

Review of Manuscript 118053v1

General points

Manuscript 118053v1 provides very interesting new data on a source of microplastic pollution that – to my knowledge- has not yet been covered elsewhere: Parking lots. This is even more important as the new data refer to microplastics in atmospheric fallout from an area with scant data: the Arctic. The MS is well-written and professional English is used throughout. Nevertheless, I suggest a few changes (see marked pdf). However, in my opinion several points need to be addressed before I can recommend its publication. As it is quite a few points, it adds up to a major revision, I am afraid, but should be doable.

My main criticism would be that because of the sampling approach chosen, we cannot be sure that the samples are comparable, if I understood correctly. We don't have any idea when and for how long dust could have accumulated in each area. This could have been circumvented by deploying the same type of pre-cleaned container at each location for the same period. This would have resulted in equal sample sizes and known deposition times, i.e. reduced uncertainty and increased comparability of resulting data. The authors briefly mention this in their critique at the end, but I think it merits further mention, e.g. also when discussing the results, especially in terms of significant differences between treatments.

While the Literature is well-covered in most areas, I recommended a few additional newer references, which might add background or should be cited in the context IMO.

The MS should have hypotheses, a necessity in any scientific study in my opinion. And you do have hypotheses judging from your sampling set up, but unfortunately you do not state them clearly. I suggest you add null-hypotheses at the end of the introduction and use them to structure your MS in each part, i.e. Materials, Results, Discussion.

More detail is needed to transparently disclose how the data were obtained. Your study should be reproducible. Currently, crucial information is lacking for this 😞 (more info below).

Abstract

L. 20: Add a (half-) sentence stating your hypotheses (s. below, Introduction).

Hard to read with so many numbers in one place. I suggest to remove at least the 'n = 8' here to ease the reading flow.

Add a sentence about the analysis used to identify microplastics in the abstract (visual pre-selection and verification/identification of subsample via ATR-FTIR down to a minimum particle size of 50 µm).

Introduction

L. 37: Add 'Particle' or 'item'

L45: Add 'fibers'

L. 46: Again, you mention textiles as a source (as in previous sentence, although this MS doesn't deal primarily with textiles). I suggest adding another source, either MPs from tyre wear, agriculture or abrasion of paints (e.g. Brännström, S., Rosengren, H., Wrange, A.-L., Olshammar, M., 2023. Microplastic Emissions from Paint. IVL <https://www.oneplanetnetwork.org/knowledge-centre/resources/microplastic-emissions-paint>)

L. 48/49: Please add big & comprehensive Review paper: Allen, D., Allen, S., Abbasi, S., Baker, A., Bergmann, M., Brahney, J., Butler, T., Duce, R.A., Eckhardt, S., Evangeliou, N., Jickells, T., Kanakidou, M., Kershaw, P., Laj, P., Levermore, J., Li, D., Liss, P., Liu, K., Mahowald, N., Masque, P., Materić, D., Mayes, A.G., McGinnity, P., Osvath, I., Prather, K.A., Prospero, J.M., Revell, L.E., Sander, S.G., Shim, W.J., Slade, J., Stein, A., Tarasova, O., Wright, S., 2022. Microplastics and nanoplastics in the marine-atmosphere environment. *Nature Reviews Earth & Environment* 3, 393–405.

L.52: Add new additional process: "soil detachment via electric forces" (Zhang, Z., Li, P., Hu, W., Li, J., Li, H., Wang, R., Li, Q., Zou, X., Zhou, B., Chang, C., Guo, Z., 2025. Electric forces can enhance the emission of microplastics into air. *Environmental Pollution* 376, 126405).

L. 51: Add after Brahney et al.: Özen, H.A., Mutuk, T., 2025. The influence of road vehicle tyre wear on microplastics in a high-traffic university for sustainable transportation. *Environmental Pollution* 367, 125536.

L. 54: Add after Evangeliou et al.: Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdt, G., 2019. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science Advances* 5 (8), eaax1157.

L. 57: Add to Wright/Dris et al.: Mutshekwa, T., Mulaudzi, F., Maiyana, V.P., Mofu, L., Munyai, L.F., Murungweni, F.M., 2025. Atmospheric deposition of microplastics in urban, rural, forest environments: A case study of Thulamela Local Municipality. *PLOS ONE* 20 (3), e0313840.

L 57 Replace 'Nonetheless' with 'However'

L. 61 Add Bergmann et al. 2022 and potentially Bergmann et al. 2019 to AMAP reports: -Bergmann, M., Collard, F., Fabres, J., Gabrielsen, G.W., Provencher, Jennifer F., Rochman, C., Van Sebille, E., Tekman, M.B., 2022. Plastic pollution in the Arctic. *Nature Reviews Earth & Environment* 3, 323–337.

-Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdt, G., 2019. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science Advances* 5 (8), eaax1157.

L. 71-78: As stated above, please formulate and add null hypotheses to be tested and discussed throughout the manuscript. What did you expect to find in road dust collected

from commercial vs industrial areas vs parking lots and in MPs vs tire wear particles, for example? Please state hypotheses clearly and pick them up again and verify/falsify them in your results and discuss why this could be so in the discussion. You could even use this to structure your paper, e.g. as headlines.

Material and Methods

L. 113: Replace: 'the addition of unwanted microplastics into' by 'contamination of'.

L. 125: Replace 'capture microplastics unintentionally added to by 'quantify contamination of'.

L. 127: Replace 'methods' by 'sampling procedure'.

L. 141: Please, add details on: Was the natural fibre brush and metal dustpan pre-cleaned? How? What natural fibers was the brush made of?

L. 143: Please, provide details on the width of the transect(s). Was it always the same width? If not, an additional Table might be needed to give the details. This is crucial information as it forms the basis of your area covered estimates and data conversions to m^{-2} .

L. 142-45: Does this mean that the sampling always began 5 days after a rain event if there was wind $<4 \text{ m/s}$? Or did it vary? If it varied, please provide details on how conditions had varied in the MS as this might have affected your deposition rates and thus the MP quantities recorded.

L. 148: Why did you not sieve at 5 mm, which is the most used definition of microplastics? This way you introduced inconsistency with other studies, which is not good as it hampers - yet again- comparability of the results. Please, mention this in your critique at the end.

L. 150: Were the paper bags de-contaminated prior to use? You don't know what happened at the manufacturing site. Please, provide details on this as it might be a source of contamination.

L. 217-218: *"The concentration of microplastics and tire wear particles were polymer corrected by multiplying the concentration by the proportion of particles identified as plastic by FTIR."*

I don't fully understand what exactly you did here or how you did this. Please, give a very detailed account of how exactly you did this interpolation as this is super-important for the resulting data presented, this is not the place for brevity. Maybe, providing an example calculation would help.

If I understood correctly, you only analysed a subset of the suspected microplastic particles (after applying your visual and hot-needle criteria, on particles matching at least 2 criteria). Please, describe in the MS, how did you decide, which of all these suspect particles to analyse by FTIR?

Please, give an account as to how many of the suspect particles in each sample turned out to be plastics. I suggest you provide an extra table on this which could go into the Supplement. And, even more importantly, please describe in an understandable detailed way, how you extrapolated from this subset to all the suspects and derived the data that you report. Maybe a flow graphic or something like this would help to understand this important process.

Please, describe how you calculated the area and provide the data for each transect done (length and width, which presumably area calculations are based on) in a supplementary Table (as stated above). This is important, so future researcher can potentially re-calculate the data, e.g. if they gave data per linear m rather than m².

Please, describe how you calculated the percentage of polymers presented in L303-308 and L335-341.

L. 235. Please, justify in the MS why a non-parametric test was chosen.

L.238: A Bonferroni or a Bonferroni–Holm correction is needed for the multiple Mann-Whitney comparisons to avoid Type 1 errors (finding significant differences, where there are none). Please, do this and state the resulting alpha levels used.

Throughout the MS, please provide the actual p-values and other sample statistic metrics rather than only " $p < 0.05$ ".

Please, provide more details on how the Simpson diversity was calculated incl. the formula used. Please, bear in mind that your methods should be repeatable.

Table 1:

Replace 'Date' by 'Day', or better, provide the full dates in the table.

Replace Tire wear with 'Tire particles' or 'Tire wear particles'

Replace '#' by 'n' to be consistent.

Provide data on how many MP particles of each sample were subject to ATR-FTIR and how many suspect MP particles you had (based on your criteria).

Table 2

Replace Site No with Number of sites

Table 4 / Diversity analysis

Of course, you are more likely to find a greater diversity of particles if you have a larger sample size (e.g. industrial roadsides (n = 8) vs parking lots and commercial road sides (n = 4 each) (e.g. [Roswell et al. 2021](#)). To overcome this imbalance and compare them properly, you could randomly select a subset of 4 of the 8 samples, and repeat the statistical tests and report these results. If you follow this procedure, please explain this in the data analysis section of Material & methods.

Fig. 1

Please, add Latitude and longitude to the map.

Legend: Replace Parking Lot's by Parking Lots

Fig. 2

Delete 'Microplastic images' as this is redundant to following text.

Add 'suspected' as you can only be certain that the particles were plastics after verification by FTIR analysis.

Please, use the same font size for the size numbers shown.

Fig.3

Rephrase: „Lowercase letters indicate statistical significance“ with “Lowercase letters and the dashed line indicate groupings based on significant differences.” Omit the Kruskal Wallis test statistic ($p < 0.005$), as actually this should refer to the **Bonferroni-corrected** Mann-Whitney comparison. But these have to be reported.

Please, explain the different y-axes in A and B. I don't understand this at all and am not sure if I like it or if it should be done like this. At the very least, you should provide an explanation in the Figure legend and also add something on the y axis itself so as to explain to which values this actually refers to.

Fig.4

Delete 'Proportion of microplastic shapes' as it is redundant.

It is difficult to grasp the jist of all these figures. It might be a lot easier to compare them as 2 Grouped and Stacked percentage barplots as in this example:

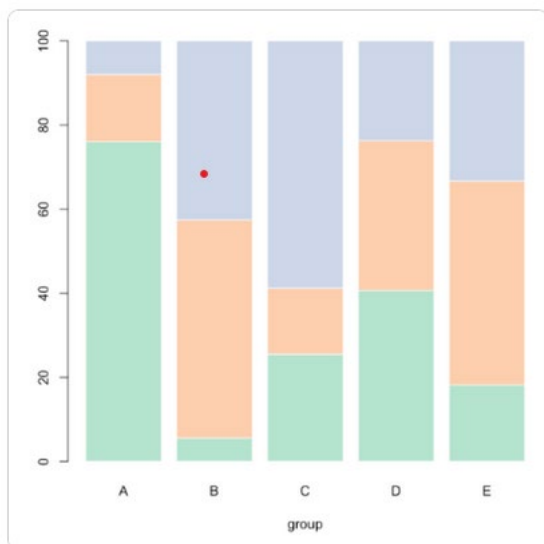


Fig. 5

Please, add the 'outliers' (e.g. as asterix or dot).

Rephrase: „Lowercase letters indicate statistical significance“ with something like

“Lowercase letters and the dashed line indicate groupings based on significant differences.”

Omit the Kruskal Wallis test statistic, as actually this should refer to the **Bonferroni-corrected** Mann-Whitney comparison. But these have to be provided.

Fig. 6

Rephrase: „Lowercase letters indicate statistical significance“ with “Lowercase letters and the dashed line indicate groupings based on significant differences.” Omit the Kruskal Wallis test statistic, as actually this should refer to the **Bonferroni-corrected** Mann-Whitney comparison. But these have to be provided. Please, explain the different y-axes in A and B. I don't understand this at all and am not sure if I like it or if it should be done like this. At the very least, you should provide an explanation in the Figure legend and also add something on the y axis itself as to which values this actually refers to.

Discussion

The choice of comparisons of results with previously published data seems a bit arbitrary, mostly from Asia or Australia (although I do get the point that you want to compare your data from a remote area with those from urban sites to show that it is just as polluted). I still think it would at least also be meaningful to compare it with data from regions more close by (e.g. north America or Northern Europe?) or similarly remote. Please, find a few studies and add comparison with them. You could present a lower range and an upper range and position your data within this range, for example.

L. 388: Very briefly, mention what the field methods were, that could have favoured non-fibrous MPs reported in Yukioka et al. (2020).

L. 396: *“The higher concentration of tire wear particles in Iqaluit may be a result of sampling and analytical techniques”*. Please explain in what way as one is left to wonder without prior knowledge of Dehghani et al. (2017). What sampling and analytical techniques might have led to lower quantities recorded?

L. 398-400: Is there evidence to support this (summer tires shed more MPs)? Please, search the literature for data on this and add the reference.

L. 402: Please, provide the mean quantity of tyre wear in the present study in brackets here, so the reader can judge how big a difference this is without having to go back to the Results etc..

L. 407: In this context it would make sense to compare the data with snow data that also came from the Arctic: Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdt, G., 2019. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science Advances* 5 (8), eaax1157.

L. 414: There is a little more known about human health effects than stated here, which could be summarized in a few sentences highlighting that this is early evidence:

-Abbasi, S., Keshavarzi, B., Moore, F., Turner, A., Kelly, F.J., Dominguez, A.O., Jaafarzadeh, N., 2019. Distribution and potential health impacts of microplastics and microrubbers in air and street dusts from Asaluyeh County, Iran. *Environmental Pollution* 244, 153-164.

-Amato-Lourenço, L.F., Carvalho-Oliveira, R., Júnior, G.R., Dos Santos Galvão, L., Ando, R.A., Mauad, T., 2021. Presence of airborne microplastics in human lung tissue. *J Hazard Mater* 416, 126124.

- Amato-Lourenço, L.F., Dantas, K.C., Júnior, G.R., Paes, V.R., Ando, R.A., de Oliveira Freitas, R., da Costa, O.M.M.M., Rabelo, R.S., Soares Bispo, K.C., Carvalho-Oliveira, R., Mauad, T., 2024. Microplastics in the Olfactory Bulb of the Human Brain. *JAMA Network Open* 7 (9), e2440018-e2440018.
- Chen, C.-Y., Chen, S.-Y., Liao, C.-M., 2025. Regional and population-scale trends in human inhalation exposure to airborne microplastics: Implications for health risk assessment. *Environmental Pollution* 371, 125950.
- Cox, K.D., Covernton, G.A., Davies, H.L., Dower, J.F., Juanes, F., Dudas, S.E., 2019. Human Consumption of Microplastics. *Environmental Science & Technology* 53 (12), 7068-7074.
- Gouin, T., Ellis-Hutchings, R., Thornton Hampton, L.M., Lemieux, C.L., Wright, S.L., 2022. Screening and prioritization of nano- and microplastic particle toxicity studies for evaluating human health risks – development and application of a toxicity study assessment tool. *Microplastics and Nanoplastics* 2 (1), 2.
- Huang, X., Saha, S.C., Saha, G., Francis, I., Luo, Z., 2024. Transport and deposition of microplastics and nanoplastics in the human respiratory tract. *Environmental Advances* 16, 100525.
- Jenner, L.C., Rotchell, J.M., Bennett, R.T., Cowen, M., Tentzeris, V., Sadofsky, L.R., 2022. Detection of microplastics in human lung tissue using μ FTIR spectroscopy. *Science of The Total Environment* 831, 154907.
- Kumar, R., Manna, C., Padha, S., Verma, A., Sharma, P., Dhar, A., Ghosh, A., Bhattacharya, P., 2022. Micro(nano)plastics pollution and human health: How plastics can induce carcinogenesis to humans? *Chemosphere* 298, 134267.
- Mehmood, T., Hassan, M.A., Faheem, M., Shakoor, A., 2022. Why is inhalation the most discriminative route of microplastics exposure? *Environmental Science and Pollution Research*.
- Pauly, J.L., Stegmeier, S.J., Allaart, H.A., Cheney, R.T., Zhang, P.J., Mayer, A.G., Streck, R.J., 1998. Inhaled cellulosic and plastic fibers found in human lung tissue. *Cancer Epidemiology Biomarkers & Prevention* 7 (5), 419-428.
- Pimentel, J.C., Avila, R., Lourenço, A.G., 1975. Respiratory disease caused by synthetic fibres: a new occupational disease. *Thorax* 30 (2), 204-219.
- Song, S., van Dijk, F., Vasse, G.F., Liu, Q., Gosselink, I.F., Weltjens, E., Remels, A.H.V., de Jager, M.H., Bos, S., Li, C., Stoeger, T., Rehberg, M., Kutschke, D., van Eck, G.W.A., Wu, X., Willems, S.H., Boom, D.H.A., Kooter, I.M., Spierings, D., Wardenaar, R., Cole, M., Nawijn, M.C., Salvati, A., Gosens, R., Melgert, B.N., 2024. Inhalable Textile Microplastic Fibers Impair Airway Epithelial Differentiation. *Am J Respir Crit Care Med* 209 (4), 427-443.
- Sripada, K., Wierzbicka, A., Abass, K., Grimalt, J.O., Erbe, A., Röllin, H.B., Weihe, P., Díaz, G.J., Singh, R.R., Visnes, T., Rautio, A., Odland, J.Ø., Wagner, M., 2022. A Children's Health Perspective on Nano- and Microplastics. *Environmental Health Perspectives* 130 (1), 015001.
- Vethaak, A.D., Legler, J., 2021. Microplastics and human health. *Science* 371 (6530), 672-674.
- Winiarska, E., Jutel, M., Zemelka-Wiacek, M., 2024. The potential impact of nano- and microplastics on human health: Understanding human health risks. *Environmental Research* 251, 118535.
- Zarus, G.M., Muianga, C., Hunter, C.M., Pappas, R.S., 2021. A review of data for quantifying human exposures to micro and nanoplastics and potential health risks. *Science of The Total Environment* 756, 144010.
- Rauert, C., Charlton, N., Bagley, A., Dunlop, S.A., Symeonides, C., Thomas, K.V., 2025. Assessing the Efficacy of Pyrolysis–Gas Chromatography–Mass Spectrometry for Nanoplastic

and Microplastic Analysis in Human Blood. Environmental Science & Technology 59 (4), 1984-1994.

-Xu, J.-L., Wright, S., Cassandra, R., V., T.K., 2025. Are microplastics bad for your health? More rigorous science is needed. Nature 639, 300-302.

L. 418-419: I really don't think that you can make such a statement on such scant knowledge. It has been shown in various studies by now that MNP are transported to remote places via the atmosphere and atmospheric fallout. Evangeliou et al., for example, suggest this as a major path to Greenland. I suggest you tweak this statement a little?

L. 425: Please, refer to the Plastchem report, the most recent and comprehensive inventory of chemicals associated with plastics: Wagner, M., Monclús, L., Arp, H.P.H., Groh, K.J., Løseth, M.E., Muncke, J., Wang, Z., Wolf, R., Zimmermann, L., 2024. State of the science on plastic chemicals - Identifying and addressing chemicals and polymers of concern.

Conclusion

Do you want to add something on the need for a globally harmonized monitoring system of airborne microplastic pollution? Or the need to control emissions to prevent harm to environmental and human health, e.g, through regulation for better design standards leading to lower tyre abrasion (it seems to vary a lot depending on chemical composition)? This is the precious place where you can add your two Pence 😊.

Are northern communities an overlooked source of microplastics and tire wear particles in the Arctic? (#118053)

1

First submission

Guidance from your Editor

Please submit by **9 Jun 2025** for the benefit of the authors (and your token reward) .



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-  **Impact and novelty is not assessed.** Meaningful replication encouraged where rationale & benefit to literature is clearly stated.
-  All underlying data have been provided; they are robust, statistically sound, & controlled.
-  Conclusions are well stated, linked to original research question & limited to supporting results.



The best reviewers use these techniques

Tip

Example

Support criticisms with evidence from the text or from other sources

Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.

Give specific suggestions on how to improve the manuscript

Your introduction needs more detail. I suggest that you improve the description at lines 57- 86 to provide more justification for your study (specifically, you should expand upon the knowledge gap being filled).

Comment on language and grammar issues

The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult. I suggest you have a colleague who is proficient in English and familiar with the subject matter review your manuscript, or contact a professional editing service.

Organize by importance of the issues, and number your points

1. Your most important issue
2. The next most important item
3. ...
4. The least important points

Please provide constructive criticism, and avoid personal opinions

I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC

Comment on strengths (as well as weaknesses) of the manuscript

I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.

Are northern communities an overlooked source of microplastics and tire wear particles in the Arctic?

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Microplastic particles (plastic 1 μm to 5 mm in length) are a contaminant of emerging concern in Arctic environments; nonetheless, few studies have evaluated microplastics in Arctic communities. This study investigated microplastics and tire wear particles across 16 sites in the community of Iqaluit, Nunavut (population = 7,429) using road dust as an indicator of microplastic atmospheric deposition (size detection primarily $>50 \mu\text{m}$). The mean concentration of microplastics (excluding tire wear particles), ranged from $1.93 \pm 2.56 \mu\text{g/g}$ ($3.90 \pm 3.18 \text{ n/g}$) in industrial sites ($n = 8$) to $3.73 \pm 4.61 \mu\text{g/g}$ ($3.91 \pm 3.08 \text{ n/g}$) in commercial sites ($n = 8$) and non-fibrous microplastics (i.e., fragments, films, and foams) were dominant across the study area. Based on the results of the microplastic diversity integrated index, commercial and industrial regions are composed of unique microplastic communities. Various polymers were identified, the dominant being polyethylene terephthalate (15%), polyester (15%), polymethyl acrylate (15%), and polystyrene (15%). The mean concentration of tire wear (dominated by rubber; 27%) in road dust was significantly greater than microplastics, ranging from $31.7 \pm 18.3 \mu\text{g/g}$ ($152 \pm 92.9 \text{ n/g}$) in industrial sites to $259 \pm 289 \mu\text{g/g}$ ($309 \pm 417 \text{ n/g}$) in commercial sites. The concentration of microplastics and tire wear particles in Iqaluit was consistent with observations from metropolitan cities, suggesting Arctic communities may be a substantial local source of microplastics and tire wear particles in Arctic ecosystems.

Title: Are northern communities an overlooked source of microplastics and tire wear particles in the Arctic?

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Abstract

Microplastic particles (plastic 1 μm to 5 mm in length) are a contaminant of emerging concern in Arctic environments; nonetheless, few studies have evaluated microplastics in Arctic communities. This study investigated microplastics and tire wear particles across 16 sites in the community of Iqaluit, Nunavut (population = 7,429) using road dust as an indicator of ~~microplastic~~ atmospheric deposition (size detection ~~primarily~~ $>50\ \mu\text{m}$). The mean concentration of microplastics (excluding tire wear particles), ranged from $1.93 \pm 2.56\ \mu\text{g/g}$ ($3.90 \pm 3.18\ \text{n/g}$) in industrial sites ($n = 8$) to $3.73 \pm 4.61\ \mu\text{g/g}$ ($3.91 \pm 3.08\ \text{n/g}$) in commercial sites ($n = 8$) and non-fibrous microplastics (i.e., fragments, films, and foams) were dominant across the study area. Based on the results of the microplastic diversity integrated index, commercial and industrial regions are composed of unique microplastic communities. Various polymers were identified, the dominant being polyethylene terephthalate (15%), polyester (15%), polymethyl acrylate (15%), and polystyrene (15%). The mean concentration of tire wear (dominated by rubber; 27%) in road dust was significantly greater than microplastics, ranging from $31.7 \pm 18.3\ \mu\text{g/g}$ ($152 \pm 92.9\ \text{n/g}$) in industrial sites to $259 \pm 289\ \mu\text{g/g}$ ($309 \pm 417\ \text{n/g}$) in commercial sites. The concentration of microplastics and tire wear particles in Iqaluit was consistent with observations from metropolitan cities, suggesting Arctic communities may be a substantial local source of microplastics and tire wear particles in Arctic ecosystems.

1.0 Introduction

The exponential growth in plastic production since the 1950's coupled with the mismanagement of waste has resulted in a plastic pollution crisis, especially given the ubiquity of microplastic particles (plastic 1 μm to 5 mm in length; MacLeod et al., 2021). Microplastic particles are complex contaminants generally characterized by their physical and chemical attributes, including shape (e.g., fibres, foams, fragments, films, and beads), size, and polymer composition (Cole et al., 2011; Rochman et al., 2019). Primary microplastic particles are manufactured to be micro-size (e.g., plastic microbeads as exfoliants in personal care products and pre-production pellets or nurdles; Rochman et al., 2019). Secondary microplastic particles form through chemical, physical, and biological fragmentation of plastic debris, including the shedding of synthetic textiles especially during laundering (Rochman et al., 2019). Microplastics have various sources, including synthetic clothing and plastic debris, and they are transported to wider environments through several pathways including atmospheric transport and deposition (Allen et al., 2019; Dris et al., 2016; Roblin et al., 2020; Welsh et al., 2022).

Atmospheric microplastics are readily entrained into the atmosphere through tire wear and vehicle turbulence (Brahney et al., 2021), soil tilling (Koutnik et al., 2021), wave breaks (Allen et al., 2020), and wind (Rezaei et al., 2019). Microplastics in the atmosphere are further deposited through wet or dry deposition processes into local or long-range environments (Evangelidou et al., 2020). Atmospheric microplastic particles have received increasing attention in urban cities during the past decade; to date, urban environments are considered significant contributors to microplastic particles in the

atmosphere (Wright et al., 2020; Dris et al., 2016). Nonetheless, the contribution of urbanized Arctic communities to atmospheric microplastics remains understudied. Despite the recognition that microplastic particles are emerging contaminants of concern in Arctic environments, there is a paucity of studies on atmospheric microplastics in Arctic communities (AMAP, 2021, AMAP, 2017).

Road dust is present in every urban environment and it is composed of natural organic and inorganic materials that arise from diverse sources, including atmospheric deposition (Gunawardana et al., 2012), and it has been widely assessed as a passive indicator of atmospheric microplastic and tire wear deposition (Dehghani et al., 2017; O'Brien et al., 2021; Patchaiyappan et al., 2021). Road dust is an advantageous monitor for microplastic because it allows a greater spatial area to be surveyed in a relatively short period with minimal field equipment, compared to active atmospheric sampling that requires fixed secure locations with electricity for deployment, which is challenging in Arctic environments.

The objective of this study was to investigate the concentration, characteristics, and deposition of microplastics and tire wear particles in an Arctic community, using road dust as an indicator of atmospheric microplastic deposition. During the summer of 2022, road dust was collected from commercial and industrial areas in Iqaluit ($\Delta^{\text{q}}\Delta^{\text{c}}$), Nunavut, and assessed for microplastics and tire wear particles. Herein, tire wear particles are presented separately from microplastics (i.e., non-rubber fibres, fragments, films, foams, and beads), despite the recognition that tire wear particles have been categorized as microplastics (Knight et al., 2020).

2.0 Materials and Methods

2.1 Study Area and Site Selection

Iqaluit, Nunavut (63.7467° N, 68.5170° W), is situated in Koojesse inlet in the northwest corner of Frobisher Bay in northern Canada. Iqaluit is the largest community in Nunavut with an area of 52.5 km² and a population of approximately 8,000. The community has few paved roads, no traffic lights, no stormwater drains, and <8,000 registered vehicles (dominated by trucks, all-terrain vehicles, and snowmobiles). Iqaluit is surrounded by barren land with low vegetation and a polar tundra climate that is strongly influenced by the Labrador Current. The average summer temperature during 2020–2022 was 6.1°C (June to September) with an average wind speed of 3.6 m/s from the south-east (Canada, 2023). In contrast, the average winter temperature during 2020–2022 was –18.9°C (December to March) with an average wind speed of 4.3 m/s from the north-west (Canada, 2023). The average annual precipitation in Iqaluit was ~217 mm between 2020–2022 (Canada, 2023). Prior to the study period (14–15 July 2022), the highest precipitation event was on June 24th, 2022 (0.6 mm; Figure S1) and the last precipitation event was on July 6th, 2022 (0.05 mm; Figure S1; Canada. 2023).

The study sites were randomly selected from commercial and industrial areas in Iqaluit (Figure 1; Table 1) by subdividing each region into equal area sampling units using k-means clustering of 10 m by 10 m land cover classified grids (Spatial Coverage Sampling and Random Sampling from Compact Geographical Strata; Version 0.4-2; Walvoort et al., 2010). A total of eight commercial sites were selected from parking lots (n = 4) and roadsides (n = 4), and eight industrial sites were selected from roadsides. Commercial sites were located within the community downtown core, while the

industrial sites were clustered to the northwest of the community (due to limited paved surfaces in industrial regions; Figure 1). Commercial areas consisted of storefronts, recreational centers, and hotels, while industrial areas consisted of construction enterprises, fuel depots, automobile shops, and storage yards. Field surveys were approved by the Nunavut Research Institute (Scientific Research License 01 011 22R-M / 01 015 23R-M; approval number 01 011 22R-M / 01 015 23R-M).

2.2 Quality Assurance and Quality Control

Due to the ubiquity of microplastics, strict quality assurance and quality control is vital to ensure estimated concentrations reflect environmental concentrations. To prevent the addition of unwanted microplastics into environmental samples, all solutions, including reverse osmosis water, hydrogen peroxide, and sodium bromide were filtered through glass-fibre filters (Fisherbrand™ Glass Filter Circle, 1.6 µm pore diameter, G6, filter diameter 4.25 cm). In the laboratory, a 100% cotton laboratory coat was worn, and hands/gloves were rinsed with filtered reverse osmosis (FRO) water throughout the extraction process to prevent microplastics contamination of the samples. Metal and glass equipment were used where possible to prevent potential contamination, and all equipment was triple-rinsed with FRO water before and in between the handling of environmental samples to remove adhered microplastics. Laboratory blanks (n = 2) were performed in sequence with environmental samples and consisted of running solutions through the same laboratory processes as environmental samples (i.e., digestion and density separation) to capture microplastics unintentionally added to environmental samples during the extraction process.

Field blanks ($n = 6$) were performed at a random subset of the commercial and industrial study sites and mimicked the field methods by sweeping microplastic-free road dust (250 g pre-baked at 500°C for 12 h) off a cork board into the sampling containers. Field blanks captured any potential microplastic or tire wear particle contamination during the sweeping process (e.g., atmospheric deposition, improper cleaning of field equipment). Further, field blanks (1 g) were also spiked with a known concentration of polyethylene (PE) beads (size ranges 75–90 μm and 212–250 μm) to assess recovery rates and visual limits of detection; blanks were processed in sequence with environmental samples. The limit of detection (LOD) was estimated as the mean microplastic count for field blanks plus three times their standard deviation (Bertrim & Aherne, 2023). Open-air laboratory blanks ($n = 2$) consisted of an exposed glass-fibre filter in a Petri dish beside the microscope to capture microplastics from the indoor atmosphere.

2.3 Sample Collection

During 14–15 July 2022, road dust was collected using a natural-fibre brush and metal dustpan (O'Brien et al., 2021). Briefly, each road site was swept along a transect (10–30 m in length depending on the quantity of road dust available) against the direction of the wind and following a minimum of five days without precipitation under stable weather conditions (wind speed less than 4 m/s). All contents in front of the metal pan (43.2 cm in diameter) were collected using a slow sweeping motion to minimize the resuspension of microplastic particles. Road dust contents in the dustpan were sieved at 2 mm to remove large rocks and non-plastic debris, and the <2 mm fraction was

retained in an aluminum dish (pre-baked at 400°C for 4 hr), which was subsequently covered with aluminum foil and stored in a brown paper bag until analysis. Between sample sites, the metal dustpan, natural-fibre brush, and sieve were wiped with 100% cotton cheesecloth and sprayed with compressed air to prevent contamination.

2.4 Microplastic Extraction

Road dust samples were oven-dried at 45°C for 48 h, homogenized by gently stirring (~1 min), and 1 g of road dust from each site was processed in 0.5 g aliquots to optimize the analytical procedure (i.e., a total of 8 g each for commercial and industrial areas). Organic matter was removed using wet oxidation; in a 250 mL Erlenmeyer flask, 40 mL of 30% filtered hydrogen peroxide was added to each road dust sample and digested at 45°C for 24 h (Hurley et al., 2018). Following digestion, samples were wet sieved (20 µm), and the residue was retained in a 100 mL tall glass beaker by rinsing the sieve with filtered reverse osmosis (FRO) water. The filtrate was retained from a subset of samples (n = 8) to determine if there was particle loss from the sieving process; no microplastics or tire wear particles were detected in the filtrate.

Microplastics in the residue were subsequently extracted using one water and two sodium bromide (NaBr; density = >1.5 g/cm³) density separations, each with a settling time of 24 h. Following each settling time, the beaker walls were washed with FRO water or filtered NaBr, and the supernatant was decanted and filtered onto a glass-fibre filter. Filters were stored in clear polystyrene petri dishes until visual analysis.

2.5 Microplastic and Tire Wear Particle Identification

Filters were visually analyzed for microplastics and tire wear particles using a stereomicroscope (AmScope version x64). The entire filter surface was analyzed for microplastics, which were identified using the following set of criteria: (1) particles were unnaturally coloured relative to the sample, and appeared homogeneous in material and texture with no visible cellular structures, (2) fibres were a consistent width throughout, (3) particles remained intact when compressed or poked with dissection instruments, (4) particles had a shiny or glossy appearance, and (5) fibres shared no similarities to natural fibres with limited fraying (Kosuth et al., 2018). Given the abundance of tire wear particles, a quarter of the filter surface was analyzed and scaled up. Tire wear particles were identified as being (1) black, (2) elongated/cylindrical in shape, (3) with a rough surface texture, and (4) spongy when poked with a dissection instrument but remained intact (Leads & Weinstein, 2019).

All suspected microplastic or tire wear particles that met at least two visual identification criteria were photographed (AmScope MU100 camera, 3584 × 2748 pixels). Suspected microplastics were touched with a heat source (400°C) (Beckingham et al., 2023), while suspected tire wear particles were not touched with a heat source as they do not melt at high temperatures. The length and width of all microplastics that melted were measured using AmScope (Version 4.11.22004.20230115); 95% of the observed tire wear particles were measured. Further, a 540 nm blue light (NightSea Stereo Microscope Fluorescence Adapter) was used to capture fluorescent particles difficult to see under a standard brightfield light. In general, visual identification is limited to particles >50 µm, but where possible, particles down to ~20 µm were also identified,

albeit a small proportion (~5%). It is important to note that one individual completed all visual analysis and detection favoured microplastics >50 µm due to visual limitations. Fourier-Transform Infrared spectroscopy (FTIR; LUMOS II, Bruker) was performed on a subset of particles (30% microplastics and 22% tire wear particles) using attenuated total reflection (ATR) to determine polymer type. The diameter of the ATR crystal (Germanium; diameter of tip = 100 µm) generally limited polymer analysis to larger particles (>100 µm); fibrous microplastics were particularly challenging due to their narrow diameter. For all particles, a scan time of 16 seconds was used under low pressure. Subsequently, tire wear spectra were corrected for 'Black Rubber' in OPUS (Version 8.7). Despite correcting for 'Black Rubber' it is important to note there are limitations to using FTIR for spectral identification of tire wear particles as their dark nature only reflects a small amount of light (Kang et al., 2022). All spectra were uploaded to OpenSpecy to identify polymer type (Cowger et al., 2021). The plastic polymer with the highest Pearson's Correlation was chosen, with a minimum correlation value of >0.5 due to the challenges of spectroscopic analysis of aged microplastics and tire wear particles.

2.6 Data Analysis

Field sites were grouped into industrial roadsides (IQ-IND-R), and commercial sites (IQ-COM) with the latter comprising commercial parking lots (IQ-COM-P) and commercial roadsides (IQ-COM-R). The concentration (n/g) of microplastics and tire wear particles per gram dry weight (dw) of road dust was estimated by summing counts from each duplicate and dividing by the sum of road dust mass from each site (~1 g).

The concentration of microplastics and tire wear particles were polymer corrected by multiplying the concentration by the proportion of particles identified as plastic by FTIR. It is important to note that the estimated concentrations of microplastics and tire wear particles represent particles that generally ranged from 20–2000 μm , however, visually identifying microplastics $<50 \mu\text{m}$ was challenging due to their small size.

Mass ($\mu\text{g/g}$) concentrations were estimated for both microplastics and tire wear particles using the volume of each particle and average polymer density following Simon et al. (2018). The volume of microplastics and tire wear particles at each site (see Supporting Material Table S1) was summed by particle shape and multiplied by the average density for shape-specific polymers (see Supporting Material Table S2). Further, deposition was calculated by dividing the total mass (g) of road dust collected at each site by the sampling area ($\text{area (m}^2\text{)} = \text{width of dustpan} \times \text{transect length}$) and multiplying that value by the concentration of microplastics or tire wear particles (n/m^2 or $\mu\text{g/m}^2$). We assumed concentration and deposition represented an accumulation of atmospheric microplastics and terrestrial particles directly emitted from their sources (such as tire wear particles). Hereafter, concentration and deposition ($\pm$ standard deviation) are reported as per gram dry weight of road dust and per square metre, respectively.

To determine if there was a statistical difference between commercial and industrial regions for concentration, characteristics, and deposition, a Kruskal–Wallis test was used with a confidence interval of 95%, followed by a pairwise Mann–Whitney U test if there was statistical significance. The Simpson’s diversity index was used to estimate the diversity of microplastic shape, colour, and size in road dust samples from

commercial roadsides and parking lots, and industrial roadsides. The microplastic community composition in road dust from commercial and industrial regions was estimated as an integrated diversity index (MDII; Li et al., 2021). All figures and statistical analyses were carried out in Past (Version 4.12; Hammer et al., 2001).

3.0 Results

3.1 Quality Assurance and Quality Control

No microplastics were found in the laboratory blanks and open-air blanks. Given the overall low concentration of microplastics (0.17 n/g) in the field blanks and that all observed concentrations were greater than the LOD (1.4 n/g), microplastic observations were not blank corrected. No tire wear particles were detected in field blank samples. The proportion of plastic polymer hits with a Pearson's correlation >0.5 was 75% for microplastics and 87% for tire wear particles (see Supporting Material Table S4). The recovery for spiked PE beads from the field blanks ($n = 4$) ranged from 70–100% (average = 83%) for sizes 75–90 μm and 90–100% (average = 98%) for sizes 212–250 μm , which is consistent with reported recovery rates (Dimante-Deimantovica et al., 2022).

3.2 Microplastics in Arctic Road Dust

Concentration and Deposition

In total, 91 microplastics (Figure 2; see Supporting Material Table S3 for count by shape) were identified at 15 of the 16 study sites (Table 1). The mean concentration of microplastic particles (excluding tire wear) was $2.83 \pm 3.72 \mu\text{g/g}$ ($3.91 \pm 3.02 \text{ n/g}$) across

the study area. The concentration was $1.93 \pm 2.56 \mu\text{g/g}$ ($3.90 \pm 3.18 \text{ n/g}$) in industrial sites and $3.73 \pm 4.61 \mu\text{g/g}$ ($3.91 \pm 3.08 \text{ n/g}$) in commercial sites, ranging from $0.47 \pm 0.48 \mu\text{g/g}$ ($1.89 \pm 1.09 \text{ n/g}$) in commercial roadsides to $7.00 \pm 4.58 \mu\text{g/g}$ ($5.93 \pm 3.17 \text{ n/g}$) in commercial parking lots (Table 2). There was a statistical difference across groups (Kruskal–Wallis, $p < 0.05$); microplastic concentration in commercial parking lots was statistically greater than both commercial and industrial roadsides (Mann–Whitney U, $p < 0.05$; Figure 3; see Supporting Material Figure S2 for n/g).

Microplastic deposition followed the same pattern; the mean across all sites was $45.8 \pm 41.3 \mu\text{g/m}^2$ ($53.8 \pm 49.0 \text{ n/m}^2$) with a mean deposition of $2.98 \pm 4.92 \mu\text{g/m}^2$ ($10.4 \pm 19.6 \text{ n/m}^2$) in industrial sites and $90.2 \pm 127 \mu\text{g/m}^2$ ($75.3 \pm 104 \text{ n/m}^2$) in commercial sites, ranging from $1.27 \pm 0.97 \mu\text{g/m}^2$ ($9.12 \pm 9.47 \text{ n/m}^2$) in commercial roadsides to $133 \pm 118 \mu\text{g/m}^2$ ($142 \pm 118 \text{ n/m}^2$) in commercial parking lots (Table 3). Further, there was a statistical difference in microplastic deposition across groups (Kruskal–Wallis, $p < 0.05$); deposition was significantly greater in commercial parking lots than both commercial and industrial roadsides (Mann–Whitney U, $p < 0.05$; Figure 3; see Supporting Material Figure S2 for n/m^2). There was also a statistical difference in the deposition of films across groups (Kruskal–Wallis, $p < 0.05$); deposition of films was significantly greater in commercial parking lots than both commercial and industrial roadsides (Mann–Whitney U, $p < 0.05$).

Characteristics (Shape, Size, and Polymer Composition)

Based on counts, commercial parking lots and industrial roadsides were dominated by fragments (51% and 95%, respectively), and commercial roadsides were

dominated by fibres (86%; see Supporting Material Figure S3). Based on mass concentration, commercial parking lots had a greater proportion of films (49%), while commercial and industrial roadsides were dominated by fibres (50%) and fragments (42%), respectively (Figure 4). Overall, a greater proportion of microplastics in commercial parking lots and industrial roadsides consisted of non-fibrous microplastics (i.e., fragments, films, foams), while commercial roadsides had a greater proportion of fibrous microplastics.

The mean (range) length of fibrous microplastics were not statistically difference ($p > 0.05$) across the study area, ranging from $792 \pm 346 \mu\text{m}$ (339–1264 μm) in commercial parking lots, to $798 \pm 642 \mu\text{m}$ (201–1695 μm) in industrial roadsides, and $819 \pm 329 \mu\text{m}$ (365–1183 μm) in commercial roadsides. The mean (range) length of non-fibrous microplastics ranged from $105 \pm 42.3 \mu\text{m}$ (67.1–151 μm) in commercial roadsides, to $119 \pm 82.1 \mu\text{m}$ (19.2–316 μm) industrial roadsides, and $280 \pm 333 \mu\text{m}$ (62.1–1223 μm) in commercial parking lots. There was a statistical difference in length of non-fibrous microplastics across groups (Kruskal–Wallis, $p < 0.05$), non-fibrous microplastics in commercial parking lots were significantly longer than industrial roadsides (Mann–Whitney U, $p < 0.05$; Figure 5).

Various polymers were identified across commercial parking lots (6 types), commercial roadsides (3 types), and industrial roadsides (2 types). Polyester (40%) was the dominant polymer for fibrous microplastics, polymethyl acrylate (50%) was the dominant polymer for fragments, polystyrene (100%) was dominant for films, and polyvinyl butyral, polyurethane, and polyvinyl chloride were equally dominant for foams (Table 3).

The results from the MDII suggest that the microplastic diversity in commercial parking lots (0.68) and commercial roadsides (0.67) are nearly identical and they both slightly differed from industrial roadsides (0.38); a breakdown of the Simpson's diversity index results can be found in Table 4.

3.3 Tire Wear Particles in Arctic Road Dust

Concentration and Deposition

Tire wear particles were pervasive across the study area, and 1,303 tire wear particles were quantified across all sites (Table 1). The mean concentration of tire wear particles was $146 \pm 230 \mu\text{g/g}$ ($231 \pm 302 \text{ n/g}$), with a mean concentration of $31.7 \pm 18.3 \mu\text{g/g}$ ($152 \pm 92.9 \text{ n/g}$) in industrial sites and $259 \pm 289 \mu\text{g/g}$ ($309 \pm 417 \text{ n/g}$) in commercial sites, ranging from $62.0 \pm 50.5 \mu\text{g/g}$ ($69.7 \pm 21.4 \text{ n/g}$) in commercial roadsides, to $459 \pm 294 \mu\text{g/g}$ ($549 \pm 501 \text{ n/g}$) in commercial parking lots. Despite this range, there was no statistical difference in the mass concentration of tire wear particles across groups ($p > 0.05$; Figure 6). In contrast, commercial parking lots had a statistically greater count concentration of tire wear particles than commercial roadsides (Figure S4). The deposition of tire wear particles followed the same pattern, with a mean deposition of $74.1 \pm 128 \mu\text{g/m}^2$ ($372 \pm 561 \text{ n/m}^2$) in industrial sites and $5,430 \pm 7,660 \mu\text{g/m}^2$ ($5,780 \pm 9,340 \text{ n/m}^2$) in commercial sites, ranging from $247 \pm 194 \mu\text{g/m}^2$ ($417 \pm 529 \text{ n/m}^2$) in commercial roadsides, to $10,600 \pm 8,080 \mu\text{g/m}^2$ ($12,800 \pm 12,900 \text{ n/m}^2$) in commercial parking lots. There was a statistical difference between groups (Kruskal–Wallis, $p < 0.05$), deposition of tire wear particles was significantly greater in

commercial parking lots than in both commercial and industrial roadsides (Mann-Whitney U, $p < 0.05$; Figure 6).

Characteristics (Size and Polymer Composition)

The mean (range) length of tire wear particles were not statistically difference between groups and ranged from $132 \pm 78.1 \mu\text{m}$ (51.8–505 μm) in commercial roadsides to $139 \pm 71.4 \mu\text{m}$ (54.5–476 μm) in industrial roadsides, and $157 \pm 143 \mu\text{m}$ (27.0–1859 μm) in commercial parking lots. Further, a total of 13 plastic polymers were identified across sites, rubber (27%) was dominant, followed by polypropylene (18%; Table 3); however, this may reflect the challenges of spectroscopic analysis of tire wear particles.

4.0 Discussion

The commercial sites (i.e., parking lots and roadsides) shared a similar microplastic diversity (i.e., shape, colour, and size), whereas industrial roadsides slightly differed from both commercial sites, suggesting there are a greater amount of microplastic sources in commercial areas compared to industrial. Overall, the concentration of microplastics and tire wear particles in road dust from Iqaluit, Nunavut, were comparable with metropolitan cities, and commercial parking lots had a notably greater concentration of microplastics and tire wear particles than roadside sites. The concentration and deposition of microplastics and tire wear particles were significantly greater in parking lots than on roadsides, indicating parking lots may serve as a temporary sink for microplastics and tire wear particles. There was also a greater

quantity of dust in parking lots, indicating parking lots have a greater retention of dust than roadside (Table 1). The greater accumulation likely reflects the slower vehicle velocity in parking lots, which ultimately reduces the resuspension of particles.

Given the population density of Iqaluit, microplastic concentrations in road dust were expected to be lower than in metropolitan cities as microplastic concentrations are positively correlated with population density (Yukioka et al., 2020). However, the count concentration of microplastics in road dust from Iqaluit (3.91 ± 3.02 n/g) was similar to Chennai, India (2.28 ± 0.89 n/g; population = 6.7 million; Patchaiyappan et al., 2021), Kathmandu, Nepal (3.90 n/g; population = 856,000; Yukioka et al., 2020), Da Nang, Vietnam (4.10 n/g; population = 1.1 million; Yukioka et al., 2020), and Kasatsu, Japan (2.50 n/g; population = 139,000; Yukioka et al., 2020). Whereas, microplastic count concentrations in Iqaluit road dust were lower than Goyang city, South Korea (~ 505 n/g; population = 1.1 million; Kang et al., 2022), and mass concentrations were lower than in Brisbane, Australia (500–6000 $\mu\text{g/g}$; population = 1.2 million; Table S5; O'Brien et al., 2021). The deposition of microplastics across Iqaluit (53.8 ± 49.0 n/m²) was comparable to Kusatsu, Japan (2.00 ± 1.60 n/m²; population = 139,000), Kathmandu, Nepal (12.5 ± 10.1 n/m²; population = 856,000), and Da Nang, Vietnam (19.7 ± 13.7 n/m²; population = 1.1 million; Table S5; Yukioka et al., 2020). Overall, the similarities and differences in microplastic concentrations in Iqaluit road dust compared with more densely populated cities, may reflect differences in sampling methodologies; for example, Yukioka et al. (2020) used a vacuum cleaner to collect road dust, and samples were sieved at 75 μm , which may have resulted in the loss of fibrous microplastics which have a narrow diameter (10–20 μm). Nonetheless, the observations

in a remote northern community are surprisingly within the same order of magnitude as studies conducted within metropolitan areas.

Dominant microplastic shape also varied across studies; a greater proportion of fibrous microplastics was reported in road dust in Bushehr City, Iran (76%; population = 220,000) using a plastic brush and pan, which was similar to commercial roadside findings in the current study (Abbasi et al., 2017). In contrast, our findings are more similar to a study in Ma'an Shan City, China (population = 2.1 million), which identified fragments (50%) as the dominant microplastic shape in road dust collected using a wooden brush and steel shovel (Wang et al., 2022). A higher proportion of fragments (68–81%) was also observed in road dust sampled from Kusatsu, Japan, Da Nang, Vietnam, and Kathmandu, Nepal (Yukioka et al., 2020); however, it is likely that the field methods used by Yukioka et al. (2020) favoured the collection of non-fibrous microplastics.

Comparing the concentration and deposition of tire wear particles in road dust to other studies is challenging as tire wear particles are generally grouped within the microplastic shape category of “fragments” or excluded from studies altogether due to the challenges of visual and spectroscopic analysis. Dehghani et al. (2017) investigated tire wear in road dust from Tehran, Iran (population = 7.7 million), and suggested a concentration of 16.6 n/g road dust. In the current study, the average concentration of tire wear across the study area was 276 n/g. The higher concentration of tire wear particles in Iqaluit may be a result of sampling and analytical techniques. It is also possible that the composition of vehicle tires differs; for instance, the majority of vehicles in the north use winter tires that are composed of a soft rubber material and

may shed more particles than all-year or summer tires. In contrast, concentrations of tire wear particles in Goyang city, South Korea (~1210 n/g) were greater than in the current study (Kang et al., 2022). Further, a study that investigated tire wear particles accumulated in roadside snowbanks in Norway identified an average concentration of $10,600 \pm 2,200$ mg/m² (Rødland et al., 2022). The higher concentration of tire wear particles in snowbanks is likely a result of the greater accumulation period throughout the winter (several months), in contrast to road dust that reflects accumulation following the most recent wash out event (approximately 7 days in the current study).

Understanding the concentration and characteristics of microplastics and tire wear particles in road dust is crucial as road dust facilitates the transport of microplastics and tire wear particles to wider environments. For instance, microplastics and tire wear particles become re-entrained into the atmosphere by wind or vehicle traffic and are subsequently deposited back to the ground in local or longer-range environments (Evangelidou et al., 2020). Microplastics in suspended dust may also be inhaled; however, associated risks are not well established (Baensch-Baltruschat et al., 2020). Road dust also facilitates the transport of microplastics to aquatic systems through stormwater drainage following precipitation washout events (Monira et al., 2021). Tire wear particles have been observed in Arctic sediments close to communities but not in more remote locations, this suggests that communities are a source to the surrounding water and sediment (Huntington et al., 2020; Adams et al., 2021). Microplastics and tire wear particles that enter aquatic environments have adverse effects, such as infiltrating the aquatic food chain and causing physical harm to aquatic species when ingested (Lim, 2021). Microplastics and tire wear particles are also

associated with chemical additives (e.g., polycyclic aromatic hydrocarbons, petroleum hydrocarbons, phthalates, and dyes) that leach into surrounding environments (Andjelković et al., 2021; Teuten et al., 2009). Such additives also have adverse effects on aquatic species, for instance, 6PPD (N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine) improves the durability of tires but its oxidation product 6PPD-quinone is highly toxic to aquatic organisms (Tian et al., 2022).

We acknowledge there are limitations to our study that may influence the estimated concentration and deposition of microplastics and tire wear particles in road dust. First, our study reports microplastics and tire wear particles in road dust over an unknown accumulation period (albeit >7 days). Second, the detection limit for microplastics in this study was between >20–2000 μm , which may have resulted in the loss of microplastics between 2–5 mm in length. Third, the recovery of spiked microplastics may not reflect the recovery of environmental fibres, films, foams, fragments, and tire wear particles. Finally, the mass concentrations are an estimate based on two measurements (longest length and width), given that microplastics and tire wear particles are intricate, three-dimensional particles with complex chemical structures, this may skew the estimated mass of microplastics and tire wear particles.

5.0 Conclusion

In this study, we shed light on the presence of microplastics and tire wear particles in Arctic road dust. The mean concentration of microplastics was $2.83 \pm 3.72 \mu\text{g/g}$ ($3.91 \pm 3.02 \text{ n/g}$) and tire wear particles was $146 \pm 230 \mu\text{g/g}$ ($231 \pm 302 \text{ n/g}$) in road dust across Iqaluit, Nunavut. The high magnitude of microplastics and tire wear

particles in commercial parking lots compared to roadsides suggests that parking lots are a temporary sink (accumulation zone) for microplastics and tire wear particles. Further, the study suggests the concentration of microplastics in Arctic road dust is comparable to observed concentrations in metropolitan areas, underscoring the importance of understanding the contribution of local Arctic communities to environmental and atmospheric microplastics and tire wear particles, and their role in the transport of microplastics and tire wear particles to the wider environment.

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Table 1(on next page)

Count of microplastic and tire wear particles at each site

Site ID, sampling date (July 2022), longitude (decimal degree; dd), latitude (decimal degree; dd), transect length (meters; m), mass of total road dust collected (grams; g), microplastic (count), and tire wear particle (count) for each study site (n = 16; commercial, COM; industrial, IND), Iqaluit, Nunavut.

Site ID	Date	Latitude	Longitude	Transect	Road dust	Microplastic	Tire wear
		dd	dd	m	g	#	#
IQ-COM-R1	14	63.74968	-68.52949	30	45.2	1	31
IQ-COM-R2	14	63.74444	-68.51241	10	158	2	23
IQ-COM-R3	14	63.74725	-68.51968	10	22.9	5	29
IQ-COM-R4	14	63.74743	-68.52410	30	71.8	3	13
IQ-COM-P1	14	63.74987	-68.52027	10	217	12	453
IQ-COM-P2	14	63.74917	-68.52545	10	378	11	81
IQ-COM-P3	14	63.74613	-68.51767	10	137	9	186
IQ-COM-P4	15	63.74877	-68.52023	10	84.2	2	66
IQ-IND-R1	15	63.75760	-68.53675	30	8.4	1	18
IQ-IND-R2	15	63.75924	-68.54053	30	2.0	6	36
IQ-IND-R3	15	63.75997	-68.54162	30	44.4	6	109
IQ-IND-R4	15	63.75794	-68.53795	30	85.6	2	74
IQ-IND-R5	14	63.75957	-68.54134	10	183	15	99
IQ-IND-R6	14	63.75455	-68.52820	30	50.2	7	17
IQ-IND-R7	14	63.75678	-68.53593	30	15.5	0	35
IQ-IND-R8	14	63.75331	-68.52574	30	30.4	9	48

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Table 2 (on next page)

Concentrations by count and mass

Microplastic (mean $\pm$ standard deviation) concentration (n/g or $\mu\text{g/g}$ dry weight) and deposition (n/m² or $\mu\text{g/m}^2$) in road dust across commercial parking lots (IQ-COM-P), commercial roadsides (IQ-COM-R), industrial roadsides (IQ-IND-R), and commercial areas (IQ-COM) in Iqaluit, Nunavut.

	Units	IQ-COM-P	IQ-COM-R	IQ-IND-R	IQ-COM
Land class	–	Commercial	Commercial	Industrial	Commercial
Surface	–	Parking lot	Roadside	Roadside	Parking lots and roadsides
Site number	n	4	4	8	8
Count (number)					
Microplastics	n	34	11	46	45
Fibre	n	11	7	7	18
Fragment	n	13	3	32	16
Film	n	8	1	6	9
Foam	n	2	0	1	2
Count concentration					
Microplastics	n/g	5.93 ± 3.17	1.89 ± 1.09	3.90 ± 3.18	3.91 ± 3.08
Fibre	n/g	1.91 ± 2.14	1.22 ± 0.36	0.60 ± 0.56	1.57 ± 1.47
Fragment	n/g	2.27 ± 1.86	0.51 ± 0.63	2.73 ± 2.43	1.39 ± 1.60
Film	n/g	1.39 ± 1.00	0.16 ± 0.33	0.49 ± 0.75	0.78 ± 0.95
Foam	n/g	0.35 ± 0.41	–	0.09 ± 0.26	0.18 ± 0.32
Count deposition					
Microplastics	n/m ²	142 ± 118	9.12 ± 9.47	10.4 ± 19.6	75.3 ± 104
Fibre	n/m ²	22.1 ± 37.1	7.57 ± 10.4	1.55 ± 2.63	27.9 ± 40.6
Fragment	n/m ²	56.4 ± 68.3	1.18 ± 1.46	7.14 ± 2.45	28.8 ± 53.6
Film	n/m ²	27.9 ± 23.3	0.37 ± 0.75	1.70 ± 4.08	14.1 ± 21.2
Foam	n/m ²	9.0 ± 12.2	–	0.006 ± 0.02	4.5 ± 6.1
Mass concentration					
Microplastics	µg/g	7.00 ± 4.58	0.47 ± 0.48	1.93 ± 2.56	3.73 ± 4.61
Fibre	µg/g	0.76 ± 0.84	0.23 ± 0.18	0.44 ± 1.10	0.50 ± 0.63
Fragment	µg/g	1.83 ± 2.70	0.07 ± 0.09	0.91 ± 1.50	0.95 ± 2.00
Film	µg/g	3.22 ± 3.01	0.17 ± 0.34	0.48 ± 0.72	1.70 ± 2.57
Foam	µg/g	1.19 ± 1.64	–	0.11 ± 0.30	0.59 ± 1.24
Mass deposition					
Microplastics	µg/m ²	133 ± 118	1.27 ± 0.97	2.98 ± 4.92	90.2 ± 127
Fibre	µg/m ²	19.0 ± 19.9	1.14 ± 1.23	0.64 ± 1.21	10.1 ± 10.6
Fragment	µg/m ²	30.8 ± 35.6	0.16 ± 0.23	1.91 ± 2.94	15.5 ± 17.9
Film	µg/m ²	90.7 ± 132.9	0.38 ± 0.77	1.42 ± 3.12	46.1 ± 66.9
Foam	µg/m ²	37.1 ± 63.1	–	0.01 ± 0.02	18.6 ± 31.6

Table 3(on next page)

Polymer types identified by shape

Proportion of polymer types for microplastic fibres, films, foams, and tire wear particles in road dust across commercial parking lots (n = 4), commercial roadsides (n = 4), and industrial roadsides (n = 8) in Iqaluit , Nunavut.

Shape Type	Polymer Type	Proportion (%)
Fibre	Polyester	40
	Polymethyl acrylate	20
	Polyethylene	20
	Polyethylene terephthalate	20
Fragment	Polymethyl acrylate	50
	Polyethylene terephthalate	25
	Polystyrene	25
Film	Polystyrene	100
Foam	Poly(vinyl butyral)	33
	Polyurethane	33
	Polyvinyl chloride	33
Tire wear particle	Rubber	27
	Polypropylene	20
	Polyethylene	18
	Polystyrene	16
	Polyvinyl chloride	12
	Nitrile	2
	Poly(vinyl butyral)	1
	Polyester	1
	Polymethyl acrylate	1
	Polyethylene terephthalate	1
	Polyacrylate nitrile	0
	Low-density polyethylene	0
	Polyurethane	0

Table 4(on next page)

Simpson's diversity index

Results from the Simpson's diversity index for microplastic shape, colour, and size in road dust from commercial parking lots (IQ-COM-P; n = 4), commercial roadsides (IQ-COM-R; n = 4), and industrial roadsides (IQ-IND-R; n = 8) located in Iqaluit, Nunavut.

1

Diversity	IQ-COM-P	IQ-COM-R	IQ-IND-R
Shape	1.28	1.26	0.92
Colour	1.47	1.17	1.28
Size	1.09	1.38	0.98
MDII	0.68	0.67	0.38

Figure 1

Site area

Location of study sites for commercial parking lots (IQ-COM-P; n = 4), commercial roadsides (IQ-COM-R; n = 4), and industrial roadsides (IQ-IND-R; n = 8), Iqaluit , Nunavut (ArcGIS Pro, Version 3.1.1) .

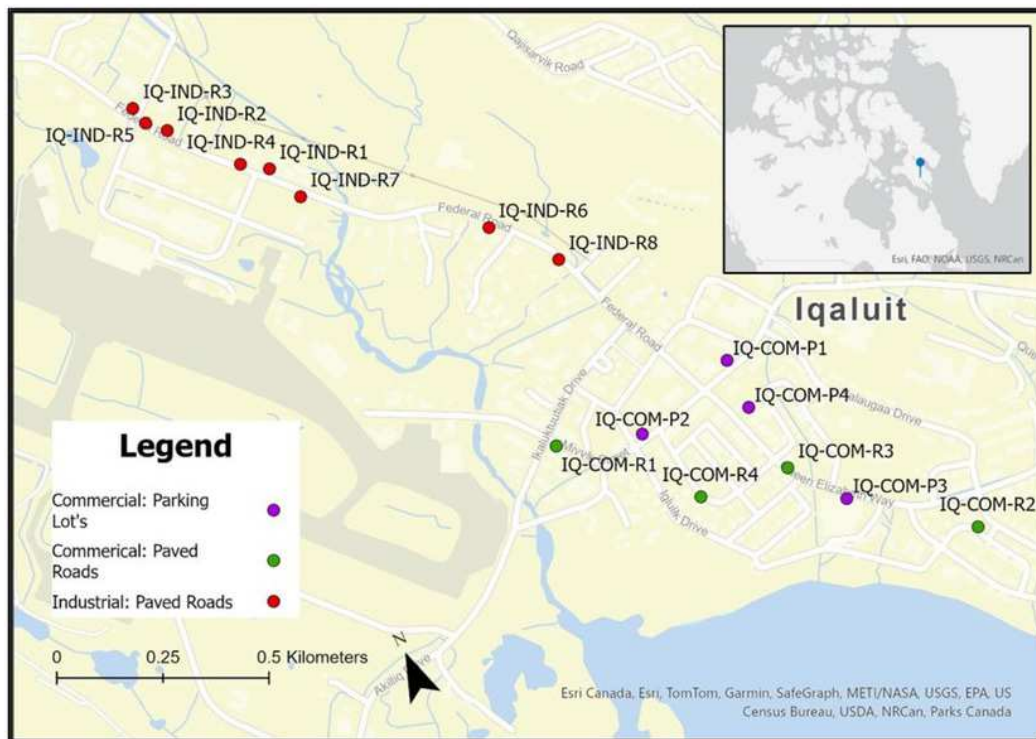


Figure 2

Microplastic images

Microscope images of microplastics identified in road dust samples collected from commercial parking lots, commercial roadsides, and industrial roadsides in Iqaluit, Nunavut; a) blue foam, b) pink fibre, c) grey film, d) green fragment, and e) tire wear particles.

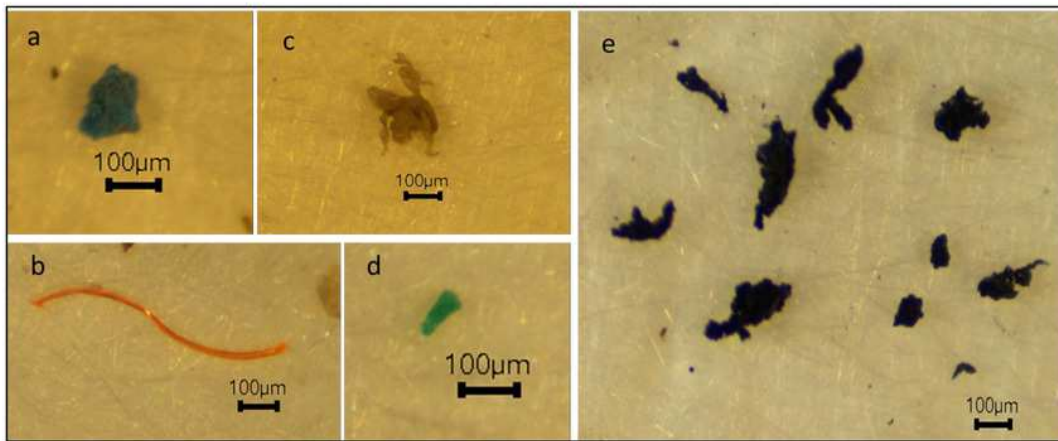


Figure 3

Concentration and deposition of microplastics

Box plots present the distribution of the (A) concentration of microplastics ($\mu\text{g/g}$) and (B) deposition of microplastics ($\mu\text{g/m}^2$) for commercial parking lots (IQ-COM-P; $n = 4$), commercial roadsides (IQ-COM-R; $n = 4$), and industrial roadsides (IQ-IND-R; $n = 8$) across Iqaluit, Nunavut. Lowercase letters indicate statistical significance (Kruskal-Wallis, $p < 0.05$). The box represents the 25 th and 75 th percentile, the horizontal line represents the median and the whiskers represent the interquartile range.

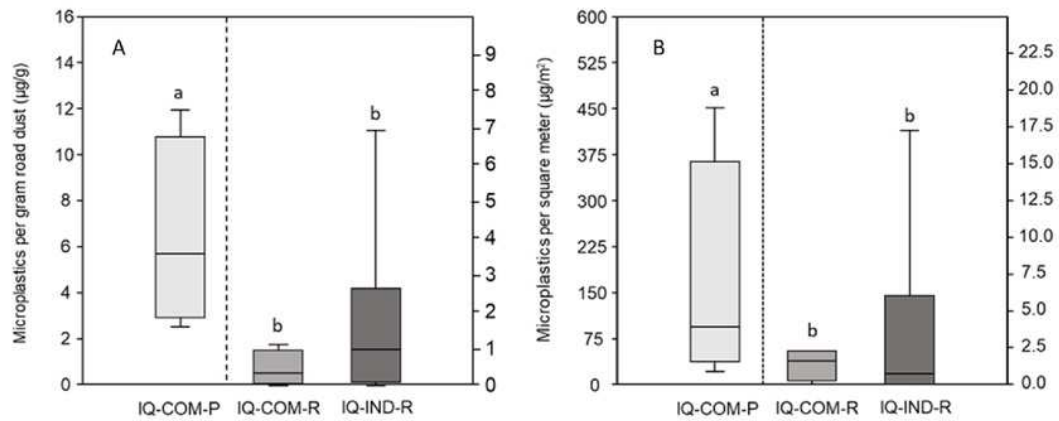


Figure 4

Proportion of microplastic shapes

Donut charts illustrating the proportion of microplastic shapes by mass (μg) per (A) gram road dust and (B) square meter across commercial parking lots (IQ-COM-P; $n = 4$), commercial roadsides (IQ-COM-R; $n = 4$), and industrial roadsides (IQ-IND-R; $n = 8$) in Iqaluit, Nunavut.

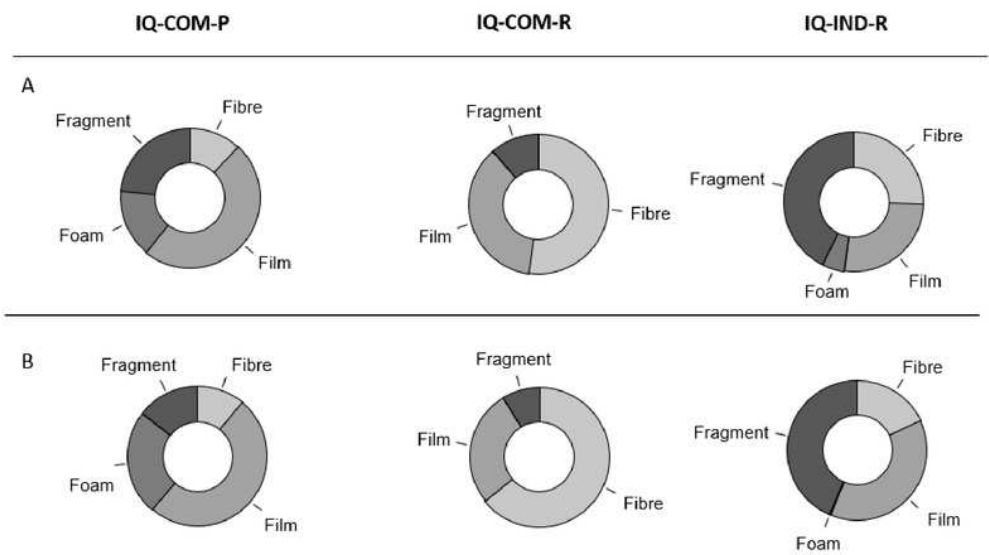


Figure 5

Distribution of microplastic length

Box plots presenting microplastic length (μm) for (A) fibrous and (B) non-fibrous (fragment, film, foam) particles from commercial parking lots (IQ-COM-P; $n = 4$), commercial roadsides (IQ-COM-R; $n = 4$), industrial roadsides (IQ-IND-R; $n = 8$) in Iqaluit, Nunavut. Lowercase letters indicate statistical significance (Kruskal-Wallis, $p < 0.05$). Two outliers ($1222.8 \mu\text{m}$ and $1146.9 \mu\text{m}$) in commercial parking lots for non-fibrous microplastics are not visible on the plot. The box represents the 25 th and 75 th percentile, the horizontal line represents the median and the whiskers represent the interquartile range.

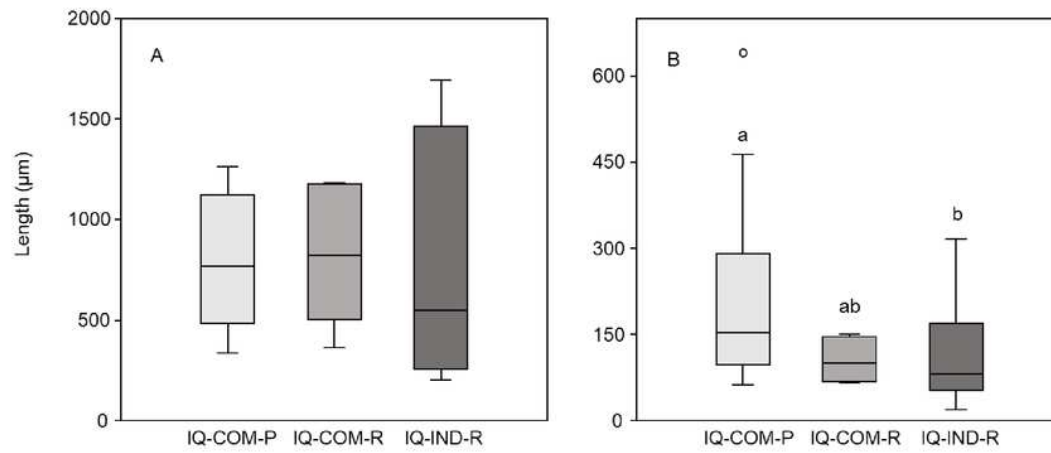


Figure 6

Concentration and deposition of tire wear particles

Box plots illustrating the (A) concentration of tire wear particles (μg) per gram dry weight road dust and (B) deposition of tire wear particle ($\mu\text{g}/\text{m}^2$) from commercial parking lots (IQ-COM-P; $n = 4$), commercial roadsides (IQ-COM-R; $n = 4$), and industrial roadsides (IQ-IND-R; $n = 8$) in Iqaluit, Nunavut. Lowercase letters indicate statistical significance (Kruskal-Wallis, $p < 0.05$). The box represents the 25 th and 75 th percentile, the horizontal line represents the median and the whiskers represent the interquartile range.

