

WHAT ARE MICROFIBERS?

Microfibers are small fibrous particles that originate from textiles as a result of laundering and wear

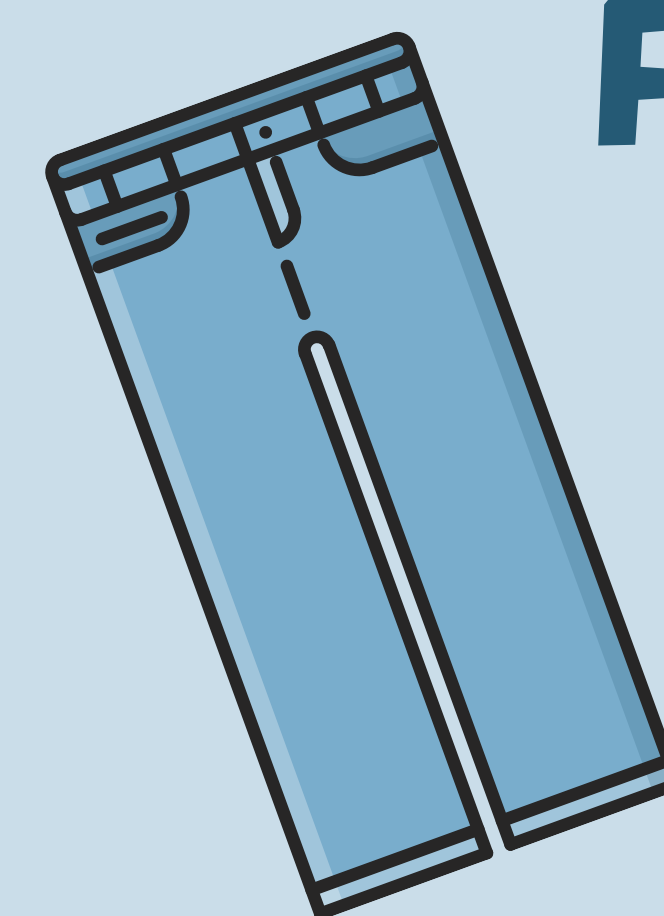


Microfibers can consist of **synthetic, natural** or **semi-synthetic** materials

Cellulosic fibers (e.g., rayon, cotton) can have **numerous chemical additives** (e.g., dyes, flame retardants, preservatives) that may enhance toxicity & persistence in the environment

Anthropogenically modified cellulosic (AC) fibers are often more abundant than synthetic fibers in environmental samples

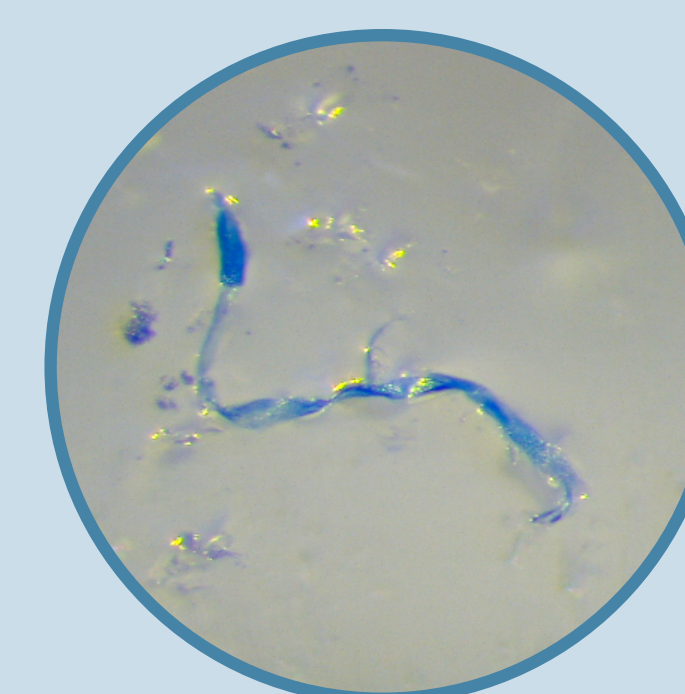
A MODERN BLUE JEAN SOCIETY



It's estimated that at any given moment **half of the world's population** could be wearing denim blue jeans

450 million pairs of blue denim jeans are sold in the US annually

Denim fibers have been documented in aquatic sediments dating from as early as 1950 to present day



Denim microfibers are often associated with an **indigo dye** and have a twisted-collapsed shape characteristic of cotton fibers

The sources, pathways and fate of anthropogenic cellulose fibers in the environment are understudied

RESEARCH OBJECTIVES

- 1 To confidently **document the abundance** of AC fibers in a broad range of geographic sinks
- 2 To investigate WWTP effluent and diffuse sources (e.g., atmospheric transport) as **release pathways** of AC fibers to aquatic ecosystems
- 3 To evaluate the laundering of **denim clothing as a source** of AC fibers (specifically denim fibers)

THE GLOBAL ENVIRONMENTAL FOOTPRINT OF INDIGO DENIM MICROFIBERS



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METHODS

COLLECTION AND PROCESSING OF ENVIRONMENTAL SAMPLES

SEDIMENTS

Surface sediment collection:

- 14 sites within the Canadian Arctic Archipelago
- 3-5 sites in Lakes Ontario and Huron
- 4 shallow lakes within the Greater Toronto Area

Sediments underwent density separation (CaCl_2 , 1.4 g mL^{-1})

Particles >125 μm concentrated onto a filter & counted

FISH

Rainbow smelt collection:

- 2 sites in Lake Ontario
- 2 sites in Lake Huron

Collected using gill nets



(*Osmerus mordax*)

GI tracts dissected & digested (10% KOH 25°C, 14d)

Particles >125 μm concentrated onto a filter & counted

WWTP EFFLUENT

WWTP effluent collection:

- 2 WWTP that discharge to Lake Ontario in 2018 and 2019

Triplicate 24 h composite samples at each site (2.2 ± 0.5 L)

Collected using peristaltic pumps

Effluent underwent density separation (CaCl_2 , 1.4 g mL^{-1})

Particles >125 μm concentrated onto a filter & counted

MICROFIBER CHARACTERIZATION

A subset of microfibers (17-35%) analyzed using μ -Raman spectroscopy

AC fibers were identified using a multi-criteria decision-process (Athey, et al. *in prep*)

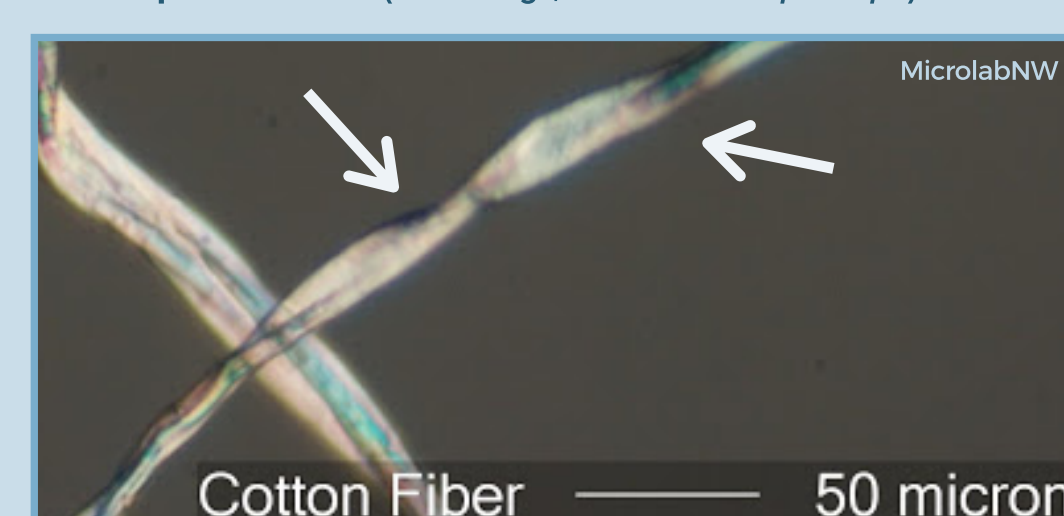


Figure 1. Cotton fibers contain a distinct twisted morphology

Microfibers made up 87-90% of anthropogenic particles found in all sediments and fish

AC fibers made up 40% of fibers ingested by fish & 22-41% of fibers found in all sediments

Denim fibers were the most abundant type of AC fiber in sediments (47%)

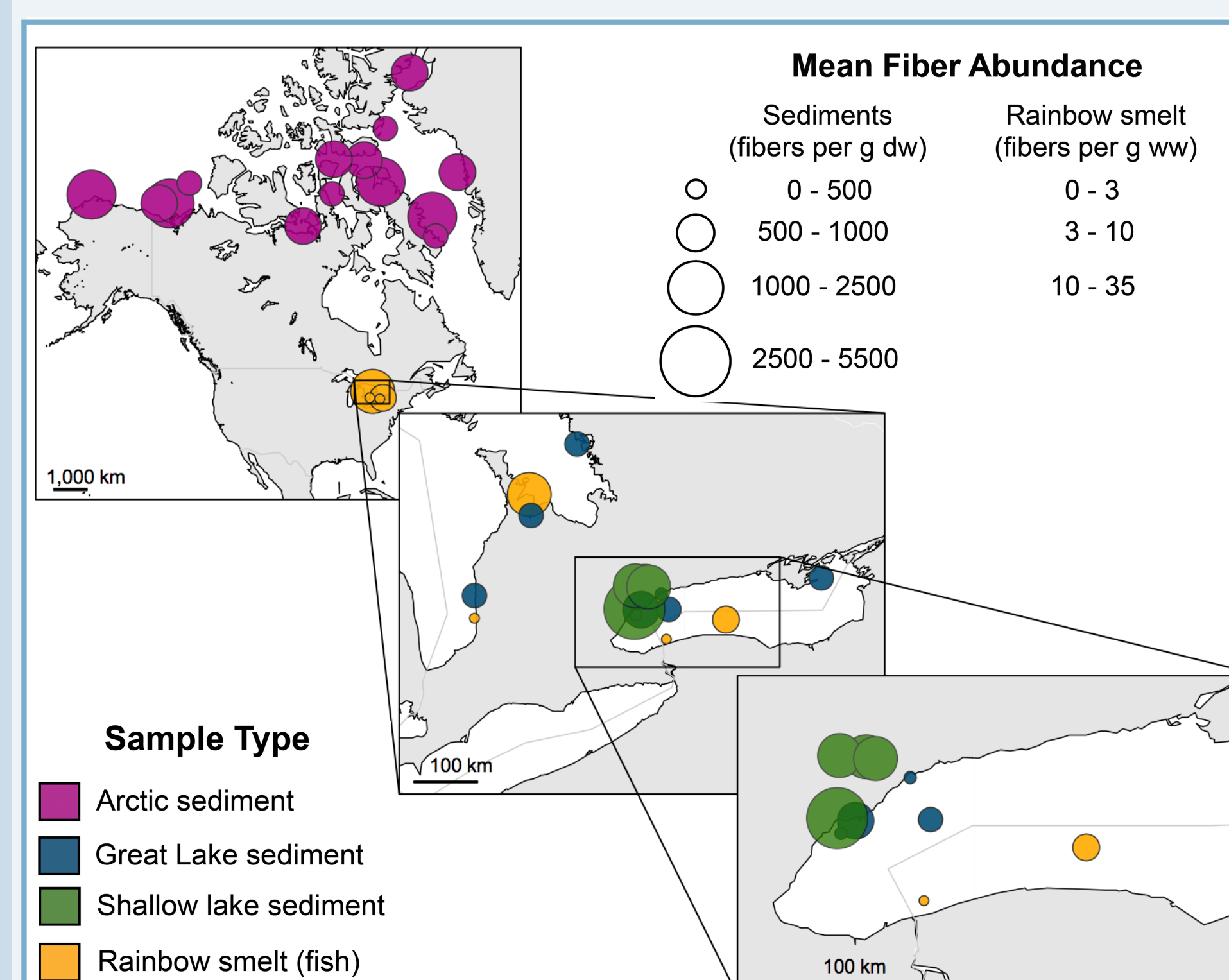


Figure 2. Spatial distribution of mean fiber concentrations found in sediments and fish.

RESULTS

Limited direct sources of microfibers to **Arctic & shallow lake sites**, as well as no correlation between distance to WWTP & fiber abundance in fish or sediments, **indicate diffuse sources of denim fibers**

92% of particles in WWTP effluent were fibers

25% of blue fibers were identified as denim in **WWTP effluent**

Most fibers found in WWTP effluent were **cotton (47%)**, including denim, and **polyester (13%)** indicating this is a **pathway of fibers** from laundering to surface waters

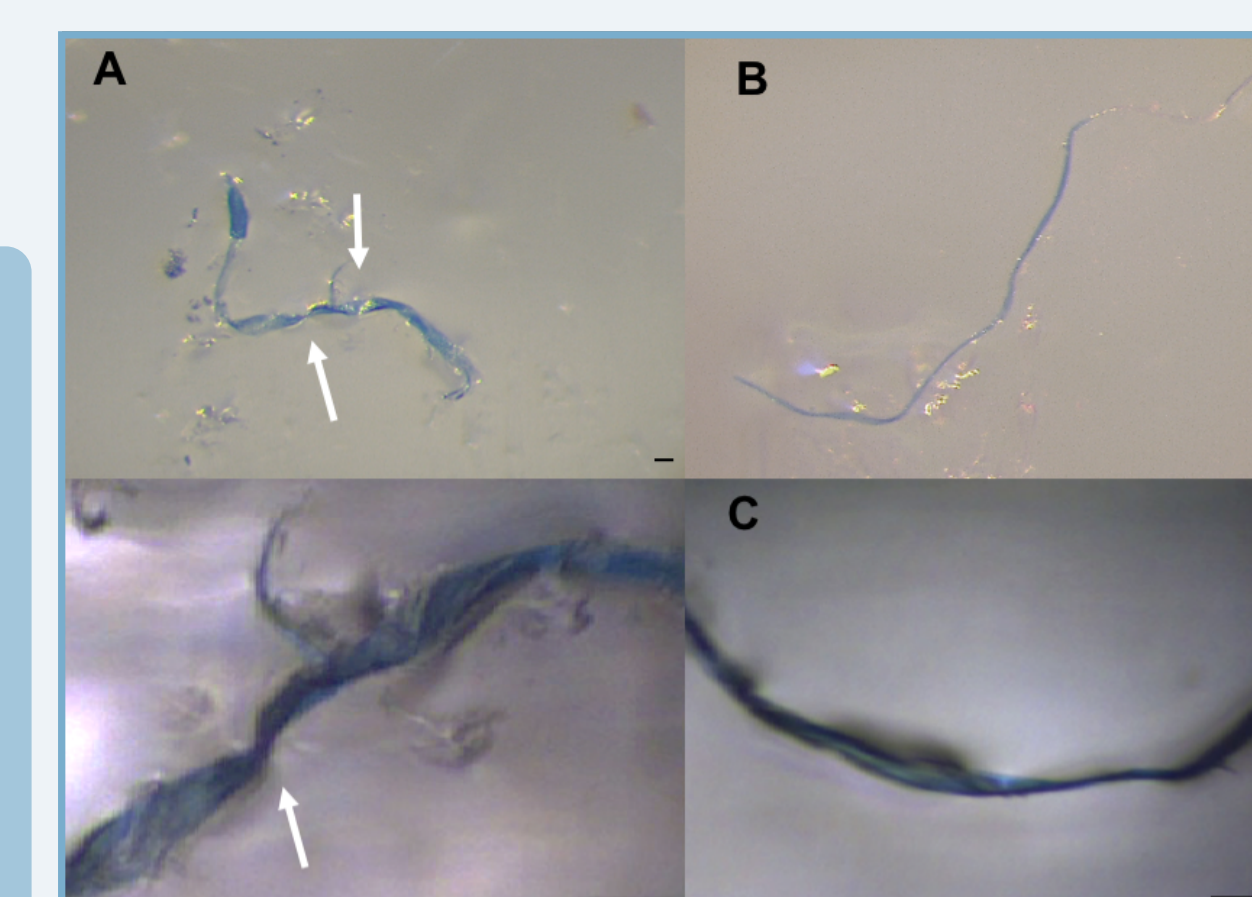


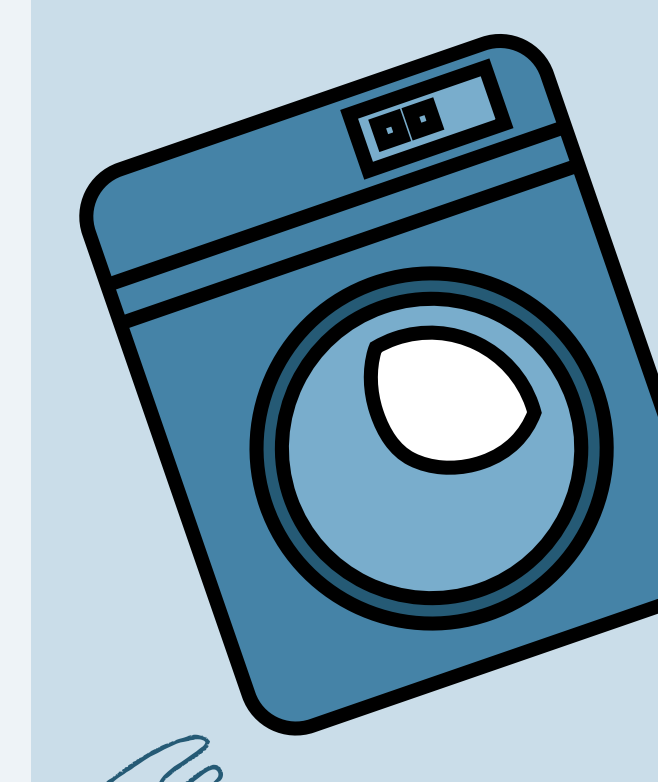
Figure 3. Denim fibers found in (A) blue jeans, (B) WWTP effluent, and (C) Arctic sediments

Denim fibers **released from blue jeans** were similar in material composition and morphology to fibers found in the aquatic environment (**Figure 3**)

New jeans ($111,00 \pm 1790$ fibers) shed more fibers than **used** ($56,900 \pm 4490$) & **distressed** ($95,800 \pm 16,200$) jeans

82% of fibers released from jeans were denim fibers (cotton with indigo dye)

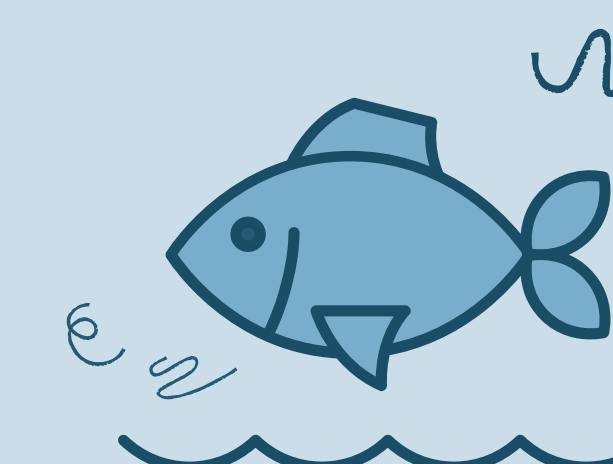
CONCLUSIONS



We estimate the average **Canadian household** releases **12.5 ± 0.01 million indigo denim fibers** from washing blue jeans into wastewater annually

AC fibers, including denim, are of ecological concern as they are **ingested by biota**

More research is needed to understand the pathways, persistence & effects of **'natural' microfibers** in the environment



Here we show blue jeans, one of world's most popular garments, are a source of microfibers to the aquatic environment from temperate to Arctic regions

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REFERENCES

1. Kroon, et al. (2018). DOI: 10.1038/s41598-018-34590-6
2. Xue, et al. (2017). DOI: 10.1021/acs.est.7b00701
3. Ladewig, et al. (2015). DOI: 10.1021/acs.est.5b04754
4. Sanchez-Vidal, et al. (2018). DOI: 10.1371/journal.pone.0207033
5. Grbić, et al. (2020). DOI: 10.1016/j.watres.2020.115623
6. Le Guen, et al. (2019). DOI: 10.1016/j.envint.2019.105303
7. Stanton, et al. (2019). DOI: 10.1016/j.scitotenv.2019.02.278
8. Memon (2017). http://www.journalijar.com/uploads/474_1JAR-17605.pdf
9. Miller and Woodward (2007). DOI: 10.1111/j.0964-0282.2007.00024.x
10. Paul (2015). DOI: 10.1016/B978-0-85709-843-6.00001-9
11. Turner, et al. (2019). DOI: 10.1007/s10933-019-00071-7
12. De Falco, et al. (2020). DOI: 10.1021/acs.est.9b06892