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Tire crumb rubber in soil surrounding artificial turf fields

Hosle, Nadderud og Føyka artificial turf fields, Norway

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Division of Environment and Natural Resources

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Tire crumb rubber in soil surrounding artificial turf fields: Hosle, Nadderud og Føyka artificial turf fields, Norway

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SUMMARY:

The presence of tire crumb rubber particles in soil surrounding three artificial football fields in Asker and Bærum municipalities, Norway, was studied. Concentrations of crumb rubber particles in soil were found to be high.

LAND/COUNTRY:	Norway
FYLKE/COUNTY:	Viken
KOMMUNE/MUNICIPALITY:	Bærum
STED/LOKALITET:	Hosle, Nadderud, Føyka

GODKJENT /APPROVED	PROSJEKTLEDER /PROJECT LEADER
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Content

1 Introduction

1.1 Background

The present report is based on the work reported in Coutris et al. (2018), which was until now only available in Norwegian. According to a Norwegian report by Tandberg and Raabe (2017), approximately half of the artificial turf fields in the Oslo region were used during winter, which led to spreading of tire crumb outside the artificial turf fields, due to snow clearing. This was the case for 22 out of 34 turf fields, where most of them use tire crumb from old car tires. The aim of the work initiated by Tandberg and Raabe (2017) was to map tire crumb spreading from artificial turf fields. Although routines were in place at artificial turf fields regarding handling of used tire crumb, there were concerns that tire crumb would still spread from these fields to the surrounding environment, and even further away if they reached waterways.

One major reason for the spreading of tire crumb outside artificial turf fields is snow clearing during winter, where snow blowers throw snow and tire crumb outside the fields. Besides, there has been a lack of recycling facilities accepting tire crumb waste in the vicinity of the fields, and once used tire crumb was collected after cleaning of the field, it was often left outside in large bags until these bags cracked and their content got washed away by rain and wind. In some cases, used tire crumb was sold or given away to riding centres.

Spreading of tire crumb from artificial turf fields has gained a lot of attention during the past years, and has been recognized to be one of the main sources of microplastics in Norway. In April 2021, the Norwegian government adopted regulations to reduce the spreading of tire crumb from artificial turf fields, including requirements for physical barriers around the fields, requirements for snow removal and treatment of the snow containing tire crumb, and measures to prevent players and referees from spreading tire crumb when leaving the field.

1.2 Short work description

NIBIO sampled soil in July 2017 around three artificial turf fields in the Oslo region (Norway), all of which were in use during winter: Hosle (GPS 59.933282, 10.582748), Nadderud (GPS 59.921211, 10.584207), and Føyka (GPS 59.834094, 10.425443). At Føyka, soil was also sampled close to the motorway E18 (GPS 59.832492, 10.423328) for a comparison with potential tire crumb particles from car traffic. Polymer identification of tire crumb was done by Simultaneous Thermal Analysis (STA) coupled to Fourier-transform Infrared Spectroscopy (FTIR). Surface area was used to calculate tire crumb concentrations in the samples. More details are provided in §2 Study sites and sampling description.

2 Study sites and sampling description

2.1 Hosle

At Hosle turf field, snow is cleared with a snow blower that throws snow and tire crumb westwards over the western side of the field. We found large amounts of tire crumb in the forest and on the grass-covered area west of the field (up to 15 m from the fence and 5 m above the level of the field), but not on the other sides of the field. Tire crumb found in soil on the western side of the field had no natural leaching pathways and will most likely remain where it is now without spreading towards drains or natural waterways.

2.1.1 Soil sample N1-1

Sampling area: 18×18 cm, in the forest located on the west side of the synthetic turf field (Fig. 1)
Sampling depth: 0-6 cm; divided in two layers: **N1-1**-1 (0-4 cm depth), **N1-1**-2 (4-6 cm depth)
Vegetation: Trees and shrubs, forest litter (withered leaves and twigs)
GPS coordinates: N59.93361, E10.58283
Slope: ca. 20 %
Distance from the artificial turf field: ca. 13 m

Figure 1. Soil sample N1-1 at Hosle, 13 m away from the artificial turf field (a), the forest floor on the western side of the artificial turf field is covered with large amounts of tire crumb (b).

2.1.2 Soil sample N1-2

Sampling area: 18×18 cm, on grassy meadow used for temporary storage of used tire crumb (Fig. 2)
Sampling depth: 0-8 cm, divided in two layers: **N1-2**-1 (0-4 cm depth), **N1-2**-2 (4-8 cm depth)
Vegetation: Grass
GPS coordinates: N59.93317, E10.58295
Slope: ca. 0 %
Distance from the artificial turf field: ca. 9 m

Figure 2. Soil sample N1-2 next to Hosle artificial turf field, on grassy meadow used for temporary storage of used tire crumb.

2.2 Nadderud

At Nadderud artificial turf field, snow seems to have been cleared without the use of a snow blower, at least in the last years. Tire crumb can be found outside the northern long side of the field, but not along the other sides. Tire crumb present in soil along the northern side has no natural leaching pathways and is likely to remain where it is now without spreading towards drains or natural waterways.

2.2.1 Soil sample N4

Sampling area: 18×18 cm, grass-covered area outside the turf field (Fig. 3)
Sampling depth: 0-6 cm, divided in two layers: **N4**-1 (0-3 cm depth), **N4**-2 (3-6 cm depth)
Vegetation: Grass
GPS coordinates: N59.92138, E10.58375
Slope: ca. 5 %
Distance from the artificial turf field: 12 m

(a)  (b) 

Figure 3. Soil sample N4, 12 m away from Nadderud artificial turf field (a), large amounts of tire crumb are visible in soil under the grass cover (b).

2.3 Føyka

At Føyka turf field, snow has been cleared for the past 10 years with a snow blower that throws snow and tire crumb outside the long sides of the field, one of which is facing the stream Drengsrudbekken. Large amounts of tire crumb are visible outside the turf field, including the footpath between the field and the stream (Fig. 4a) and in soil all the way down to the stream. Drains on the turf field are equipped with geotextile to prevent leakage of tire crumb down the drain (Fig. 4b), and an effort is now made to collect used tire crumb.

There are also visible amounts of tire crumb under the soil surface, down to 6 cm depth (Fig. 5b). The slope (ca. 20 %) between the turf field and the footpath, and then between the footpath and the stream, constitutes a spreading pathway for tire crumb from the turf field to the stream. However, the vegetation present between the footpath and the stream, including trees, shrubs and herbaceous plants, partly prevent tire crumb from being washed further down the slope to the stream. Exceptions to this are several smaller footpaths going down to the stream, where there is no vegetation.

(a)  (b) 

Figure 4. High amounts of tire crumb are visible on the southern footpath between the artificial turf field and the stream Drengsrudbekken (a), drains next to the turf field are lined with geotextile (b).

2.3.1 Soil sample X4

Sampling area: 40×40 cm, in the vegetated area between the southern footpath and the stream Drengsrudbekken (Fig. 5a)
Sampling depth: 0-6 cm; divided in three layers: **X4**-1 (surface), **X4**-2 (0-1 cm depth), **X4**-3 (1-6 cm depth)
Vegetation: Coltsfoot, grass
GPS coordinates: N59.833925 E10.425139
Slope: ca. 20 %
Distance from the artificial turf field: ca. 10 m
Distance from the stream: ca. 4 m

(a)  (b) 

Figure 5. Soil sample *X4 close to Føyka artificial turf field, soil is covered with coltsfoot and grass (a), and both tire crumb and artificial grass are visible in between plant roots (b).*

2.3.2 Soil sample X5

Sampling area: 18×18 cm, on the roadside of the motorway E18 (Fig. 6), ca. 170 m south of sampling point X4
Sampling depth: 0-2 cm, divided in two layers: **X5**-1 (surface), **X5**-2 (0-2 cm depth)
Vegetation: Grass
GPS coordinates: N59.83227, E10.42533
Slope: ca. 2 %
Distance from the motorway: 30 cm
Distance from the stream: 170 m

Figure 6. Soil sample X5, along the motorway E18.

3 Sample treatment and analysis

3.1 Separation of sand, tire crumb particles and organic matter

3.1.1 Føyka

Samples **X4**-1 (surface), **X4**-2 (0-1 cm depth), **X4**-3 (1-6 cm depth) were first treated with a saturated salt and sugar solution (1 L distilled water, 400 g salt (NaCl), 500 g sugar (sucrose), density 1.28 g/mL), to separate gravel and sand (fraction 1, sinks in saturated salt-sugar solution) from the rest of the sample (Fig. 7).

The fraction that floated in saturated salt-sugar solution was thoroughly washed with water over a 100-µm steel mesh filter and transferred to a large glass beaker filled with water (density 1.0 g/mL) to separate **tire crumb** (**fraction 2**, sinks in water) from organic matter (fraction 3, floats in water). Fraction 3 also contained small amounts of artificial grass, which was not quantified.

Fraction 2 (tire crumb) was dried at 80 °C and weighed to determine tire crumb concentrations per m², in each layer.

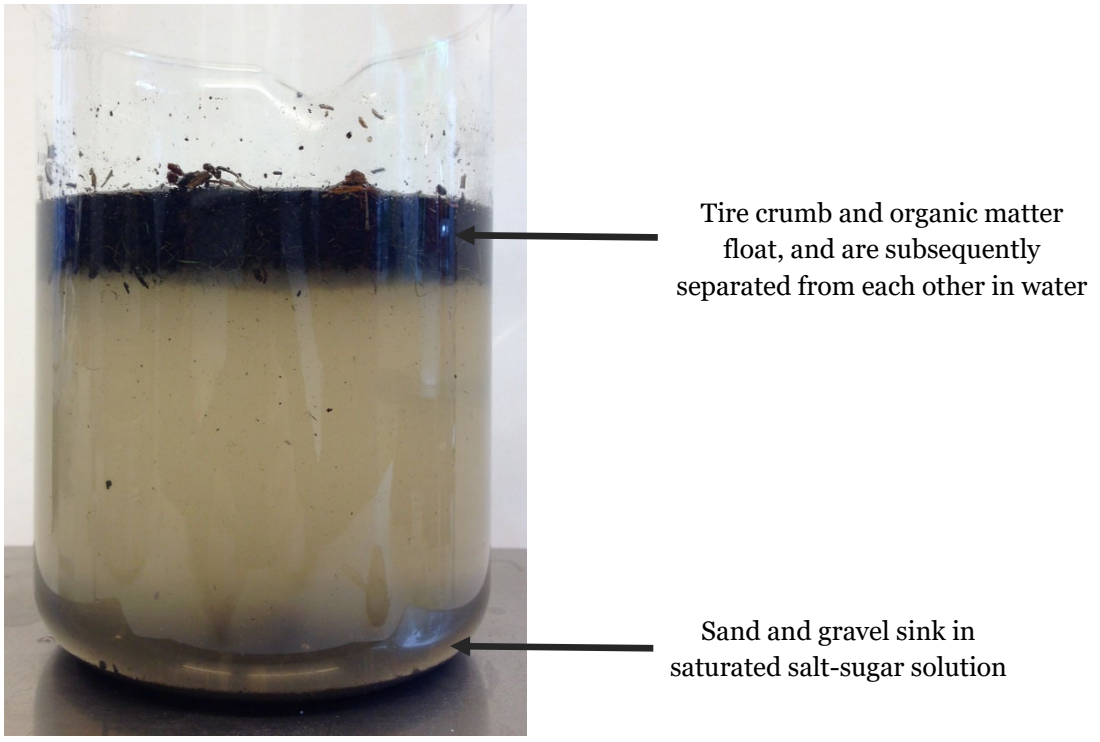

Figure 7. Separation in saturated salt-sugar solution.

3.1.2 Hosle and Nadderud

Samples from Hosle and Nadderud were also treated using the method described above. However, these samples contained tire crumb with various densities (from <1.0 g/mL to >1.28 g/mL), and tire crumb particles were therefore found in all three fractions in samples from Hosle, and in fractions 1 and 2 in samples from Nadderud. Therefore, a visual determination of the proportion of tire crumb particles in each fraction was made, using figures adapted from Terry and Chilingar, 1955 (Fig. 8).

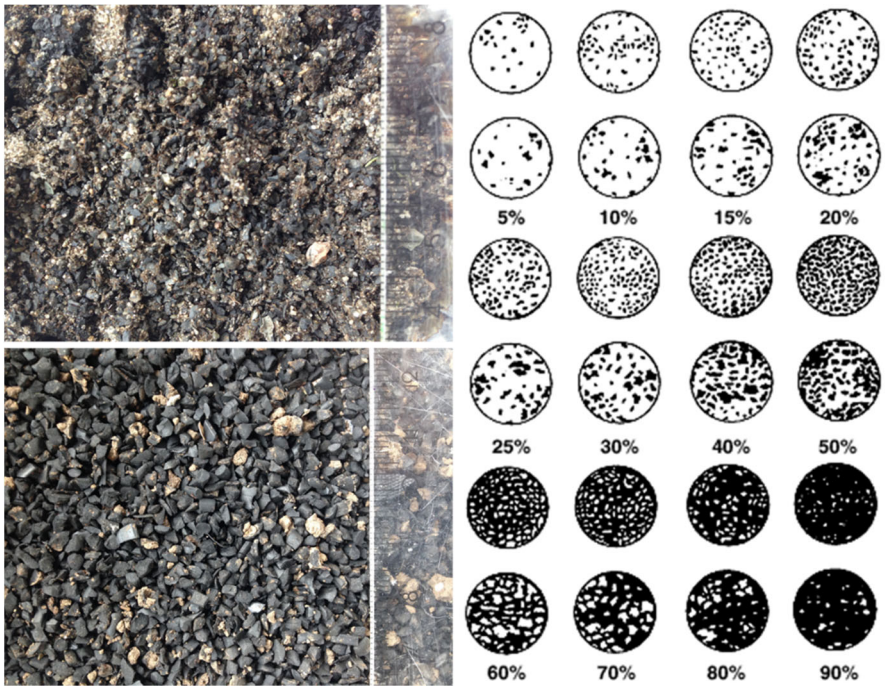

Figure 8. Visual determination of the proportion of tire crumb particles in samples from Nadderud (upper picture, fraction 1 of N4-1, ca. 50 % tire crumb) and Hosle (lower picture, fraction 1 of N1-1-1, ca. 90 % tire crumb).

3.2 Simultaneous thermal analysis and Fourier-transform infrared spectroscopy (STA-FTIR)

The method is using a combination of Simultaneous Thermal Analysis (STA) and Fourier-transform Infrared Spectroscopy (FTIR). During STA, samples are heated from 20 to 550 °C under N_2 atmosphere, while sample mass loss and caloric properties are continuously recorded (by thermogravimetry and differential scanning calorimetry, respectively). The gas evolved in STA are continuously transferred to the FTIR, for further polymer identification. Both STA and FTIR spectra are then compared to those of known materials (polymer library).

The samples listed below were analysed by STA-FTIR:

- Hosle N1-1-1, fractions 1,2,3
- Hosle N1-2-1, fractions 1,2,3
- Pristine tire crumb used at Nadderud artificial turf field
- Nadderud N4-1, fractions 1,2
- Nadderud N4-2, fractions 1,2
- Pristine tire crumb used at Føyka artificial turf field
- Føyka X4-1, fraction 2
- Føyka X4-2, fraction 2 (only 0.45-50 µm)
- Føyka X5

4 Results

4.1 Hosle

4.1.1 Soil sample N1-1

- Tire crumb concentrations

0-4 cm depth: **15.1 kg/m²**

4-6 cm depth: **3.7 kg/m²**

- Tire crumb particle size: ca. 2 mm
- STA-FTIR analysis

The upper soil layer (0-4 cm depth) was analysed by STA-FTIR. Despite various densities (from <1.0 g/mL to >1.28 g/mL), FTIR spectra indicated that all tire crumb particles (Fig. 9) in this soil sample shared features with thermoplastic styrenic elastomer (TPS, hit quality 966/1000).

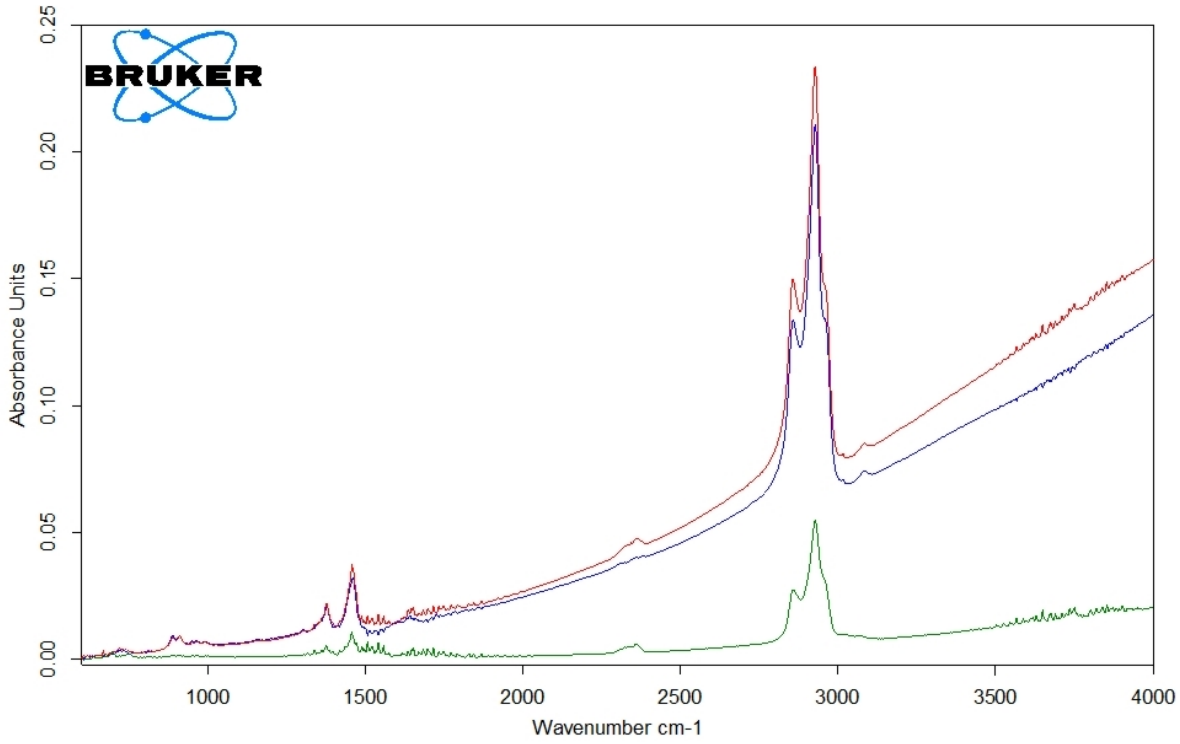

Figure 9. **FTIR spectra of sample Hosle N1-1-1 (0-4 cm depth), with fraction 1 in green, fraction 2 in red, and fraction 3 in blue.**

4.1.2 Soil sample N1-2

- Tire crumb concentrations

0-4 cm depth: **7.8 kg/m²**

4-8 cm depth: **3.8 kg/m²**

- Tire crumb particle size: ca. 2 mm

- STA-FTIR analysis

The upper soil layer (0-4 cm depth) was analysed by STA-FTIR. Fig. 10 shows that tire crumb in the three fractions had different contents of organic and mineral components. Under pyrolysis at up to 550 °C, tire crumb in fraction 1 (density >1.28 g/mL) had the highest ash content (55 %), while tire crumb in fraction 3 (density <1.0 g/mL) had the lowest ash content (13 %). Tire crumb in fraction 2 (density 1.0-1.28 g/mL) had an intermediate ash content (36 %).

Fig. 11 shows the FTIR spectra of fractions 1-3 in sample Hosle N1-2-1 (0-4 cm depth). The searches in chemical polymer databases gave varying matches with reference materials, with best match for thermoplastic styrenic elastomers (TPS, 792/1000) for fraction 1, ethylene propylene diene rubber (EPDM, 751/1000) for fraction 3, and butadiene rubber (BR, 463/1000 for fraction 2, 358/1000 for fraction 3).

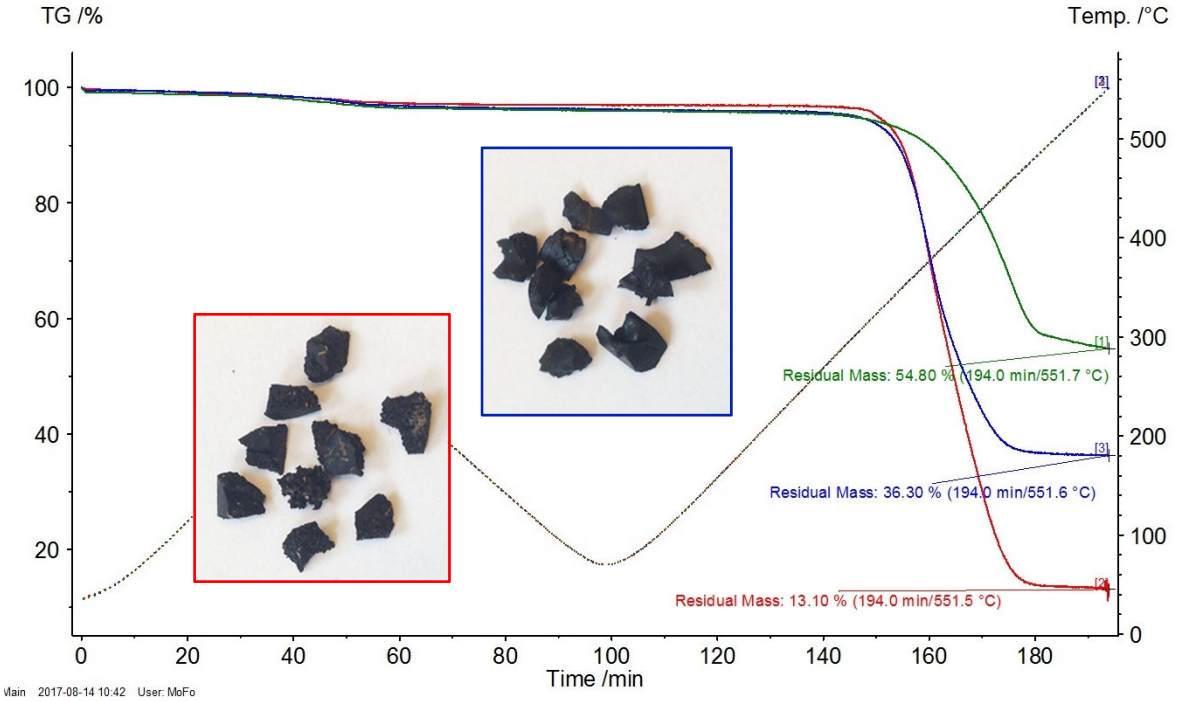

Figure 10. Thermogravimetric curves from STA show mass loss during the pyrolysis of sample Hosle N1-2-1 (0-4 cm depth), with fraction 1 in green, fraction 2 in blue, and fraction 3 in red.

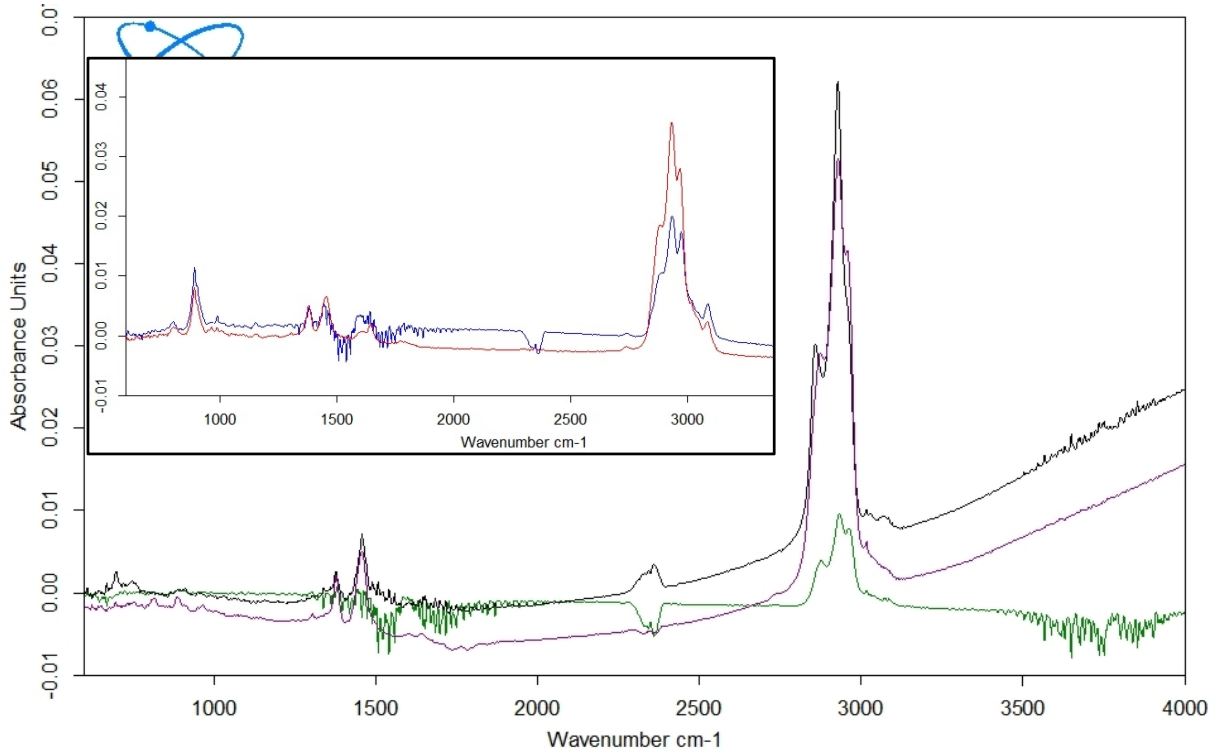

Figure 11. FTIR spectra of fraction 1 (black), fraction 2 (green), and fraction 3 (purple) in sample Hosle N1-2-1 (0-4 cm depth). The insert shows FTIR spectra of another material found in fractions 2 (blue) and 3 (red).

4.2 Nadderud

4.2.1 Soil sample N4

- Tire crumb concentrations

0-3 cm depth: **5.2 kg/m²**

3-6 cm depth: **10.1 kg/m²**

- Tire crumb particle size: ca. 2 mm
- STA-FTIR analysis

Fractions 1 and 2 of N4-1 (0-3 cm depth) and N4-2 (3-6 cm depth) were analysed by STA-FTIR. Thermogravimetric curves from STA (Fig. 12) show that tire crumb in fraction 2 (density 1.0-1.28 g/mL) had a lower ash content than those in fraction 1 (density >1.28 g/mL), as also observed in the samples from Hosle.

FTIR spectra of tire crumb in sample N4-1 (0-3 cm depth, fractions 1 and 2) were very similar to that of tire crumb in sample N4-2 (3-6 cm depth, fraction 1) (Fig. 13). These spectra got a reasonably good match (523/1000) with styrene butadiene rubber (SBR). The FTIR spectrum of N4-2 fraction 2 (in black in Fig. 13), on the other hand, shows a different type of material. However, the material only gave very poor matches with reference polymers (181/1000 with cyclo olefin copolymer and 136/1000 with butadiene rubber).

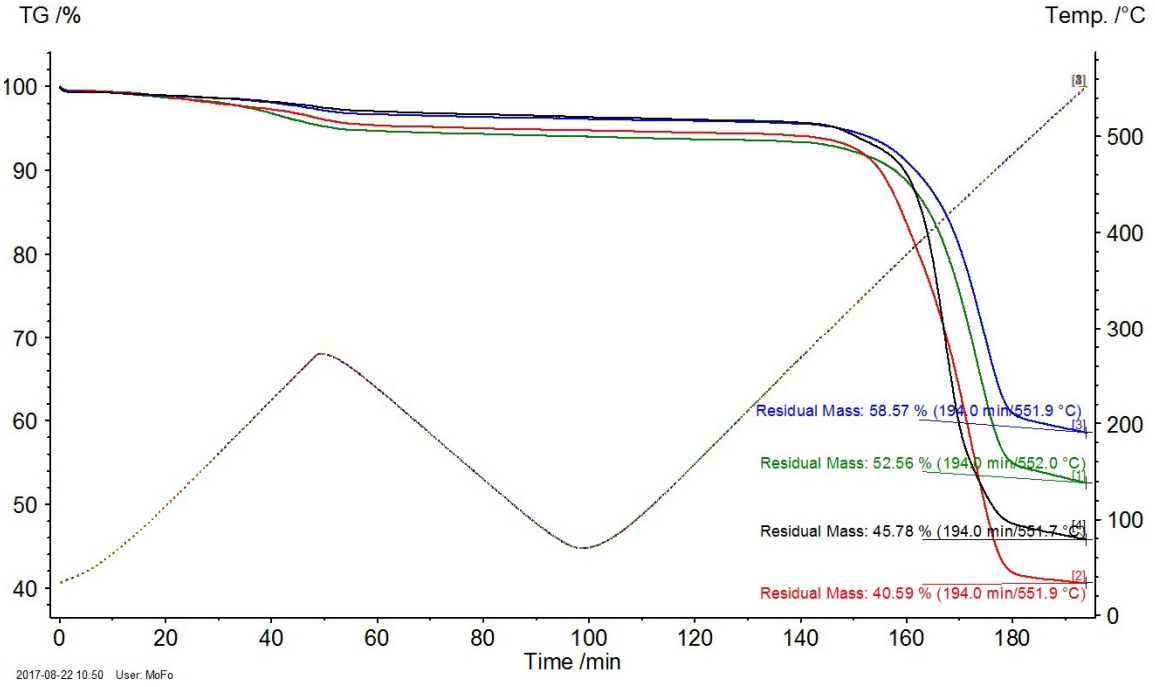

Figure 12. ***Thermogravimetric curves from STA show mass loss during the pyrolysis of sample*** **Nadderud N4-1 (0-3 cm depth), with fraction 1 in green, fraction 2 in red, and Nadderud N4-2 (3-6 cm depth), with fraction 1 in blue and fraction 2 in black.**

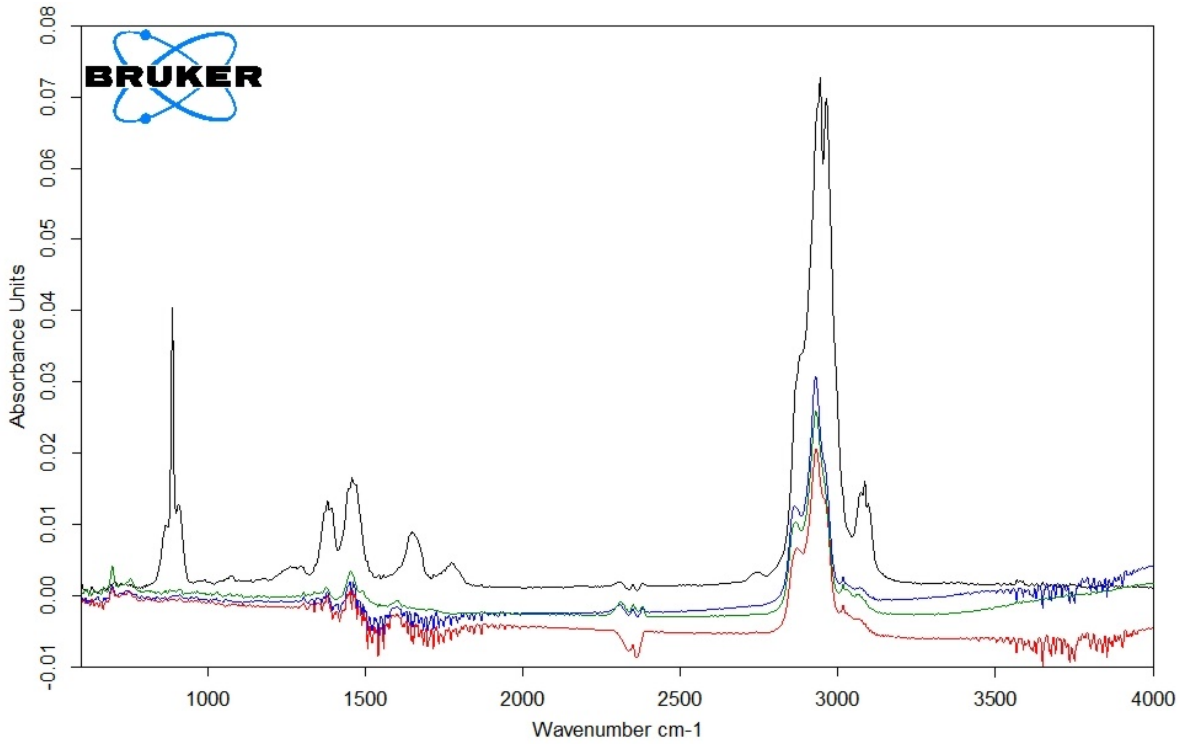

Figure 13. **FTIR spectra from Nadderud N4-1 (0-3 cm depth), with fraction 1 in green, fraction 2 in red, and Nadderud N4-2 (3-6 cm depth), with fraction 1 in blue and fraction 2 in black.**

4.3 Føyka

4.3.1 Soil sample X4

- Tire crumb concentrations

Surface: **20 g/m²**

0-1 cm depth: **1.65 kg/m²**

1-6 cm depth: **15.05 kg/m²**

- Tire crumb particle size: ca. 2 mm
- STA-FTIR analysis

STA and FTIR spectra of pristine tire crumb from Føyka and Nadderud were similar to each other (see Fig. 14 for FTIR spectra). The similarity between tire crumb from Føyka and Nadderud is also visible in Fig. 15, which shows FTIR spectra of tire crumb from samples Føyka X4-1 (surface) and Nadderud N4-2 (3-6 cm depth). Comparison of pristine tire crumb from Føyka with the FTIR library did not give any good match, while the middle part of the spectrum in Fig. 14 gave 961/1000 for acrylonitrile butadiene rubber NBR.

Comparison of the FTIR spectra of tire crumb from Føyka X4-1 (surface) with those of sample X5 taken along the motorway E18 showed a completely different composition (Fig. 16). In addition, FTIR analysis showed that the fine particles (0.45-50 µm) in fraction 2 from Føyka X4-2 (0-1 cm depth) were different both from tire crumb in X4-2 and from the soil sample X5 (Fig. 16).

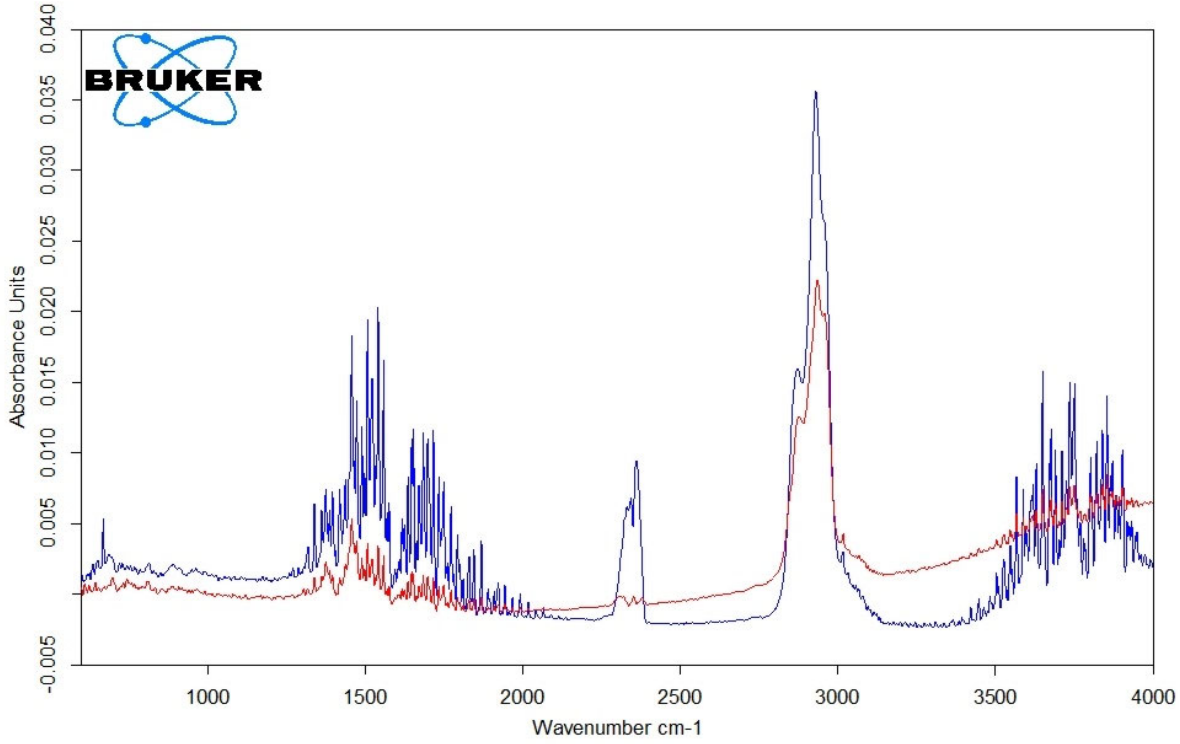

Figure 14. FTIR spectra of pristine tire crumb from Nadderud (red) and Føyka (blue).

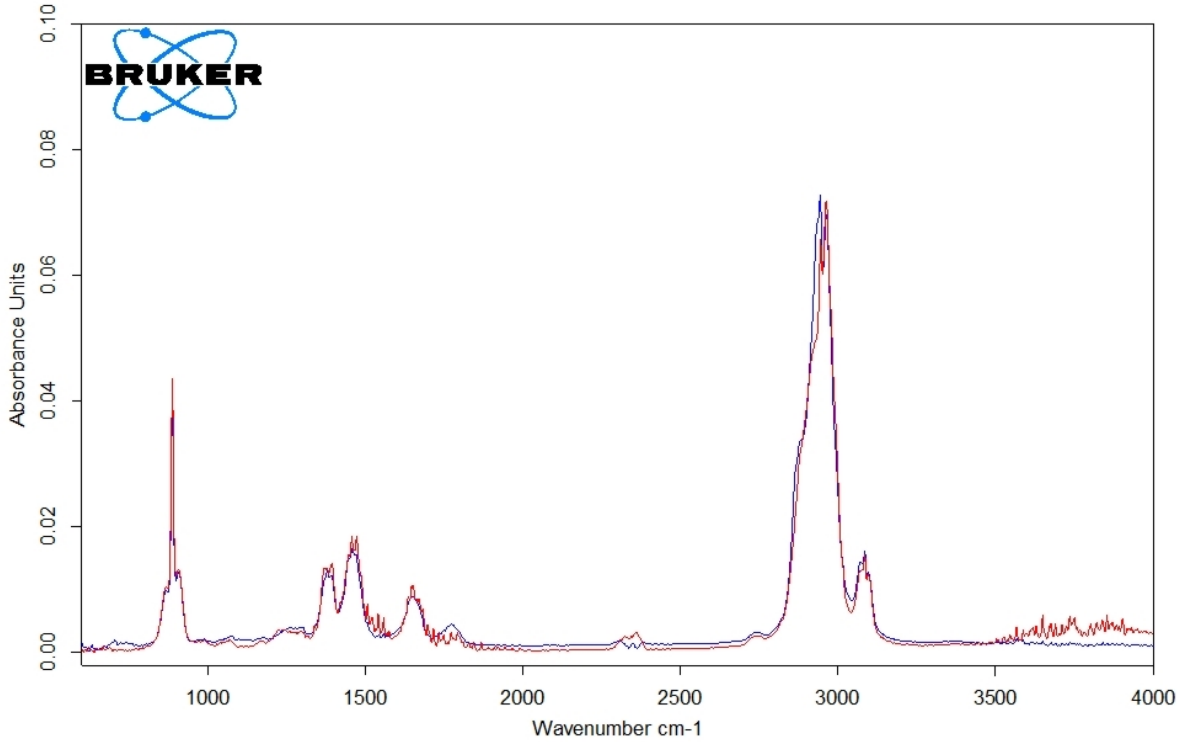

Figure 15. FTIR spectra of tire crumb from Føyka X4-1 fraction 2 (red) and Nadderud N4-2 fraction 2 (blue).

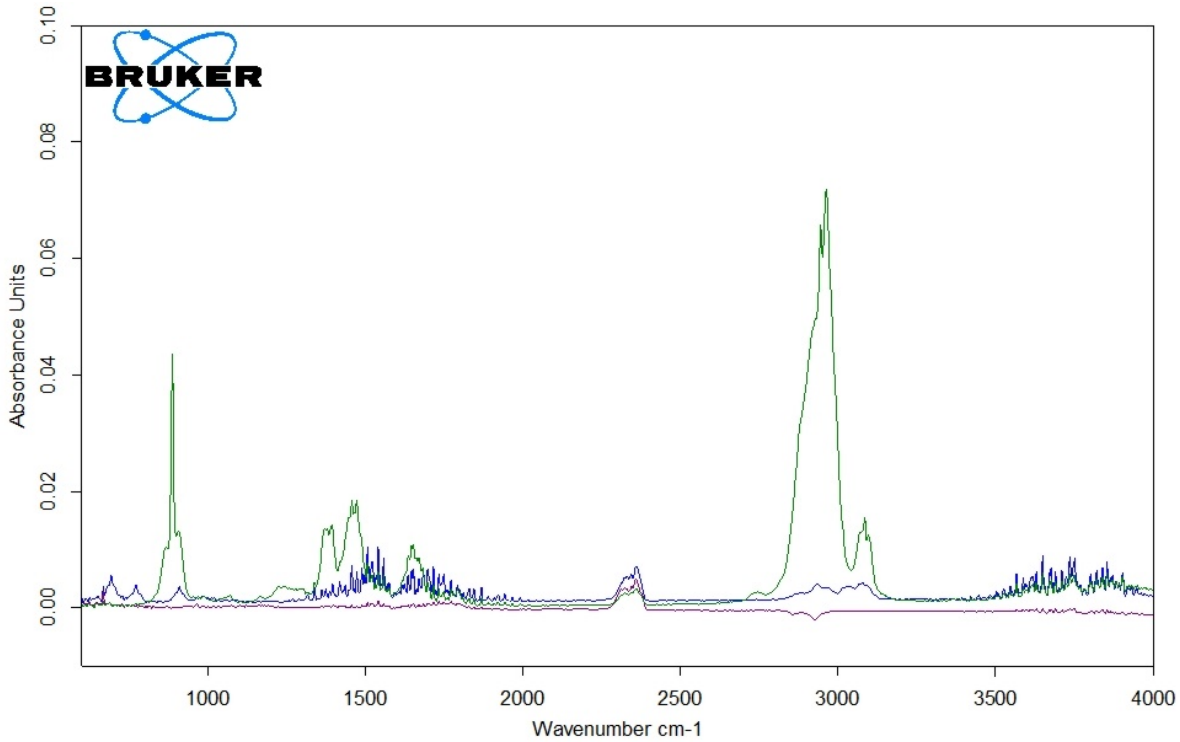

Figure 16. FTIR spectra from Føyka X4-1 fraction 2 (green), Føyka X4-2 fraction 2 (<50 µm, purple) and Føyka X5 (blue).

4.3.2 Soil sample X5

As mentioned above, no similarities were found between soil sample X4, taken along the artificial turf field, and soil sample X5, taken along the motorway E18. Small polystyrene beads were the only visible synthetic polymer particles in sample X5.

5 Discussion

The present study showed that large amounts of tire crumb, up to several kg per m^2, are found near the artificial turf fields at Hosle, Nadderud and Føyka, Norway. Tire crumb outside the artificial turf field at Nadderud was found in soil below the grass cover, and thus not directly visible. At Hosle and Føyka, on the other hand, tire crumb was present both in soil and at the soil surface, making tire crumb spreading clearly visible. The forest floor at Hosle was covered with large amounts of tire crumb, up to 15 m from the fence and 5 m above the level of the field.

At Hosle and Nadderud, tire crumb found outside the fields had no natural leaching pathway and their further spreading would most likely be limited to transportation by wind. At Føyka, on the other hand, tire crumb lying at the soil surface outside the field is likely to be washed down the stream Drengsrudbekken, especially in the steepest and least vegetated areas.

The separation method we used showed that tire crumb found in soil outside artificial turf fields had various densities (ranging from <1.0 g/mL to >1.28 g/mL), and simultaneous thermal analysis showed that these differences in density were due to different mineral contents in tire crumb. The lightest fraction (with the lowest density) also contained the most porous tire crumb particles, but it remains unclear where and when these changes in porosity and density occurred, e.g. as a result of biological, physical and chemical degradation processes in soil.

FTIR analysis encounters optical challenges from the filler components in tires, especially carbon black, which causes near-complete absorption of IR light. In addition, polymer identification is more challenging in environmentally aged materials (lower hit quality with pristine reference polymers), and the results should therefore be considered with caution. Tire crumb in the forest along Hosle (sample N1-1-1) showed FTIR features of thermoplastic styrenic elastomer (TPS), while tire crumb closer to the field (sample N1-2-1) contained both TPS, ethylene propylene diene rubber (EPDM), and maybe also butadiene rubber (BR). At Nadderud (sample N4), most tire crumb found in soil shared FTIR features with styrene butadiene rubber (SBR). There was high similarity between tire crumb from Føyka (sample X4-1, fraction 2) and Nadderud (sample N4-2, fraction 2), but the analysis gave no good match with any known polymers in the FTIR database. No similarities were found between sample X4 (along the artificial turf field at Føyka) and sample X5 (along the motorway E18), suggesting that rubber materials from these two sources (artificial turf vs. tire and road wear particles in road runoff) will probably be distinguishable in e.g. sediment samples from streams receiving microplastic materials from both sources.

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NIBIO - Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossile economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.
NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own board. The main office is located at Ås. The Institute has several regional divisions and a branch office in Oslo.

Cover photo: Erik Joner, NIBIO

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