	20	0.69	0.24	194.76	0.30	11.73	206
East Canada Creek, Manheim/St. Johnsville	43.006018°	-74.740952°	N	6/19/18	15	1.01	0.26	238.96	0.37	38.10	301
Flat Creek, Sprakers	42.891245°	-74.513916°	S	6/20/18	20	0.88	0.15	164.13	0.18	4.57	24
Fulmer Creek, Mohawk (S. Herkimer)	43.013887°	-75.012169°	S	6/19/18	25	0.12	0.10	18.31	0.19	14.78	72
Hans Groot Kill, Union campus, LOW FLOW	42.819551°	-73.929573°	S	7/5/18	27	0.13	0.05	11.33	0.18	1.52	75
Hans Groot Kill, Union campus, HIGH FLOW*	42.819591°	-73.929674°	S	6/23/18	8	0.30	0.34	49.27	0.61	4.00	5849
Kayaderosseras Creek, Fort Johnson	42.957294°	-74.240022°	N	6/24/18	22	0.24	0.15	46.88	0.24	7.92	66
Lisha Kill, Niskayuna	42.791351°	-73.847322°	S	6/25/18	20	0.88	0.13	135.17	0.21	6.71	29
Mohawk River, Rome (upstream)	43.214106°	-75.433122°	N	6/21/18	25	0.34	0.24	119.02	0.67	27.43	76
Moyer Creek, Frankfort	43.042684°	-75.070449°	S	6/25/18	20	0.37	0.27	120.75	0.46	7.62	10
Ninemile Creek, Marcy	43.189319°	-75.327899°	N	6/21/18	17	0.53	0.32	173.33	0.49	10.67	37
North Chuctanunda Creek, Amsterdam	42.938610°	-74.181256°	N	6/24/18	22	0.18	0.30	72.51	0.40	8.75	859
Otsquago Creek, Fort Plain	42.931028°	-74.620606°	S	6/20/18	25	0.30	0.25	112.36	0.37	21.03	48
Plotter Kill, Rotterdam	42.846345°	-74.012739°	S	6/25/18	25	0.40	0.14	81.15	0.27	4.36	45
Sandsea Kill, Pattersonville	42.889079°	-74.077880°	S	6/25/18	25	0.12	0.19	34.96	0.37	10.67	107
Sauquoit Creek, Whitesboro (W. Utica)	43.117354°	-75.284347°	S	6/25/18	20	0.52	0.29	181.11	0.55	12.95	24
Schoharie Creek, Fort Hunter	42.930877°	-74.278290°	S	6/18/18	17	0.27	0.25	71.31	0.55	80.77	106
Shakers Creek, Colonie	42.778406°	-73.791492°	S	6/23/18	20	0.07	0.22	17.58	0.40	5.03	139
South Chuctanunda Creek, South Amsterdam	42.935566°	-74.202117°	S	6/24/18	22	0.27	0.18	65.92	0.27	11.28	94
West Canada Creek, Herkimer	43.027478°	-74.972273°	N	6/19/18	16	1.06	0.28	287.33	0.46	61.87	69
Zimmerman Creek, St. Johnsville	42.997097°	-74.686761°	N	6/19/18	20	0.47	0.19	107.67	0.30	7.32	90

*Particle counting still underway for Hans Groot Kill high-flow sample. Estimated final total: 15,000 particles.

Stream dimensions, flow velocity, and sampling intervals were measured at each sampling location. Stream width ranged from 1.5 m (Hans Groot Kill low-flow) to 81 m (Schoharie Creek). Stream depth (at the sampling location within each stream) ranged from 0.18 m (Hans Groot Kill low-flow and Flat Creek) to 0.61 m (Hans Groot Kill high-flow). Flow velocities ranged from 0.067 m/s (Shakers Creek) to 1.06 m/s (West Canada Creek). Sampling intervals ranged from 15 to 27 minutes for all streams except the high-flow June sampling of the Hans Groot Kill, which was sampled for 8 minutes in a rainstorm. The calculated volume of water passing through the net opening during sampling ranged from 11 m^3 (Hans Groot Kill low-flow) to 287 m^3 (West Canada Creek).

Laboratory procedure. Organic material was chemically removed from the sieved samples using the NOAA protocol (Masura et al., 2015) for wet peroxide oxidation (WPO). Processed samples were

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transferred to glass petri dishes with covers for examination and storage. Samples were examined under a binocular dissecting microscope. Microplastic particles identified in each sample were transferred to a separate dish with a cover. Particles were categorized by form: fragment, foam, pellet/bead, film, or fiber. All counting was performed by the same person. Particle counts should be viewed as minimums. It is possible and even likely that additional microplastic particles in a given sample remain uncounted. The efficacy of identifying particles in a post-WPO sample is limited by the presence of residual organic material that may hide particles and by the visual acuity of the examiner.

Findings

Microplastic particles were found in all of the samples collected in the tributaries and in the sample from the Mohawk River in Rome (Table 2). All of the tributaries and the Mohawk River in Rome were sampled under low-flow conditions; only the Hans Groot Kill was sampled under high-flow conditions.

Microplastic particles in low-flow samples. In the low-flow samples, abundance ranged over an order of magnitude (10-859 particles). The highest abundance of microplastic particles was found in the sample from North Chuctanunda Creek (859), followed by Canajoharie Creek (470), East Canada Creek (301), Cayadutta Creek (206), and Shakers Creek (139). The lowest abundances were found in samples from Moyer Creek (10), Flat Creek (24), and Sauquoit Creek (24). Relatively low particle abundances were found in the Mohawk River at Rome (76) and in two of the major tributaries, West Canada Creek (69) and Schoharie Creek (106).

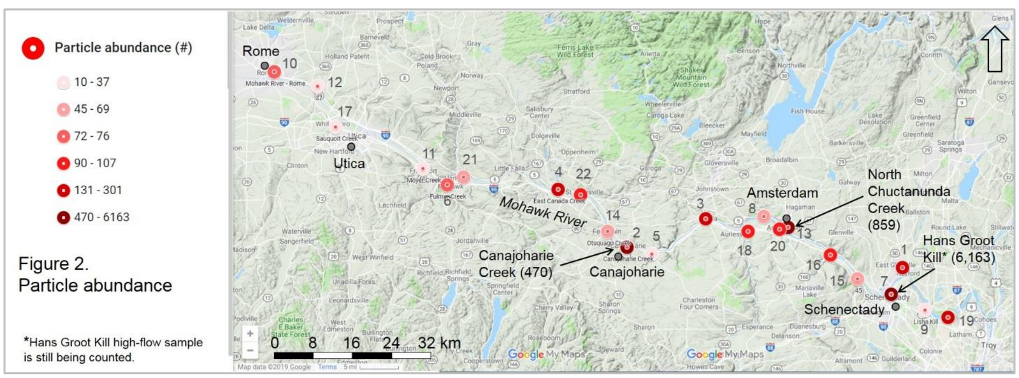

Figure 2. Particle abundance (# particles) in samples collected from 21 Mohawk tributaries and the Mohawk River main channel in Rome. The highest abundance by an order of magnitude is found in the high-flow sample from the Hans Groot Kill on the Union College campus in Schenectady (5,849), followed by the low-flow sample from North Chuctanunda Creek in Amsterdam (859 particles).

Fibers dominate the microplastic particles identified in the low-flow samples (Table 2). Percent fibers ranges from 72% to 99%. Fibers constitute 98.4% of the particles found in the North Chuctanunda Creek sample. Fragments, foams, and films were found in lesser abundance, while pellets/beads were rare.

Concentration of microplastic particles (in particles/m^3; Table 2) is the ratio of particle abundance to the calculated volume of water passing through the sample net during the sampling interval (15-27 minutes). The highest concentration of particles was found in the sample from North Chuctanunda Creek (11.8 particles/m^3), followed by the samples from Canajoharie Creek (9.0 particles/m^3), Shakers Creek (7.9 particles/m^3), and the Hans Groot Kill low-flow sample (6.6 particles/m^3).

Particle load is the concentration extrapolated to the entire stream during the sampling interval, calculated using the measured stream width at the sampling point (from field measurements, or, for large streams, measurements on Google Earth) and the stream depth at the sampling point (Table 1). Uncertainty related to the estimate of the channel cross-sectional area is intrinsic to the calculated value of particle load. The highest calculated particle load is in Schoharie Creek (~18,400), ~80.8 m wide at the sampling point and one of the three major tributaries to the Mohawk River; followed by North Chuctanunda Creek (~9,900 particles), ~8.8 m wide; Canajoharie Creek (~8,900 particles), ~9.9 m wide; and the Mohawk River at Rome (~5,900), ~27.4 m wide.

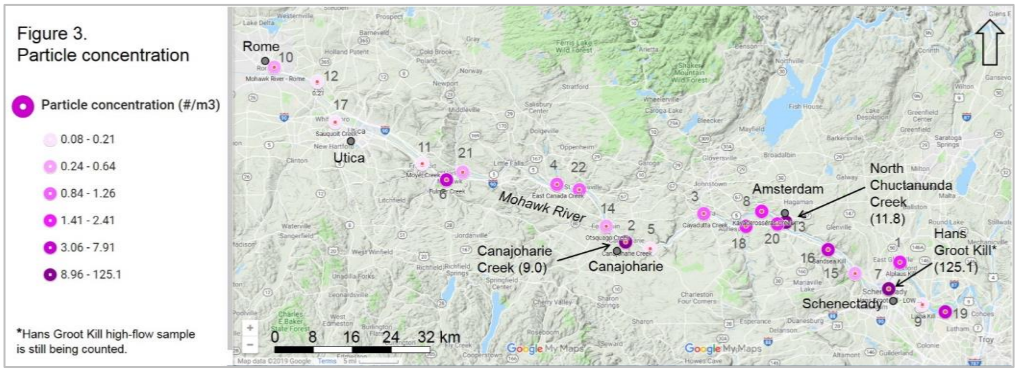

Figure 3. Particle concentration (# particles per m^3 of water passing through the sampling net during the sampling period) in samples collected from 21 Mohawk tributaries and the Mohawk River main channel in Rome. The highest concentration by an order of magnitude is found in the high-flow sample from the Hans Groot Kill on the Union College campus in Schenectady (118.7 particles/ m^3), followed by the low-flow sample from North Chuctanunda Creek in Amsterdam (11.9 particles/ m^3).

Further extrapolation of particle load to an entire year (Table 2) yields rough estimates of the total number of particles delivered to the Mohawk River by each of the tributaries assuming consistent low-flow conditions year round (i.e., near-minimal estimates). Annual particle load estimates range from ~570 million particles for Schoharie Creek and ~557 million for East Canada Creek to ~3.3 million for Moyer Creek. The estimated annual load for North Chuctanunda Creek under these conditions is ~237 million particles.

The estimated total annual load reaching the Mohawk River in 2018 from the tributaries we sampled, based on the low-flow conditions under which samples were collected, is nearly 2.1 billion microplastic particles. This estimate does not include an estimated annual load of ~124 million particles already in the Mohawk River by the time it reaches the sampling point in Rome.

Microplastic particles in the high-flow sample from the Hans Groot Kill. The high-flow sample collected in the Hans Groot Kill during a rainstorm in June 2018 is in a class of its own. With approximately 30-35% of the sample counted thus far, the abundance of particles in the high-flow sample from the Hans Groot Kill (5,849 at the time of writing), nearly twice the total in all other streams combined (3,078), and the highest particle concentration (118.7 particles/m^3). The high-flow sample from the Hans Groot Kill is notable for the high abundance of Styrofoam particles (1,173) and fragments present (1,087) relative to fibers (3,475). The percent fibers currently stands at 59.4%, the lowest percentage among all of the samples. If, as appears likely, the total abundance ends up exceeding 15,000 particles, the estimated particle load during sampling will be >108,000 particles, five to six times that of the highest low-flow sample (Schoharie Creek, ~18,400 particles). Extrapolating this predicted particle load to an entire year yields a value for estimated annual load that exceeds 7 billion particles.

Weather data collected by the Union College weather station in 30-minute periods indicate that a rainfall rate of 2.74 inches/hour and rainfall amount of 0.3 inches occurred in the 30-minute period during which the Hans Groot Kill high-flow sampling was completed (6/23/18, 12:00-12:30 pm). This rainfall rate was exceeded in 13 periods during 2018 (rates from 2.78 to 8.11 inches/hour). The Hans Groot Kill low-flow sample was collected on 7/5/18 during the 30-minute period from 9:30-10:00 a.m., during which there was no precipitation. Interestingly, the highest rainfall rate of the year (8.11 inches/hour) occurred on the same day (2:00-2:30 p.m.), producing 0.53 inch of rain. Extrapolating the predicted final particle load for the high-flow sample from the Hans Groot Kill (>15,000 particles) over the top 14 high-intensity rainfall periods yields >5.7 million particles.

TABLE 2. Microplastic data for Mohawk tributaries

Tributary	Particle abundance (total # particles)	fragments	foams	pellets and beads	films	fiber and lines	Percent fibers (%)	Particle concentration (particles/m^3)	Stream load (particles/ sampling period)	Estimated streamflow during sampling (m3)	Estimated annual load in stream (# particles/year)
Alplaus Kill, Glenville (at Rt 146)	131	10	2			119	90.8	2.4	2,413	1,002	57,655,432
Canajoharie Creek, Canajoharie	470	6	7		4	453	96.4	9.0	8,911	994	187,347,133
Cayadutta Creek, Fonda	206	10	7		14	175	85.0	1.1	3,114	2,944	81,840,542
East Canada Creek, Manheim/St. Johnsville	301	3				298	99.0	1.3	15,895	12,618	556,945,100
Flat Creek, Sprakers	24	2	1			21	87.5	0.1	130	887	3,408,935
Fulmer Creek, Mohawk (S. Herkimer)	72	3	1			68	94.4	3.9	2,020	514	42,474,089
Hans Groot Kill, Union campus, LOW FLOW	75	4	15	1	1	54	72.0	6.6	383	58	7,452,661
Hans Groot Kill, Union campus, HIGH FLOW*	5849	1087	1173	19	95	3475	59.4	118.7	42,359	357	2,782,971,919
Kayaderosseras Creek, Fort Johnson	66	6	3			57	86.4	1.4	876	622	20,927,073
Lisha Kill, Niskayuna	29	9				20	69.0	0.2	326	1,518	8,558,636
Mohawk River, Rome (upstream)	76	16	3		1	56	73.7	0.6	5,909	9,253	124,225,089
Moyer Creek, Frankfort	10	1	1			8	80.0	0.1	128	1,541	3,328,732
Ninemile Creek, Marcy	37	3			1	33	89.2	0.2	604	2,831	18,686,014
North Chuctanunda Creek, Amsterdam	859	0	0	0	0	0	84.6	11.8	9,915	837	236,878,520
Otsquago Creek, Fort Plain	48	4	2		1	41	85.4	0.4	1,503	3,518	31,594,515
Plotter Kill, Rotterdam	45	7				38	84.4	0.6	394	711	8,287,121
Sandsea Kill, Pattersonville	107	8	3		1	95	88.8	3.1	2,185	714	45,932,243
Sauquoit Creek, Whitesboro (W. Utica)	24	2	2			20	83.3	0.1	586	4,420	15,393,472
Schoharie Creek, Fort Hunter	106	17	1	4	2	82	77.4	1.5	18,435	12,403	569,982,053
Shakers Creek, Colonie	139	13	4			122	87.8	7.9	1,268	160	33,330,724
South Chuctanunda Creek, South Amsterdam	94	9	1			84	89.4	1.4	1,598	1,121	38,173,616
West Canada Creek, Herkimer	69	11			3	55	79.7	0.2	6,919	28,813	227,299,563
Zimmerman Creek, St. Johnsville	90	11	8		1	70	77.8	0.8	1,050	1,256	27,596,141

*Particle counting still underway for Hans Groot Kill high-flow sample. Estimated final total: 15,000 particles.

Discussion: potential sources of microplastic pollution

Our findings indicate that the Mohawk River receives microplastic particles from all of the tributaries that we sampled and from additional sources upstream of the study area within the northwestern-most portion of the watershed that includes much of the city of Rome, the Delta Reservoir, and the headwaters of the river (Figure 2). Potential sources of microplastic pollution in the tributaries include outflow from storm drains, leakage from sewage pipes and septic systems, surface runoff and other non-point sources, outflow from wastewater treatment plants, direct introduction of plastic waste into streams and their drainage areas, airborne transport, and inflow from groundwater. In the tributaries that we studied, high abundance and/or concentration of particles appears to correlate strongly with storm-drain inflow, sewage leakage, and runoff that transports plastic waste to the stream channel.

North Chuctanunda Creek: low-flow. Among the low-flow samples, North Chuctanunda Creek in Amsterdam had the highest abundance (859) and highest concentration (11.9 particles/m^3) of microplastic particles (Figures 2 and 3). The stream originates in a rural area but reaches the north bank of the Mohawk River in Amsterdam, an old industrial city. The lowest 1.5-km of the stream is partly or wholly channelized within concrete walls below a dammed pool. The sample was collected ~1.4 km upstream of the mouth of the stream and ~0.1 km downstream from the dammed pool. Pipes emerged from the channel wall both upstream and downstream within a few meters of the sampling location. North Chuctanunda Creek has a documented history of sewage contamination by leaking pipes (e.g., Times Union, 2016).

Hans Groot Kill: high-flow. The Hans Groot Kill on the campus of Union College in Schenectady is exposed at the surface for only ~1.2 km. Both upstream and downstream reaches are carried within buried culverts so that the source of the stream is obscured and the lowermost 0.8 km of the Hans Groot Kill flows northwestward beneath the city of Schenectady to the stream's junction with the Mohawk

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River. Storm-drain outfalls punctuate the banks of the open-air stream, which is incised along much of its length (Willard-Bauer et al., 2019). The samples were collected at the downstream end of the exposed section on the Union College campus. Bacteria levels in the Hans Groot Kill suggest that sewage is reaching the stream (Willard-Bauer et al., 2019), potentially carrying microplastic particles, particularly fibers from laundry wastewater and microbeads from personal-care products. Macroplastic litter is ever-present within the stream channel and was abundant in the high-flow sample.

Conclusions

Our research supports the conclusion that microplastic pollution is pervasive in the aquatic environment and that one small stream at high flow (the Hans Groot Kill) can deliver more microplastic particles to the main channel of the Mohawk than twenty larger streams at low flow during longer time intervals. The dramatic difference between the abundance and concentration of particles in the Hans Groot Kill low-flow and high-flow samples hints at the likely role of high-flow events as major mobilizers of microplastics in the watershed as a whole. If the concentration of microplastic particles in the tiny Hans Groot Kill under high-flow conditions can exceed that of any of the other tributaries under low-flow conditions, the implications are staggering. Truly extreme events such as hurricanes that affect the Mohawk Watershed (e.g., Hurricane Irene and Tropical Storm Lee in 2011) likely result in microplastic transport far exceeding anything that occurs under average flow conditions.

References

Avio, C.G., Gorbi, S., and Regoli, F., 2017, Plastics and microplastics in the oceans: from emerging pollutants to emerged threat: Marine Environmental Research, v. 128, p. 2-11, doi: 10.1016/j.marenvres.2016.05.012.

Baldwin, A.K., Corsi, S.R., and Mason, S.A., 2016, Plastic debris in 29 Great Lakes tributaries: relations to watershed attributes and hydrology: Environmental Science and Technology, v. 50 (19), p. 10377–10385, doi: 10.1021/acs.est.6b02917.

Barnes, D.K.A., Galgani, F., Thompson, R.C., and Barlaz, M., 2009, Accumulation and fragmentation of plastic debris in global environments: Philosophical Transactions of the Royal Society B, v. 364, p. 1985-1998. doi: 10.1098/rstb.2008.0205.

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R., 2011, Accumulation of microplastic on shorelines worldwide: sources and sinks: Environmental Science and Technology, v. 45, p. 9175-9179. doi: 10.1021/es201811.

Chae, Y., and An, Y-C., 2018, Current research trends on plastic pollution and ecological impacts on the soil ecosystem: A review: Environmental Pollution, v. 240, p. 387-395. doi: 10.1016/j.envpol.2018.05.008.

Koelmans, A.A., Bakir, A., Burton, G.A., and Janssen, C.R., 2016, Microplastic as a vector for chemicals in the aquatic environment: Environmental Science & Technology, v. 50, p. 11532-11538. doi: 10.1021/acs.est.5b06069.

Masura, J., Baker, J., Foster, G., and Arthur, C., 2015. Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. NOAA Technical Memorandum NOS-OR&R-48.

Smith, J.A., Hodge, J.L., Kurtz, B.H., and Garver, J.I., 2017a,The distribution of microplastic pollution in the Mohawk River, in Cockburn, J.M.H. and Garver, J.I., Proceedings of the 2017 Mohawk Watershed Symposium, Union College, Schenectady, NY, March 17, 2017, p. 67-71.

Smith, J.A., Garver, J.I., Hodge, J.L., and Kurtz, B.H., 2017b, Fly ash and coal ash in the Mohawk River, in Cockburn, J.M.H. and Garver, J.I., 2017. Proceedings of the 2017 Mohawk Watershed Symposium, Union College, Schenectady, NY, March 17, 2017, v. 9, p. 63-66.

Smith, J.A., Hodge, J.L., Kurtz, B.H., and Garver, J.I., 2018, Microplastic pollution in the main channel of the Mohawk River: final results of the 2016 sampling program, in Cockburn, J.M.H. and Garver, J.I., Proceedings of the 2018 Mohawk Watershed Symposium, Union College, Schenectady, NY, March 23, 2018, v. 10, p. 69-73.

Times Union, August 1, 2016, https://www.timesunion.com/local/article/Major-sewage-leak-mostly-fixed-in-Amsterdam-8989038.php

Willard-Bauer, E., Smith, J.A., Garver, J.I., 2019, Baseline monitoring of physical parameters and Enterococci levels in the Hans Groot Kill, Schenectady, NY, in Garver, J.I., Smith, J.A., and Rodak, C., Proceedings of the 2019 Mohawk Watershed Symposium, Union College, Schenectady, NY, March 22, 2019, Volume 11, 72 pages.