"Assessment of Glass Fiber in the Cowichan Estuary and its Impact on Benthic Fauna and the Food Chain"

Phase I: Glass Fiber Assessment of Estuarine Sediment and Biofilm

CERCA Research Project 2024-2026

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Background and Rationale

Although the impacts of microplastics and anti-fouling paint on benthic fauna and flora in estuaries and shoreline habitats continue to be reported, there is a recently identified further risk to benthic organisms in the form of glass microfibers (Ciocan et al., 2024). Fiberglass is a synthetic, hard, narrow, and elongated filament commonly used in various industries, including building and shipping. Composed mainly of silica (SiO_2) with the addition of other inorganic materials to enhance durability and resistance, glass fiber reinforced plastic (GRP) is a very versatile material, consisting of fine strands of glass embedded in a resinous matrix to form a strong, hydrophobic, and flexible structure. GRP offers significant advantages over other materials like concrete, steel, and other metals, in particular, due to their high ratio of surface area to weight. It shares similar chemical and physical characteristics with asbestos. Both materials exhibit a fibrous structure, giving them comparable aerodynamic properties. Human exposure to fiberglass and asbestos, primarily through inhalation, has been associated with serious health effects, including fibrosis and lung cancer. Ingestion of glass fibers, although considered accidental and rare, has also been linked to severe gastrointestinal disorders in humans and others.

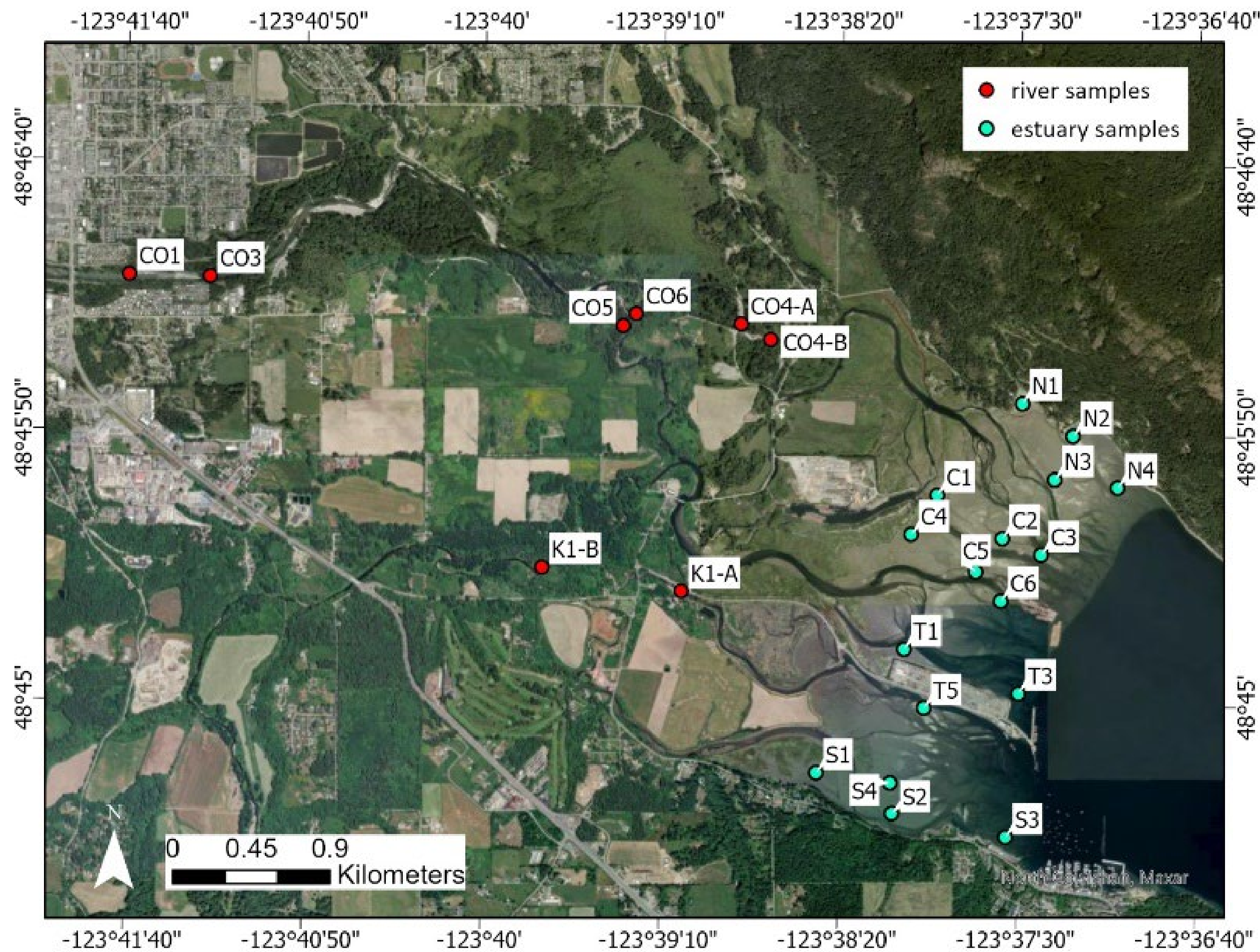
GRP was created in the 1930s and made commercially available for boat production from the 1950s. Hulls for small boats, produced by hand lay-up, were one of the first applications of fiberglass. Nowadays, all types of boats including rigid inflatable boats, large multi-hulls, canoes, warships, and other craft are using this versatile material. Glass fibers are easily released during the cutting or sanding of boats and other structures manufactured, stored, and abandoned, released through normal aging processes. Although very few studies have investigated the accumulation of glass fibers in aquatic organisms the adverse effects of fiberglass ingestion and accumulation in benthic organisms such as mussels and oysters are documented. Such research has provided evidence that glass fibers in mussels' digestive tubules and gills have led to inflammations in all examined organs. GRP has been shown to degrade and contaminate estuaries and coastlines posing an increasing threat to benthic fauna in estuaries, with bivalves considered especially high-risk species being very susceptible due to their sessile nature and as filter feeders.

Against this background, CERCA initiated a possible two-phased research project on the assessment of glass fiber presence and accumulation in sediments, and biofilm of the Cowichan Estuary's inter-tidal and near-shore habitats in 2024. While Phase I concentrates on the analysis of sediment samples collected in 2023 as part of CERCA's Microplastics Project, and biofilm samples collected in August 2024 from the inter-tidal zone of the Cowichan Estuary, Phase II, starting in 2025, would concentrate on GRP ingestion by bivalve species with samples from Dungeness crabs, oysters and clams. The results of Phase I are summarized as follows.

Results of Sediment Sampling

The glass fiber analysis from sediment samples taken at 26 locations in the Cowichan estuary (s. Fig. 1) was conducted on behalf of CERCA by Dr. Zeinab Zoveidadianpour, as part of her Postdoc fellowship from Mitacs using the laboratory facilities of Dr. Bendell at Simon Fraser University.

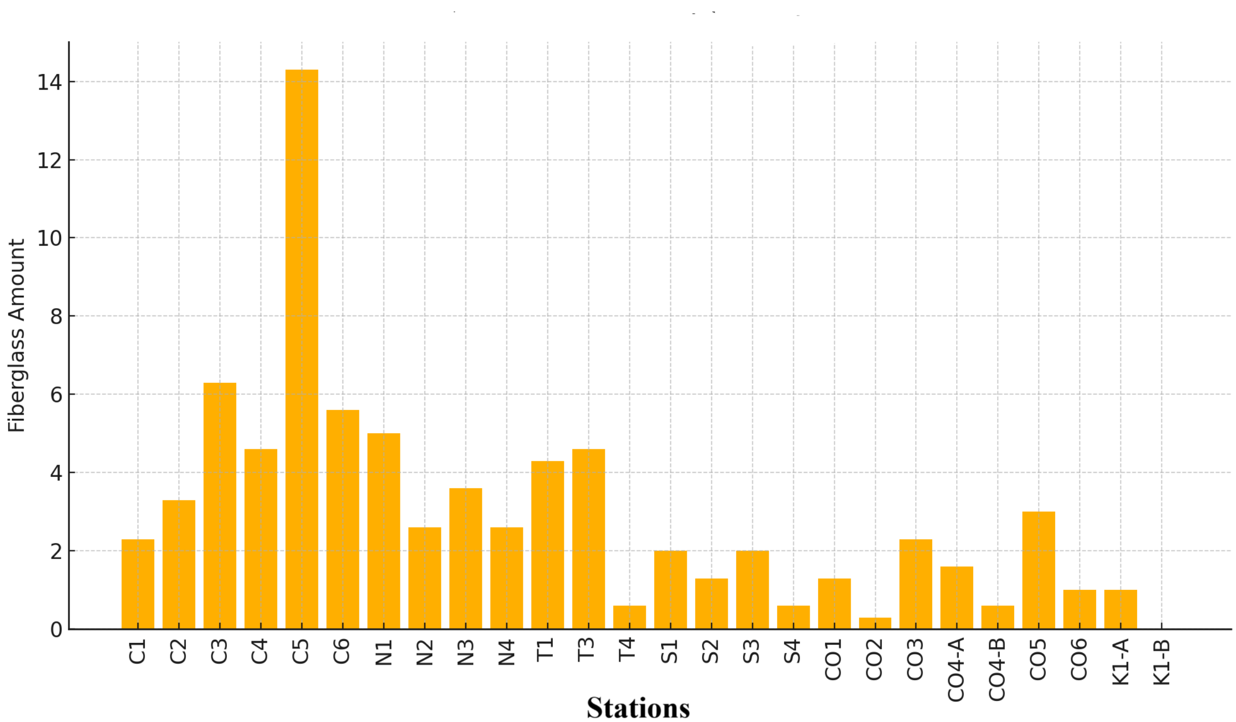
<u>Figure 1</u>: Locations of sediment samples taken in 2023 from the Cowichan Estuary



The sample locations were selected based on a so-called purposive (judgment) sampling design where the sample stations are subjectively chosen using the knowledge of the researcher of the study area. Although this sampling method may be considered the most cost- and time-effective method it has its disadvantages due to possible judgement error by the researcher and the inability to extrapolate research data. Limited resources were the major reason for this choice. However, to minimize the bias, each location formed a cluster with three samples taken within a radius of 4 meters. For this study, the inter-tidal area of the estuary was divided into 4 sections. The northern section with 4 stations (N1- N4) located within the vicinity of residences along the northern shoreline of the estuary, the central section with six stations, three along the north side of the so-called log transport channel (C1-C3), and three to the south of the channel, subject to the influence of the Cowichan River South Fork discharge (C4-C6). The third section was represented by two stations along the north shore of the Westcan Terminal (T1 and T3), and one along its southern shoreline (T5). The four stations representing the southern section were located close to the south shoreline of the estuary experiencing high traffic by pleasure boats and kayaks (S1-S4). Additionally, samples from the Cowichan River above (CO1 and CO3) and below (CO5, CO6, and CO4 A and B) the Duncan sewage outfall, and the lower Koksilah River (K1A and B) were analyzed.

The overall results are shown in Figure 2. Glass fibers were counted as particles identified per gram, ranging from 0 to 20 particles.

Figure 2: Glass fiber count of sediment samples taken in 2023 per station measured in particles/g



The central part of the estuary's mudflats exhibited the highest abundance of glass fibers ranging from 2.2 to 20 particles per gram. The overall highest concentration was found at station C5, with a mean of 14.3 particles/g, and the second highest at C3 with 6.2/g. Station C5 is located at the edge of the Cowichan River South Fork channel and C3 at the edge of the log transport channel. Whether the high concentrations at these locations are linked to the South and North Forks of the Cowichan River is unknown. High concentrations were also found along the north shore of the Westcan Terminal area (T1 and T3). This may be directly linked to the industrial manufacturing of structures containing fiberglass enforced materials. Another potential source of glass fiber pollution originating from the Terminal is the storage of abandoned and deteriorating structures with fiberglass components, being washed into the estuary by uncontrolled stormwater discharge.

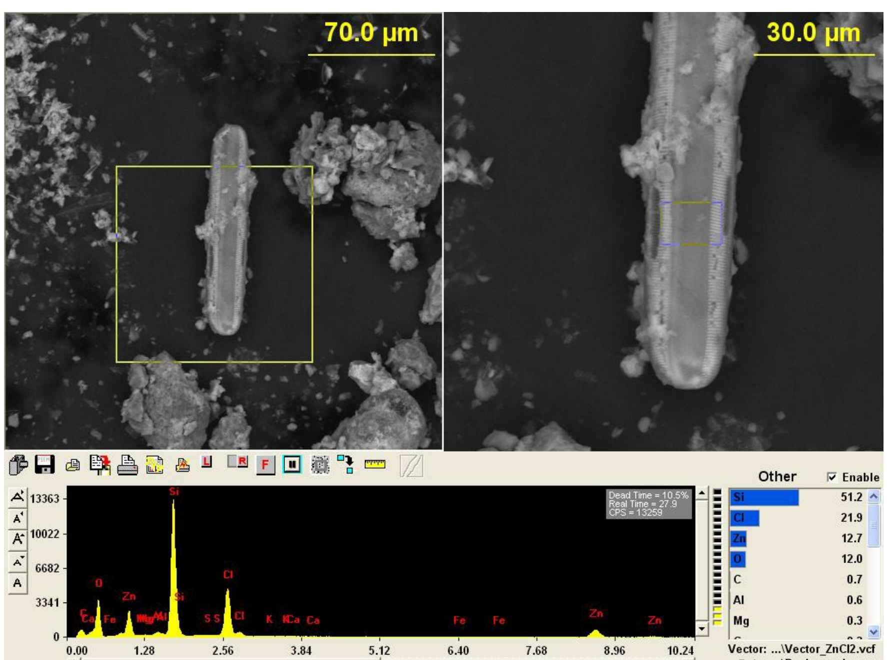
Large concentrations were also found in the northern section of the estuary at the three sample stations located within a rather secluded Bay covered by a thick layer of "mud" in front of residences along the northern shoreline. It is believed that the high amount of 14.5 particles/g at sample station N1 may be linked directly to an adjacent residential property. Counts of the northern stations ranged from 0 to 8 particles per gram and a mean concentration of 3.45 particles/g, with station N3 showing a count of 3.6 particles/g.

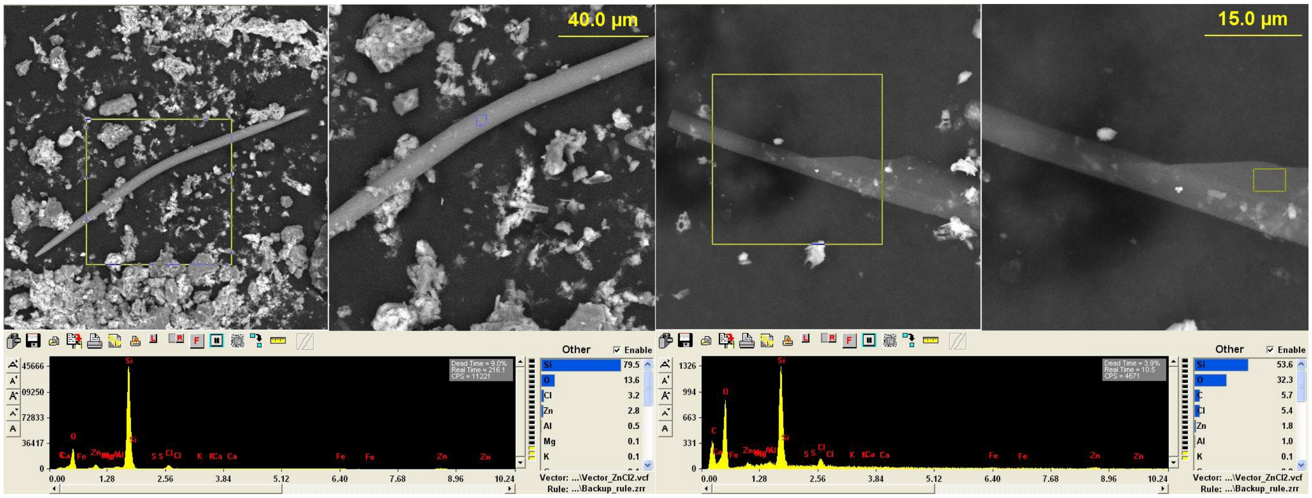
The southern section showed the lowest amount of glass fibers at all four sample locations. This section happens to be one of the least disturbed by anthropogenic influences bordered by a mostly treed shoreline free of settlements. Furthermore, this area is not subject to the large-scale freshwater discharge events typical for the northern sections of the estuary caused by the Cowichan River carrying pollutants from point sources. The low count of less than 1 particle/g at K1-A and none at K1- B stations at the lower Koksilah River draining into the southern section of the estuary may be indicative of the Koksilah River which runs substantially cleaner than the Cowichan.

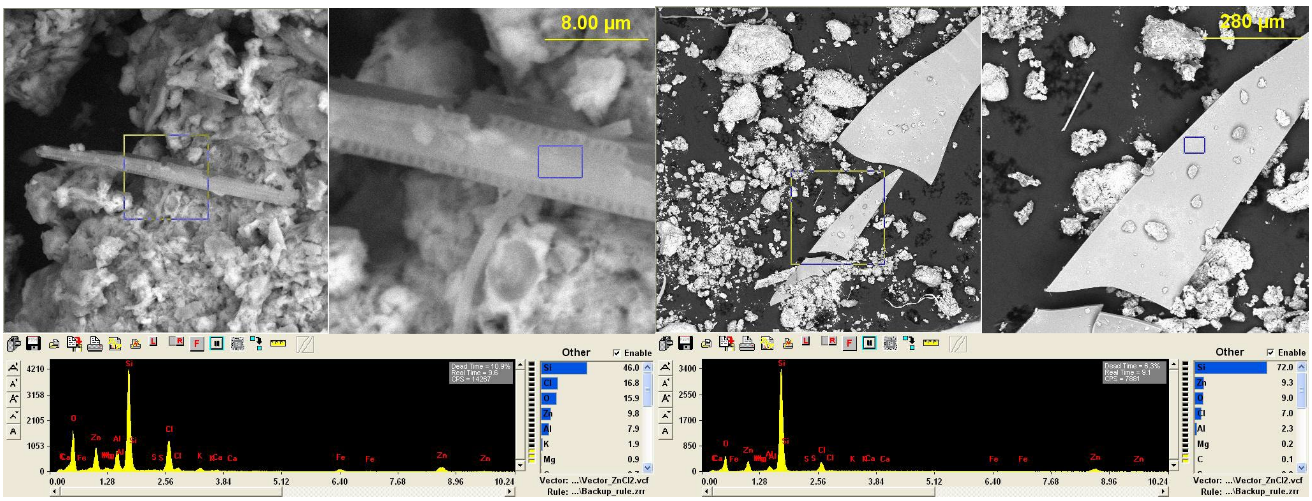
Samples taken from Cowichan River Stations CO1 and CO2 above the Duncan sewage outfall showed lower amounts of glass fiber than samples from CO3 located below the sewage outfall. CO5 and CO6 located at a very secluded part of the southern arm of the Cowichan River revealed an unexpectedly high number of fibers (i.e., close to 2 particles/g). Whether this is related to a recently established campground is unknown.

Examples of fiber images produced by the scanning electron microscope (SEM) for the sediment sample analysis are shown in Figure 3. The observed sizes of fiberglass particles varied, with an average size range from 80 to 260 micrometers (=0.8 to 2.6 mm).

<u>Figure 3</u>: SEM images of different-sized glass fiber particles







Results of Biofilm Sampling

The glass fiber analysis of biofilm samples taken at 15 locations (in triplicates) from the intertidal mudflats of the Cowichan Estuary was conducted by Dr. Tamara Kazmiruk contracted by CERCA, using the same facilities as used for the sediment analysis by Dr. Zeinab Zoveidadianpour at Simon Fraser University..

Intertidal biofilm is rich in fatty acids that provide critical nutrients for long-distance flights of migratory birds researched by Dr. Drever, a main financial contributor to this research. Potential glass fiber embedded in the biofilm is of special concern to Dr. Drever's research since glass fiber particles accidentally ingested by the birds feeding on the biofilm may pose a serious health hazard.

The biofilm samples were analyzed for (1) organic matter (OM) content and (2) glass fiber presence/concentration.

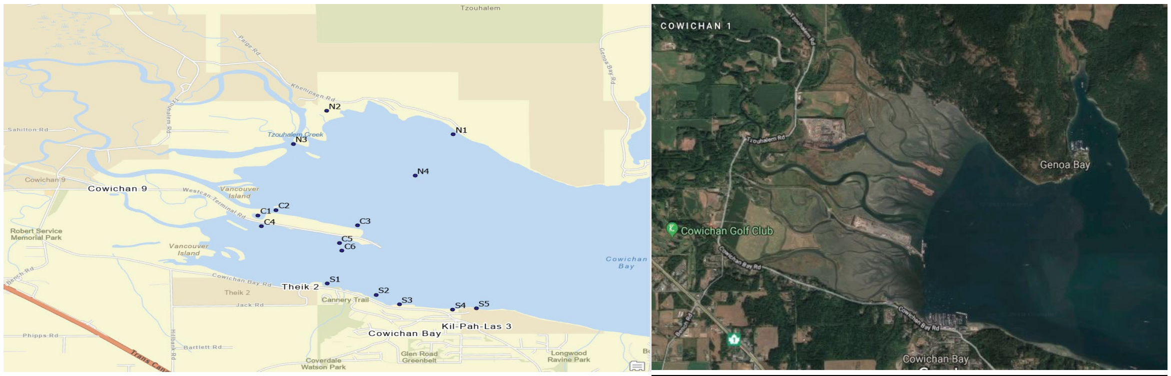
The locations and coordinates of the sampling stations are presented and described in Figures 4 and 5. Sample stations were subjectively chosen with due consideration of potential glass fiber point sources in the estuary.

Figure 4: Coordinates of 2024 sampling stations for glass fiber analysis

Biofilm Samples from the Cowichan Estuary
Glass Fiber Project 2024

Location	Coordinates		Date	
N1	48.762248	123.617011	19-Jun	dock residence at the end of Khenipsen
N2	48.765193	123.629062	19-Jun	dock residence at Greenpoint
N3	48.761063	123.632238	19-Jun	north side entrance WFP's mill pond
N4	48.757102	123.620651	20-Jun	north side end of the log transport channel
C1	48.752122	123.635586	19-Jun	North-west of Westcan Terminal
C2	48.752801	123.633869	19-Jun	NW corner of Westcan Terminal
C3	48.750877	123.626144	20-Jun	NE corner of Westcan Terminal
C4	48.750764	123.635242	19-Jun	SW corner of Westcan Terminal
C5	48.74867	123.627861	19-Jun	SE of Westcan Terminal
S1	48.74361	123.628992	21-Jun	Kayak-launch
S2	48.742211	123.624346	20-Jun	Boat ramp/nature center
S3	48.741002	123.622128	21-Jun	WB society
S4	48.740345	123.617064	21-Jun	Hotel
S5	48.740536	123.614813	21-Jun	First Nation
C6	48.747712	123.627589	20-Jun	South Eastern corner of Eelgrass Field

Figure 5:	Locations of 2024 biofilm sampling stations



The overall results of the 2024 biofilm sample analysis are shown in Figure 6. Glass fibers were found at only three of the 15 sample stations, and glass fiber fragments at two of the 15 stations. Each sample site consisted of three sub-samples.

Figure 6:	Number of glass fiber and glass fragments of 2024 biofilm samples (particles/kg).

Sample Station	Org matter %	Substrate	Fiber PP/kg	Fragments
(N1a; N1b; N1c)	2.8	sand fine, silt fine	**0**	**0**
(N2a; N2b; N2c)	7	silt fine, mud	**0**	**0**
(N3a; N3b; N3c)	9.5	silt fine	**62**	**0**
(N1a; N1b; N1c)	6	sand fine, silt fine, mud	**0**	**0**
(C1a; C1b; C1c)	11.5	sand fine, mud	**34**	**0**
(C2a; C2b; C2c)	4.7	sand fine, silt, mud	**0**	**0**
(C3a; C3b; C3c)	2.4	sand medium, silt fine	**0**	**0**
(C4a; C4b; C4c)	8.5	sand fine, silt fine, mud	**0**	**30**
(C5a; C5b; C5c)	7.8	sand medium, silt fine	**0**	**0**
(C6a; C6b; C6c)	3.5	sand fine, silt fine	**0**	**32**
(S1a; S1b; S1c)	5.5	sand fine, silt fine, mud	**0**	**0**
(S2a; S2b; S2c)	2.5	sand fine, silt	**0**	**0**
(S3a; S3b; S3c)	4.5	sand fine, silt, mud	**34**	**0**
(S4a; S4b; S4c)	4	sand medium, silt fine, mud	**0**	**0**
(S5a; S5b; S5c)	1.8	sand fine, silt fine, mud	**0**	**0**

Surprisingly, the highest concentration of fibers was found at station N3, located at the mouth of the Western Forest Product's mill pond (s. Figure 7), suggesting that the mill site could be a major point source for glass fiber pollution.

C1 and S3 are the other two locations with identified fibers; each showing identical numbers of 34 fibers per kg but only approximately half of the N3 sample with 62 particles/kg. Station C1 is located directly below the hand-made earthen run-off ditch to the south of the Westcan Terminal (s. Figure 7) suggesting that fibers resulting from operations at this site may be washed uncontrolled in the estuary.

Figure 7: Location of sampling stations N3 (left photo) at the mouth of the WFP mill pond and C1 (right photo) to the northwest corner of the Westcan Terminal.

The two photos below show the western section of the Westcan Terminal, a suspected source of glass fiber pollution.

The number of glass fibers at station S3 taken from samples in front of one of the Marinas in Cowichan Village is relatively high. This is likely linked to heavy boat traffic, repairs, and shoreline cleaning of boats as typical for marinas.

Fragments of fiberglass have only been found at two sample sites both located to the South of the Westcan Terminal, C4 at the south-western corner, and C6 southeast of the Terminal at the edge of the only eelgrass field left in the estuary (Figure 8).

Figure 8: Location of sample sites C4 (black arrow) and C6 (red bar)

In 2023 biofilm samples were collected from 14 of the 17 inter-tidal sample sites used for the CERCA's Microplastics research Phase II and the glass fiber analysis of sediment samples described in Figure 2 of this report. The samples were also analyzed by Dr. Kazmiruk. The results are presented in Figure 12.

Figure 9: Results of the glass fiber assessment from biofilm samples collected in 2023

Sample Station	Org matter %	Substrate	Fiber PP/kg	Fragments
(N1a; N1b; N1c)	4.7	sand fine, silt fine, mud	**0**	**0**
(N2a; N2b; N2c)	2.9	silt fine, mud	**0**	**0**
(N3a; N3b; N3c)	3.3	sand fine, silt fine, mud	**0**	**0**
(N1a; N1b; N1c)	3.9	silt fine, mud	**0**	**0**
(C1a; C1b; C1c)	5.2	sand medium, silt fine, mud	**0**	**0**
(C2a; C2b; C2c)	4.7	sand fine, silt fine	**0**	**47**
(C4a; C4b; C4c)	8.9	silt fine, mud	**0**	**0**
(T1a; T1b; T1c)	5.3	sand fine, silt fine, mud	**0**	**0**
(T3a; T3b; T3c)	2.4	sand medium, silt, mud	**0**	**0**
(T5a; T5b; T5c)	10.2	silt fine, mud	**0**	**0**
(S1a; S1b; S1c)	8.2	silt fine, mud	**0**	**0**
(S2a; S2b; S2c)	5.5	silt fine, mud	**0**	**0**
(S3a; S3b; S3c)	11.3	sand fine, silt	**0**	**30**
(S4a; S4b; S4c)	5.9	sand fine, silt fine, mud	**0**	**0**

Glass fiber particles were only discovered in two of the 14 biofilm samples. It is noteworthy that the highest number of particles (47 particles/kg) were found at sample site C2 along the northern edge of the log transport channel that connects the mill pond with the deep water of the estuary. This appears to confirm the suspicion that the WFP Mill is a primary source of glass fiber pollution since the highest number of particles of all samples collected in 2024 were found at site N2 (62 particles/kg), the mouth of the mill pond.

Site S3 of the 2023 sample locations was the second site where glass fiber particles were detected (30 particles/kg). This site is located adjacent to the largest pleasure boat launch in the estuary, experiencing year-round heavy traffic of boats, mostly built of fiberglass.

Discussion and Conclusions

The fiberglass assessment in the Cowichan Estuary focused on the analysis of sediment and biofilm samples. 25 sediment samples were taken in triplicate at each sample station of the intertidal flats of the estuary and its tributaries, the Koksilah and Cowichan Rivers, in 2023. Glass fibers and fiber fragments were found in **all samples** ranging from a low of 2 to a high of 14 particles per gram. It is noteworthy that the difference of particles taken from samples above and below the Duncan sewage outfall proved to be not as pronounced as expected, although the number of fragments below the outfall was slightly higher. The central part of the estuary exhibited the highest abundance of glass particles with the highest concentration found at station C5. Very high concentrations were found at the mouth of the Western Forest Products Mill Pond. Samples of stations close to the Westcan Terminal also showed high concentrations. Samples from the lower Koksilah River had the lowest fiberglass count. Glass fiber particles varied in size with an average size range from 80 to 260 micrometers.

Of the 15 biofilm stations used in 2024 distributed over the inter-tidal flats of the estuary and along its southern shoreline only 5 contained fibers and glass particles. The highest concentration was found at a station located at the edge of the log transport channel. High concentrations were counted at stations close to the Westcan Terminal and a Marina in Cowichan Bay Village.

Of the 14 biofilm samples from the inter-tidal flats collected in 2023 only 2 contained glass fiber fragments; one at the mouth of the WFP mill pond, the other at the boat launching site, south of the estuary.

In summary, the data from both the sediment and biofilm samples appear to suggest that the main sources of fiberglass pollution in the Cowichan Estuary are the WFP Mill, the Westcan Terminal, Marinas and slipways, and to a lesser extent possibly upstream sources along the Cowichan River. The overall data also appear to suggest that glass fiber fragments that have a higher density than seawater will tend to accumulate in sediments rather than the biofilm, which constitutes the top layer of 3-5 millimeters of the mudflats.

To our knowledge, this is the first report on glass fiber accumulation in the intertidal sedimentary and biofilm environment of the Cowichan Estuary and possibly BC at large. The adverse effects of glass fiber ingestion and accumulation in benthic organisms are yet to be deciphered since very few studies have investigated the uptake and accumulation of glass fibers in aquatic organisms. Further studies on the potential transfer up the food chain and likely consequences for human health should therefore be prioritized, the reason for a proposed follow-up to this project with a focus on key bivalve species of the estuary to be checked for glass fiber content.

The results highlight the need for better regulation of public access to slipways, and commercial boat maintenance facilities, but also to create a better ethos of end-of-life boat management in general, to minimize further exposure and spread of glass fiber and microplastic contaminants in aquatic environments.

Since the research findings of this project are subject to a scientific publication only a summary of the findings is provided in this report elaborated for the CERCA website.

Acknowledgements

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