Airborne emissions of microplastic fibres from domestic laundry dryers

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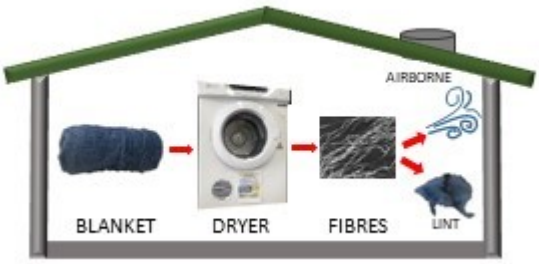
Graphical Abstract:



Mandatory Highlights:

1. Emissions of microplastic fibres from residential dryers into air investigated.
2. Mechanical drying of polyester emits microplastic fibres into the surrounding air.
3. Over 20 mins operation, MP emissions for a 660 g blanket were ~1.6 – 1.8 fibres/ m^3.
4. Lint of 77 ± 22.4 mg ≈$1.1 \times 10^6 \pm 3.2 \times 10^5$ fibres captured by inbuilt filtration.
5. Lint emissions were approximately 0.012% of the blanket mass/ wash.

Abstract:

An emission source of microplastics into the environment is laundering synthetic textiles and clothing. Mechanical drying as a pathway for emitting microplastics, however, is poorly understood. In this study, emissions of microplastic fibres were sampled from a domestic vented dryer to assess whether mechanical drying of synthetic textiles releases microplastic fibres into the surrounding air or are captured by the inbuilt filtration system. A blue polyester fleece blanket was repeatedly washed and dried using the 'Normal Dry' program of a common domestic dryer operated at temperatures between 56 and 59 °C for 20 minutes. Microfibres in the ambient air and during operation of the dryer were sampled and analysed using microscopy for particle quantification and characterisation followed by Fourier-Transform Infrared Spectroscopy (FTIR) and Pyrolysis Gas Chromatography-Mass Spectrometry (Pyr-GC/MS) for chemical characterisation. Blue fibres averaged 6.4 ± 9.2 fibres in the room blank (0.17 ± 0.27 fibres/ m^3), 8.8 ± 8.5 fibres (0.05 ± 0.05 fibres/ m^3) in the procedural blank and 58 ± 60 (1.6 ± 1.8 fibres/ m^3) in the sample. This is the first study to measure airborne emissions of microplastic fibres from mechanical drying, confirming that it is an emission source of microplastic fibres into air – particularly indoor air.

Key words:

Microplastic, emission, air, fibre, dryer, Pyr-GC/MS

1. Introduction

Microplastics are small pieces of synthetic polymers with their size commonly defined as being between 1 μm and 5 mm (Dris, 2016; Henry et al., 2019). While typically defined by the length of their longest dimension, they have also been defined according to their diameter (Napper and Thompson, 2016) or ratio of dimensions (Obbard et al., 2014) for characterisation. Microplastic fibres have been reported as prevalent in all environmental compartments including atmospheric air and deposition (Cai et al., 2017; Dris et al., 2015; Dris, 2016), on beaches (Claessens et al.), surface sea water (Cózar et al., 2014), the water column (Dai et al., 2018), marine sediments (Cole et al., 2011; Van Cauwenberghe et al., 2013), sea ice (Obbard et al., 2014), freshwater lakes (Eerkes-Medrano et al.; Eriksen et al., 2013; Gasperi et al., 2014), sediments (Horton et al., 2016; Klein et al., 2015) and soils (Hurley and Nizzetto, 2018; Nizzetto et al., 2016). Microplastic fibres have been detected in both urban (Dehghani et al., 2017; Dris et al., 2015; Dris et al., 2016) and remote regions (Allen et al., 2019; Free et al., 2014), including the Arctic (Lusher et al., 2015) and Antarctic (Cincinelli et al., 2017) and at high altitudes (Ambrosini et al., 2019) suggesting the capacity for long range atmospheric transport (Allen et al., 2019). Fibres are the most commonly identified microplastic shape reported in the gastrointestinal tracts of biota at all trophic levels; present within food (Barboza et al., 2018) and deposited onto food destined for human consumption (Catarino et al., 2018). Microplastic fibres have also been identified within the human lung (Pauly et al., 1998) and examined in simulated respiration models operated within indoor environments (Vianello et al., 2019), therefore, potentially posing a risk to human health through inhalation and ingestion exposure (Gasperi et al., 2018; Prata, 2018; Wright and Kelly, 2017).

Despite the environmental prevalence and research importance of microplastic fibres (Henry et al., 2019), little is known about their emission sources. Point source laundry emissions of wet lint from simulated industrial (Cocca et al., 2018; De Falco et al., 2018) and residential laundry effluent have been examined using laboratory based (Carney Almroth et al., 2018; Cocca et al., 2018; De Falco et

al., 2018; Hernandez et al., 2017; Jönsson et al., 2018) and commercially available (Browne et al., 2011; Folko, 2015; Hartline et al., 2016; Karlsson, 2014; McIlwraith et al., 2019; N. Bruce, 2016; Pirc et al., 2016; Sillanpää and Sainio, 2017) laundering equipment. Early studies found that >1900 fibres are emitted per wash of a single blanket/ fleece or shirt garment, equating to >100 fibres/ L of captured laundry effluent (Browne et al., 2011). Subsequent research has calculated that each blanket releases approximately 1.1×10^5 fibres per wash (Carney Almroth et al., 2018). Total laundry emissions could release anywhere from 7×10^5 fibres per 6 kg load (Napper and Thompson, 2016) (1.16×10^5 fibres/ kg) to between $6 – 17.7 \times 10^6$ fibres ($1.2 – 3.5 \times 10^6$ fibres/ kg) based on 0.43 to 1.27 g lint weight from a 5 kg load (De Falco et al., 2018). Variability could be attributed to mesh sizes used in different studies, material composition, weave and fibre structure (De Falco et al., 2018), or the use or absence of chemical confirmation methods.

Despite previous studies identifying that laundering clothing is a significant point source for emissions of microplastics (Carney Almroth et al., 2018; De Falco et al., 2018; Hernandez et al., 2017; McIlwraith et al., 2019; Pirc et al., 2016; Salvador Cesa et al., 2017; Sillanpää and Sainio, 2017; Zambrano et al., 2019), as far as we are aware, only two studies have examined the process of mechanical drying of clothing and textiles. Limited to microfibre emissions captured within the internal filtration mechanisms (Pirc et al., 2016), one study established that mechanical drying resulted in greater microplastic emissions captured in emitted microfibres than fibres released into laundry effluent (Pirc et al., 2016). The second study examined laundering of clothing with wash and dry cycles, however dryer emissions were unreported (Zambrano et al., 2019). The hypothesis was that residential dryers contribute microplastic fibres into the surrounding atmospheric environment. The aim of the current study was to determine whether microplastic fibres are captured in inbuilt filtration or are emitted into the surrounding indoor/ outdoor atmospheric environment during the mechanical drying of synthetic textiles.

2. Materials and Methods

2.1 Sampling details

A blue coloured fleece blanket, labelled by the manufacturer as 100% polyester (fleece) and suitable for mechanical drying, was purchased from a prominent Australian retail outlet. The blanket, measuring 152 cm x 203 cm in size, was repeatedly laundered alone consecutively for five individual wash and dry cycles. Gravimetric analysis was conducted both prior to and post laundering cycles using a laboratory balance (Metter Toledo, New Classic MS Balance). The average (± standard deviation) of the dry blanket mass prior to and during consecutive laundry processing was 665 ± 6.73 g.

Laundering was performed within an 8 kg sensor washing machine (Bosch Australia, Clayton, VIC) using a standard 45-minute-cycle at 40 °C and 1400 revolutions per minute (RPM). Samples were mechanically dried for 20 minutes using a 6.5 kg sensor dryer (Electrolux, Alexandria, NSW) representative of the Australian market. The dryer was operated using the 'Normal Dry' program described by the manufacturer as "suitable for everyday fabrics". Technical details of the drying program are unable to be provided by the manufacturer as the internal program varies the RPM and temperature automatically based on a combination of exhaust and ambient air temperature. However, internal maximum temperatures were monitored by using a temperature button (iTemperature, Instrument Choice) during operation both with and without a blanket, with temperatures ranging between 56 and 59 °C, achieved at approximately 10 min of dryer operation. The dryer was installed within a room approximately 21 m^3 in size, with no active ventilation. Access to the room during the sampling program was prevented to minimise air flow and potential contamination. The only air exchange occurred when opening and closing the door immediately prior to and post sampling.

159

160 2.1.1 Airborne particulate matter and inbuilt dryer filter sampling of polyester microfibres

161 Airborne particulate matter was sampled using a high volume total suspended particle air sampler
162 (Komoto, Japan) with a sampling volume of 55 m^3/ hour to collect all airborne particles
163 indiscriminate of size. Samples were collected onto a Whatman GF/A glass filter (1.6 µm), muffle
164 furnaced at 500 °C for 4 hours prior to use. Based on the extraction efficiency of the air sampler and
165 room volume, sampling was limited to the first 20 minutes of dryer operation to avoid over sampling
166 the air. Air samples were collected prior to the experiment as an ambient air room blank, during
167 operation of the empty dryer as a procedural blank and whilst mechanically drying a blanket as five
168 replicate samples (n=5). Microfibres were collected by manually wiping the inbuilt dryer filter after
169 procedural blanks and samples with paper towel, then stored wrapped in aluminium foil. At least ten
170 minutes between each sample collection of air and lint was provided to allow time for deposition of
171 resuspended particles (Cheng et al., 2016).

172

173 **2.2 Microscopy**

174 Analysis of the blanket, total particle count (fibres and fragments) and characterisation (colour,
175 morphology and size) was undertaken using an Olympus SZ-CTV microscope coupled with a Motic
176 Images Plus (Software Version 3.0) camera. To facilitate representative sub sampling, the samples
177 (filters) from two room blanks, one procedural blank and one sample were divided into quarters and
178 microscopically analysed separately to test homogeneity within the sample. Applying an ANOVA test
179 to the null hypothesis that there was no variance between quarters for blue fibre count resulted in
180 an f statistic of 0.173 respectively, with a significance of $p = 0.913$. A Brown-Forsyth test assessing
181 homogeneity within the sample indicated a significance of $p = 0.912$ for blue fibres inferring
182 moderate homogeneity between the quarters – both confirming the null hypothesis. Quartile
183 analysis of the entire filter was acceptable, consistent with the recommendation of Koelmans et al

(Koelmans et al., 2019). Quarter 3 (respective to sampler orientation) was selected for sub sampling as it demonstrated the least variability between sample types and replicates.

2.3 Chemical composition

2.3.1 Fourier-transform infrared spectroscopy (FTIR)

The blanket, both prior to and post laundering, and inbuilt dryer filter contents were characterised using Fourier-Transform Infrared Spectroscopy (FTIR) (Spectrum 2, Perkin Elmer) against a plastic specific spectral library (ATR Polymer Introductory Library, Perkin Elmer). After obtaining background spectra, samples were analysed in absorbance mode from 4000 cm^{-1} to 400 cm^{-1} at 300 scans/ minute, data interval of 0.2 cm^{-1} and resolution of 16 cm^{-1}. A random sub sample of larger visible blue fibres were manually extracted from the filter papers to examine for fibre composition analysis purposes to match to the blanket source. Identification was based on the library spectra with the highest percentage match to the sample. Only matches above 80% were used for positive identification.

2.3.2 Pyrolysis- gas chromatography -mass spectrometry (Pyr-GC/MS)

Pyrolysis gas chromatography mass spectrometry (Pyr-GC/MS) was used for chemical characterisation to verify the blanket material and confirmation/ assist in determining the composition of collected fibres.

Pyrolysis was undertaken using a multi-shot micro-furnace pyrolyser (EGA/ PY-3030D) equipped with an auto sampler (AS-1020E) (Frontier Lab Ltd., Fukushima, Japan) coupled to a GC/MS – QP2010-Plus (Shimadzu Corporation, Japan). Being for identification and confirmation purposes only against the reference material of the blanket and PET analytical standard, the pyrolyser was operated in single shot mode. Based on the optimisation parameters in Okoffo et al (Okoffo et al., 2020), the furnace

was programmed to 650 °C with pyrolysis occurring for 12 seconds. The pyrolyser interface and GC injection port temperature was set at 300 °C with the samples injected at a split of 1:5 onto an Ultra Alloy® 5 capillary column (30 m, 0.25 mm I.D., 0.25 µm film thickness) (Frontier Lab). The GC oven temperature was held at 40 °C for 2 minutes, increased to 320 °C at 20 °C min^{-1}, then held for 14 minutes. Helium was used as a carrier gas at 1.0 mL/ min with a constant linear velocity. The mass spectrometer was operated in full scan mode, acquiring data from 40 to 600 m/z, and the pyrogram was recorded from 2 to 30 minutes.

2.4 Statistical Analysis

All quantification figures are based on a confidence interval of 95%, being ± two times the standard deviation of the mean calculated in Microsoft Excel version 16. Microscopy quantification of one quarter of the sample were extrapolated to the whole filter (number of fibres detected/ m^3 based on Quarter 3 of the sample multiplied by 4) for whole of sample quantifications.

2.5 Contamination controls, QA/ QC

2.5.1 Room Control QA/ QC

Efforts to reduce contamination were undertaken during all procedures. A restricted access room was utilised, cleaned thoroughly with Ethanol 70%, wiping all surfaces with paper towel and vacuuming the rubber floor twice two days prior to commencement. Access was prohibited during sampling episodes. However, contamination was possible through people entering the restricted room on days between sampling episodes; one small open but not operational air vent and an exposed section of 2.6 m x 0.15 m between the upper levels of the building which could have contributed particles to the results.

2.5.2 Sampling and Storage QA/ QC

Sampling and laboratory contamination controls included placing the sample inside of a white cotton pillowcase when not in use and stored within a metal container. The samples were extracted from a new mechanical dryer, wiped clean with paper towel and Milli-Q water prior to each use (Napper and Thompson, 2016). The dryer was operated empty between the room blank and sample. The internal drum was also wiped clean with paper towel between replicates and the inbuilt dryer filter was wiped clean after each procedural blank and sample to remove potential carry over. Workspace controls included wiping all surrounding laboratory surfaces with Ethanol 70% and paper towel prior to use and operating without gloves where possible. Particle free gloves were used where necessary. Green cotton laboratory coats were worn and the clothing of attendees was noted during each sampling process. Subtraction was undertaken for any coloured fibre which was not blue, matching the blanket. The filter papers were stored within aluminium foil and during microscopy blank filter papers were exposed to determine whether baseline subtraction of laboratory contamination was required (Dris, 2016). Contamination mitigation for pyrolysis analysis included using new sample cups for each sample, collecting fibres using Ethanol 70% and MilliQ cleaned forceps, wiped with paper towel.

2.5.3 Analysis QA/ QC

Blank Whatman GF/D (2.7 µm) filters were exposed at all times during microscopy. Although the samples themselves were covered while not directly being examined, establishing baseline deposition contamination during microscopy analysis was prudent.

Particles were collected immediately prior to pyrolysis analysis and deposited into the pyrolysis sample cups under microscopy, confirming particle discharge from the forceps into the cup and correct placement for analysis. Samples were covered with aluminium foil during the physical transfer to the automatic sampler and while loading the samples. The pyrolysis unit itself also features a plastic guard which protects samples from atmospheric deposition during the duration of

processing time.

3. Results

3.1 QA/ QC Results

Contamination during microscopy varied between 0 - 8 particles, averaging across all room blanks, procedural blanks and samples to be 2.6 ± 2.5 (95% CI) fibres of various colours. No blue fibres were detected in the room blank, 0.4 ± 1.1 blue fibres in the procedural blank and 1.7 ± 2.2 blue fibres in the sample. This is considered to be negligible compared to the average number of blue fibres (8.8 ± 8.54 fibres) in the procedural blank and in the sample (58 ± 60 fibres), and therefore no baseline subtraction of contamination during analysis was undertaken. Contamination during microscopy consisted of particles which were 87% fibre shaped and 14% fragments, with the most dominant colour being black. Over 70% of the contamination particles were <50 µm in size. The size fractions and colour characteristics of the contamination is detailed in Figures S1 – S2 of the SI.

3.2 Air concentration

The number of blue particles on the analysed quarter of each sample was 1.6 ± 2.5 fibres in the room blank, 2.2 ± 2.3 fibres in the procedural blank and 14.6 ± 16.96 in the sample. (Figure 1)

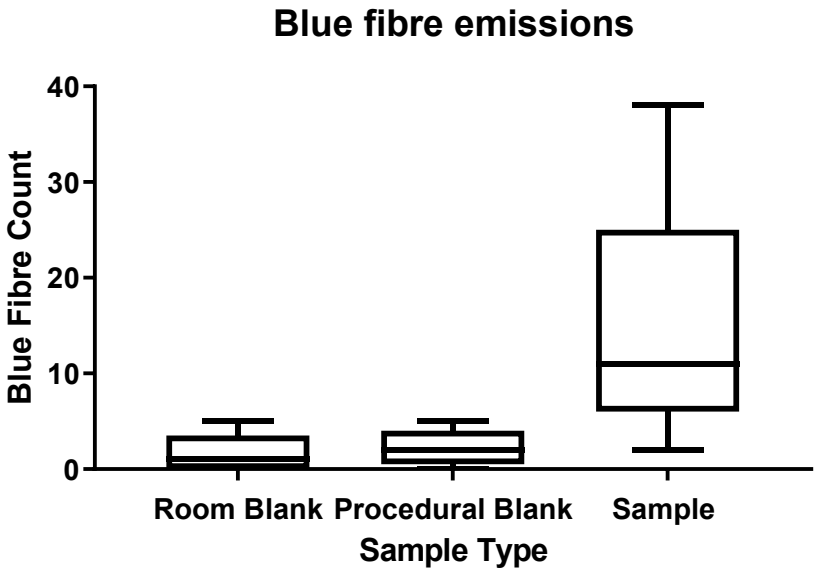


Figure 1: Counts of blue particles per sample type.

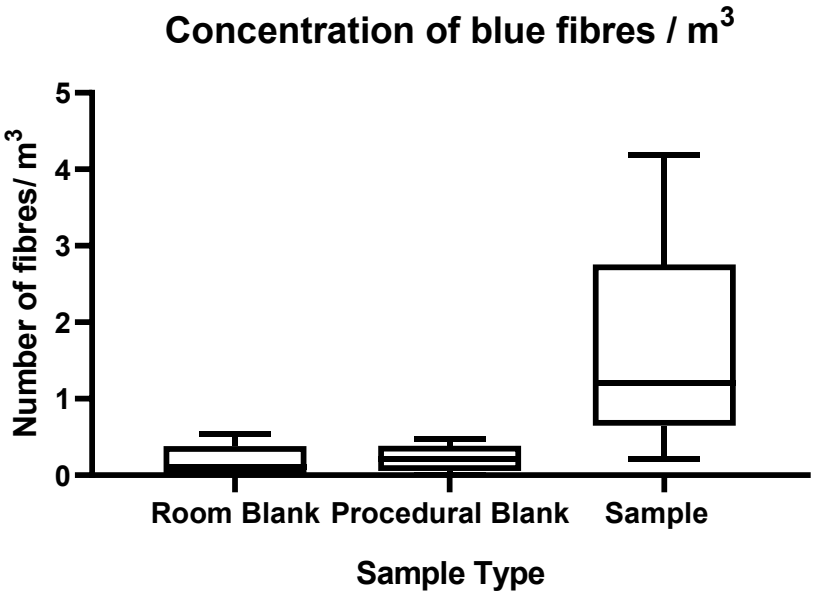
***Box indicates 25th and 75th percentiles, line is the median and whiskers represent minimum and maximum values. *Procedural Blank is the operation of the empty dryer without the blanket sample.**

Extrapolated to whole filter calculations, the room blank contained 6.4 ± 10.3 blue fibres, 8.8 ± 9.6 blue fibres in the procedural blank and 58.4 ± 67.9 blue fibres in the sample.

An ANOVA grouping the room blank and procedural blank against the sample demonstrated an f statistic of 8.9 and a p value = 0.01, indicating with statistical significance that the blanket emits microplastic fibres into the airborne environment.

3.2.1 Particle concentration in the air

Normalised against the operation of the sampler, the number of blue fibres in the air was calculated to be 0.17 ± 0.27 fibres/ m^3 in the room blank, 0.5 ± 0.5 fibres/ m^3 in the procedural blank and 1.6 ± 1.8 fibres/ m^3 in the sample. (Figure 2)



297

298 **Figure 2: A) Quantification of blue fibres per cubic metre (m^3) based on sample type.**

299 ***Procedural Blank references the operation of the empty dryer without the blanket sample.**

300

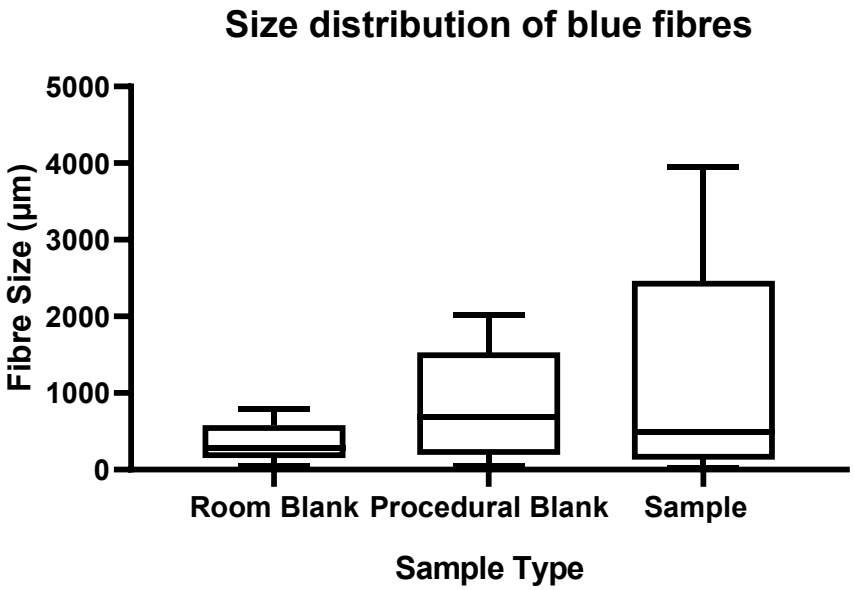
301 **3.3 Air Particle Characterisation**

302 3.3.1 Size Classification

303 All blue particles were fibre shaped. The length of the blue fibres varied from 43 – 799 µm in the

304 room blank (average 341 ± 273 µm), 47 – 2016 µm (average 844 ± 819 µm) in the procedural blank

305 and 19 – 3948 µm (average 764 ± 940 µm) in the sample. (Figure 3)



306

307 **Figure 3: Blue fibre size comparison between sample types.**

308

309 3.4 Particle counts and consecutive laundering

310 The number of blue fibres in the atmosphere increased over consecutive laundering. No stability of
311 fibres release was reached over time from five replicates. This is in contrast to Pirc et al (Pirc et. al;
312 2016), who demonstrated that shedding of a PET blanket during laundering and mechanical drying
313 (captured lint in inbuilt filtration) decreased over consecutive laundering, reducing substantially post
314 wash 3 to account for new garment shedding and stabilising after wash 7. Carney Almroth et al
315 determined that aged garments shed more fibres than new garments. However, overall shedding of
316 fibres from PET fabric during laundering decreased over time, reaching stability for one type of PET
317 weave after wash 5 whilst no stability was reached for a second PET weave after 10 washes (Carney
318 Almroth et al., 2018). Hernandez et al found that laundered PET fabric released decreasing amounts
319 of microplastic fibres, stabilising after wash cycle 3 to 4 depending on laundry surfactant (Hernandez
320 et al., 2019). It is unknown what attributed to the increased shedding of fibres into the atmospheric
321 environment in these results. It is hypothesised that the increase of fibres into the air could be a
322 result of degradation of the fibre from mechanical drying, possibly from the physical abrasion of the
323 fabric within the internal drum of the dryer during rotation or the weakening of the fibres from the

heat generated internally whilst mechanically drying the blanket. The cause remains unknown as does the impact of repeated laundering past 5 replicates, which should be examined further in future research. (Figure 4).

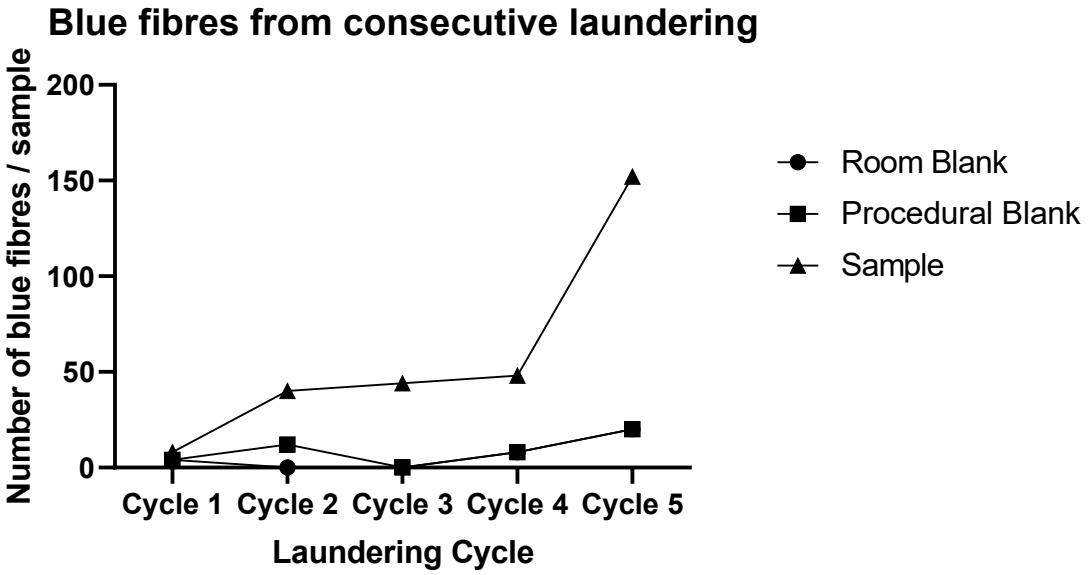


Figure 4: Blue fibre emissions from consecutive laundering.

***Extrapolated whole of filter calculations.**

Chemical and Visual Characterisation of Material and Fibre Composition

3.5 FTIR analysis

FTIR characterised the blanket as poly (1,- cyclohexanedimethylene terephthalate) with 80 % and 78 % accuracy (Figure S3) prior to processing, and poly (1,- cyclohexanedimethylene terephthalate) with 80 % accuracy (Figure S4) for the inbuilt dryer filter contents. Examination of randomly selected visible individual blue fibres proved unsuccessful based on difficulties ensuring correct placement of the particle for examination and library comparisons of very low accuracy.

3.6 Pyr-GC/MS analysis

Fibres from the blanket that were unlaundered; washed and oven incubated at 60°C for 20 minutes,

along with pools of three to six individually picked blue coloured fibres from the samples to determine if they originated from the blanket fibres. Pyrograms from the blankets demonstrated consistent peaks in the chromatograms between replicates in total ion chromatograms (TIC) and indicator compounds/ ions regardless of laundering effects. The chemical composition of the blanket was identified to be polyethylene terephthalate (PET) based on the presence of benzene, vinyl benzoate and benzoic acid. Insufficient indicator compounds were present for the positive identification of Poly (1,-cyclohexanedimethylene terephthalate), identifying discrepancy between FTIR and Pyr-GC/MS. Pyrograms following oven exposure for 20 minutes at 60 °C were consistent with PET. Pyrograms of pools of blue fibres indicated a PET composition in two replicates. All pyrograms are presented in the Supporting Information (Figure SI 5 – SI 7).

3.7 Microfibre emissions from mechanical drying captured by inbuilt filtration

Drying one 660 g polyester blanket generated 77 ± 22 mg of lint which equates to ~1.1 ± 0.3 x 10^6 fibres into the inbuilt filter. This is approximately 0.012% of the blanket mass. Additionally, 54 ± 60 fibres would be released into the air. It is noted these calculations have many associated uncertainties and assumptions, including that the per fibre weight is the same as that used in the calculations by de Falco et al (De Falco et al., 2018) of 7 x 10^{-8}g/ fibre: 6 x 10^6 to 17.7 x 10^6 fibres corresponding to a lint weight of 0.43 - 1.27g of lint = 1.27g/ 17.7 x 10^6 = 7 x 10^{-8} g/ fibre. Inherent variability in dryer emissions also exists regarding dryer characteristics such as different load capacities/ venting options and different shedding propensities of the load composition and fabrics based on manufacture differences and fibre characteristics. As such, future estimates of microplastic emissions from laundering of synthetic materials should include drying as an emission source, however emission amounts require refinement and further research.

4. Discussion

Airborne emissions of 58 ± 60 fibres per 660 g blanket sample were higher than the amount of blue

368 fibres present in the ambient air, being 6.4 ± 9.21 fibres. Subtracting the room blank and procedural
369 blank values, mechanical drying contributes ~2 fibres/ m^3 into the surrounding atmospheric
370 environment. Working from the average of 58 fibres/ 660 g blanket, drying 1 x 660g blanket/ once
371 per week (consistent with Australian dryer operation (Statistics, 2008a; Statistics, 2011)) could emit
372 3 x 10^3 airborne fibres into households and/ or the atmospheric environment per household, per
373 annum. A whole 6.5 kg polyester blanket load (being 6.5 kg wet weight capacity/ average blanket
374 wet weight of 830 g = 7.8 blanket capacity per drying load) could emit 406 ± 468 airborne fibres/
375 load operated with exclusively polyester blankets. These figures do not consider discretionary dryer
376 usage, differences in fabric, variability in usage both nationally and internationally or mechanical
377 variations between dryer types.
378
379 As many of these fibres escape inbuilt filtration or are released when cleaning the filter (Cheng et al.,
380 2016), human health implications should also be considered and examined. When vented indoors,
381 these fibres are likely to accumulate in dust and contribute to microfibre abundance being reported
382 in dust, as well as exposure via dust. Dryer placement within the household, clothing composition
383 and frequency of use are expected to vary between countries. In Australia, 56% of households own a
384 mechanical dryer and operate their dryer once per week (Statistics, 2008a; Statistics, 2008b),
385 however frequency of operation would vary nationally, with differing climates and dryer ownership
386 and operation frequency varies internationally. For example, in 2018, 58% of UK households owned
387 a dryer and in 2017, 42% of households in Germany. In some countries such as the UK, the dryer is
388 located within or adjoining the kitchen (Wendy Wills, 2013) which could potentially increase human
389 exposure to airborne particulates and/ or result in deposition onto food (Catarino et al., 2018) and
390 food preparation surfaces, providing another avenue of human ingestion exposure as well as
391 respiratory exposure.
392
393 **5. Conclusion, limitations and future work**

The major limitations of this work are the small sample size, the examination of one type of polyester blanket and one type of domestic dryer. Limitations also include the inability to calculate mass loss of the blanket and mass of the airborne fibres/ filters, making gravimetric mass balance unachievable. Calculations of fibres per m^3 are approximate, based on variability of the air volumes sampled. Drying time was limited during treatments to the first 20 minutes of the cycle in consideration of room capacity to avoid over sampling the air. Retained water could have impacted the mass based outcomes.

Future work is required to gain an understanding of airborne dryer emissions, including the influence of technical specifications such as dryer composition (condenser/ vented), temperature, RPM variability, textile materials or their length and weave composition impact on the prevalence of emissions into the environment (De Falco et al., 2018), as well as considering general laundry load composition or commercial laundromat emissions. These specifications could be applied into lifestyle or policy adaptations to reduce environmental and human exposure to microplastic fibres.

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Microscope.

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Supplementary Information

Microscopy Contamination Results

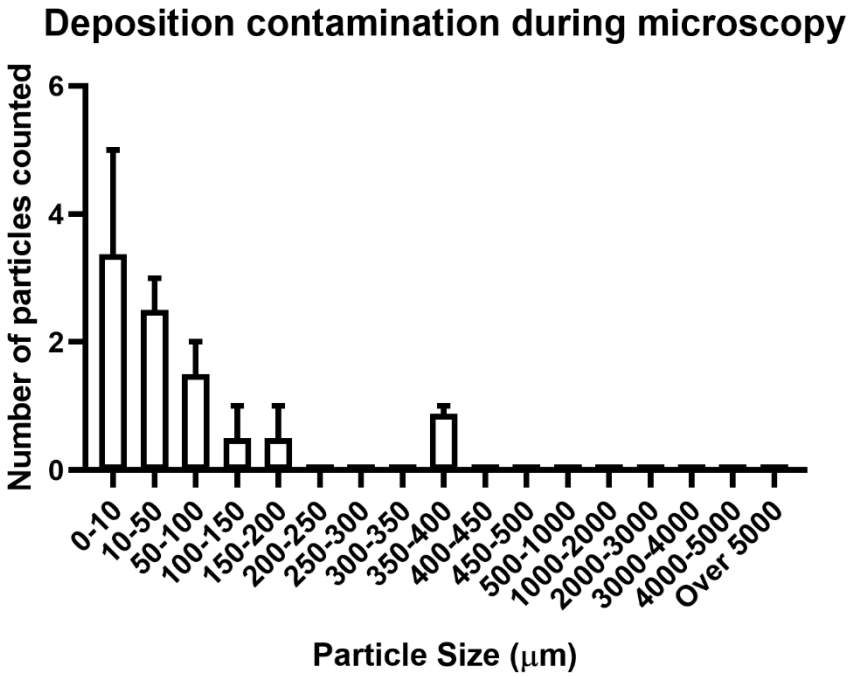


Figure S1: Size fractionation of atmospheric deposition particles within the laboratory environment during microscopy. This was undertaken as part of the QA/QC of sample analysis.

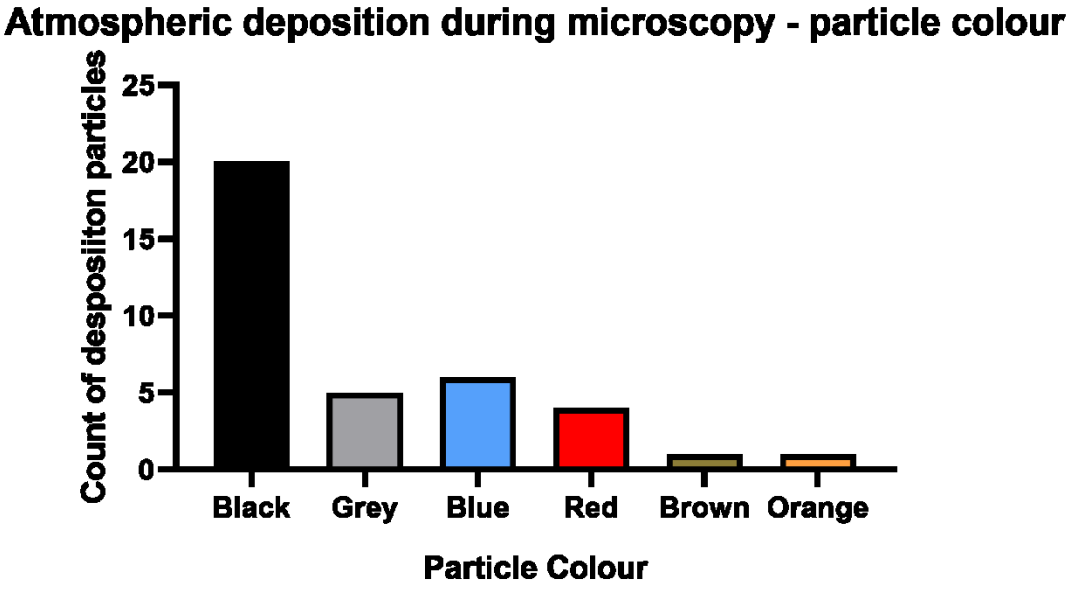
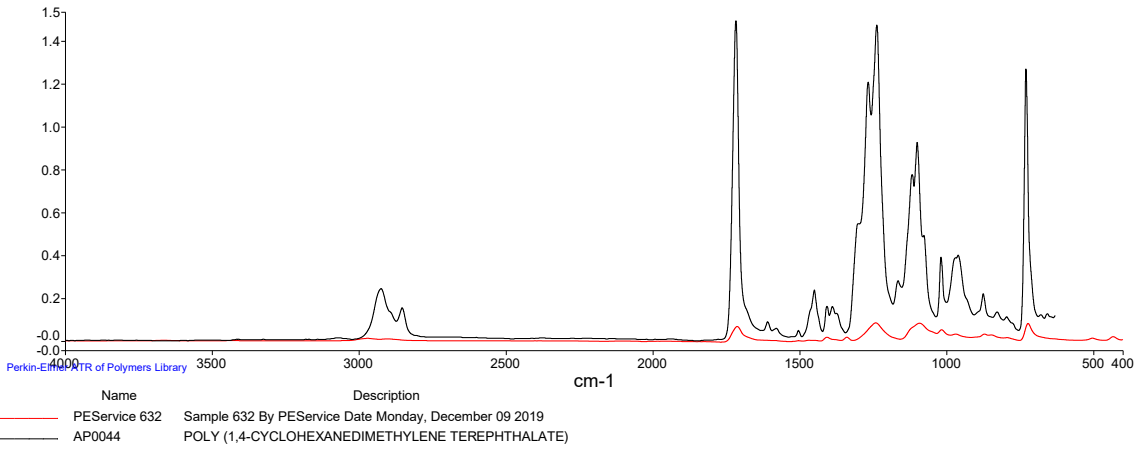
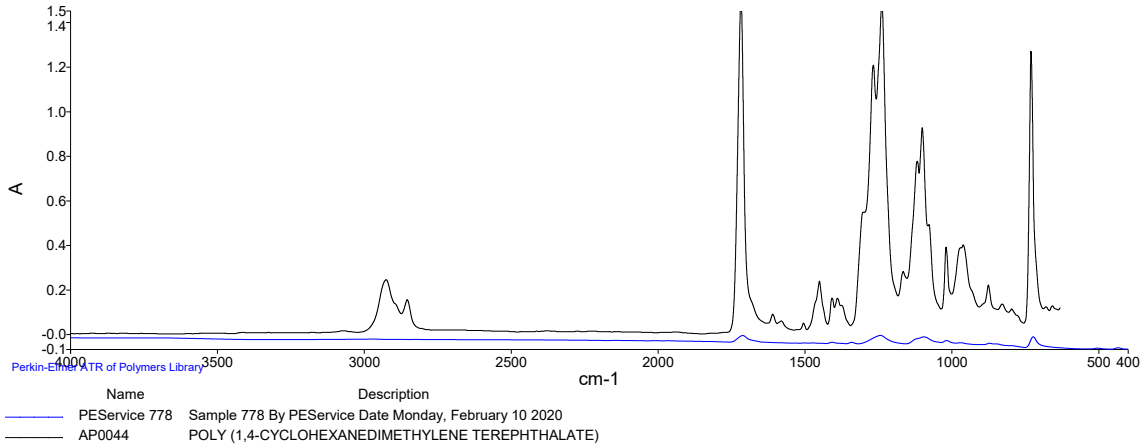


Figure S2: Colour composition of atmospheric deposition particles within the laboratory during microscopy.



Search Score	Search Reference Spectrum Description
0.782612	POLY (1,4-CYCLOHEXANEDIMETHYLENE TEREPHTHALATE)

Figure S3: Fourier Transform Infrared Spectroscopy of the blanket sample showing an identification of Poly (1,4-Cyclohexanedimethylene) from the library search with 78% accuracy.



Search Score	Search Reference Spectrum Description
0.808173	POLY (1,4-CYCLOHEXANEDIMETHYLENE TEREPHTHALATE)

Figure S4: Fourier Transform Infrared Spectroscopy of the lint showing an identification of Poly (1,4-Cyclohexanedimethylene) from the library search with 80% accuracy.

Pyrolysis – GC/MS Results

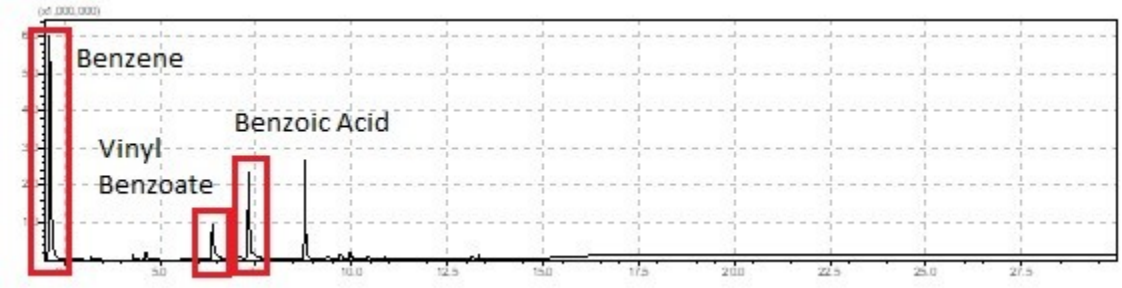


Figure S5: Pyrogram of the laundered blanket using Pyr-GC/MS for chemical characterisation. This was undertaken prior to sampling to obtain the chemical signature of the blanket for chemical identification and comparative purposes with the samples. Indicator compounds of Benzene, Vinyl Benzoate and Benzioc Acid at specific retention times identified the blanket composition to the Polyethylene Terephthalate (PET).

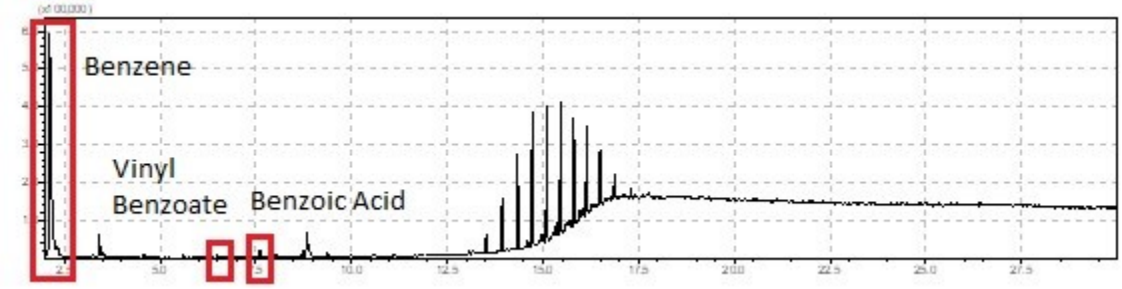


Figure S6: Pyrogram of a pool of 5 visually identified blue fibres using Pyr-GC/MS (n=5). Indicator ions of Benzene, Vinyl Bezoate and Benzoic Acid at the same retention times, characteristic of PET were identified to confirm chemically that the selected blue fibres were sourced from the blanket.

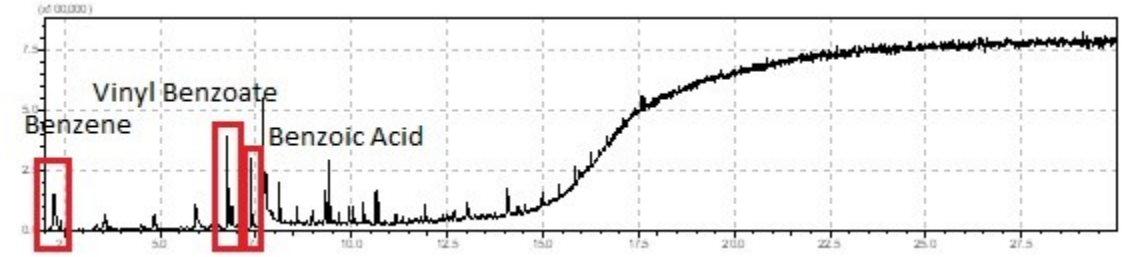


Figure S7: Pyrogram of a pool of 3 visually identified blue fibres from Pyr-GC/MS (n=3). Indicator ions of Benzene, Vinyl Benzoate and Benzioc Acid at the same retention times, again showed consistency that the visually identified blue fibres were also of PET composition.