Fluorescence-based sensor for continuous monitoring of microplastic in sea water

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INTRODUCTION

Microplastic contamination has been discovered in the most remote sections of the oceans [1] and in most ecosystems around the world. Sources of marine microplastic include rubber from tire wear, fibers from synthetic clothing, fishing nets, buoys and waste from the shipping industry, pellets of raw plastic material, packaging and bottles, overspill of sewage treatment plants and microplastic beads from cosmetic products. Exposure to sunlight, microorganisms and salt water degrades the plastic material over time, thereby fragmenting into ever smaller microplastic pieces. Systematic investigation of microplastic contamination in the ocean necessitates continuous monitoring to obtain high density data samples both spatially (to map the origin and effect of marine currents) and temporally (to understand long-term trends). Ideally, the data gathered should include detailed information such as particle counts, size fractions and composition.

To date, most microplastic studies rely on samples collected manually at specific times and locations, which later are analysed in research labs using state-of-the-art techniques such as optical microscopy or Raman/FTIR spectroscopy. This approach provides valuable insights on the microplastic composition, but only a limited understanding of its spatial and temporal distribution, and it is labour-intensive and time-consuming. Within the framework of the EU Horizon 2020 project NAUTILOS, several compact and cost-effective sensors for autonomous continuous in-situ monitoring of ocean parameters are being developed. CSEM and NIVA (Norwegian institute for water research) are jointly developing a new in-line microplastic sensor, capable of analysing marine microplastic in an automated manner.

METHODS

A sampler unit mounted onboard a ship filters microplastic particles in the size range of 30-300 µm from sea water at regular intervals. After sampling, the microplastic particles are oxidized to remove biomaterials such as algae and shells. Next, staining with a Nile Red turns the microplastic fluorescent, making it easier to measure its size and assess its type. Afterwards, the treated and stained microplastic samples are run through a detector unit, which is equipped with optical fluorescence detectors capable of detecting blue and UV fluorescence intensity in multiple spectral channels.

A high-power 450 nm laser excites the fluorescence response of the stained microplastic particles, which is measured in multiple spectral time traces. By clustering time-series data from several sensors, we measure and partly identify marine microplastic on-site and in real time. The identification step is enabled by the Nile Red stain, whose fluorescence colour changes, depending on the plastic type, from green to yellow to red. The measurement platform developed by CSEM contains the driver and cooling electronics for the excitation fiber laser, analog-to-digital readout of up to 6 photodiode channels at 5 kHz, support for up to two photomultipliers and a Raspberry Pi computer for instrument control, data analysis and communication. Additional side illumination for autofluorescence (250 nm) is supported but not implemented yet.

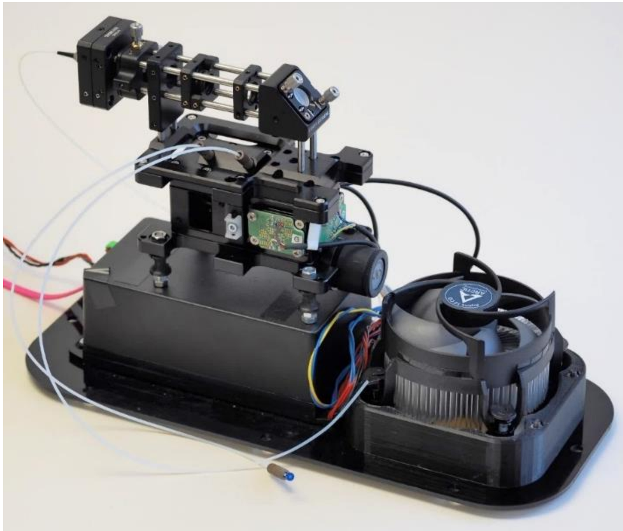

Figure 1: NAUTILOS microplastic detection system, consisting of an inline fluorescence detection system, a laser unit, readout electronics for fluorescence time traces and a Raspberry Pi for data analysis and communication.

RESULTS

The microplastic sampler (NIVA) was successfully developed and tested onboard a ferry ship. The oxidation procedure was optimized in the lab and is awaiting further tests onboard the ship. The microplastic detector (CSEM) is operational and reference microplastic samples have been characterized. The laser control system, digital readout firmware and data transfer to the Raspberry Pi was tested and optimised. The analysis software extracts particle event data into flow cytometry standard data.

Further work is being performed on better transfer of the microplastic samples from the sampler to the detector, and for optimizing the size measurement and identification capability of the detector. Communication of the detector with the FerryBox is currently being established.

DISCUSSION & CONCLUSIONS

It is planned to deploy the microplastic sensor in a through-flow analysis system (FerryBox) installed on board of a Ferry operating in the Norwegian waters. The goal is to collect consistent datasets of microplastic occurrences along the navigated route, for long-term monitoring and research. The microplastic data will be synchronised with GPS positions, time stamps and other sensor data from the FerryBox. Subsequently, this data will be transmitted via satellite internet to a central server for further analysis. Such systematic monitoring of microplastic pollution can in the future lead to a better understanding of the contamination origin and sources, the microplastic distribution and ultimately the fate of all the plastic ending up in the oceans, which is still not well understood.

REFERENCES

Tirelli, V., Suaria, G., Lusher, A.L. (2020). Microplastics in Polar Samples. In: Rocha-Santos, T., Costa, M., Mouneyrac, C. (eds) Handbook of Microplastics in the Environment. Springer, Cham. https://doi.org/10.1007/978-3-030-10618-8_4-1

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