“Plastic Smog”: Are We Breathing Plastic?

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Abstract

There is no doubt that the modern world without plastic would be a very different place. The obvious prevalence of plastic in day-to-day lives as well as previous studies which found plastic in the world’s beaches, shorelines and bodies of water including: oceans, lakes, and rivers prompted the question: Is there plastic in the air we breathe? To answer this question, air samples were taken using vacuum filtration in multiple locations. These locations were both indoors and out on the University of Wisconsin – Superior campus and the surrounding area. The results have shown plastic fibers in every sample location. The fibers range in size between 0.010 to 7.5 mm and are primarily blue, red and white in color. They were confirmed to be plastic through qualitative analysis. Based on average number of microplastic per liter of air filtered the average human inhales up to 989 fibers per day.

Introduction

Throughout the world, 300 millions of tons of plastic are produced annually and used in countless ways, from packaging to parts in automobiles (Plastics Europe, 2015). Plastic’s wide popularity stems from its desirable properties, such as being aesthetically pleasing and cost effective. Much of the plastic on the market consists of disposable, one-time-use items. Discarded plastic then accumulates in the environment; so far many studies have shown that plastic accumulates in marine ecosystems (Capenter et al., 1972; Thompson et al., 2004; Derraik, 2006; Browne et al., 2011) and freshwater systems (Corcoran, 2008; Eriksen et al., 2013; Free et al., 2014). Typically, classification of plastic debris occurs in two ways 1) primary or debris in manufactured form (i.e., microbeads used as exfoliants in cosmetic products, bottle caps, and cigarette filters) or 2) secondary, plastic derived from primary debris, (i.e., degradation products produced by photodegradation and abrasion) (Browne et al., 2007; Cooper and Corcoran, 2010; Andrady, 2011; Driedger et al., 2015).

Plastic is renowned for its durability, although the downside to the durability is its persistence in the environment for centuries, which has led to predictions that future geologists will refer to this geological time period as the Plasticene age (Cooper and Concoran, 2010; Reed, 2015). Microplastics, defined by the National Oceanic and Atmospheric Administration (NOAA) as particles lower than 5mm in size, poses an added threat to the environment. It has been shown that microplastic will adsorb persistent organic pollutants (POPs) where levels become highly concentrated due to the large surface area (Mato et al., 2001; Teuten et al., 2007; Rios et al., 2010; Lee et al., 2014). Potential exists for chemicals added to plastic during the manufacturing process, such as phthalates, antioxidants, flame retardants and dyes to leach into the environment (Gouin et al., 2011). Both the chemicals sorbing onto the plastic and leaching from it are possible endocrine disruptors and are carcinogenic which qualifies the microplastics

as chemicals of emerging concern and they were recommended to be classified as hazardous waste (Rochman et al., 2013).

Fibers are commonly found morphology of microplastic; brightly colored fibers have been reported in surface waters of the ocean, lakes and rivers, sediments, and even German beer (Liebezeit and Liebezeit, 2014). One theory as to the origin of the fibers is synthetic fabrics and waste water treatment plant effluent. According to a 2011 study by Brown et al. washing one garment can disperse more than 1900 fibers and at the moment waste water treatment plants are not designed to remove synthetic particles in this size range. Thus, an additional pathway for synthetic fibers into the environment is from the application of sewage sludge onto farmland (Habib et al., 1996; Zubris and Richards, 2005).

Somewhat surprisingly, microplastic accumulation in systems other than marine and aquatic habitats, especially in the inland environment, has yet to be explored in great depth (Rillig, 2012). An emerging area of concern is "plastic smog" as microplastic fibers have been shown to be present in the total atmospheric fallout (Gaspari et al., 2015). Therefore, it can be inferred that microplastic can be transported through the atmosphere. One consequence of this new type of transportation is the deposition of microplastic into remote ecosystems such as mountain lakes (Eriksen et al., 2013). These recent developments prompt the question: Are we breathing plastic? One study found synthetic and cellulosic fibers in 97% of malignant and 83% non-cancerous human lung tissue (Pauly et al., 1998). This study will examine microplastic fibers suspended in and transported through the air we breathe. Characterization based on abundance, size and composition of microplastic fibers will occur.

Methods

Collection of Samples

Air Sampling. The air sampling procedure was derived from the U.S. Occupational Safety and Health administrations' (OSHA) method for quantifying particulates not otherwise regulated. Particulates not otherwise regulated are defined by OSHA to be dusts from solid substances without specific occupational exposure standards. To clarify, particulate matter, also known as particle pollution, has been identified by the Environmental Protection Agency (EPA) as one of the six common forms of air pollution. The EPA defines two size categories: inhalable course (PM10) and inhalable fine particles (PM2.5). Inhalable coarse particles have a diameter between 2.5 and 10 micrometers (mm), while inhalable fine particles are anything less than 2.5 micrometers in diameter. Particles greater than 10 micrometers in size are not regulated by the EPA. The size of particles is very important in determining their effect on human health. Particles less than 10 μm in diameter can penetrate deep into your lungs, and could potentially enter the bloodstream. In accordance with method OSHA PV2121, samples were collected using a constant flow air sampler (PCXR8 Universal Sample Pump) set at a flow rate of 2.0 L/min. Air samples filtered through a 37 millimeter (mm) diameter glass fiber filters (Whatman GF/A) pore size 1.6 μm for sample durations ranging from 1 to 6 hours in the preliminary data set and 5.5 hours in the second data set. The filter was housed in a cassette set at a height of approximately five feet. Samples were collected both indoors and outdoors. The indoor sample locations were on the University of Wisconsin – Superior campus in the chemistry lab and two residence halls The outdoor locations were on campus, at Wisconsin Point, Minnesota Point, and a more remote

location at a private residence in Wrenshall, Minnesota (20 miles South of Superior) which acted as a blank because it was assumed the presence of plastic would be proportional to the amount of people. After sample collection, filters were stored wrapped in aluminum foil (previously cleaning and baking in an annealing oven at 450 ºC for 4 hours) at room temperature.

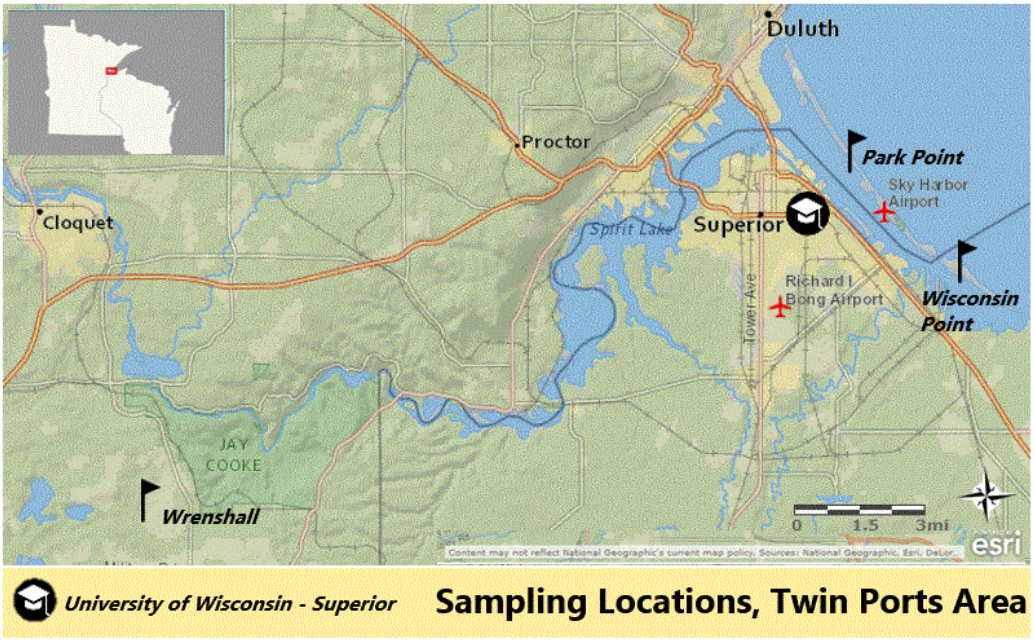

Figure 1: The above figure shows the locations of all the sampling areas. University of Wisconsin-Superior (N 46.718553, E -92.089758), Wisconsin Point (N 46.699572, E -91.999719), Park Point (N 46.727656, -92.046105), and Wrenshall, MN (N 46.623791, E -92.405394)

Passive Sampling. The initial form of sample collection included using pieces of clear packaging tape and clean glass fiber filters and hanging them from the air input vents in the chemistry lab. Filters and pieces of tape were left for around a week then replaced.

Figure 1: A glass fiber filter hanging from the air exchange in the chemistry lab.

Historic Data: Midwest Energy allowed us to observe air filters from samples taken in Superior, Wisconsin in 2009 the samples were taken in order to measure total particulate matter. A 14 cm^2 area was observed and fibers counted on each filter.

Analysis of Samples

Microscopy. The first step in the analysis was to observe filters under a dissecting microscope. Fibers were counted and characterized by color and size. Synthetic fibers were distinguished from natural fibers by their color; bright, unnaturally colored fibers were considered synthetic. For confirmation, the fibers behavior when exposed to a hot-wire to observe melting or burning behave, the results were recorded. To guard against extraneous fiber contamination after the initial sample collection, analysis was completed while wearing cotton lab coats. Prior to use all glassware and fiberglass filters were cleaned and baked in an annealing oven (450ºC/4 hours), this served to remove all organic matter and plastic from the surface. A clean fiberglass filter was set out near the microscope. If a fiber or particle was found on the blank filter after analysis was finished, the sample would be disqualified. However, no filters were disqualified in this manner.

Qualitative Analysis. The physical properties of synthetic resins differ quite a bit from their natural counterparts; one property where the difference is especially apparent is melting point. Plastic, when exposed to heat, has two common responses; one being it readily changes shape (thermoplastic) or two it will be resistant to changes in temperature (thermoset). On the other hand, natural substances will burn up. Therefore, touching these fibers with a hot soldering iron (524° C) and observing what happens is a method to quickly test whether the particulate is synthetic or natural.

Results

*Preliminary Results***.** During initial sample collection, no uniformity in collection duration existed. Total collection time varied from one hour up to six hours in each sample. The number of samples in each location also varied. However, microplastic fibers were discovered in all locations including the blank location, Wisconsin Point. Fiber coloration most commonly recorded were blue, white and red. Interestingly, the color distribution was the same for all indoor samples compared with the outdoor samples. The length of the fibers ranged from 6 to 7,550 μm with an average value of 300 μm (n=77).

*Further Results***.** *Fiber Size.* The second round of air sample collection was much more uniform with samples collected at 263 L of air filtered for each sample. Using qualitative analysis 47(±28)% of fibers were confirmed to be plastic.

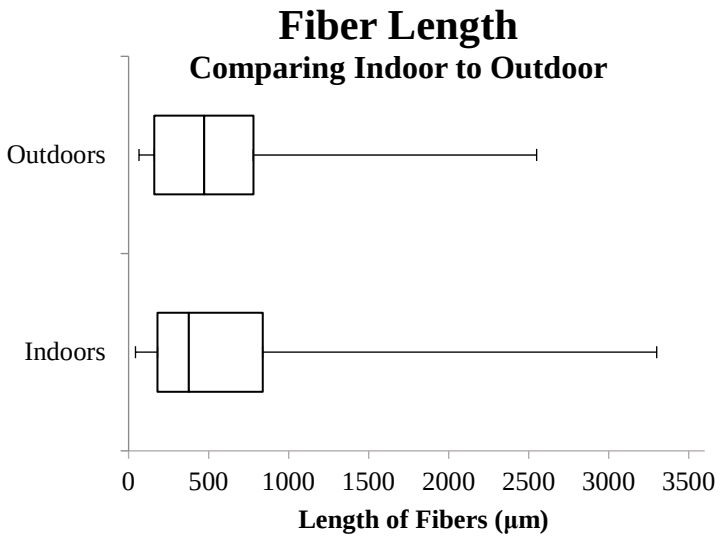

Figure 3: The above chart shows boxplots of fiber length comparing fibers found indoors to those collected outdoors. It was confirmed through statistical analysis that no difference exists between the averages of the two data sets (student's t).

Fiber Color. The most common color of plastic fibers was blue they consisted of 80 percent of the total sample. They were also most likely to obtain a positive confirmation by qualitative analysis at 66 percent success rate. White and red were the next most common color for fibers at 10 and 6 percent of the total sample and 14 and 36 percent positive confirmation rates respectively. Other colors of fibers were black, brown, and yellow, which together consisted of the remaining 4 percent of confirmed plastic fibers and obtained qualitative confirmation 14 percent of the time.

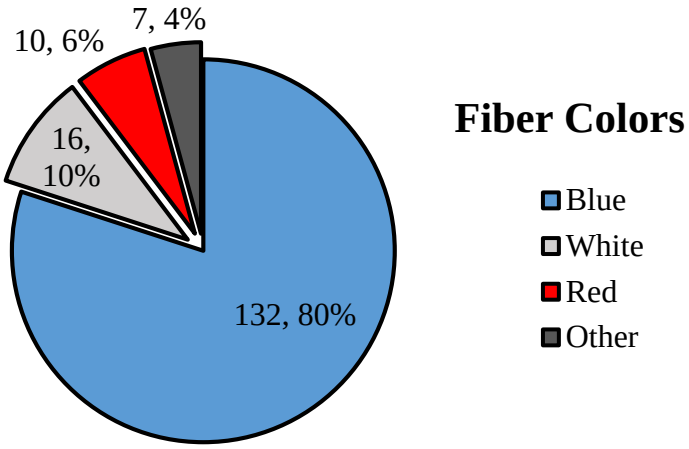

Figure 4: Shown is the amount and relative percentage of fibers found in each of the various colors. Other includes black, brown and yellow fibers.

Fiber Abundance. There was no significant difference (student $t < t_{critical}$) in the amount of plastic fibers collected per liter of air filtered when comparing samples collected indoors to those collected outdoors, or in samples collected on campus as opposed to off campus.

Discussion

The percentage fibers confirmed to be plastic through qualitative analysis was low because the heat source was high and the small size made it difficult to observe the fibers true response. This method is a simple and cost-effective way to confirm that a sample is plastic; however, it is better suited to fragments of larger size. The average adult human has a respiratory rate of 12-15 breathes per minute with each inhalation about 0.5 liters on average. Therefore, assuming homogeneity, the average adult would inhale 5.9(±6.4) fibers over an hour period, or up to 989 fibers over 24 hours. It was surprising to find that there was no difference in samples collected indoors compared to outdoors. The expected outcome would have the outdoor samples containing less fibers and the amount of fibers would be proportional to the human population in the area but neither correlation was seen.

Conclusion

Fibers were found in all locations. There was no statistically significant difference in fiber length, color, or abundance between samples collected indoor compared with those collected outdoors (student $t < t_{critical}$). These findings further demonstrate that microplastic can be transported through the atmosphere. This type of transport has many implications for the global environment; remote locations could potentially be impacted and of bioaccumulation of POPs and other emerging chemicals of concern may occur through various pathways in ecosystems the world over. Additionally, plastic smog may be a condition that plagues cities of the near future; even indoor environments are at risk. Further work in microplastic pollution must be undertaken to understand the specific sources of microplastic fibers as well as its extent and availability to life within terrestrial ecosystems.

References

Andrady, A. L. Microplastic in the marine environment. *Marine Pollution Bulletin,* 2011, 62, 1596-1605.

Browne, M. A., Dissanayake, A., Lowe D. M., Thompson, R. C. Ingestion of Microplastic Translocates to the Circulatory System of the Mussel, Mytilus edulis (L.). Environ. Sci. Technol. 2008, 42, 5026-5031.

Browne, M. A.; Crump, P.; Niven, S. J.; Teuten, E.; Tonkin, A.; Galloway, T.; Thompson, R. Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. *Environ. Sci. Technol.* 2011, 45, 9175-9179.

Browne, M. A.; Galloway, T. S.; Thompson, R. C. Microplastic – An emerging contaminant of potential concern? *Integr. Environ. Assess. Manage.* 2007, 3, 559-561.

Carpenter, E. J.; Anderson, S. J.; Harvey, G. R.; Miklas, H. P.; Peck, B. B.; Polystyrene Spherules in Coastal Waters. *Science.* 1972, 178, 749-750.

Cooper, D. A.; Corcoran, P. L. Effects of mechanical and chemical processes on the degradation of plastic debris on the island of Kauai, Hawaii. *Marine Pollution Bulletin,* 2010, 60,650-654.

Corcoran, P.L.; Biesinger, M. C.; Grifi, M. Plastics and beaches: A degrading relationship. *Marine Pollution Bulletin,* 2009, 58, 80–84.

Driedger, G. J.; Dürr, H. H.; Mitchell, K.; Van Cappellen, P. Plastic debris in the Laurentian Great Lakes: A review. *Journal of Great Lakes Research.* 2015, 41, 9-19.

Eriksen, M.; Mason, S.; Wilson, S.; Box, C.; Zellars, A.; Edwards, W. et al. Microplastic Pollution in the Surface Waters of the Laurentian Great Lakes. *Marine Pollution Bulletin.* 2013, 77, 177-182.

Free, C. M.; Jensen, O. P.; Mason, S. A.; Eriksen, M.; Williamson, N. J.; Boldgiv, B. High-levels of microplastic pollution in a large, remote, mountain lake. *Marine Pollution Bulletin.* 2014, 85, 156-163.

Gasperi, J.; Dris, R.; Rocher, V.; Tassin, B. Microplastics in the Continental Area: an Emerging Challenge. *Norman Bulletin.* 2015, 4, 18-19.

Gouin, T.; Roche, N.; Lohmann, R.; Hodges, G. A Thermodynamic Approach for Assessing the Environmental Exposure of Chemicals Absorbed to Microplastic. 2011. *Environ. Sci. Technol.* 45, 1466–1472.

Habib, B.; Locke, D. C.; Cannone, L. J. Synthetic Fibers as indicators of municipal sewage sludge, sludge products and sewage treatment plant effluents. *Water, Air, Soil Pollut.*1996, 103, 1-8.

Liebezeit, G.; Liebezeit, E. Synthetic Particles as Contaminants in German Beers. *Food Additives & Contaminants, Part A: Chemistry, Analysis, Control, Exposure & Risk Assessment.* 2014, 31(9), 1574-1578.

Lee, H.; Shim, W. J.; Kwon, J. H.; Sorption capacity of plastic debris for hydrophobic organic chemicals. *Sci. Total Environ*, 2014, 470, 1545-1552.

Mato, Y.; Isone, T.; Takada, H.; Kanehiro, H.; Ohtake, C.; Kaminuma, T. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environ. Sci. Tech.* 2001, 35, 318-324.

Pauly, J. L.; Stegmeier, S.J.; Allaart, H. A.; Cheney, R.T.; Zhang, P. J.; Mayer, A. G.; Streck, R. J. Inhaled cellulosic and plastic fibers found in human lung tissue. *Cancer Epidemiol Biomarkers and Prevention*, 1998, 7, 419-428.

Plastics Europe. Plastics the Facts 2014/2015. *PlasticsEurope.org.* 2015.

Rillig, M. C. Microplastic in Terrestrial Ecosystems and the Soil? *Environ. Sci. Technol*. 2012, 46, 6453–6454.

Reed, C. Dawn of the Plasticene Age. *New Scientist.* 2015, 225(3006), 28-32.

Rios, L. M.; Jones, P. R.; Moore, C.; Narayan, U. V. Quantitation of persistent organic pollutants adsorbed on plastic debris from the Northern Pacific Gyre's 'eastern garbage patch'. *J. Environ. Monit.* 2010, 12, 2226–2236.

Rocha-Santos, T.; Duarte, A. C. A critical overview of the analytical approaches to the occurrence, the fate and the behavior of microplastics in the environment. *Trends in Analytical Chemistry,* 2014, http://dx.doi.org/doi:10.1016/j.trac.2014.10.011.

Rochman C.M., Browne, M.A., Halpern, B., S., Hentschel, B.T., Hoh, E., Karapanagioti, H.K., Rios, L.M., Takada, H., The, S., Thompson, R.C. 2013. Classify plastic waste as hazardous. Nature 494:169-171.

Song, Y. K.; Hong, S. H.; Jang, M.; Han, G. M.; Rani, M.; Lee, J.; Shim, W. J. A comparison of microscopic and spectroscopic identification methods for analysis of microplastics in environmental samples. *Marine Pollution Bulletin* 2015, 93(1-2), 202-209.

Thompson, R. C; Olsen, Y.; Mitchell, R. P.; Davis, A.; Rowland, S. J.; John, A. W. G.; McGonigle, D.; Russell, A. E. Lost at Sea: Where Is All the Plastic? *Science* 2004, 304, 5672, 838.

Teuten, E. L.; Rowland, S. J.; Galloway, T. S.; Thompson, R. C. Potential for Plastics to Transport Hydrophobic Contaminants. *Environ. Sci. & Tech.* 2007, 41: 7759-7764.

Teuten, E. L.; Saquing, J. M.; Knappe, D. R. U.; Barlaz, M. A.; Jonsson, S.; Bjoern, A.; Rowland, S. J.; Thompson, R. C.; Galloway, T. S.; Yamashita, R.; Ochi, D.; Watanuki, Y.; Moore, C.; Viet, P. H.; Tana, T. S.; Prudente, M.; Boonyatumanond, R.; Zakaria, M. P.; Akkhavong, K.; Ogata, Y.; Hirai, H.; Iwasa, S.; Mizukawa, K.; Hagino, Y.; Imamura, A.; Saha, M.; Takada, H. Transport and release of chemicals from plastics to the environment and to wildlife. *Philos. Trans. R. Soc., B* 2009, 364, 2027-2045.

Zubris, K. A. V.; Richards, B. K. Synthetic fibers as an indicator of land application of sludge. *Environ. Pollut.* 2005, 138, 201-211.