Microplastics found in high concentrations around Kantamanto, the world's largest secondhand textile market in Accra, Ghana: A citizen science study

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The raw data from this paper are freely available from the Deheyn Lab or The Or Foundation, in addition to the ones made available already in the Online Resources.

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Authors biography

Dimitri Deheyn, PhD

Dimitri is a Research Scientist at the Marine Biology Research Division of Scripps Institution of Oceanography, University of California San Diego, where he conducts cross-disciplinary research on biomimicry. In this frame, he studies alternative materials to emerging pollutants, which includes plastics, textile microfibers and associated additives. Some key steps of his studies include assessing plastic and fiber biodegradation (from both natural and synthetic fibers, untreated and treated with additives). His research has a global perspective, across a diversity of ecosystems, around the world. Dimitri grew up in Africa, and earned his PhD in marine sciences and ecotoxicology from the Free-Thinking University in Brussels, Belgium where he started his academic career.

Joe Ayesu

Joe is an integral member of the Accra Arts Centre beachfront community, where he has a shop selling works from across West Africa's arts and crafts industry, including many of his own creations. Living and working in this location for decades he has observed Accra's waste management challenges firsthand, particularly those related to textiles. Joe majored in science in his secondary school days and studied the fundamentals of medical laboratory technology at Accra Technical University. He manages The Or Foundation's team of citizen scientists, mobilizing dozens of people for beach monitoring and cleanup efforts, sample collection and imaging.

The Or Foundation

Headquartered in Accra, Ghana, The Or Foundation is the leading not-for-profit implementing Globally Accountable Extended Producer Responsibility for textiles through a voluntary program in service of Accra's Kantamanto Market community, the largest secondhand clothing market in the world. Working at the intersection of environmental justice, education and fashion innovation since 2011, the mission of the NGO is to identify and manifest alternatives to the dominant model of fashion – alternatives that bring forth ecological prosperity, as opposed to destruction, and that inspire citizens to form a relationship with fashion that extends beyond their role as consumer.

Branson Skinner

Branson was studying in Ghana when he was confronted with the impact of textile waste on the environment and communities in the country. This led him to co-found The Or Foundation, a Ghana-based non-profit working at the intersection of environmental justice, education and fashion development. At The Or Foundation, Branson has combined his diverse background as an educator, farmer, urban planner, and musician to work closely with the local community in Accra and lead the organization's work implementing innovative solutions and science-backed research initiatives to address fashion's global waste crisis. Branson studied Globalization of Public Health and Societies at NYU Gallatin, where he was a Reynolds Scholar for Social Entrepreneurship. He also holds a Masters of Community Planning degree from the University of Cincinnati.

Abstract:

Located in Accra, Ghana, Kantamanto is the world's largest secondhand resale and upcycling market for clothing and textiles, receiving tons of garments every week exported under HS Code 6309 by countries in the Global North. We looked at the abundance of microplastics and microfibers from textiles and other sources in this dynamic environment. Our primary interest was assessing how microfibers in a textile-rich environment contribute to overall microplastic pollution. Continuous monitoring of air quality using PurpleAir sensors showed large concentrations of airborne microparticles around the market, which were shown to drop with rain events. Water collected from rain contained dozens to hundreds of microfibers and microplastics (roughly in a 1:10 ratio), depending on the intensity of the rain and on whether the rain was preceded by a significant period of dry weather. Microfiber and microplastic counts from airborne samples showed concentrations about >20x to >100x greater, respectively, than those reported from other metropolises around the world. A comparison of concentrations from water in the adjacent Korle Lagoon was similarly striking, with up to 45x more microfibers, and up to 200x more microplastics than what has previously been reported for lagoon waters worldwide. Beyond the microscale, the issue of whole garments as waste was also demonstrated, with a strong similarity found between the global brand garment tags from fashion items discarded in the market and those that were washed up on nearby beaches, highlighting the need for more holistic regulatory frameworks to address textile waste.

Keywords: Microplastic epifluorescence; Textile microfibers; Airborne dispersion; Rain flush; Lagoon water contamination; Fast Fashion Waste; Sampling methods for citizen science

INTRODUCTION

Significant work has been undertaken to establish the environmental footprint of textile manufacturing operations (Madhav et al. 2018; Niinimäki et al. 2020; Grazzini et al. 2021; Farhana et al. 2022; Lim et al. 2022) and to characterize pollution resulting from garment use and maintenance at the primary consumer level (Carr 2017; Carney Almroth et al. 2018; Liu et al. 2019; Nowack et al. 2021; Liu et al. 2023). In contrast, efforts remain largely limited with regards to assessing the environmental impact of garments once they are discarded for secondhand reuse or for end-of-life in a landfill or incinerator. In general, fashion waste originating worldwide ultimately ends up in the Global South, particularly in African countries (Manieson and Ferrero-Regis 2021; UNComtrade 2023; OEC 2024), where the socio-environmental impacts of the waste remain poorly addressed.

Accra (Ghana) is the recipient of tons of fast fashion garments weekly and is home to Kantamanto Market, the largest secondhand textile trade market in the world. The market is adjacent to Korle Lagoon, a major water body found in the city's center with an outlet that connects to the Gulf of Guinea. The market is connected to the lagoon via a network of small drainage systems and outflow pipes feeding a tributary canal that leads to the lagoon. The area is mostly pedestrian, and the market has over 10,000 stalls, all exposed to some degree of open-air circulation though most are protected under a partial roof. About 15,000,000 garments exported from Global North countries enter the market every week, primarily on Thursdays, in the form of 55 kg bales that the market retailers purchase from importers (The Or Foundation 2022). The retailers work to recommodify the individual items through resale, repair and remanufacturing during the week. As for the undesired or damaged items that go unsold (the majority of which are pre-sorted for

reusability prior to arrival in Ghana), they are eventually cast aside, accumulating as waste around the market, with piles of them being burned during the night to avoid excessive build-up, as more space is continuously needed. As such, with Accra's waste infrastructure unable to handle and safely process the continuously increasing volume of low-quality garments (Niinimäki et al. 2020), the resulting textile waste can easily enter the surrounding ecosystems. This can take place through airborne processes, by burning textiles with microparticles flying into the air, and/or though waterborne processes by dumping garments regarded as waste (full or in pieces) in uncontrolled sites of the lagoon shoreline that are adjacent to the market.

Over the years, the market has grown to become a critical economic center for the region, where an estimated 30,000 people converge every day to work as market traders, upcyclers or to provide auxiliary support. Considering customers, the number of people buzzing through the market goes up to around 60,000 total daily. This large number of people combined with the constant traffic of large volumes of textiles across the market makes Kantamanto a place with potential exposure to microparticles, both microplastics (from packaging material, bags or film wraps) and microfibers (from clothing). Indeed, although the washing and drying of textiles are obvious sources of shed microfibers, another important source is related to wearing them and hanging them outside where they are exposed to various environmental conditions (including high temperatures, humidity, wind and UV) that facilitate their shedding (Carney Almroth et al. 2018; Belzagui et al. 2019; De Falco et al. 2020; Lim et al. 2022; Zhang et al. 2022). Thus, this study offers new evidence on the release of textile microfibers (viz. fiber fragments, with a length greater than the diameter) in a dense urban setting and additional paths through which textile waste can enter the surrounding ecosystems.

The dominant textile materials in Kantamanto are made of cotton but also plastic material, such as polyester, nylon and elastane (and often in blends of two or more of these), particularly given the global proliferation of cheaply made (and quicker to break down) fossil-based fast fashion and the quick turnover between consumption and then disposal as secondhand textiles (Niinimäki et al. 2020). The area is also the recipient of single use plastics like plastic bags, plastic bottles and food containers that litter the market and surroundings.

Knowing all of the above, we hypothesized that the air and water would contain high concentrations of microplastics, and plastic microfibers as well as cotton microfibers. It is also fair to assume that anyone living or working in Kantamanto, or passing through the market, would be exposed to air pollution, and potentially water pollution, in relation to the ambient load of microplastics and microfibers (both synthetic and natural). We also hypothesized that whole garments found as waste on beaches outside the lagoon would originate from the textile dumpsite of the market, which overflows into the lagoon. As such, the garments would show similarities (in terms of brand assemblage and polymer constituent as identifier) to the garments discarded in the market.

Within this context, the research presented here involved a large contingent of citizen scientists who worked to establish whether Kantamanto Market and its main dumpsite nearby generate environmental changes on the surroundings, specifically with regard to the load of microparticles in the air and in lagoon waters. Our effort was cross-disciplinary, performing the best possible environmental sampling with tools and supplies readily available for citizen scientists to monitor the environment in which they live, to address their concerns in terms of environmental and public health, as well as for strategies to develop more sustainable socio-eco-environmental services. This study is the first to establish the close relationship between fast fashion waste and its subsequent

release of microplastics and microfibers in the environment, both in the air and water. Our results add to the evidence emphasizing the significant environmental burden disproportionately borne by the communities that have become the de facto stewards of global waste (Clapp 2025).

METHODS

The study area was the Kantamanto secondhand textile market in Accra, Ghana, the nearby Korle Lagoon and the contiguous beachfront (Fig. 1), which we investigated in May 2023 for microplastic and specifically microfiber concentrations, using waterborne samples as well as airborne samples. Considering the dependence of our analyses on environmental conditions, we used an ATMOS41 ZL6 weather station (https://metergroup.com/products/atmos-41/) placed at the headquarters of The Or Foundation, which is located on the outskirts of the market, to track weather data. The weather station recorded a series of parameters every 15 min., the most important ones used in this study being the time of day when episodes of rain occurred and the amount of rainfall recorded in mm. For microplastic counts, we needed to collect actual volumes of rainwater (expressed in mL), which we did using a Stratus Rain Gauge (https://www.scientificsales.com/6330-Stratus-Rain-Gauge-p/6330.htm) placed next to the ATMOS Station (Online Resource 6). Although the ATMOS Station collected data continuously, the rain gauge collected rainfall water only during time periods that were possible and safe for the citizen scientists to place the gauge in and out of its operating location on the roof. As such, the volumes of rainwater analyzed did not correlate exactly with the precision rainfall measurements of the ATMOS Station due to the difference in the respective range of operating periods. Our study does not intend to be a weather study and for this reason we referred to the amount of rainwater collected in mL, which is the most accurate for our purpose, while disclosing mm of precipitation

116 for reference. Following collection, rainwater was then analyzed for concentration of microplastics
117 and microfibers as described below, based on volumes of mL collected.

118 Sample collection for microplastics and microfibers has become (since 2020) a routine
119 monitoring activity of The Or Foundation (Ghana), which was put together and optimized over the
120 years with the Deheyn lab at Scripps Oceanography (California, USA). The work in the field, and
121 in the lab, is always done with what is readily available locally in a non-academic infrastructure,
122 keeping in mind the possibility of contamination (Chen et al. 2020; Prata et al. 2020; Song et al.
123 2021; Ma et al. 2024), which is addressed with various precautions and controls. In the field,
124 collectors wear bright yellow safety jackets and bright blue/yellow gloves (the microfibers of
125 which are easy to detect under an imaging microscope in brightfield illumination), and samples
126 are collected standing downstream from the actual collection process. Samples are brought back
127 in closed and cleaned containers to The Or Foundation headquarters. There they are processed in
128 an enclosed laboratory with no windows and no direct exposure to outside air, thus being relatively
129 sealed off from the surrounding activities of the local area. The samples are processed using
130 conventional guidelines against contamination, only using tap water passed through a ceramic clay
131 filter (pore size < 1μm) and limiting direct exposure to air flow (samples are protected by non-
132 sticky parchment paper and aluminum foil when needed). Negative (blank) controls of all the
133 processing steps are performed on a regular basis (on average once a month or when something is
134 changed in the laboratory, e.g. water containers) in order to identify possible airborne and
135 waterborne sources of contamination. This includes running the processing steps of sample
136 preparation as usual but without the sample. Such blanks are also run for each solution used, for
137 each step (e.g., sitting in an oven, fridge or under the microscope), considering the same volumes
138 and times as for regular sample processing. The concentrations of microparticles found in this

range of controls are considered "negative" because they are not associated with the sample and are removed from the data presented. For this paper we focused on the month of May 2023, because this was a month of heavy rain during which all of our sensors worked without interruption (viz. there was no power outage from the city grid).

On-line monitoring of airborne microparticles. A key air quality monitoring sensor is the PurpleAir, a small "accessible-to-everyone" instrument that detects concentrations of particulate matter in air at a given time point (Ko et al. 2020), which has been used widely around the world by people (technically citizen scientists) interested in knowing the quality of the air they breathe (note that the PurpleAir does not collect or trap the airborne microparticles). The monitoring is continuous and the data (often made publicly available in real-time) characterizes the air quality in a few categories (www.PurpleAir.com), which are in line with the US EPA Clean Air Act quality standards (Barkjohn et al. 2021; Jaffe et al. 2023).

In this study, PurpleAir PA-II-Flex air quality sensors were used to monitor concentrations of PM2.5 (smaller than 2.5 microns) and PM10.0 (smaller than 10 microns) particles expressed as mass concentration ($\mu g/m^3$) in the air, which is the conventional unit to report air quality under the standards of the US EPA Clean Air Act. This mass concentration output, however, originates from raw numbers of particles that are transformed into mass considering specific algorithms (see www.PurpleAir.com) and assumptions about the particles (mostly that they are pollen, dust, and/or black carbon from improper fuel combustion). This mass concentration could therefore be biased under conditions with heavy concentrations of airborne microplastics (which we assumed would be the case around Kantamanto Market, considering its substantial volume of synthetic clothing). As such, we also used the raw data of these sensors, using the PM2.5 and PM10.0 particle counts

161 directly, which are expressed in dL by the sensor (and expressed in L here). These particle count
162 concentrations can therefore be more reliable to compare to the data obtained from the Coriolis®
163 air sampler (see section below).

164 One PurpleAir sensor was located next to the ATMOS41 weather station, in the area near
165 the market corresponding to the upper deck (4th floor, about 12 m above street level) of The Or
166 Foundation headquarters (Fig. 1). Another sensor was positioned on a metal pole at either 5 m or
167 10 m height and moved around for measurements in different locations, including in the heart of
168 the market. Measurements were also taken 5 km away from the market, in Osu, a residential area
169 of Accra. Data from the PurpleAir were processed according to the protocol recommended by the
170 vendor. (The raw data, which was collected every 2 min, was organized in a spreadsheet and
171 curated for any missing data, such as for when the instrument was saturated e.g., or for when power
172 supply instability would make it miss some measurements). Although PurpleAir sensors measure
173 the concentration of particles within their range size, they do not identify what the particles are in
174 terms of their chemical makeup. As such, they do not identify whether particles have a natural
175 basis (dust, pollen vs black carbon) or are purely synthetic, like microplastics (e.g., such as tire
176 shred particles or microfibers from textile fabrics). For this reason, airborne particles had to be
177 collected for infrared fingerprint analysis to identify their chemical nature.

178 *Airborne sample collection.* A Coriolis Compact portable air sampler instrument (Bertin
179 Technologies) was used to collect airborne microparticles between 0.5 and 10 µm from the same
180 locations as the PurpleAir sensors. (Note that the manufacturer has validated the optimal efficiency
181 of the Coriolis for this size range of microparticles, which does not exclude that larger particles
182 can also be collected, since there is no physical size exclusion mechanism in place but rather

183 pelleting of particles from generated cyclonic air flow conditions in the instrument;
184 https://www.bertin-technologies.com/products-range/air-samplers/). Because the instrument
185 collects the microparticles, it cannot be run 24/7 like the PurpleAir, which is used for monitoring
186 the microparticles in the air without collecting them and knowing what they are. Thus, the
187 PurpleAir and the Coriolis instruments appear to complete complementary functions, which we
188 took advantage of in this study. Here, the Coriolis was run for 2 hrs each time at each location,
189 with a vacuum rate of 50 L/min as indicated by the manufacturer specifications. The particles that
190 were collected in the 10 mL cone receiver of the instrument were retrieved according to the
191 following process (given that MilliQ water is not readily available): Tap water filtered through
192 ceramic clay filters with pore size <1 µm was added to the cone, shaken using a Vortex, and poured
193 into a 50 mL Falcon tube. The process was repeated five times to make sure all the particles were
194 transferred.

195 *Waterborne sample collection from the lagoon.* Water was collected from 7 sites (named OKS8
196 through OKS18) along the lagoon, in order to have samples upstream, running next to, and
197 downstream from the dumpsite that receives significant quantities of textile waste leaving
198 Kantamanto Market (Fig. 1). A permanent cement beam structure (aka surface barrier) crosses the
199 width of the lagoon between OKS20 and OKS26. This surface barrier is about 40 m long and about
200 1.5 m tall, and the watermark reaches about half-way up the height of the barrier. As such, the
201 surface barrier stops floating waste from moving further down the lagoon and causes items to build
202 up in massive amounts upstream, to the point where the water surface can barely be seen in OKS20.
203 In contrast, OKS26 (located just downstream from the surface barrier) has much less floating waste
204 since it receives the water that flows under the surface barrier, from about 0.75 m below the water
205 surface. The surface barrier thus does not prevent heavier waste (sub-surface, midwater or

206 tumbling on the seafloor) from flowing under the structure, downstream in the lagoon and into the
207 ocean.

208 Considering the poor quality of the water in the lagoon, which is due in part to raw sewage
209 input (Nixon et al. 2007; Koppelaar et al. 2018; Owusu et al. 2023), surface water collection was
210 performed using an extended pole. The pole was equipped with a dedicated 5 L bucket made of a
211 clean, bright blue plastic easily identifiable under microscope imaging (for blank background).
212 This way, the water collection was safe for the operator. Water was collected with the bucket, the
213 bucket was rinsed and emptied on the ground, and water was collected again 2 separate times at
214 the same site. Each time two 50 mL Falcon tubes (N=4 total) were rinsed three times with lagoon
215 water from the bucket, shaken vigorously. emptied, and rinsed/emptied again two times, and then
216 filled with water from the bucket for the fourth time (for analysis), ensuring that the tubes were
217 submerged sub-surface during collection (to limit any possibility of airborne contamination). The
218 tubes were capped, labelled and transported in a cooler back to the laboratory.

219 The water collection method put in place in this study, based on collecting 50 mL Falcon
220 tubes of liquid, is unique in allowing samples to be collected from almost anywhere, and by almost
221 anyone. This is powerful for gathering a large number of samples (and replicates) from places that
222 are difficult to access in time or space. This methodology therefore leads to numbers of
223 microplastics and microfibers for every 50mL of sample collected, which is the concentration that
224 will be expressed throughout the study (counts/50mL), since expressing the data per L (as is
225 common) could induce a biased extrapolation. Our data can be compared to microplastic
226 concentrations found in the literature, yet keeping in mind the difference in methodology and the
227 difference in sample size and processing. Indeed, most studies focusing on microplastics use the

228 Manta Net to trawl large volumes of water, thus results are expressed in unitary m^3 or L, and only
229 available from coastal areas where boats can operate. The Manta Net usually has a mesh size of
230 100-500 μm, thus collecting larger microplastics, rather than the smaller microplastics (<100 μm),
231 as we do in this study. This difference in methodology relative to coastal baseline studies on
232 microplastics and the difference in size range of microplastics collected, needs to be kept at the
233 forefront when reading this paper, with the difference in units a reminder of these fundamental
234 differences.

235 *Samples processing for microplastic and microfiber counts*. Samples were brought back to the
236 laboratory where they were processed for microplastic and microfiber counts following a routine
237 protocol used in the Deheyn Lab at Scripps Oceanography, (UC San Diego, USA) and
238 implemented at The Or Foundation (see Online Resources). This involved filtering the samples on
239 glass fiber filters (0.6 μm mesh size to retain very small microplastics) and imaging the dried filters
240 under a stereomicroscope. The imaging was done in bright field as well as epifluorescence (ex.
241 360-380 nm, em. >415 nm Long Pass filter; see Online Resource 1-2 for details). Microplastics
242 and microfibers were counted by at least 3 individuals (and up to 6 individuals) using both the
243 bright field image and the epifluorescence images, since they showed different items (Online
244 Resources 1-2).

245 The epifluorescence property of materials of different colors was addressed in the Deheyn
246 Lab, using reference fabric material provided by industry (Lenzing AG and Archroma). We
247 showed that synthetic white polymers (e.g., polyester, elastane, nylon) displayed vivid blue/cyan
248 blue fluorescence, while their colored counterparts showed no visible fluorescence under the same
249 settings. When mixed with plant debris or phytoplankton, the blue/cyan blue fluorescence was

250 visible together with the red fluorescence of chlorophyll, which we expected was the most
251 representative of what we would find on our filters. As for the nature-based polymers (e.g., cotton,
252 lyocell), they had no visible fluorescence, whether white or colored, under the settings used for
253 viewing their synthetic equivalent (Online Resource 1).

254 The intent was not to perform an exhaustive study on the effect of color dyes on the
255 fluorescence but to demonstrate using key polymers and representative colors that our combination
256 of bright field and epifluorescence counting was comprehensive enough to sort microparticles into
257 four categories: (1) Colored microparticles from a variety of sources, including textiles, degrading
258 plastic items, or even just silt grains (bright field counts); (2) Microparticles from natural debris
259 rich in chlorophyll, whether decaying plants, filamentous algae or cyanobacteria (red fluorescence
260 counts); (3) Synthetic microplastics (blue fluorescence dots, flakes or particles); and (4) Synthetic
261 microfibers (blue fluorescence fibers) (Online Resource 2). This combination of bright field and
262 epifluorescence imaging thus allowed us to broadly cover different situations of the life of plastic.
263 For example, an unweathered piece of colored plastic will be seen in bright field but not necessarily
264 in fluorescence, since dyes could affect the innate synthetic polymer fluorescence by shifting its
265 intensity and/or color (Grieve et al. 2005; Biermann 2007). In contrast, weathered pieces of plastic,
266 invisible in bright field, will emit bright blue fluorescence. As for red fluorescent items, they will
267 likely represent a rich content in chlorophyll, which could be seen in bright field as well since they
268 display a green color, unless the red fluorescence originates from a synthetic dye, which would
269 likely be seen in red in bright field (Online Resource 2).

270 The synthetic microfiber counts, which represented our main interest, are discussed in the Results
271 section. (The counts from the other analyses, which are from bright field, microparticles red

272 fluorescence, and synthetic blue, fluorescent microparticles are available as Online Resources.
273 They show the same trends as the synthetic microfibers but in different ranges. Nonetheless,
274 similar conclusions can be drawn from this data.)

275 A subset of samples (35 items) was processed for polymer chemical identification using Quantum
276 Cascade Laser InfraRed (QCL-IR) spectral imaging, using the Spero® IR system (DLS
277 DayLightSolutions Inc.) (Primpke et al. 2020), which is available at the Deheyn Lab (see Online
278 Resource for detailed methodology). The infrared hyperspectral cubes (950 to 1800 cm^{-1})
279 generated from each sample were compared to those of 23 reference standards for plastics
280 (PolymerKit 1.0; Hawaii Pacific University) and 7 raw textile fibers that were provided by industry
281 collaborators at Lenzing AG and Archroma. The infrared fingerprint spectral data for three
282 common polymers standards were overlapped over the spectral data collected from some
283 microparticles to illustrate our polymer assignment (see Online Resource 3).

284 *Textile waste by brand tag*. We assessed the relationship between the textile waste as whole
285 garments collected directly from retailers in Kantamanto Market and the macro textile waste
286 pollution found in the lagoon and at the beaches flanking the opening of the lagoon. For this, we
287 compared the brand tags from garments found at the market (172 garments) with those found at
288 the beach (128 garments) (see Online Resource for details). We expected the assembly of brands
289 from the beach textiles to reflect the ones from the market, since we presumed that the discarded
290 garments somehow (through the lagoon flow) made their way to the ocean, where the tides then
291 pushed them back on the local beaches. We then correlated the two sets of tags using a Pearson
292 correlation coefficient to assess their potential relationship, viz. the market, via the dumpsite, being
293 the source of the textile waste found on the beach. In addition, we recorded the polymer textile

294 fiber composition of the garments (relative content of cotton and polyester in each garment, for
295 example) as indicated in the product tag. In that case, we expected their polymer composition to
296 reflect the one of microfibers found in the airways and waterways.

297 *Statistical analysis.* This study aims to provide a snapshot of the concentration of microplastics
298 and microfibers in the dynamic environment of the world's largest second-hand textile market. A
299 diversity of variables is considered, from textile-related merchandising activities to textile burning,
300 in addition to weather variables and to the schedule of the crowd coming in and out of the market.
301 Our analyses therefore mainly rely on descriptive statistics using box plot displays, with data
302 curing performed in Excel (Microsoft Corp) and figures made in Delta Graph (Red Rock
303 Software). Although our intentions were not to test the particular level of significance of variables,
304 we performed the research with as many replicates and independent controls as possible, in order
305 to provide a robust assessment of effects and trends. The only "experimental" assessment we did,
306 which deserved statistical assessment, was when we compared the assembly of brand tags from
307 the market textile waste (which we manually pulled out of the market) versus the one from the
308 beach textile waste (which we dug out from the sand). We therefore ranked the brands from the
309 most abundant to the least abundant based on the number of tags found for each brand and used
310 Excel to run a Spearman ρ correlation coefficient analysis considering a significance level of
311 $\alpha<0.05$.

312

313 **RESULTS**

314 The results showed that the clothing from global sources sold into Kantamanto Market and
315 discarded from the market as waste is a source of microparticles, but that the release and

316 distribution of these microparticles can show large discrepancies, based mostly on market activities
317 and weather (rain), which are variables both in time and space. The synthetic microfiber counts
318 we report here always showed high values compared to their blank controls equivalent for
319 background contamination. In general, our various controls accounted for <2 % of counts
320 compared to those from processed samples (Online Resource 4-8).

321 Of the microparticles collected via air sampling (Coriolis analysis) and counted by microscope
322 imaging, we show here the data for the synthetic microfibers and microplastics identified in
323 epifluorescence, while the other imaging data is shown in Online Resource 5-8. Overall, all the
324 imaging data followed the same trend but in different ranges of counts. In general, bright field
325 counts were always the lowest and below one hundred, followed by red fluorescence counts and
326 the blue fluorescence microfiber counts (both about 10x greater than the bright field counts) and
327 blue fluorescence microparticle counts (about 10x greater than the blue fluorescence microfiber
328 counts). Broadly, this indicates our samples contained a sustained level of recently released
329 microparticles: a large amount of natural microparticles and synthetic microfibers and a much
330 greater amount of microplastics (Online Resource 5-8).
331

332 *PurpleAir data were up to 5x greater within the market*. PurpleAir sensors allowed us to collect
333 data over a continuous 24 hr period and to measure both mass concentration and raw counts of
334 particles (N=720 data points each). The PurpleAir sensors across the different areas of town and
335 at the different height (5 m, 10 m) all showed similar mass concentration data in terms of the
336 relative abundance of PM10 and PM2.5 particles (as expected since PM10 data encompass PM2.5
337 data), which systematically showed PM10 mass concentration data up to 125% greater than that
338 of PM2.5 (Online Resource 4A). The most striking difference across sites was regarding the

339 variability of the data, which was more variable in the market than off market, and which thus
340 translated into a greater difference between the means and the medians for each of these sites
341 (Online Resource 4A). Over the course of May 29, 2023, which was a day with no rain (last rain
342 event was about 40 hrs prior) PM2.5 in the air at a given timepoint ranged from 3 to 356 μg/m^3,
343 while those of PM10 ranged from 4 to 372 μg/m^3. The mass concentration was systematically
344 greater for the sensors placed in the market, especially for the one at 10 m height (PM10 up to 372
345 μg/m^3), which was slightly greater than the one at 5 m height (PM10 up to 332 μg/m^3). The mass
346 concentration decreased when moving away from the market, whether at its outskirts at The Or
347 Foundation headquarters at 12 m (up to 103 μg/m^3) or in the residential area control at 2 m (with
348 up to 94 μg/m^3) (Online Resource 4A). The corresponding data with respect to microparticle count
349 concentration (raw data generated by the PurpleAir) showed similar characteristics, with greater
350 count concentration and greater variability for sites within the market (Online Resource 4B). This
351 was especially true for data of PM2.5 particles, which was up to 3,467 counts/L in the market and
352 up to 912 counts/L off the market. The particle count concentration for PM10 were lower than for
353 PM2.5, as expected, reaching 172 counts/L in the market and up to 226 counts/L off the market,
354 indicating that larger microparticles can also be found off market (Online Resource 4B), but
355 whether they originate from the market remains to be determined (see assessment from the section
356 on the Coriolis data below).

357 The trend in the data, showing greater values in the market relative to the outskirts and
358 residential areas, and, within the market, higher concentrations at 10 m relative to 5 m, was
359 observed throughout our study, yet was highly variable from day to day and within a given day.
360 This was dependent on the activities at the market (most active from 05:00 until 18:00 every day
361 but starting as early as 02:00 for the vendors) with possible burning of waste in locations

362 immediately surrounding the market occurring overnight. Vehicle traffic on the market periphery
363 and foot traffic across its web of stalls could also affect the PurpleAir data, but also, and most
364 importantly perhaps, the weather, especially in relation to wind and rain. Indeed, data collected
365 during days when rain occurred decreased sharply as soon as rain started before increasing again
366 gradually after the rain stopped (Fig. 2). Microplastic particles can make up a portion of the overall
367 PM10 and PM2.5 data, and therefore are a component of the air we breathe, with potential impacts
368 on human health. It was therefore critical for us to look at the actual content of microplastics and
369 microfibers for both airborne and rainwater samples.

370 *Airborne microparticles were dominated by synthetic textile microfibers*. Data from the Coriolis
371 air sampler showed relatively high concentrations of microfibers across all sites of investigation
372 within the market, ranging from about 20 at HQ to about 180 microfibers per 6,000 L in the market
373 at 10 m height, equivalent to 0.004 to 0.029 microfibers/L (Fig. 3). In general, we found that the
374 microfiber concentrations were greater for the samples analyzed at 10 m height compared to the 5
375 m analysis (even within a ventilated warehouse); this was particularly evident for the samples
376 taken in the open-air area of the market (Fig. 3). Measurements in the market were about 2x to 5x
377 greater than the ones made 1 km away, at the outskirts of the market (Fig. 3), which correlated
378 with the data found with the PurpleAir. Greater concentrations of microfibers were also observed
379 in bright field conditions, indicating that these microfibers were not weathered and thus likely
380 originating from the area where the air sample itself was collected (see BF MFs; Online Resource
381 5). We also found greater concentrations of microplastic particles at 10 m in the market compared
382 to the same location at 5 m. We assumed that such greater concentrations of microplastic particles
383 at 10 m were mostly originating from textiles as well considering that their values were also high
384 in the warehouse where textiles are shredded for upcycling activity, while lower for HQ where

385 textile work is not performed. (see UV MPs, Online Resource 5). These microplastic particles were
386 in much greater concentrations than their synthetic microfiber equivalent, which correlated well
387 with the trend observed for the PurpleAir data where PM2.5 count concentrations were greater
388 than the ones for PM10.

389 *Rainwater and lagoon samples contained large concentrations of synthetic textile microfibers.*
390 Rainfall was highly variable and characteristic of a tropical weather regime, thus more often with
391 heavy "showers" scattered in space and time across Accra. We recorded rainfall from 1.5 mm/day
392 to 80 mm/day. Rainwater samples that were collected from the rainfall ranged from a few mL to a
393 couple hundred mL. Analyses showed that the rainwater contained synthetic microfibers (Table 1;
394 Online Resource 6-7) within a range of concentrations (counts/50 mL) that varied with the duration
395 of the rain event, with greater concentrations of synthetic microfibers (up to 300/50 mL) found in
396 rainfall from shorter rain events. Indeed, in situations where we collected over 40 mL of rainwater,
397 which equate to about 19.8 mm of rainfall under weather standards, the concentration of synthetic
398 microfibers decreased sharply (Fig. 4A). In addition, the concentration of synthetic microfibers
399 found in rainwater changed based on when the last rain event occurred, and as such, the greater
400 the extent of dry weather between two rain events, the greater the concentration of synthetic
401 microfibers found in the rainwater. This was especially observed after 3 days of dry weather (Fig.
402 4B).

403 Water samples from Korle Lagoon contained large concentrations of synthetic microfibers,
404 ranging from 2 to 80 counts/50 mL (Table 1; Online Resource 8-9), which were greater when
405 closer to the dumpsite and market compared to the locations that were further away (Fig. 5). In
406 addition, and as expected, the concentrations of synthetic microfibers peaked at OKS20 (between
407 60 and 80 counts/50 mL, where surface waste is stopped from flowing downstream by the surface

408 barrier crossing the lagoon (Fig. 5). The data was not as clear for the concentration of microfibers
409 identified in bright field, suggesting that the microfibers in the water were mostly weathered and
410 not originating directly from airborne microfibers recently generated in the market (see BF MFs,
411 Online Resource 8). As for microplastic particles, they too increased in concentration in the lagoon
412 areas facing the market (up to 550 particles/50 mL), up to where the surface barrier crosses the
413 lagoon.

414 *Chemical composition of waterborne microparticles reflects that of garments from the market*.
415 Infrared fingerprint analyses (see Online Resource 3 for matching of some spectra with standards)
416 showed that waterborne microparticles represented a variety of polymers, the most dominant ones
417 being cotton (29%), polypropylene (26%), polyester (14%), nylon (11%), and polyethylene (9%).
418 Garments in the market reflect this pattern of polymer ratio as well (Fig. 6), with 40% of the
419 garments made primarily of cotton, 13% of polyester and 10% of nylon. As for polypropylene and
420 polyethylene, these polymers are mostly used in plastic bags (used as single-use water containers
421 and takeaway bags) and single-use water bottles, respectively, which are also found spread all over
422 the market and lagoon where they are being weathered and breaking down.

423 *Textile waste showed similar brand assemblages between beach and market*. Collected tags
424 showed that the 10 most common brands found in the textile waste were Marks & Spencer,
425 Associated British Foods (Primark), Asda (George), Sainsbury's (Tu), Next, Boohoo Group, Tesco
426 (F&F), H&M Group, New Look Group, and GAP, representing up to 63% and 77% of the items
427 found at the beach and in the market, respectively (Fig. 7). There was a 59% correlation of brands
428 occurring between the two sites of waste collection, based on the tags analyzed, which was
429 statistically significant ($P < 0.05$; Pearson ρ correlation coefficient).

DISCUSSION

Our research around Kantamanto Market showed the extensive presence of microplastics and synthetic microfibers, in both the surrounding air and water, with concentrations seemingly representative of the varying attributes of the market activity. The data indicate that the concentrations of airborne microparticles we found varied depending on the day of the week and activities taking place on those days, with concentrations notably being higher after every Thursday, when bales of globally sourced secondhand clothing are delivered to the market. The concentrations were also higher during early morning on Saturdays, a busy market day when bales are opened and garments are displayed for sale in Kantamanto Market (Skinner 2019). Our study focused on microfibers, especially their synthetic version, because those are directly related to the secondhand textile activities in the market, yet keeping in mind that such microfibers could also have other origins (from outside the market or even a far-away location), while not dismissing the microplastic components, which can come from a diversity of sources (from tire wear to microplastics from burning waste, including textiles).

Our study showed, at least during the daytime when analyses were conducted, that microfibers that are released can float around and be carried to higher elevations (we tested at 10 m height), likely due to warm upward convection currents caused by heat generated by the hot surfaces heated by the sun, and to which the high number of people in the market can also contribute (Belzagui et al. 2019; De Falco et al. 2020; Periyasamy and Tehrani-Bagha 2022). Such upward hot air convection currents are known to occur in nature, where they help with plant seed dispersal for example (Inatsu et al. 2021; Mun et al. 2024) although they can also be very important in urban areas where they are considered by city managers for airflow improvements (Xie et al. 2006; Xue and Li 2017; Di Bernardino et al. 2018; Muniz-Gäal et al. 2020). Here, we evidenced

453 that the microfibers could be carried at least as high as 10 m into the air, although one cannot
454 exclude that some of them could originate from other sources nearby as well. From there, they
455 could potentially spread around with winds (we indeed found unweathered microfibers in
456 neighborhoods around the market; see Online Resource 5) and fall back onto the ground at night,
457 either when heat-driven convection currents stop or when they become entrained down onto the
458 ground by rain events (Miao et al. 2023; Liu et al. 2025). Indeed, rainwater was polluted with
459 microfibers (and microplastics), which was especially true for rain events occurring after 3-4 day
460 periods of no rain. In such a case, we showed that the first flush of the rain (within the first hour
461 or so, varying based on the rain intensity) could bring down microfibers in high concentrations.
462 Practically, from a public health perspective, this indicates that people who collect rainwater for
463 drinking usage should skip the first flush of the rain event, especially if it has not rained in several
464 days, or should deploy filtration technology if any is available (like the clay filters commonly
465 found across Africa).

466 Our data thus indicates that microplastics and microfibers can enter Korle Lagoon waters
467 via two routes: One concentrated around the piles of discarded garments that shed fragments upon
468 mechanical abrasion and weathering in the environment; and the other one more diffuse and
469 associated with aerial deposition of airborne microplastics and microfibers, that can also be
470 precipitated during rain events, and reach the lagoon via runoff and surface water drain outflows.

471 Ultimately, using Kantamanto as a case study representing the communities that receive,
472 sort and process global fashion waste, we show that the high volume and low quality of garments
473 arriving in these communities and the lack of infrastructure and capital to safely and efficiently
474 deal with this waste, results in significant microfiber pollution. This pollution has the capacity to

impact local air quality as well as local aquatic ecosystems and their associated services, thus potentially contributing to chronic public health issues (Manisalidis et al. 2020; Sridharan et al. 2021; Zhao et al. 2023; Song et al. 2024; Vasse and Melgert 2024).

Global textiles as a source of airborne microparticles. Using the PurpleAir sensors, we demonstrated that the mass concentrations of PM2.5 and PM10 particles were high and varied extensively around and near the market, decreasing when going further away from it. This indicated that the market was a source for airborne microparticles.

PM2.5 airborne microparticle mass concentrations in different neighborhoods in Accra have been reported to often be above the healthy air quality guidelines recommended by the World Health Organization, which is set at 10 μg/m^3 (Zhou et al. 2011; Ofosu et al. 2012), while rarely surpassing 100 μg/m^3 (Alli et al. 2021). Our study showed PM2.5 mass concentrations within the market can often reach levels up to between 125 and 175 μg/m^3 (Online Resource 4A), sometimes peaking at much higher concentration levels around 1,300 μg/m^3 (Fig. 2), which thus can be 10x-20x greater than for various areas in Accra. Because our study took place in the core of a textile market, and knowing that textiles shed microfibers (and/or fiber fragments that could be shorter and more like "elongated" microplastics) that can be <10 μm in size, it is fair to assume that our PM2.5 as well as PM10 mass concentrations could also include microfiber and/or shorter fiber fragments. This would be in addition to other microparticles typically found in cities (related for example to energy combustion, industry and road traffic) but also pollen and sand dust, often carried by sub-Saharan winds to Accra (Amegah et al. 2017).

496 Aside from the abnormally high airborne microparticle mass concentrations in
497 Kantamanto, another peculiarity was that the PM10 mass concentrations were only about 1.0-1.2x
498 greater than those of PM2.5. This was unlike other studies in Accra that showed PM10 values
499 being 2.0-2.5x greater than PM2.5 (Arku et al. 2008; Dionisio et al. 2010). Because our PM10
500 mass concentrations were relatively elevated, the lower PM2.5/PM10 ratio in our study indicates
501 that the source of PM2.5 is likely greater in the market environment, relative to its surroundings.
502 PM2.5 values tend to be associated with byproducts of combustion such as those from fuel-
503 powered engines (Arku et al. 2008; Dionisio et al. 2010). However, because the interior of the
504 market (where measurements were made) is largely closed to vehicular traffic, the increased
505 PM2.5 count concentration cannot be from on-site fuel-powered engines but likely stems from
506 incomplete fire combustion of plastic material. Burning plastic waste is indeed a common practice
507 in Kantamanto, which is done without wood, and not for the need of cooking or getting warmer,
508 but for the need to discard waste and gain space. Such frequent (almost every night) and
509 uncontrolled incineration of waste material is also done using textile waste, which is mostly made
510 of plastic that, when burned, releases large numbers of PM2.5 microparticles (Bardales Cruz et al.
511 2022; Islam et al. 2022). Although another source of PM2.5 could originate from the individual
512 use of cooking stoves across the market (Zhou et al. 2011), the importance of this practice is
513 definitely less than the textile waste burning. The latter is likely the most prevalent indeed
514 considering the many small fluorescent particles that were observed under epifluorescence in our
515 study, which makes them synthetic (plastic), since black carbon microparticles from engine
516 combustion and incineration practices with wood (both important sources of PM2.5 and PM10
517 microparticles in general) have not been previously reported to show native epifluorescence
518 properties. In fact, additional staining methods are needed to image black carbon microparticles in

519 fluorescence (Chen et al. 2019). The native fluorescence of microparticles in our study then
520 indicates their synthetic (plastic) nature.

521 As expected, air quality in Accra shows daily variation relative to people's activities,
522 whether from cooking or driving to/from work (Alli et al. 2021), and/or from textile market
523 activities and the burning of garments, as indicated by this study. We also showed here that
524 airborne PM2.5 and PM10 microparticle concentrations decreased sharply in events of rain
525 indicating that rainfall can be a major process to help microparticles, including microplastics and
526 microfibers, transition from the airborne phase to the waterborne phase. This indicates that rain
527 can be a major process by which airborne microfibers enter the waterways, in addition to wind
528 driven processes that can deposit them onto water surfaces. Such an effect of rain bringing down
529 airborne microplastics was recently described in other industrial settings (Do et al. 2023).

530 *Global textile waste as a source of microparticles for waterways*. We evidenced that Korle Lagoon
531 is a receptacle of textile microfibers from runoff. Indeed, water samples collected from the lagoon
532 showed high concentrations of microfibers (and other microplastics as well), with a spatial
533 distribution along the lagoon and chemical makeup indicative of an origin associated with market
534 activities. In particular, runoff following rain events and/or weathering fragmentation of garments
535 discarded directly in the environment are likely a sustained source of microparticles for the lagoon.
536 This is in addition to the microfibers probably reaching the water surface from airborne deposition.
537 A majority of garments in the market contain polyester and/or cotton, which was also reflected in
538 the waterborne microparticles, especially in waterways next to, and downstream from, the market.
539 Our study thus highlights the extent to which the increase in textile production, and therefore textile
540 waste, contributes to the release of microplastics and microfibers in the environment, either

541 atmospheric or aquatic. This information is critical because microplastics and plastic microfibers
542 are not biodegradable in a biologically relevant timeframe, making them accumulate in the
543 environment where their long residence time makes them available to enter the food web and
544 accumulate in organisms, including humans (Sharma et al. 2022; Thompson et al. 2024; Zhao et
545 al. 2024). This, in turn, can affect the overall ecosystem services (Santana et al. 2017, Olmo-
546 Gilabert et al. 2024).

547 *Concentrations of microfibers and microplastics were greater than in other parts of the world*.
548 The concentrations of microplastics, including microfibers, found in our study, whether in the air
549 or in the water, were usually by far the highest ever reported in an environment (e.g., Sazli et al.
550 2023). This does not come as a surprise considering that methodologies used can lead to
551 underestimation of microplastics, both from airborne and waterborne sources (Xu et al. 2020). In
552 addition, a direct comparison across studies is challenging because the methodology for sample
553 collection and/or for microparticle counting usually varies from study to study, based on local
554 environmental limitations, local expertise, the distinction (or not) between microplastics and
555 microfibers, but also on the scientific question driving a particular study. Zhao et al. (2023)
556 provided a relevant range of comparison for levels of airborne microplastics in megacities, with
557 concentrations of microplastics possibly ranging broadly from <1 to >1,000 per m^3, depending on
558 environmental factors (e.g., winds, wildfires, smog conditions) and methods of collection (e.g.,
559 dry or wet passive atmospheric fallout vs. active suspended particle measurement). However,
560 under normal circumstances and using suspended particle measurement as a reference (thus not
561 brought down by rain or snow), others have measured relatively low concentrations, e.g. around 4
562 microplastics per m^3 in Shanghai (Sridharan et al. 2021), 1.5 per m^3 in Paris, and 0.6 m^3 in the
563 French Alps (Xu et al. 2024), often with no quantified distinction between microfiber and

564 microplastic particles, except for Xu and colleagues who identified that 10% to 25% of the
565 microplastics were microfibers. In our study, the Coriolis data showed about 100 to 700
566 microplastics per m^3, thus about 100x what was found in Shanghai, and about 3 to 30 microfibers
567 per m^3 (considering only UV synthetic MFs, and not the BF MFs; see Online Resource 5), which
568 is about 20x greater than in Shanghai and about 125x the numbers from the French Alps.

569 A similar analysis can be done with waterborne microfibers and microplastics.
570 Microplastics in Kantamanto can originate from degrading plastic bags and disposable individual
571 drinking water pouches (the main source of drinking water around the market), used extensively
572 and discarded on the ground, with limited direct contribution from tire wear as otherwise found
573 elsewhere in the city (Arku et al. 2008; Zhou et al. 2011; Knight et al. 2020; Amegah et al. 2022;
574 Safo-Adu et al. 2024). As for microfibers their main source would be shedding from clothing (Carr
575 2017; Carney Almroth et al. 2018; Liu et al. 2019; Nowack et al. 2021; Liu et al. 2023).
576 Concentrations of microfibers have been reported at around 2-30 counts per L in coastal waters
577 (Suaria et al. 2020; Tang et al. 2023), which does not include lagoons as these have been much
578 less investigated around the world for their content in microfibers. The same can be said for
579 microplastics, although in this case one comprehensive study gathered data from the literature
580 since 2000 (Garcés-Ordóñez et al. 2022), showing concentrations of 20 to 90 counts per L on
581 average for lagoons around the world, with about 40% of these numbers attributed to microfibers,
582 thus making the count to about 12-54 microplastics per L and thus about 8-36 microfibers per L.
583 This is in line with studies reporting up to 30 counts of microplastics per L in harbors and with
584 0.5-2.0 counts per L in coastal and more open ocean waters (Suaria et al. 2020; Tsang et al. 2020).
585 The difference in concentrations relative to what we found in Korle Lagoon waters (between 100
586 to 1,600 microfibers per L and between 1,000 to 11,000 microplastics per L; Online Resource 8)

587 is staggering and likely due to the source being the abundance of textiles in the market as well as
588 in the dumpsite (as waste) along the lagoon. Such high concentrations (up to 25,000 counts per L)
589 were previously observed in lagoons in the Florida Keys (USA) (Badylak et al. 2021) and were
590 considered the result of debris (mostly polystyrene pellets) coming from recent hurricane activities
591 and accumulation in specific areas of lagoons due to winds and currents. This was not the case for
592 the data collected in Korle Lagoon, which shows a slow but steady flow to the ocean.

593 Another factor possibly contributing to the difference in concentrations of microplastics
594 found across studies could also originate from the differences in methods used to collect water
595 samples and to analyze the water samples. Indeed, a common way to collect microplastics involves
596 a Manta net, which is not easily used in a shallow lagoon (Royer and Deheyn 2019); this method
597 has also been documented to underestimate the numbers of microfibers that can pass through the
598 mesh due to their elongated shape, and because the mesh size is usually larger, around 500 μm
599 (Barrows et al. 2018; Du et al. 2022; Concato et al. 2023). Hence, the technique to collect set
600 volumes of water for subsequent filtration and counts of microfibers (and microplastics) retained
601 on filters, is likely more representative of the actual waterborne microfiber concentrations.

602 *Textile waste from global sources passing through Kantamanto Market contaminates the coastal*
603 *ecosystem.* Beaches in Accra have masses of entangled garments that arise on and under the sand.
604 Composed of dozens of garments, these masses develop into long tentacles (bundles as much as
605 30 cm in diameter and meters long) that go deep into the sand, and their extraction, through beach
606 cleanups organized weekly by The Or Foundation, represent a monumental effort. It is unclear
607 how long it takes for garments to form tentacles like these with the back and forth of the waves
608 and tides, and for them to be buried deep into the beach. However, the local coastal community,

609 including The Or Foundation's Beach Monitoring team, which counts the tentacles every week,
610 has observed them for several years (The Or Foundation 2022). Taking tags from garments on the
611 beach and comparing them to the tags from the textile waste in the market demonstrated that
612 garments found at the beach originate as part of the global secondhand clothing trade passing
613 through Kantamanto.

614 The tags showed that the 10 most abundant brands found at the beach and as market waste
615 correlate well with one another. While it is possible that some of the garments are trashed directly
616 at the beach after purchase and use for a little while, it is unlikely that such "isolated"
617 circumstances would lead to the formation of the long tentacles that have been observed.

618 Brands of the garments most commonly found as waste on the beach and as waste within
619 Kantamanto Market were from the Global North, with companies headquartered and distributed
620 principally within the USA, the EU and the UK. Most of these companies are well known to be
621 involved in the fast fashion economy (Boohoo, Gap, George, H&M, New Look, Next, Primark),
622 although not always recognized as such by consumers (as is the case for Marks & Spencer, for
623 example). Thus, within the fast fashion economy, whereby consumers are influenced to rapidly
624 change wardrobes at relatively affordable prices (The Economist 2015), garments can be
625 considered environmental pollutants of emerging concern when discarded as waste at their end of
626 life due to the rapid turnover and high volumes of garments in circulation.
627
628 *A simple collection and processing technique to enable citizen science*. In this study, we worked
629 together with the local community to access sites for collecting samples, to engage community
630 leaders to implement new waste management practices, and to empower citizens to help with

sample collection. As such, we used a simple and straightforward technique that easily could be performed by any citizen, with only brief training needed. The technique is effective in collecting and quantifying microfibers, but also microplastics. The technique relies on small amounts of water (50 mL) that can easily be sampled by scientists and citizen scientists alike using standardized tubes, making this attractive for large sampling collection involving the community. The use of water volumes greater than 50 mL was tested as well (including 1,000 mL, 500 mL, 200 mL; data not shown) but shown to be more challenging due simply to the larger volume to handle (with increased risks of clogging). It was also more challenging for counting the microfibers, due to excess debris on the filters, or due to difficulty counting because of the excessive number of microfibers overlapping each other in the field of view. It must be noted that in some instances here, the 50 mL volume had to be analyzed 10 mL at a time, using several filters, to facilitate accurate counting and then added together at the end to represent the one sample (see Online Resources for more details). The proposed technique thus provides flexibility when dealing with water masses that are heavily charged with silt, plankton and/or debris, which can clog the filtration process early on (before reaching the complete 50 mL volume). The proposed technique (which by default uses triplicates of 50 mL volumes) thus complements the most common one used for microplastics in particular, using Manta Net towing/trawling, which is bulky, requires a boat, and is thus difficult for citizens to access.

CONCLUSION

This citizen science-led study provides a comprehensive assessment of microplastic and microfiber concentrations in the air, rainwater and lagoon water around Kantamanto Market and its known dumpsites of global secondhand textile waste. The global textiles and textile waste passing through

655 the market appear to be a significant source of microfibers (and microplastics), with concentrations
656 within and around the market sometimes more than 100x greater than in other metropolises around
657 the world. We demonstrated the dynamic distribution of microparticles following their generation
658 in the market, with particles in the air precipitating back down with rain events, and possibly with
659 wind and cooler temperatures. The effects of global textile waste passing through the market and
660 entering the surrounding environment go beyond the microscopic particles. Indeed, we showed a
661 strong correlation between garments considered waste at the market and the ones found on the
662 surrounding beaches, by comparing brand composition of the garments. Overall, we emphasize
663 the fact that fast fashion contributes to poor water and air quality, which is likely the case across
664 other densely populated cities worldwide considering that the processes we highlighted in
665 Kantamanto are not site specific, and could take place in other secondhand clothing markets. As
666 such, the study highlights the global need for new policy regulations and programs to ensure that
667 cleanup programs and proper waste management efforts are sufficiently funded along the entire
668 life cycle of the garments, including for existing and future waste, repurposing and recycling
669 streams.
670

GLOSSARY

Fast fashion - An approach to the design, creation, and marketing of clothing fashions that emphasizes making fashion trends quickly and cheaply available to consumers. Fast fashion is characterized by overproduction and the use of cheap (often exclusively synthetic) materials and fabrication techniques.

Fiber fragment - A microscopic fragment that arises from the shedding or degradation of fiber threads from either natural or plastic (synthetic) textile materials. Fiber fragments are characterized by a diameter usually around 8-12 μm and a length that can be greater than the diameter, in which case it would be known as "microfiber." Shorter fiber fragments (with diameter shorter than their length) would then be reported as microplastics.

Kantamanto Market - The world's largest secondhand clothing and upcyling market, located in Accra, Ghana, and featuring over 10,000 vendor stalls.

Microfiber - A microscopic fragment that arises from the shedding or disintegration (physical break off) of both natural and plastic textile thread materials. Also known as a "fiber fragment."

Microparticle - Any microscopic particle, regardless of shape, whether synthetic or originating directly from nature (mineral dust or small organic debris).

Microplastic - A microscopic fragment that arises from the disintegration of plastic materials, or that is made small to begin with, such as microplastic beads from cosmetics. As used here, the

term “microplastic” is distinct from “microfiber”, although microplastics could be short microfibers (see fiber fragment definition above) As such, in this study, microplastic counts represent something distinct from microfiber counts.

Natural microfiber - A microscopic fiber fragment shed from a natural textile material, such as cotton, wool, or other plant-based sources.

Plastic (or synthetic) microfiber - A type of microplastic with a “fiber shape”. Plastic microfibers typically arise from the shedding or disintegration of textiles, although they can also originate from tire wear, carpets or upholstery.

710 **FIGURE CAPTIONS**

711 **Figure 1.** Map (ESRI) of the areas of investigation around Kantamanto Market, indicating the
712 locations for the PurpleAir sensors and the Coriolis air sampler (green and blue stars, respectively),
713 and the water sampling sites in the Korle Lagoon (orange circles). Location of the surface barrier
714 is also visible (green arrow). Main directions of surface water runoff and surface wastewater are
715 also indicated (yellow arrows). HQ: Headquarters of The Or Foundation; WH: Warehouse, large,
716 enclosed space immediately adjacent to the market where textile waste is prepared for reuse; OSU:
717 Residential neighborhood in central Accra, about 5 km from the market.

718

719 **Figure 2.** PM2.5 (grey line) and PM10 (black line) particles mass concentration ($\mu g/m^3$) from the
720 PurpleAir data recorded every 2 min during a 24 hr period starting at midnight, for 3 different days
721 with distinct intensity of rain events (date, duration of rain and volume of rainwater collected are
722 indicated). Period of rain (gray shade) and volume of rainfall was provided by ATMOS41 weather
723 station. Period of market activity is indicated on each panel. Of note: Thursdays are when new
724 bales of garments are delivered to the market to be opened; the garments inside are sorted on
725 Wednesdays and Saturdays.

726

727 **Figure 3.** Airborne synthetic microfiber concentrations (box plots; N=9) across the various sites
728 of investigation showing that the values were greater in the market and, within the market, greater
729 at 10 m compared to 5 m. Data were collected with the Coriolis air sampler for 2 hrs each time,
730 thus representing concentrations of "counts/6,000 L of air". HQ: Headquarters of The Or
731 Foundation; WH: Warehouse; KM: Kantamanto Market.

732

733 **Figure 4.** Rainwater microparticle count concentrations (box plots; N=9) collected with the Stratus
734 Rain Gauge (with rain event volumes validated by an ATMOS41 weather station) set on the roof
735 of The Or Foundation headquarters. **A.** Concentrations of synthetic microfibers from rainwater
736 samples that correspond to different rain events, thus each with their own volumes (on the X axis).
737 Data counts on the Y axis are expressed per set volume of 50 mL. The concentration of synthetic
738 microfibers was high for short rain events (up to 2 hrs long) and decreased steadily as rainfall got
739 heavier and/or lasted longer. *These samples were collected the same day as the 185 mL rain
740 event, but just a few hours earlier. This shows that the concentration of synthetic microfibers in
741 volume of rainwater depends on precedent episodes of rain. **B.** Concentrations of synthetic
742 microfibers for rain events expressed in relation to the time (number of days) since the last rain
743 event. Data show that the concentration of synthetic microfibers increases greatly in the rainwater
744 after 4 days with no rain. Data counts are expressed per set volume of 50 mL.
745
746 **Figure 5.** Concentrations (counts/50 mL) of synthetic microfiber (box plots; N=9) from Korle
747 Lagoon water showing that the site directly flanking the market in terms of runoff (OKS13) has
748 the greatest concentrations compare to upstream/downstream of the market, this until the flow of
749 the lagoon water is slowed down by a surface barrier (OKS20), where floating debris and
750 microparticles accumulated. All data counts are expressed per set volume of 50 mL of water
751 collected.
752
753 **Figure 6.** Pie chart representation of the percent occurrence of polymer types found in the
754 microparticles collected in the lagoon water adjacent to the landfill (OKS 12.5, OKS20) (A, from

755 InfraRed fingerprint analysis of microplastics) and those found in the waste pile of garments at
756 Kantamanto Market (B, from material composition tags of garments).
757
758 **Figure 7.** Pie chart representation of the percent occurrence of name tags for each brand found in
759 the waste pile at Kantamanto Market (top) and found entangled and buried in the sand at the nearby
760 beach (bottom). More than 60% of the tags originated from just 10 brands (Marks & Spencer,
761 Associated British Foods, Asda, Sainsbury's, Next, Boohoo Group, Tesco, H&M Group, New
762 Look Group, and GAP).
763
764

765 **Table 1.** Minimum (Min), Maximum (Max), Mean and Median values for the counts of synthetic
766 microfibers and microplastics (both found with native blue fluorescence) from samples of air (in
767 6,000 L), rainwater (in variable volumes), and Korle Lagoon water (in 50 mL set volume sampling
768 standard of our methodology). For all counts, N=9, except for the airborne sampling counts (N=3).
769 Airborne microparticle samples originated from 6,000 L of processed air, and were thus expressed
770 in concentration of "counts/6,000 L", whereas lagoon water samples were expressed in "counts/50
771 mL". Data on concentrations for unweathered microparticles (bright field microscope imaging)
772 and natural microparticles (red fluorescence) can be found in Online Resource 9.
773 Abbreviations. HQ: Headquarters of The Or Foundation (roof) at two different times (a,b); WH:
774 Warehouse space adjacent to the market at two different heights (5 m, 10 m); KM Kantamanto
775 Market (center) at two different heights (5 m, 10 m).
776

777

		Synthetic Microfibers					Microplastics			
		Min	**Max**	**Mean**	**Median**		**Min**	**Max**	**Mean**	**Median**
Airborne particles (counts/6,000 L)	**HQa**	8	22	14	11		311	485	414	446
	HQb	7	15	11	10		252	290	275	282
	WH – 5m	12	35	21	16		1034	1700	1454	1629
	WH – 10m	27	48	37	35		1348	1855	1636	1704
	KM – 5m	52	74	60	54		1170	1400	1290	1300
	KM – 10m	99	144	124	128		1195	2930	1790	1244
Rainwater (HQ)	**16 mL**	92	96	94	94		946	1020	971	947
	20 mL	92	101	95	92		1358	1900	1600	1541
	160 mL	23	32	28	30		385	663	486	411
	190 mL	14	18	16	15		421	661	515	462
	180 mL	25	43	35	36		3149	3601	3331	3243
	200 mL	14	16	15	14		1365	1484	1427	1433
	185 mL	100	112	107	108		972	1264	1082	1009
	70 mL	62	71	67	69		738	1092	949	1017
	40 mL	94	126	108	105		1181	1479	1370	1449
	20 mL	9	18	12	10		273	285	279	279
Korle lagoon sites (counts/50 mL)	**OKS18**	3	11	7	6		125	253	187	174
	OKS14	4	10	7	7		251	489	328	269
	OKS13	5	46	24	22		293	600	443	435
	OKS12.5	9	18	13	12		208	532	350	395
	OKS20	53	81	68	68		246	485	357	364
	OKS26	7	15	11	12		74	284	194	182
	OKS8	6	19	13	13		42	267	170	165

778

Author's contribution. DDD and BS conceptualized the project. JA performed the field and laboratory work in Ghana, under DDD guidance. DDD performed analysis in California. DDD wrote the first draft of the paper, which was then reviewed and finalized by BS and JA, and several members of The Or Foundation.

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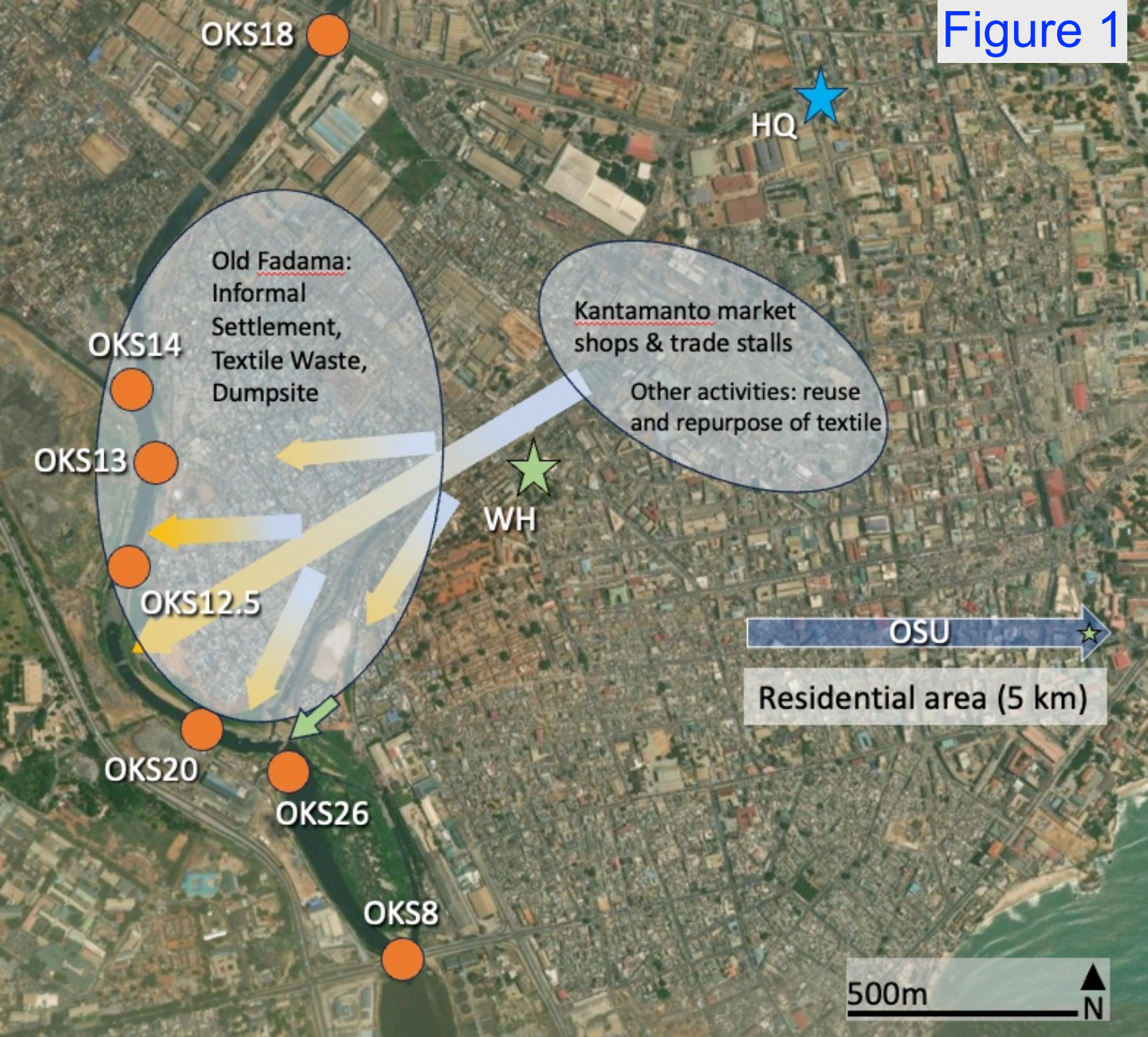


Figure 1
OKS18
HQ
Old Fadama: Informal Settlement, Textile Waste, Dumpsite
Kantamanto market shops & trade stalls
Other activities: reuse and repurpose of textile
OKS14
OKS13
WH
OKS12.5
OSU
Residential area (5 km)
OKS20
OKS26
OKS8
500m
N

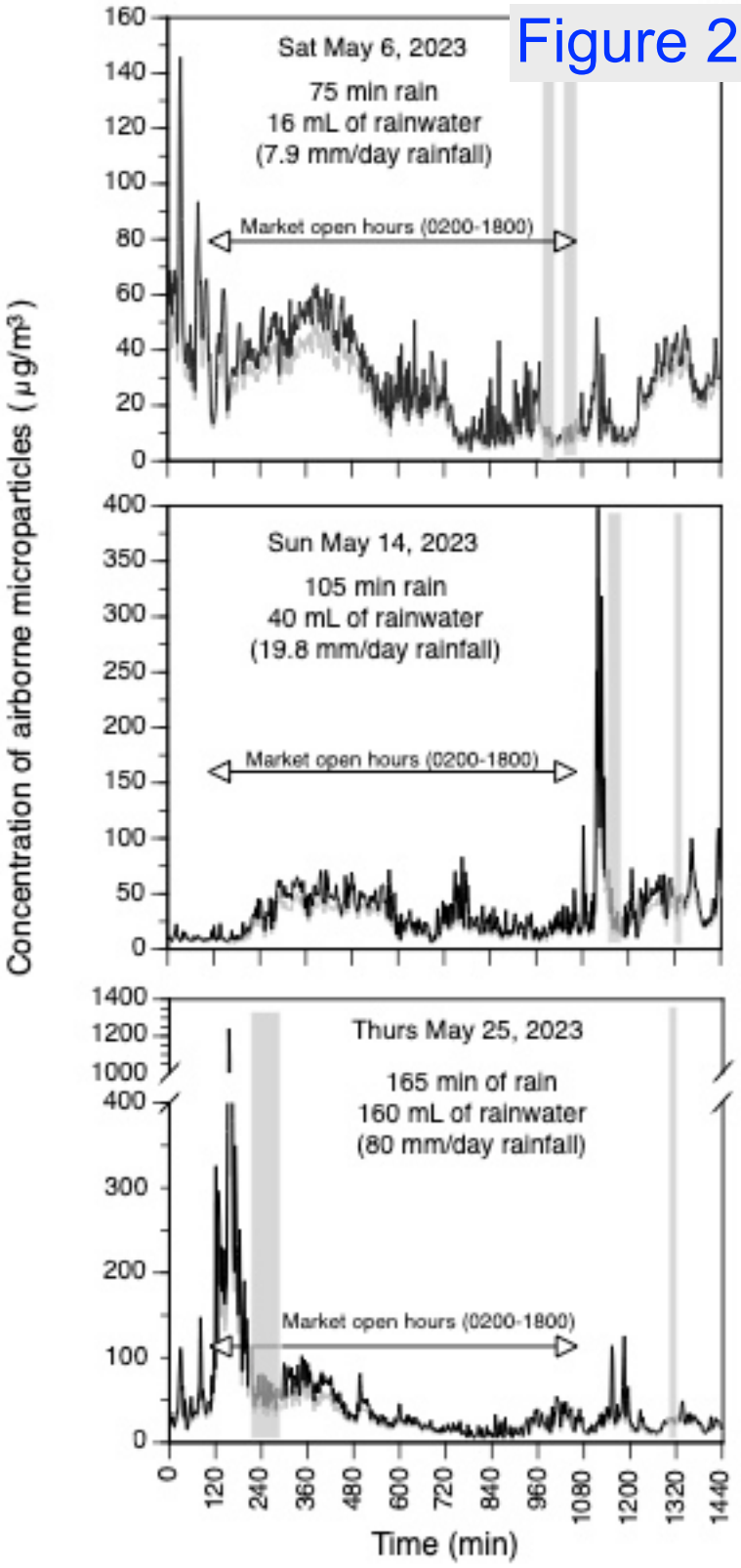


Figure 2
Sat May 6, 2023
75 min rain
16 mL of rainwater
(7.9 mm/day rainfall)
Market open hours (0200-1800)
Sun May 14, 2023
105 min rain
40 mL of rainwater
(19.8 mm/day rainfall)
Market open hours (0200-1800)
Thurs May 25, 2023
165 min of rain
160 mL of rainwater
(80 mm/day rainfall)
Market open hours (0200-1800)
Concentration of airborne microparticles (μg/m³)
Time (min)

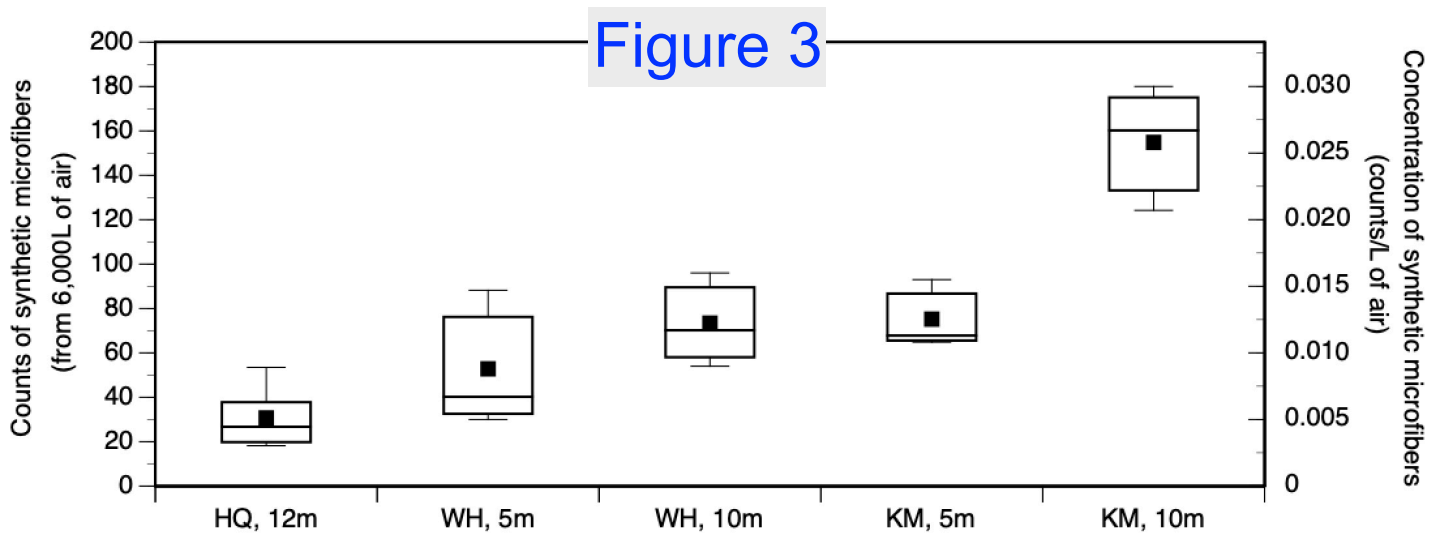
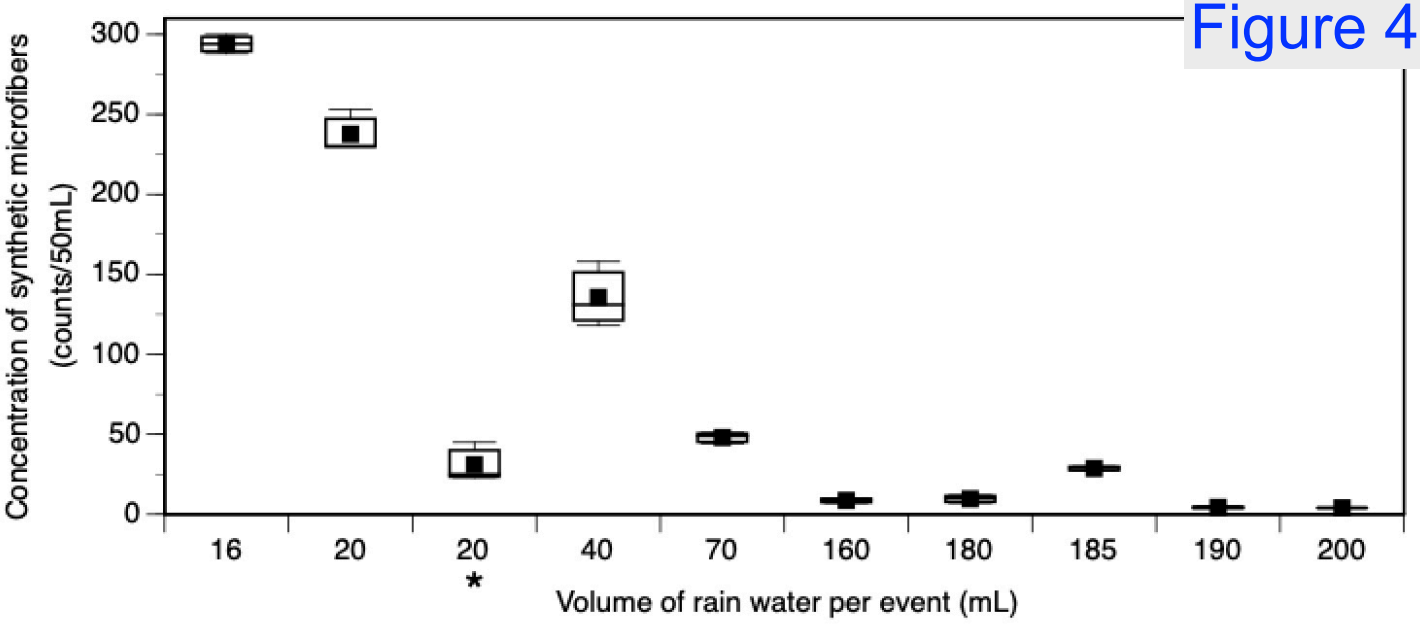
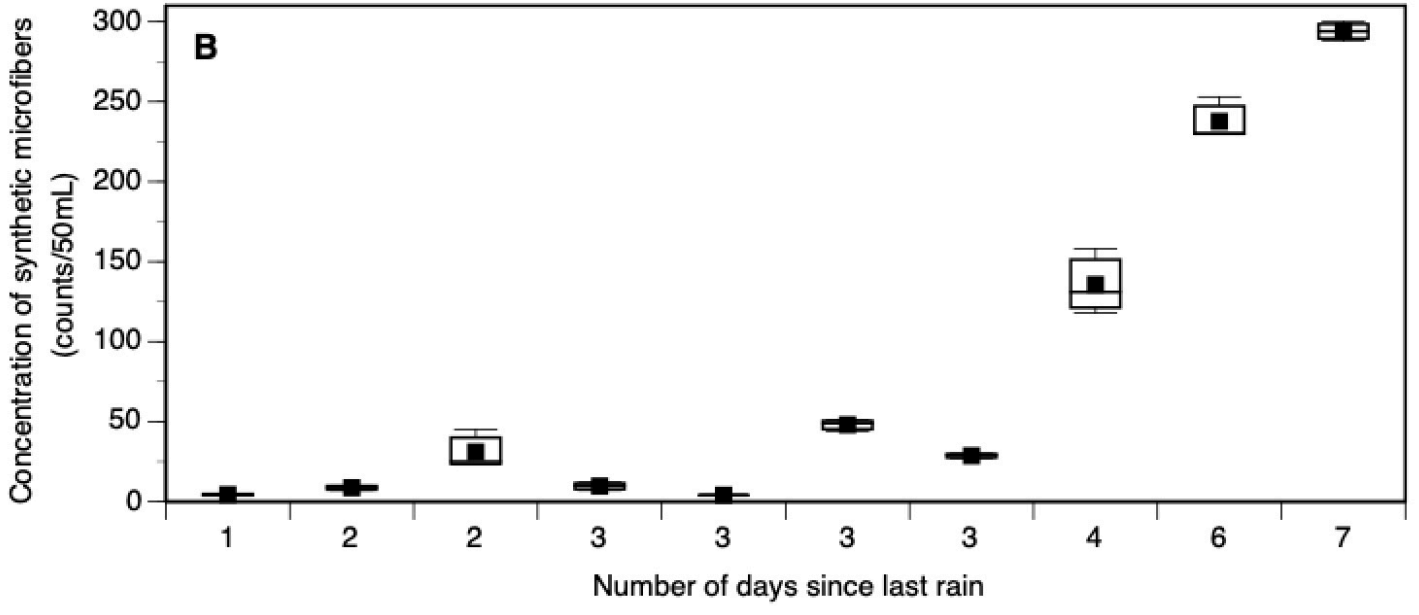


Figure 3
Counts of synthetic microfibers
(from 6,000L of air)
Concentration of synthetic microfibers
(counts/L of air)
200
180
160
140
120
100
80
60
40
20
0
0.030
0.025
0.020
0.015
0.010
0.005
0
HQ, 12m
WH, 5m
WH, 10m
KM, 5m
KM, 10m

Figure 4


Concentration of synthetic microfibers (counts/50mL)
300
250
200
150
100
50
0
16
20
20
*
40
70
160
180
185
190
200
Volume of rain water per event (mL)


B
Concentration of synthetic microfibers (counts/50mL)
300
250
200
150
100
50
0
1
2
2
3
3
3
3
4
6
7
Number of days since last rain

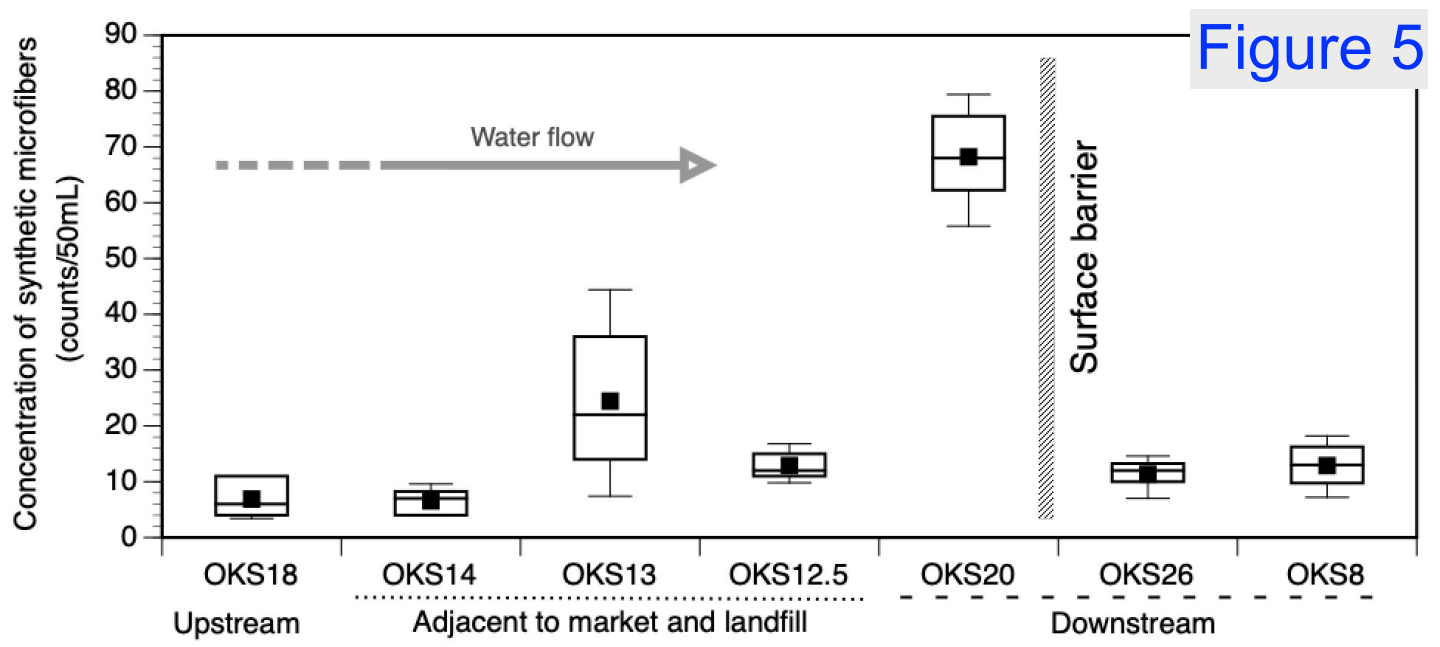


Figure 5
Concentration of synthetic microfibers (counts/50mL)
90
80
70
60
50
40
30
20
10
0
Water flow
Surface barrier
OKS18
OKS14
OKS13
OKS12.5
OKS20
OKS26
OKS8
Upstream
Adjacent to market and landfill
Downstream

Figure 6

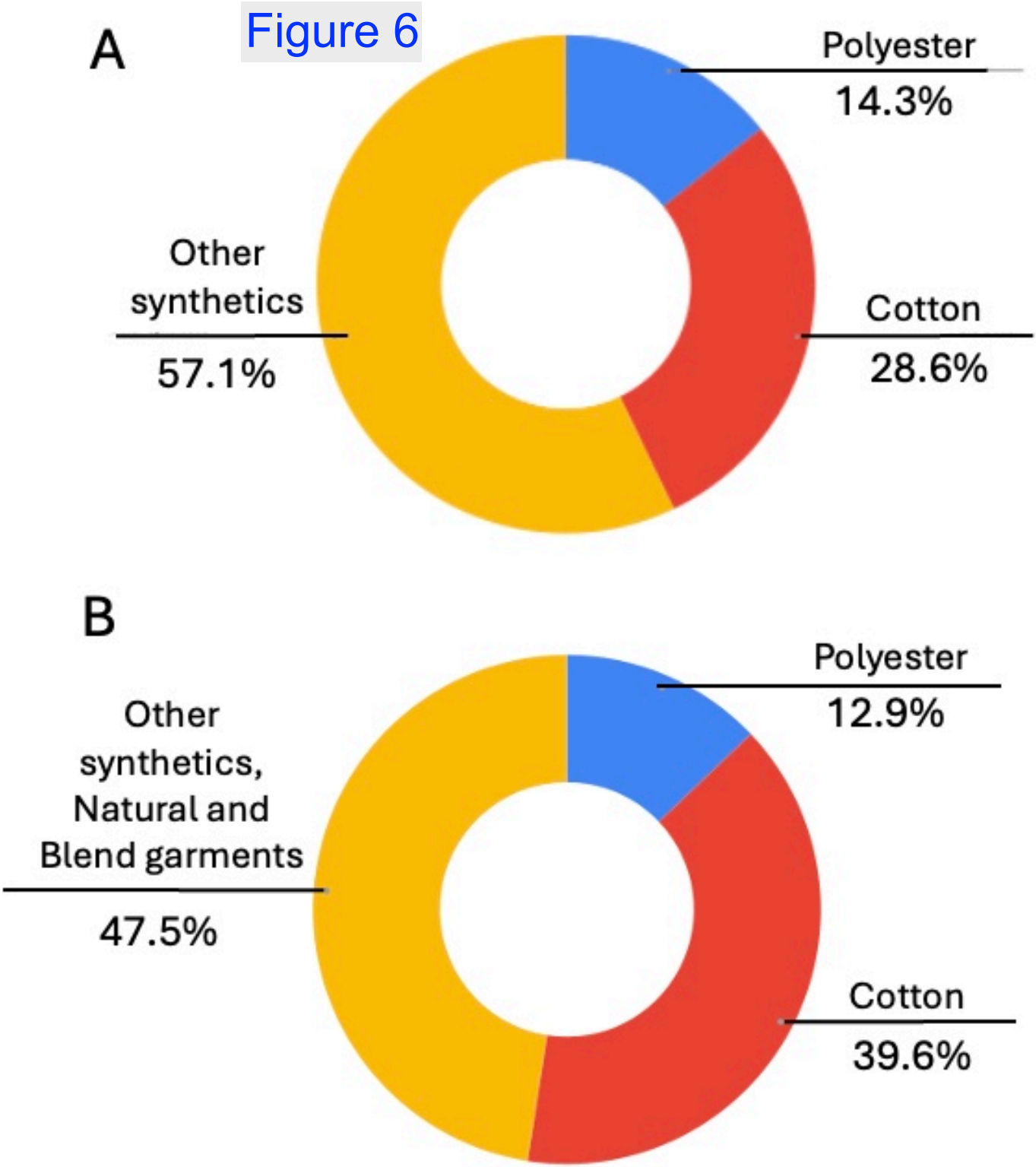
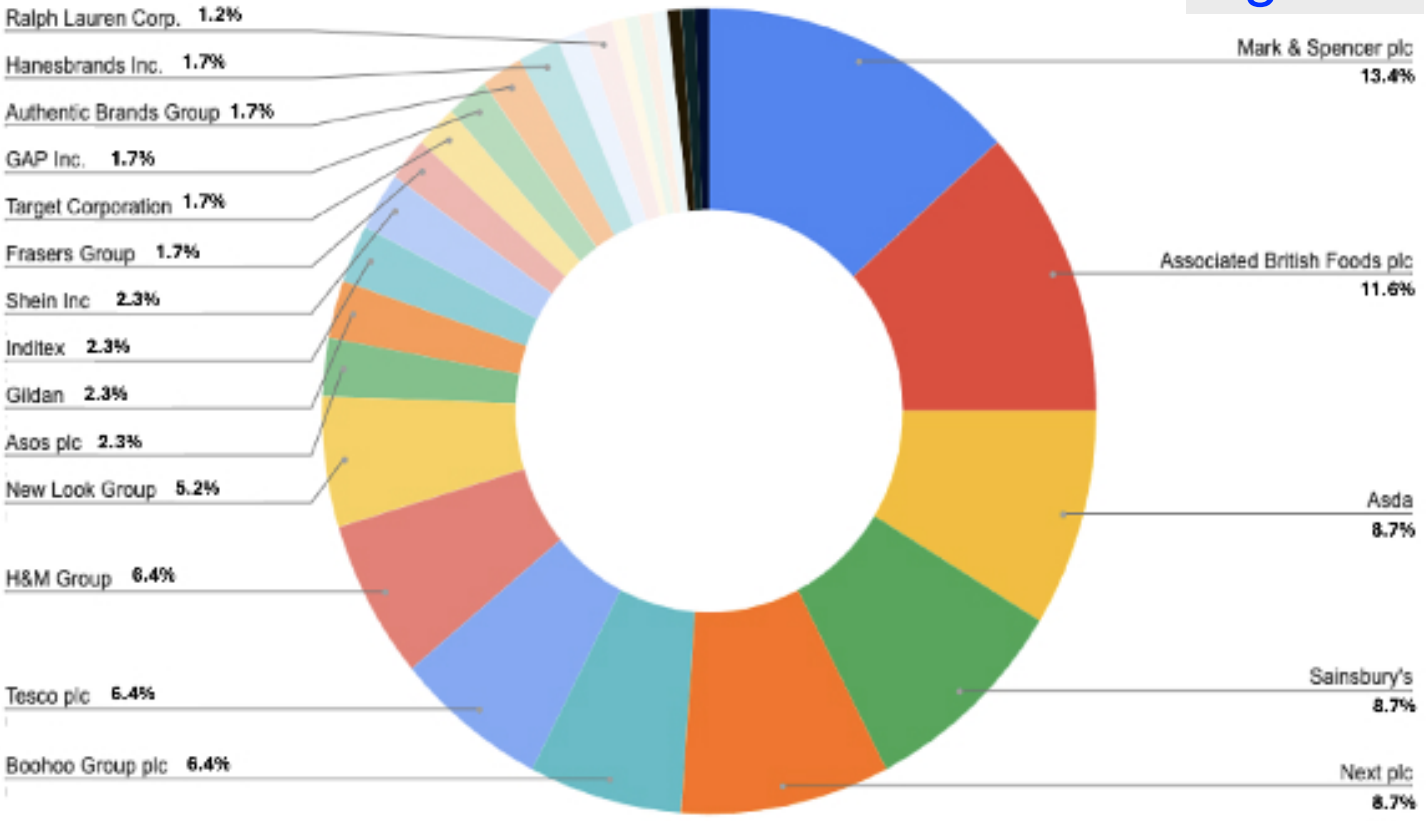
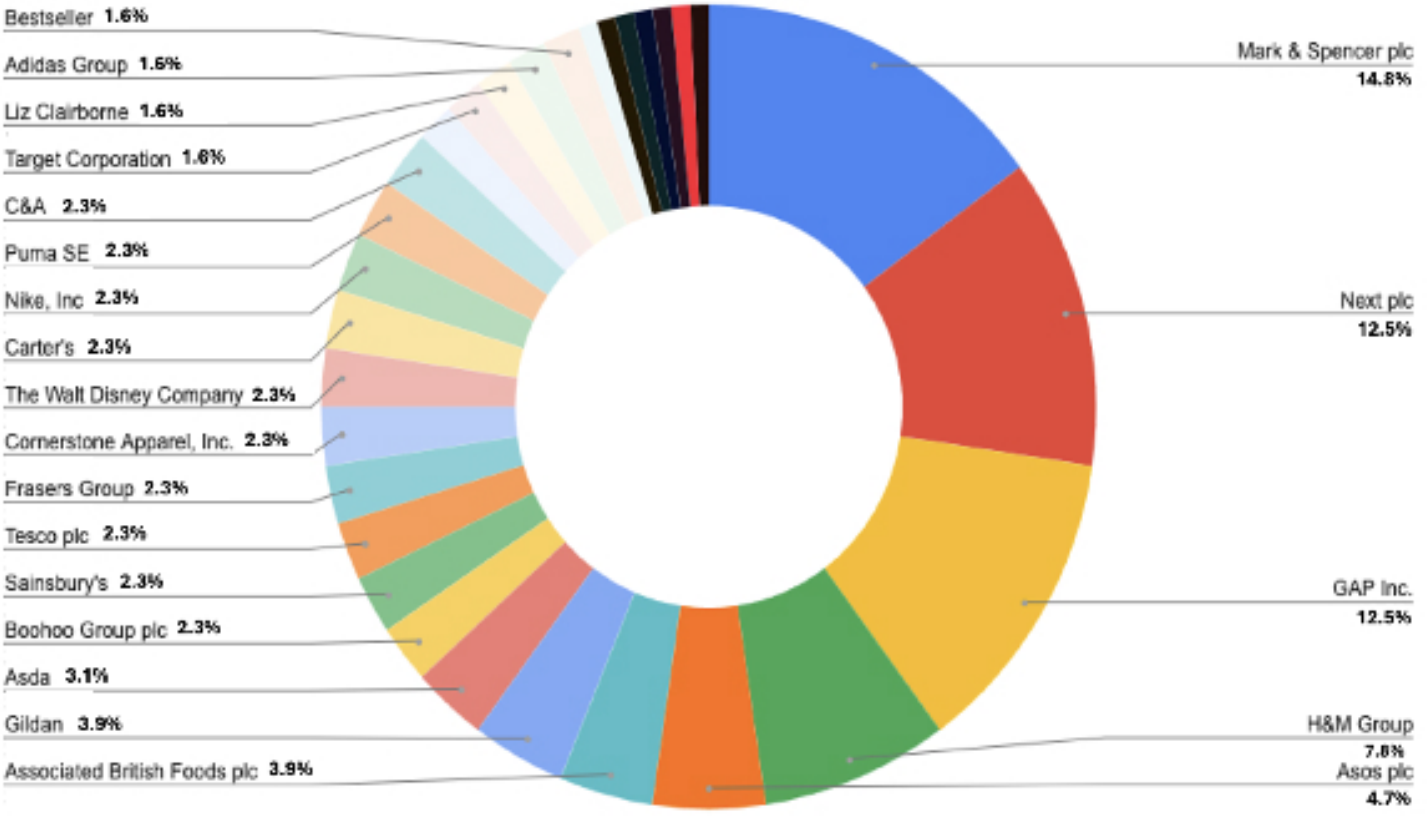

A
Polyester
14.3%
Other
synthetics
57.1%
Cotton
28.6%
B
Polyester
12.9%
Other
synthetics,
Natural and
Blend garments
47.5%
Cotton
39.6%

Figure 7

Market Waste Known Conglomerate %



Beach Waste Known Conglomerate %