Completion Report of Marine Ecology Enhancement Fund (MEEF)

PART I: Executive Summary

Microplastics, defined as plastic particles or fibers smaller than 5 mm, pose significant environmental threats due to their widespread contamination of aquatic ecosystems. These pollutants include a variety of forms, such as beads, fragments, pellets, film, and fibers. Notably, vehicle tire wear particles (VTWP) have emerged as a significant contributor to microplastic pollution, particularly near urban coastal areas. Traditional microplastic detection methods of microplastics are often slow, labor-intensive and require sophisticated laboratory equipment. To address these challenges, we have developed the Smart Fish – an autonomous robotic system designed for efficient microplastic sampling and identification. The first generation, launched in 2020, demonstrated the feasibility of autonomous sampling but was limited by its heavy weight (~100 kg) and the ability to identify only a limited range of plastic types.

This project aimed to redesign and optimize the Smart Fish prototype, reducing its weight to 75 kg to enhance mobility while upgrading the staining method to detect a broader range of plastic types. The newly designed Smart Fish integrates several advanced components, including a sampling unit with peristaltic pumps, a filtration unit with filter mesh size of 0.7 mm, an innovative dyeing system, lithium batteries for power, a Raspberry Pi-controlled camera for image capture, and a communication system for remote data transfer. The redesigned Smart Fish autonomously collects and filters 10 L of water, stains the retained microplastics for identification, captures high-resolution images, and remotely transmits data for real-time analysis. The upgraded dyeing method effectively differentiates 10 different plastic types including rubber tires from non-plastic debris, significantly enhancing detection accuracy.

The second-generation Smart Fish prototype was completed in October 2024, followed by rigorous field testing between November 2024 and February 2025. Before trial run, 10 L of water sample was collected at the HKUST pier and bought to the lab for microplastics sampling verification on 18 October 2024. Sampling conducted at multiple coastal locations revealed high concentrations of common microplastics such as polystyrene (PS), polyethylene (PE) and polyethylene terephthalate (PET). Additionally, VTWPs were detected near public ferry piers, roads and highways, highlighting the environmental impact of urban runoff and transportation networks. Some of these particles may be carried by waves and oceans, or by boats to other areas in proximity. These pollutants pose significant ecological risks by potentially spreading pathogens and toxic chemicals to coastal habitats, threatening ecologically important species.

In addition to technological advancements, the project prioritized community engagement and education. A total of 10 seminars and 2 hands-on workshops were conducted between July 2024 and January 2025 to raise public awareness about microplastic pollution and showcase the innovative capabilities of Smart Fish. The outreach programs successfully engaged participants from primary school to university levels, with over 90% acknowledging Smart Fish as an effective and innovative solution for real-world microplastic challenges. Furthermore, the workshops

provided practical experience in microplastic identification, enhancing STEM education and fostering environmental stewardship.

The project achieved the following key outcomes:

- Successfully reduced the weight of Smart Fish from 100 kg to 75 kg with compact design, improving mobility and operational efficiency.
- Enhanced microplastic detection capabilities with a new staining method that identifies 10 different plastic types.
- Validated the device's effectiveness through field trials, corroborating findings with traditional detection methods.
- Increased public awareness and understanding of marine microplastics through targeted education initiatives.

Moving forward, the project aims to expand this field trials to diverse aquatic environments, further enhance image analysis algorithms for improved accuracy, and collaborate with environmental agencies for broader data sharing and application.

This initiative demonstrates the potential of Smart Fish as a pioneering solution to the global microplastic crisis, offering a scalable, efficient, and cost-effective approach to monitoring and mitigating microplastic pollution. Continued investment and support will enable further technological advancements, contributing significantly to environmental protection and sustainable marine ecosystems.

PART II: Project information

Project Title: Smart Fish for Oceanic Microplastics Degradation in the Coastal Area

Project Reference: MEEF2023009

Project Leader: Dr Cindy LAM

Other Project Team Members: Dr Frank LAM

Name of the Applicant Organization: The Hong Kong University of Science and Technology

Project Start Date: 01/07/2023

Project End Date: 31/12/2024

Project Duration (in months): 18

Reporting Period: 1 July 2023 – 31 December 2024

Brief Description of the Project:

Microplastics contamination in the natural water bodies, which resulted from disintegration from plastic waste, has raised public concern due to high level of fragmentation and disturbance in ecosystem. The associated problem will significantly affect the sustainability of aquatic animals and human beings. Tire Wear Road Particles account for a large proportion of microplastics in the environment (Spanheimer and Katrakova-Krueger, 2022). For example, emission of tire wear particles is nearly 100,000 tons per year in Germany (UMSICHT, 2018). The friction between the tire and the pavement during driving, speeding up and braking causes particles to be worn out from both, the tire and the pavement. Tire wear is also possible from aircraft and vehicle tires. Although limited data on the contribution of tires abrasion, or project would fill up the information gap by developing a prototype device to provide real-time sampling, detection, and degradation of vehicle tire wear particles (VTWP) in the coastal area of Lantau Island near Hong Kong International Airport. The prototype combines autonomous sampling using remote sensing and GPS technology, real-time detection of contaminants with treatment unit to mitigate microplastics problem in the region.

Major deliverables in this project include: (i) an autonomous device to sample VTWP in surface waters; (ii) an universal staining technique for quick quantification and characterization of VTWP from other microplastics; (iii) a capturing system using digital cameras controlled by built-in Raspberry Pi or other computer programmes; (iv) an interactive mobile app controlling the device and showing the results on screen; (v) a treatment unit to remove VTWP and other microplastics. Success of this project will build a solid foundation in environmental protection and ocean science technology. Our model allows flexible sampling in various coastal/ freshwater areas that is impossible for traditional sampling on cruise and provides good demonstration to the community through STEM education.

References:

1. Spanheimer V, Katrakova-Krueger D. (2022) Analysis of tire wear airstrip particles (TWAP). Sci. Rep. 2022 Sep 23;12(1):15841.doi:10.1038/s41598-022-19986-9.
2. Fraunhofer-UMSICHT (2018): Plastics in the environment.

PART III: Completed activities against the proposed work schedule

There are no changes in the project objectives, deliverables and work schedule and budget. As stated in the proposal, our project includes 4 phases:

Phase 1 (Prototype Design)	**Date**	**Status**
1. RA recruitment	Jul-Aug 2023	Completed
2. Design and modify smart fish prototype	Aug-Sep 2023	Completed
3. Purchase of sensors and probes	Oct-Nov 2023	Completed
4. Degradation unit development	Nov 2023-May 2024	Completed
Phase 2 (Prototype Assembly)	**Date**	**Status**
1. Staining method development	Sep-Nov 2023	Completed
2. Imaging and computer programmes	**Dec 2023- Oct 2024**	**Completed**
3. Data acquisition and data transfer using home-built mobile app	**Aug 2024 - Oct 2024**	**Completed**

Phase 3 (Field Validation)	**Date**	**Status**
1. Investigation on collection and degradation efficiencies of microplastics	Apr-Jun 2024	Completed
2. Trial run in the HKUST laboratory/ swimming pool (buoyancy test and real-time detection)	**Oct-Nov 2024**	**Completed**
Phase 4 (Education & Outreach)	**Date**	**Status**
1. Monthly measurement at proposed sampling sites (coastal areas)	Aug-Dec 2024 **Revised (Oct 2024 - Feb 2025)**	**Completed**
2. Public education and outreach with technology demonstration		
• **project website & video**	Apr-Jun 2024	**Completed**
• **seminars**	Jun-Jan 2025	**Completed**
• **workshops**	Jun-Dec 2024	**Completed**

PART IV: Results/ descriptions on the completed activities, with the support of photos, videos, social media platform, etc.

Phase 2 (Prototype Assembly)	**Results/ Descriptions**
1. Overall design and operation of Smart Fish	The overall size of the Smart Fish is smaller (L900mm x W1200mm x H760mm) and lighter (reduction by 25% from 100 kg down to 75 kg) than the first generation. Considering the light weight and rigidity, the body of the Smart Fish is made of glass fiber, aluminum 6061 and nylon. The buoys, which are made of polyvinyl chloride (PVC), provide buoyancy of the prototype. There are 4 propellers (Blue Robotics T200 Thruster) supporting the movement of the fish. The new design comprises of various main units, including **(i) water sampling unit** with 2 peristatic pumps (seawater pump is pumping in water at flow rate of 530 mL/ min while ocean drain pump pumping out water back to the sea); **(ii) filtration unit** with mesh size of 0.7 mm to collect microplastics and vehicle tire wear particles; **(iii) two dye tanks** (dye tank with composite dyes while the clean water tank keeping clean water); **(iv) lithium batteries** to support power of 4 propellers, dye vision unit, image capture unit (camera) and peripherals during operation; **(v) image capture unit** including Raspberry Pi-controlled

Camera Module 3 with wide angle equipped with 6 white LEDs, 3 lightings with UV 365nm and 254 nm respectively; **(vi) computer hardware, Raspberry Pi 4,** to control water sampling unit, filtration unit, dye staining and rinsing process, image capture unit (camera) and ftp server for data transfer; (vii) **two waste tanks** keeping the excessive dye and the dyed samples after image capture. All the dyed samples will be sent to laboratory for treatment under Fenton's reaction. The specification and design layout of the Smart Fish are listed in **Appendix I**.

As the power provided by the lithium batteries support the propellers with runtime for 15-30 minutes, the Smart Fish has adopted fixed-point sampling strategy instead of continuous sampling along the route. Upon **sampling**, both the seawater pump and the ocean drain pump are turning on. About 10 L of seawater will flow through the filter and back to the ocean. Microplastic samples will be filtered. Next is the **staining process.** The power of both seawater pump and ocean drain pump is off. Then the dye pump is on until the microplastics are fully immersed in the composite dye. The staining process will last for 20 minutes. The dye pump is on and the dye will be recycled back to the dye tank. The dye pump is off when the draining process is completed. For the **cleaning process**, the clean water pump is on until the microplastics are fully immersed in clean water. The cleaning process will last for 5 minutes to remove excessive dyes on the filter. The clean water pump is on to drain the wastewater to the waste tank. Now, the samples are ready for **image capture**. Lightings can be controlled by the user platform/ mobile phone (remote control). The clean water pump is off. Here, white LED lights (which is in the image capture unit on top of the filter) are on and a picture is captured by the camera. For UV illumination, white LED lights are off. The 254 nm UV lights are on, and a picture is captured. For 365 UV illumination, 254 nm UV lights are off and turn on 365 nm UV lights before a picture is captured. Pictures under white light, 254 nm UV lights and 365 nm UV lights will be transferred to the server using router and Message Queuing Telemetry Transport (MQTT) system. Results will be analyzed by image processing program (written in python and OpenCV) in the Smart Fish, as well as in the server.

Previous staining methods for microplastics and vehicle tire wear particles (rubber) were established using Nile Red (NR) at effective concentration of 1 mg/L in methanol and Oralith Brillant Pink R (BPR) at effective concentrations ranging between 600 and 800 mg/L in ethanol (refer to first progress report, **Appendix XIV** in the completion report). **A composite dye** in a combination of Nile Red and Oralith Brillant Pink R (BPR) was developed and tested against a wide range of plastic types. The dye is highly specific under alkaline condition (pH = 10) in differentiating 10 different plastic types as the fluorescence level and color of each plastic type is unique under 254 nm UV illumination (see results in **Appendix II**). The dye is effective in identifying plastics from non-plastic items as there is no fluorescence and color developed on non-plastic items such as broken shells, woods, glass and bio-materials (e.g. algae) under 254 UV illumination, in which these items are commonly suspended in surface waters. The staining performance is stable and applicable to all types of plastics with transparent and colored-items. It requires at least 15 minutes to make the composite dye into effective in the staining process. We have decided to **set the staining process in the Smart Fish to 20 minutes** to ensure all samples are dyed in the staining process. The fluorescence level and color are crucial in training the computer programme on microplastics identification at a later stage. Results of the dye performance on 10 different plastic types is listed in **Appendix II**.

The **overall runtime** for each sampling would be **around one hour** with the estimated time of each process listed as follows:

- **Movement of the Smart Fish**: the runtime of 4 propellers is ranging from **15-30 minutes**, depending on the travelling distance, sea current and waves
- **Water sampling**: given that the seawater pump is pumping in water at flow rate of 530 mL/ min, it may take around **20 minutes** to finish filtering 10 L of seawater sample

	• **Staining of microplastics**: the whole process will be **25 minutes** (20 minutes for staining and 5 minutes for cleaning)
2. Imaging and computer programmes	A user platform has been developed to control image processing system inside and outside the Smart Fish. The platform can be accessed via website link using mobile phone or other electronic devices. For image processing, users can control the lightings (e.g. white LEDs, 254 nm UV, 365 nm UV) before image capture. Once the photo is captured by the camera inside the Smart Fish, the photo will be sent to Raspberry Pi 4 where the image processing program is encoded by python with OpenCV. The image processing system contains color filters which allow the desired wavelength to pass through (e.g. black filter is used to target vehicle tire wear particles). The computer programme will search and count for any objects larger than 100 pixels sitting on the filter. The result of the object count will be shown in the user platform. Meanwhile, the photo captured in the Smart Fish can be sent/ uploaded to main server via 4G router. Both photo and the number of object count will be shown in the user platform. Users can download the results to their own devices for record. The image processing system with the interface of the web application (user platform) is listed in **Appendix III**.
3. Data acquisition and data transfer using home-built mobile app	The data acquisition and data transfer system between the Smart Fish (controller) and the server is connected by Message Queuing Telemetry Transport (MQTT). The controller in the Smart Fish contains Raspberry Pi 4, Arduino mega, Raspberry Pi Camera Module 3 (wide angle) and a 4G router coped with a SIM card. Raspberry Pi 4 connects Arduino mega via serial port. Arduino mega is used to control sample collection and processing, while camera is controlled by Raspberry Pi 4 for image capture and processing in the Smart Fish. The system in the main server contains another Raspberry Pi 5 with a static IP address provided by the university. There are three main components installed: node-red server, mosquito server and ftp server. Ftp server is used to transfer the image file captured by the camera in the Smart Fish to the server for further analysis and processing. The image processing unit in

	the Smart Fish can perform data analysis, but no image can be shown in the user platform. The image can be further exported and uploaded to the server for analysis. Both the image and the results can be shown and downloaded from the server for sharing and recording. The flowchart showing data acquisition and data transfer is listed in **Appendix IV**.
Phase 3 (Field Validation)	**Results/ Descriptions**
2. Trial run in the HKUST laboratory/ swimming pool (buoyancy test and real-time detection)	We planned to launch the trial run at the outdoor swimming pool on 25 October 2024 afternoon. The aim of the trial run is to test the buoyancy and swimming (moving) ability of the Smart Fish in water. Due to safety concerns to other swimmers (i.e. avoid electrical leakage), our request conducting a water test was rejected. We then selected the HKUST pier for the trial run and water sampling on that day. As the Typhoon Trami was approaching, we have decided to postpone the water test to another week or early November. Unfortunately, there were three tropical cyclone episodes in November 2024 so that we had to **re-arrange it on 29 November 2024**. Apart from the water test, water sampling was also conducted on the same day. Photos showing our trial run/ water test at HKUST pier are listed in **Appendix V**.
Phase 4 (Education & Outreach)	**Results/ Descriptions**
1. Monthly measurement at proposed sampling sites (coastal areas)	Due to delay in prototype re-design and assembly, we could start our monthly measurement since October 2024. Before water test, 10L of water sample was collected at the HKUST pier and brought to the lab for microplastics sampling verification in the Smart Fish on 18 October 2024. Monthly measurements were conducted with details as follows (two measurements at a location): • 18 October 2024 (Fri) at HKUST Pier • 29 November 2024 (Fri) at HKUST Pier • 24 December 2024 (Tue) at HK International Airport (near third runway) • 27 January 2025 (Sat) at Tung Chung Pier • 15 February 2025 (Sat) at Tung Chung Bay The location of sampling sites is recorded by GPS function installed in GoPro 13. The selection criteria of sampling sites are the coastal areas with easy access or

close to public ferry pier so that we can deploy our Smart Fish onto the boat for sampling at another location. Another consideration is to compare our results on microplastics abundance and diversity in coastal areas under different degrees of human activities or influence.

There were 4 fragments of PS (25%), 2 fragments of PE (12.5%), 3 fragments of PET (18.75%), 1 fragment of PA66 (6.25%) and 6 non-plastic items (37.5%) (total 16 items) in our first sampling at HKUST pier on 18 October 2024. No vehicle tire wear particles (VTWP) were found. In November sampling, consistent results were found with relatively higher PS fragments were found at both locations (3 fragments (27.27%) at HKUST pier #1 and 2 fragments (22.22%) at HKUST pier #2) (see results in summary table in **Appendix VI**). PE and PET fragments were also found at both locations. But a fragment of VTWP was found at HKUST pier #1 but not #2. Microplastics like polystyrene (PS), polyethylene (PE) and polyethylene terephthalate (PET) are reported to be abundant in surface waters, as well as in other coastal habitats like mudflats and sandy beaches (Lo et al., 2018). Unlike other public pier, there is not much human activities at the HKUST pier as the place is closed at all times by security due to safety. PA6 and PA66 are known as nylon, are thermoplastics that deliver strength, temperature and chemical resistance, which allow them to perform under intense conditions (Nexeo Plastics). Our assumption of high PS fragments maybe from the near-by fish farms as they may use PS as buoys and PA66 (nylon) as fishing nets. Other fragments like PE and PET would be probably coming from ocean plastics like drinking bottles and packaging bags, as these items are always seen on the boulder shore close to HKUST pier (see photo in **Appendix VI**).

In December sampling, more PS and PE fragments were found in samples at both locations near HK Airport (3 fragments of PS (18.75%) and 2 fragments of PE (12.5%) in HK Airport #1; 2 fragments of PS (16.67%) and PE (16.67%) in HK Airport #2) (see summary table in **Appendix VI**). One to two fragments of PET and PA66 were also found at both locations. However, fragments of vehicle tire wear particle

(VTWP) were found near the airport. Previous study showing microplastic abundance was significantly higher on the west coast than on the east coast, indicating that the Pear River, may be a potential source of plastic debris (Fok and Cheung, 2015). Among the three groups of microplastic debris, expanded polystyrene (EPS) represented 92%, fragments represented 5%, and pellets represented 3%. Our results support their research findings as PS and PE were abundant in our water sample. However, we found 1-2 fragment(s) of VTWP in our sample by confirming it using advanced instrumentation (e.g. Raman or FTIR) in laboratory. Although the sampling site is close to airport, the VTWP could be from near-by vehicles running on highways (e.g. HK-Zuhai-Macao Bridge).

In January sampling, there were more PS, PE, PET and PA66 fragments found at both sampling locations in Tung Chung pier (see summary table in Appendix VI). A fragment of PVC was found at the Tung Chung pier #1 but not #2. However, 3 fragments (18.75%) of vehicle tire wear particles (VTWP) were found at the Tung Chung #1 while 2 fragments (18.18%) of VTWP were found at the Tung Chung #2. As the sampling sites are close to the ferry pier, we believe VTWP are fragmented from the ferries during mooring (see photo in **Appendix VI**). Our results support previous study showing the Ferry terminal has the highest presence of PE particles in the water samples (Ghanadi et al., 2024). The contribution of PE in seawater samples around the Ferry terminal could be related to the presence of many HDPE or PVC protective pile sleeves in the water. There are human activities (e.g. fishing using fishing lines, keeping fishes inside polystyrene box, visitors using the ferry pier) happening at the pier or in proximity, we would expect more microplastics are found in the area.

In February sampling, there were more PS and PE fragments found at both sampling locations in Tung Chung Bay (**see summary table in Appendix VI**). There was one fragment of PET found at both sampling locations. However, there was a fragment of PMMA and VTWP found in Tung Chung Bay #1 but not #2. Polymethyl methacrylate (PMMA) is known as acrylic. Due to its transparency, PMMA is used in car windows, smartphone screens to aquarium. It is a tough plastic, easy to shape and a great alternative to the high-cost and less resilient glass (Nexeo Plastics). Our results support previous study showing PE (49.6%) was the most abundant and followed by PP (13.8%) and PET (13.5%) from 10 mudflats and 10 sandy beaches in Hong Kong spanning from the eastern and western waters. Expanded polystyrene was the most abundant in the strandline samples (Lo et al., 2018). The fragment of VTWP could be circulated by waves as it is close to the Tung Chung pier. The negative impacts of microplastics and VTWP could not be underestimated as these pollutants may adhere harmful pathogens (Beans, 2023) and/or toxic chemicals (Lvleva, 2021) threatening the nursery grounds of marine organisms such as juveniles of Chinese horseshoe crabs *Tachypleus tridentatus* in San Tau Special Site of Scientific Interests (SSSI). High microplastic contamination in juvenile tri-spine horseshoe crabs has been reported by Wang et al., (2022) to confirm microplastics availability in benthic macroinvertebrates, and pose ecological risks in aquatic ecosystem.

References:

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3. Ghanadi M, Joshi I, Dharmasiri M, Jaeger JE, Burke M, Bebelman C, Symons B, Padhye LP. (2024) Quantification and characterization of microplastics in coastal environments: Insights from laser direct infrared imaging. Sci. of the Total Environ. Volume 912, 20 Feb 2024,168835
4. Lvleva N. (2021) Chemical analysis of microplastics and nanoplastics: challenges, advanced methods and perspectives. Chemical Reviews. August 26, 2021, v.121/issue19
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	Pollut. 2018 May; 236:208-217. doi: 10.1016/j.envpol.2018.01.031. 6. Nexeo Plastics. Website: https://nexeoplastics.com 7. Wang X, Lo HS, Fu Y, Wu Z, Qin D, Huang X, Zhu J, Cheung SG, Kwan KY (2022). High microplastic contamination in juvenile tri-spine horseshoe crabs: a baseline study of nursery habitats in Northern Beibu Gulf, China. J. Ocean Univ. China 21,521-530 https://doi-org/10.1007/s11802-022-5163-3
2. Public education and outreach with technology demonstration • **project website & video** • **seminars** • **workshops**	**<u>Project Website</u>** The project website has been completed since June 2024 with the weblink as follows: https://hkust-smartfish.com Website content is listed in the following pages: 1. Home page • Project title • Background • Project objectives 2. About us 3. Development of Smart Fish 4. Staining method and results 5. Distribution of microplastics and vehicle tire wear particles 6. Events • Seminars • Workshops 7. Resources • Leaflet Project activities and information (e.g. microplastic abundance and diversity, seminar/ workshops) is updated on a regular basis. The layout and content of project website is listed in **Appendix VII**. **<u>Project Video</u>** The 3-min project video summarizing the development of new design of Smart Fish and our work in the project is attached in the report. The video is also available in the project website. **<u>Seminars</u>** Seminar invitation to the international aircraft manufacturers such as Bridgestone Aviation Tires,

	Goodyear Aviation Tires and Yokohama Rubber has been sent between late May and early June 2024. Unfortunately, no verbal nor written reply received (see email invitation in **Appendix VIII**). The seminar was about an hour, the aim was to raise public awareness of microplastics (including vehicle tire wear particles) in the marine environment and introduce our project (Smart Fish) to the participants. To keep the project rolling, we planned to organize ocean microplastic seminars starting from summer. Our target audiences were primary school students, secondary school students, university students and the stakeholders. Leaflets (with QR code) were available on the reception desk for take away if needed. A survey was also invited to the participants at the end of each seminar (**Appendix IX)**. Of 560 respondents, 40% were primary school students, 19% were secondary school students and 41% were university students. In terms of seminar content and delivery, majority of the participants (88%) were satisfied with our seminars, and over 70% of them agreed that the information was clear and informative. Over 90% of them agreed that the duration (one-hour) of seminar was appropriate. For the awareness of post-seminar, majority of the participants would increase their understanding of the impact of microplastics on the marine environment. Around half of them would like to explore more about marine microplastics and related environmental topics. For the Smart Fish project introduction, over 90% of the participants agreed that Smart Fish was an innovative device in tackling microplastics problem in real-life environment, and over 80% of them would like to get involved in our project (e.g. workshops) in future. Schedule of the seminars, as well as leaflets distributed, and photos taken during the seminars are listed in **Appendix X**. **<u>Workshops</u>** The purpose of the workshop has two folds: offer hands-on experience to the participants on microplastics identification in environmental samples in laboratory and introduce the Smart Fish (first and second generations) models/ concepts via demonstration. A set of procedures identifying microplastics was printed out to the participants to

follow during the workshop (**Appendix XI**). The duration of the workshop was about two hours. The target audience were secondary school and university students. A survey was sent to the participants at the end of each workshop (**Appendix XII**). Of 76 participants, around 95% have responded to our survey. Around 85% of them were secondary school students and 15% were university students. Before joining the workshops, over 91% of the participants were not familiar with microplastics laboratory procedures and none of them had participated in similar hands-on lab activity. In terms of workshop structure and duration, 78% of the participants agreed that the two-hour workshop was appropriate and over 70% of them were satisfied with the overall organization and flow. For the lab activity effectiveness, over 60% of the participants agreed the hands-on activity helping them to better understand microplastics identification in environmental samples. Over 60% of the participants found that our Smart Fish was innovative for microplastic sampling. Most of them were interested in learning Smart Fish or similar projects in future. Around 76% of the participants were satisfied (good and excellent) with the overall workshop experience. Over 75% of the participants agreed that our workshop had moderately and significantly increased the awareness and understanding of marine microplastics.

Schedule of the workshops, as well as photos taken during the workshops are listed in **Appendix XIII**.

PART V: Evaluation of the project effectiveness in achieving the proposed objectives as well as the impact (benefits) of the Project.

Our project has demonstrably achieved its proposed objectives and made a significant impact in addressing microplastics contamination in coastal waters. Through a series of innovative technical advancements, we have effectively overcome the limitations of conventional sampling methods and provided real-time, precise monitoring and remediation of these pollutants.

One of the key technical achievements was the development of an autonomous sampling device that efficiently collects microplastics, including vehicle tire wear particles (VTWP), from surface waters. By integrating GPS technology, the device is capable of delivering spatially precise, real-time data that is essential for monitoring the dynamic coastal environment. In addition, we created a novel universal staining technique that quickly quantifies and characterizes at least 10 different types of plastics, thereby enhancing our analytical precision and enabling a more accurate assessment of contamination levels.

Furthermore, our project streamlined the detection process by integrating a digital capturing system, which employs a digital camera controlled by a Raspberry Pi to capture high-resolution images for immediate analysis. This system not only provides critical visual confirmation of microplastics presence but also supports robust data collection. Complementing these technical tools is an interactive user platform—a web application via electronic devices (e.g. mobile phone) that offers seamless control of image capture over the autonomous device and displays real-time results through an intuitive interface. This platform has proven invaluable for facilitating field operations, enabling remote monitoring, and ensuring that all stakeholders have immediate access to vital information. Additionally, the implementation of a treatment unit designed to remove microplastics, including VTWP, from coastal waters directly mitigates the environmental impact of these contaminants, thereby enhancing water quality and protecting marine life.

Beyond the technical successes, our project has delivered significant broader benefits. By focusing on VTWP—a notable contributor to microplastic pollution—we have filled a critical information gap, supporting improved management of aquatic ecosystems and contributing to long-term environmental sustainability. The integration of autonomous sampling, rapid detection, and remediation technologies represents a significant advancement in ocean science and environmental engineering, setting a new benchmark for microplastics monitoring across various coastal and freshwater settings. Moreover, our interactive user platform and on-field demonstrations have been powerful tools for public engagement and STEM education. By showcasing cutting-edge environmental technology through seminars and workshops, we have raised public awareness about microplastic contamination and inspired future innovation in environmental protection.

PART VI: Summary and Way Forward

Our project has successfully achieved its stated objectives and generated a meaningful impact in addressing the critical issue of microplastics contamination in coastal waters. Through the development of cutting-edge technologies, we have created an autonomous device capable of real-time, spatially-specific sampling and detection of various types of microplastics including vehicle tire wear particles (VTWP). These particles are among the major contributors to microplastic pollution, and our project has filled a significant gap in the knowledge surrounding these pollutants. The integration of GPS technology into autonomous sampler, coupled with the advancement of a universal staining technique, has enabled us to quantify and differentiate between various types of plastics with increased accuracy. Additionally, the incorporation of a Raspberry Pi-controlled digital camera system for high-resolution image capturing and an interactive web application for real-time reporting has contributed to the project's success. Our work has resulted in an integrated system for monitoring and mitigating microplastic contamination, producing tangible environmental benefits by improving water quality and protecting aquatic ecosystems. Moreover, our public outreach efforts through STEM education have raised awareness of the global microplastics crisis, encouraging further innovation in environmental protection technologies. Looking ahead, the successful deployment of this project provides a strong foundation for future research and the development of scalable solutions to combat microplastic pollution worldwide. By drawing on the methodologies we have developed, our work will inform future policy decisions and environmental management strategies, positioning this project as a key stepping stone toward a more sustainable future for our oceans and freshwater ecosystems.

Moving forward, our project will continue to advance in several key areas. One of our main directions is the ongoing work toward patenting the innovative smart fish technology, a key component of our system. We have submitted the patent application to the Intellectual Property Management System at the university for record/ review (System ID: IDF-03477; IP reference: IP.PA.12505) in early February 2025. This will help secure intellectual property rights and open opportunities to scale up the technology for broader use. Meanwhile, we will prepare manuscript on the novel staining method for publication. By partnering with local authorities and governmental organizations, we aim to enhance the impact of our project and contribute to global efforts in microplastic reduction. Further, we are exploring the potential for real-time data integration with governmental bodies, allowing for more effective policy development related to microplastic pollution. With the continued refinement of our technologies, we also plan to explore possibilities for deploying our system in freshwater bodies, enabling the system to address diverse aquatic environments. Finally, collaboration with industry stakeholders will be pursued to integrate commercial-scale applications of the developed treatment and detection technologies, ensuring that the tools we have can be widely adopted across industries and regions, paving the way for a cleaner, more sustainable future. This will be achieved by participating Geneva International Exhibition of Inventions 2025 from 9 to 13 April 2025 in Geneva, Switzerland.

PART VII: Audited statement of account

Audited statement of account is not disclosed due to confidentiality reasons.

PART VIII: A listed of all project assets

Below is the comprehensive list of project assets developed under the Smart Fish project:

1. Autonomous sampling device prototype

A fully integrated prototype designed for the real-time collection of microplastics, including vehicle tire wear particles (VTWP). This device incorporates GPS technology to provide spatially precise and time-sensitive data, effectively overcoming the limitations of traditional cruise-based sampling. The new design of Smart Fish prototype and its photo is listed in **Appendix I**.

2. Universal staining protocol and technique

A novel staining method developed to rapidly quantify and characterize up to 10 different types of plastic. This asset includes detailed protocol, testing data, and results to ensure accurate differentiation of microplastics. The testing condition and results is described in **Appendix II**.

3. Digital capturing system

A high-resolution imaging system controlled by a Raspberry Pi, Arduino mega and a camera. This asset facilitates immediate visual confirmation of microplastic presence, supporting robust data collection and real-time analysis through digital imaging. The image processing system is listed in **Appendix III**.

4. Interactive user platform/ web application

An intuitive, user-friendly interface that allows seamless control of autonomous sampling of Smart Fish. This platform displays real-time results and supports remote monitoring, providing the stakeholders with immediate access to vital information and user guidelines, contributing directly to mitigating environmental impacts. The data acquisition and data transfer via ftp server, as well as user interface is listed in **Appendix IV**.

5. Treatment protocol for microplastics removal

Our Smart Fish prototype is dedicated to remove microplastics, including VTWP, from coastal waters. This asset includes both the operational prototype for microplastic removal and the protocol to degrade microplastics in laboratory. This will contribute directly to mitigating environmental impacts. The degradation efficiencies of microplastics and VTWP submitted to the second progress report is now re-attached in the completion report in **Appendix XIV**.

6. Smart Fish initiative and patent application

Documentation related to this Smart Fish design and technology, which combines novel staining method and sensor technology for real-time water quality and microplastic monitoring. We have submitted the patent application to the Intellectual Property Management System at the university for record/ review (System ID: IDF-03477; IP reference: IP.PA.12505) in early February 2025. This marks a significant step towards commercialization and future research.

7. Supporting Documentation and Educational Materials

A suite of technical documents such as design layout and specifications, alongside STEM educational resources, workshop materials and other outreach activities developed to engage the community and support further innovation. Workshop materials is attached in **Appendix XI**.

PART IX: Staff attendance record

Staff attendance record is not disclosed due to confidentiality reasons.

PART X: Recruitment record for all project staff

Recruitment record for all project staff is not disclosed due to confidentiality reasons.

Declaration

I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorization has been obtained in respect of information owned by third parties.

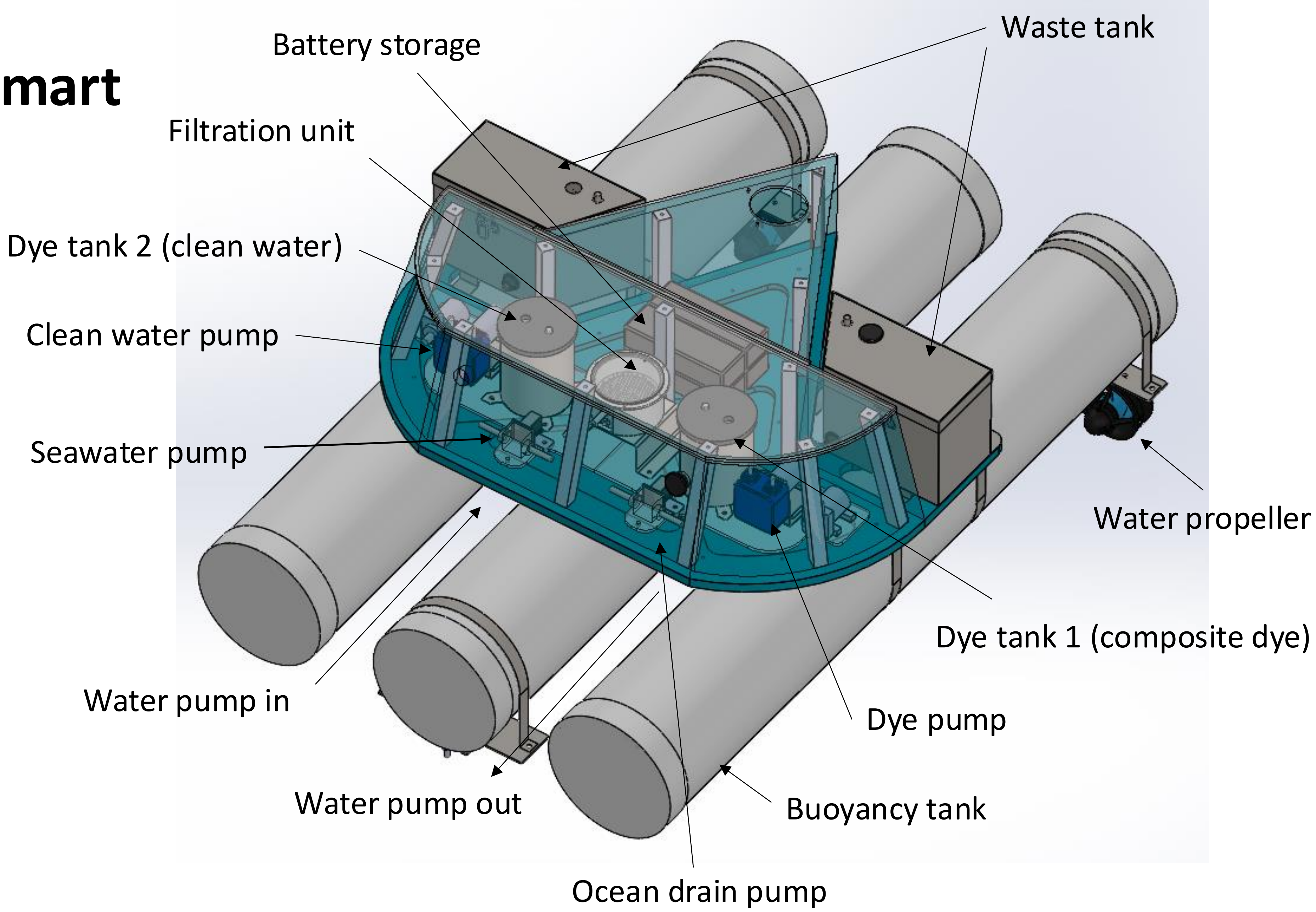
Any opinions, finding, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.

Signature of Project Leader:

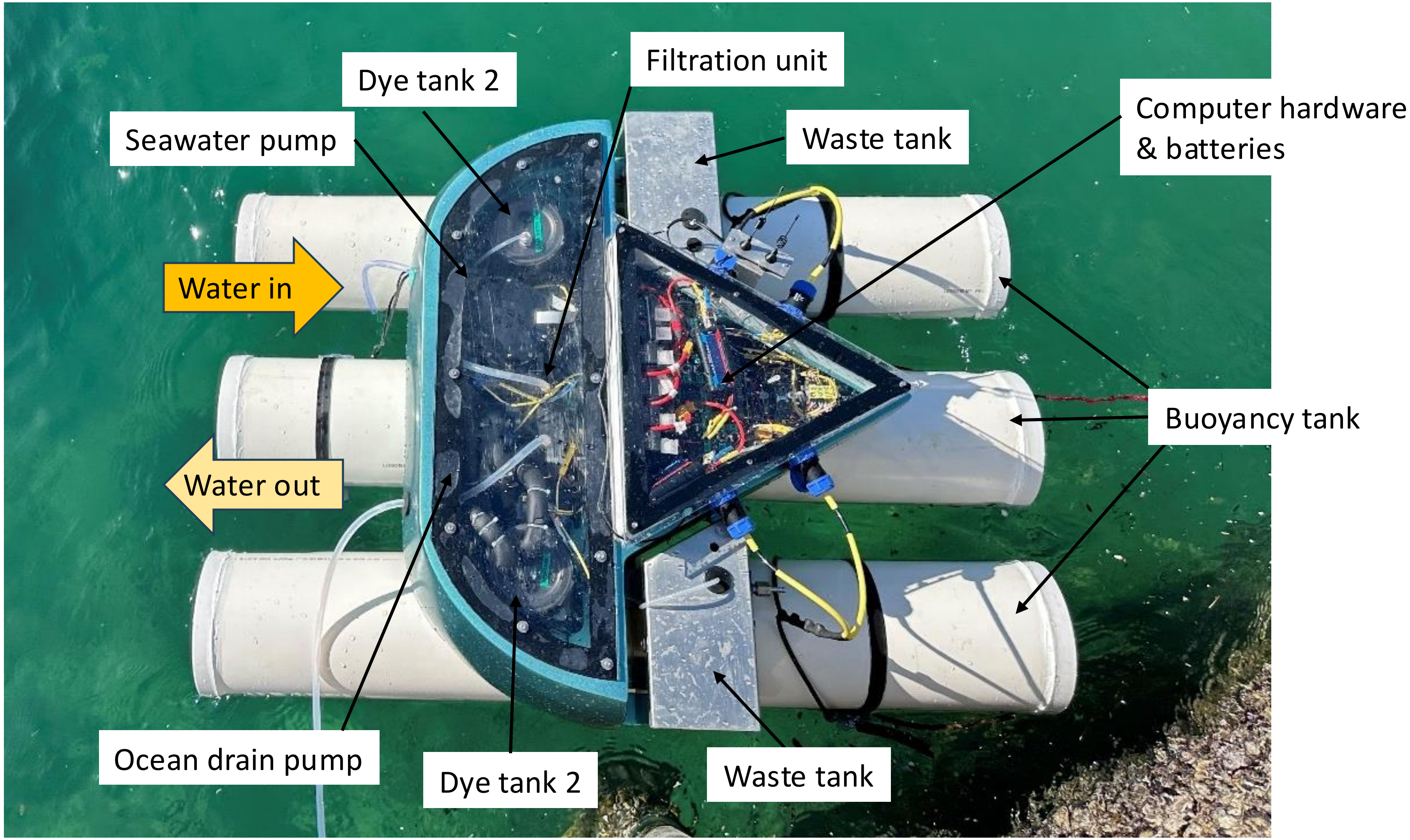
Dr Cindy Lam
Department of Ocean Science, HKUST

New Design of Smart Fish Prototype

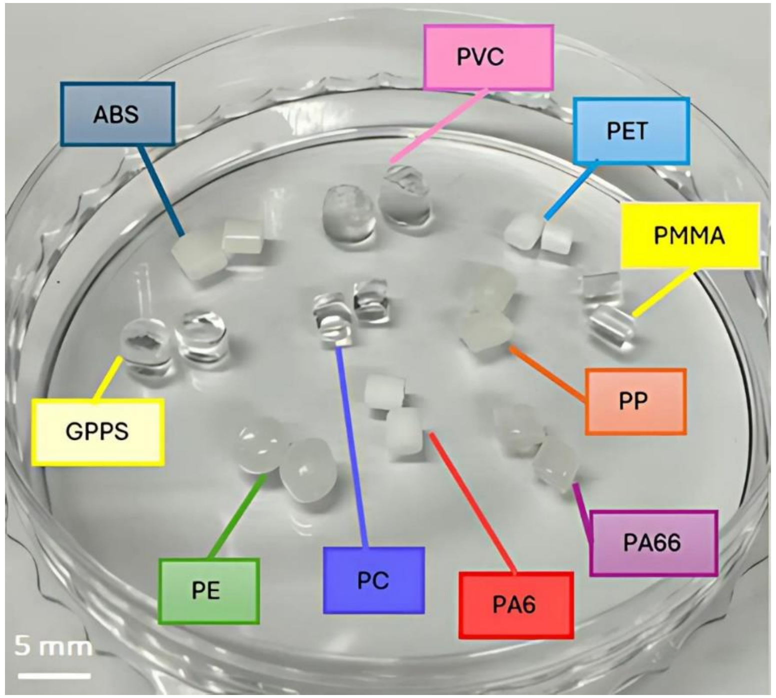
Total weight = 75 kg
Frame = carbon fiber

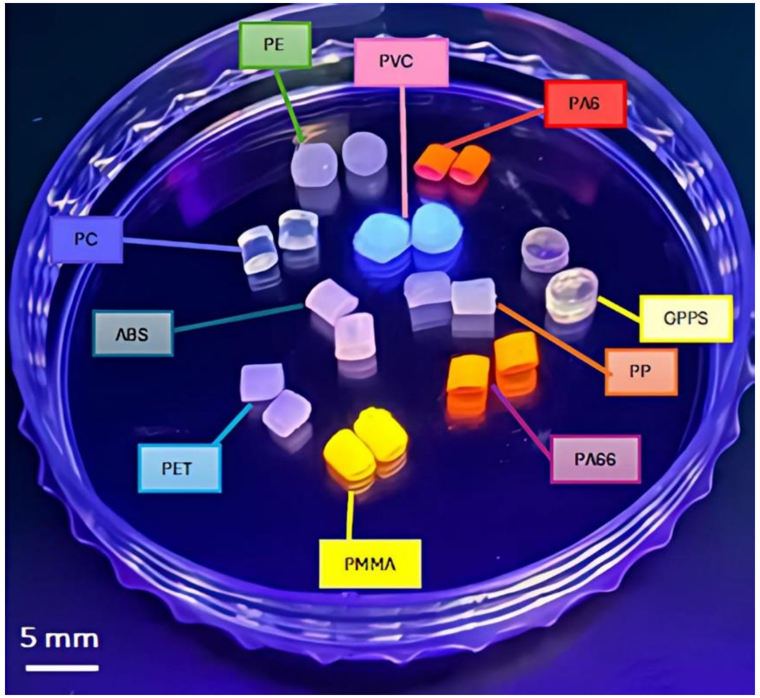


New Design of Smart Fish Prototype



Staining Performance of a Composite Dye





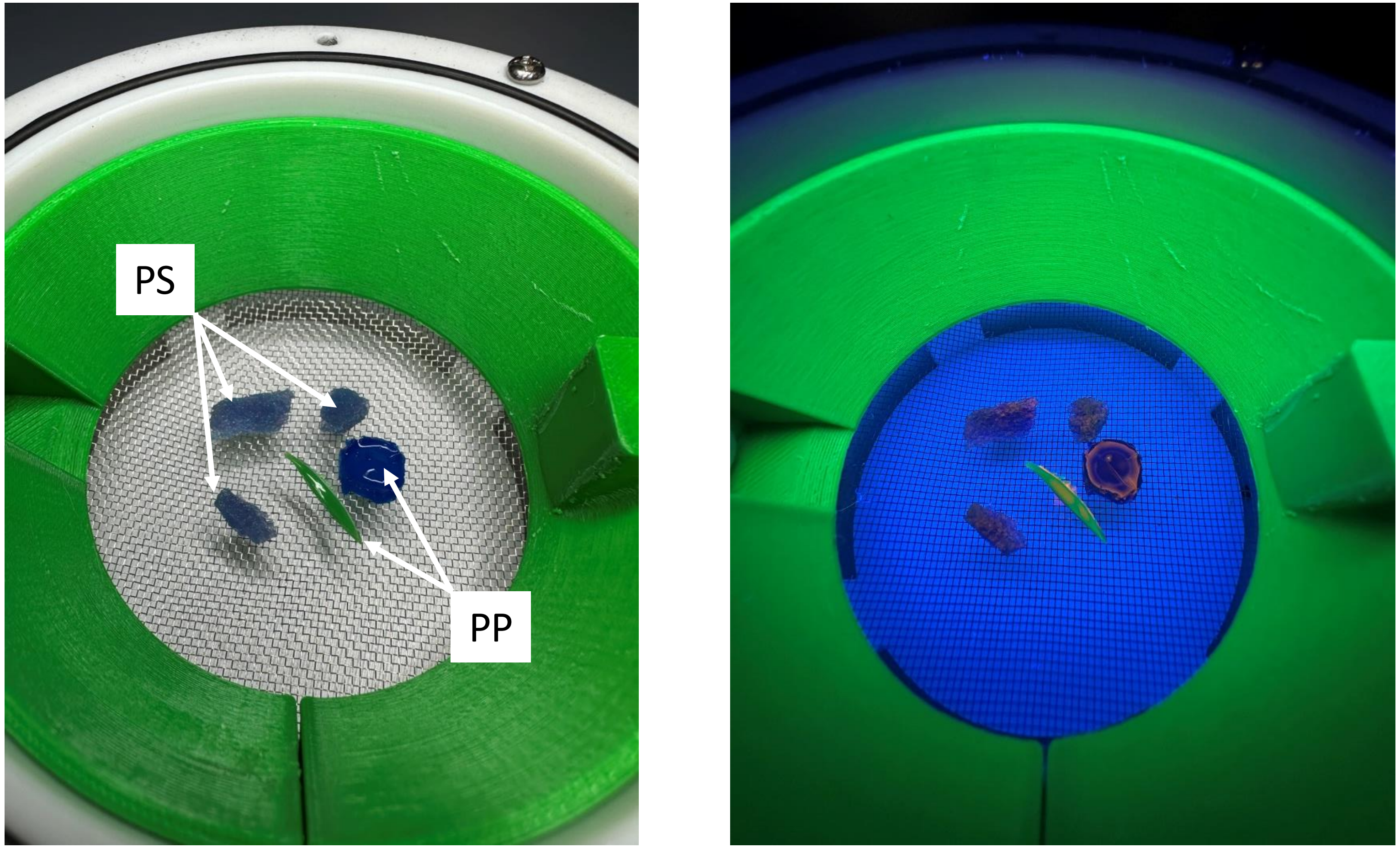
PE	Polyethylene
PET	Polyethylene terephthalate
PP	polypropylene
PC	Polycarbonate
PVC	Polyvinyl chloride
PA6	Polyamide 6
PA66	Polyamide 66
GPPS	General purpose polystyrene
PMMA	Poly(methyl methacrylate)
ABS	Acrylonitrile butadiene styrene

Staining 10 different plastic types before staining (left) and after staining w (right) 254 nm UV illumination.

Specificity of the Composite Dye

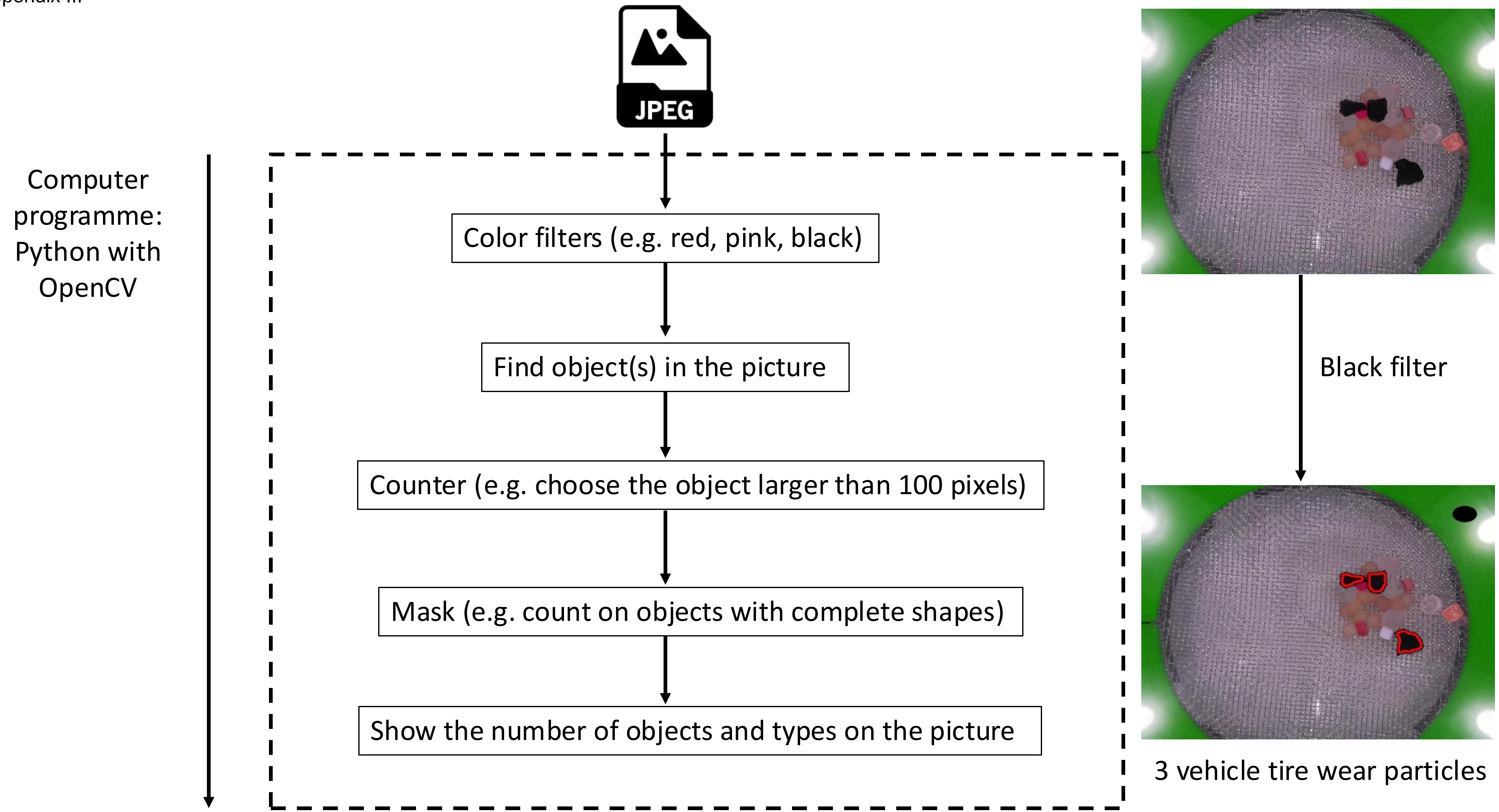
Staining selected non-plastic items using a composite dye before (left) and after (right) 254 nm UV illumination.

Specificity of the Composite Dye



Staining selected colored plastic items (PS and PP) using a composite dye before (left) and after (right) 254 nm UV illumination.

Appendix III



Camera

Operation

White LED

UV254

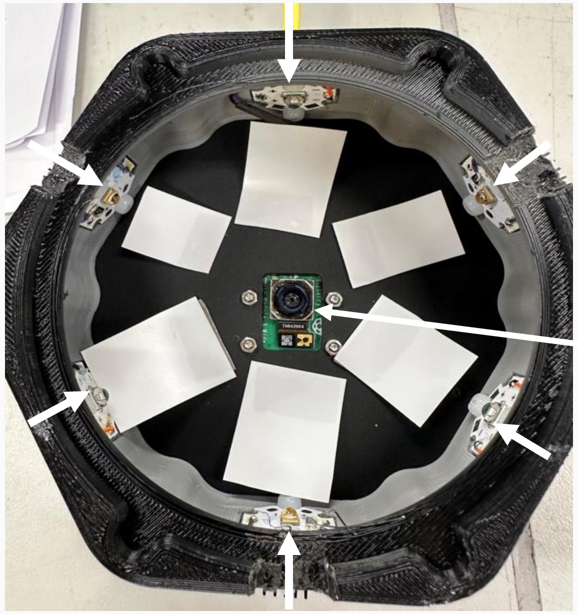
UV365

TAKE PHOTO

RESET

Camera status: **20250221-144047.jpg**

Control camera lighting (on the side) and photo taking in the image capture unit (in the middle) inside the Smart Fish.



Raspberry Pi Camera

Automatic Processing

Operation

▶ START

STOP

RESET

Command To Controller

Message from Controller

White LED

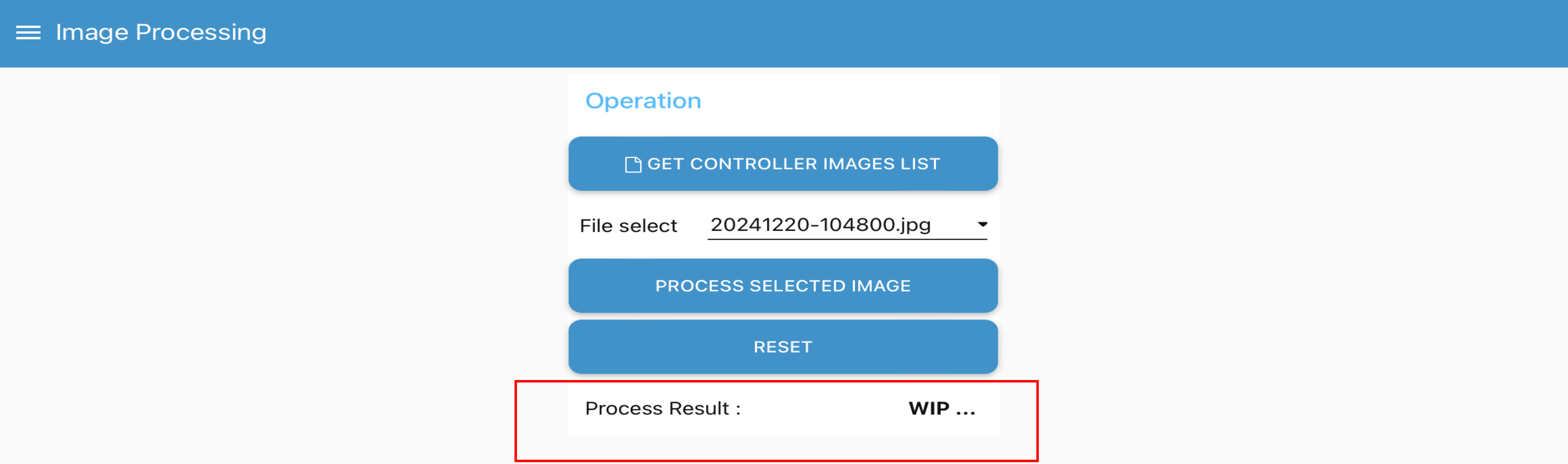
UV LED

Upload

UPLOAD TO SERVER

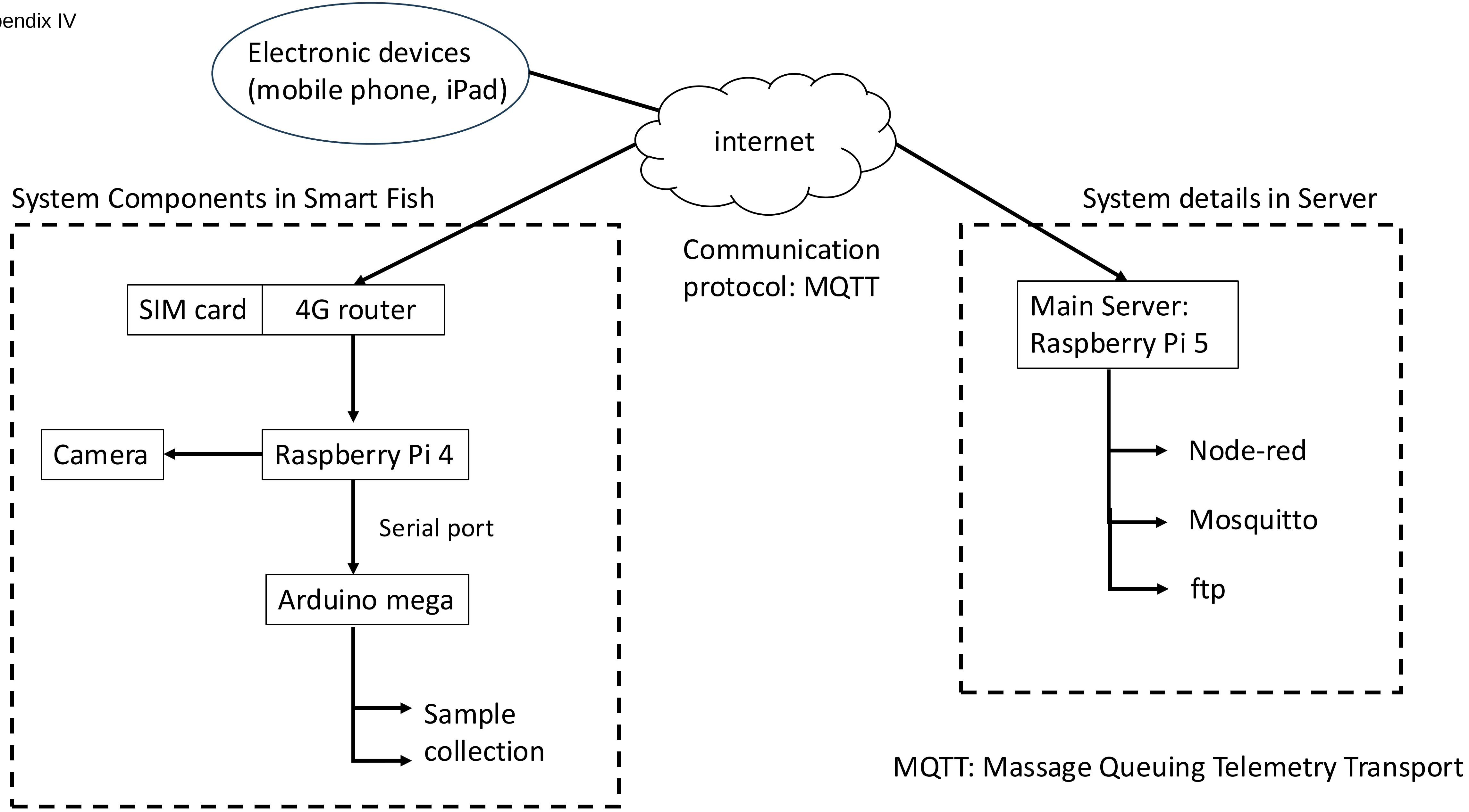
White Led Message

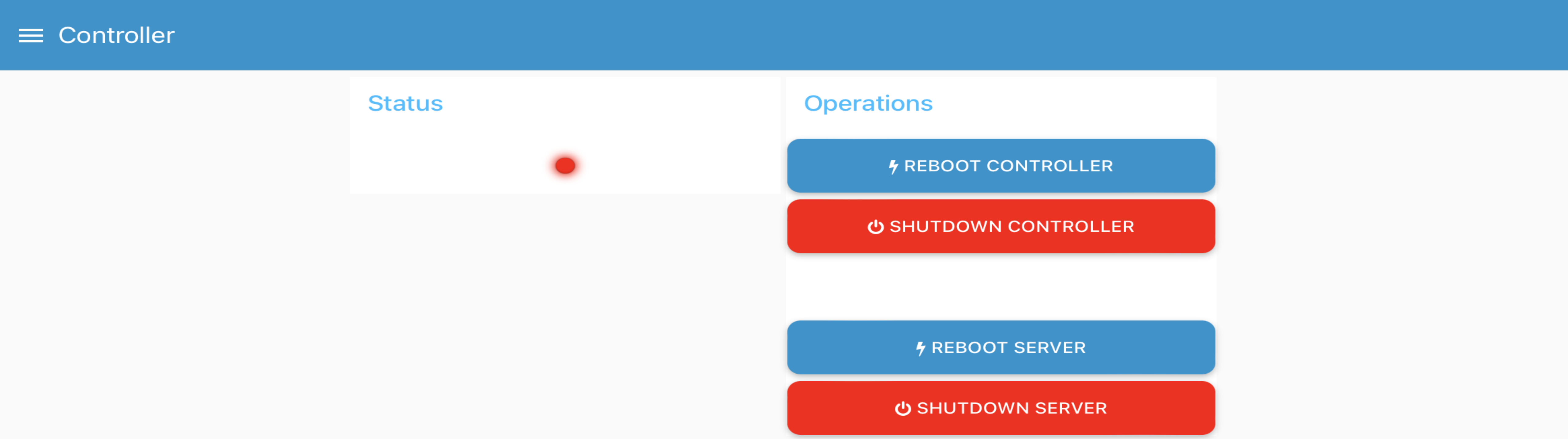
UV Led Message



Show image processing results on screen (no image)

Appendix IV

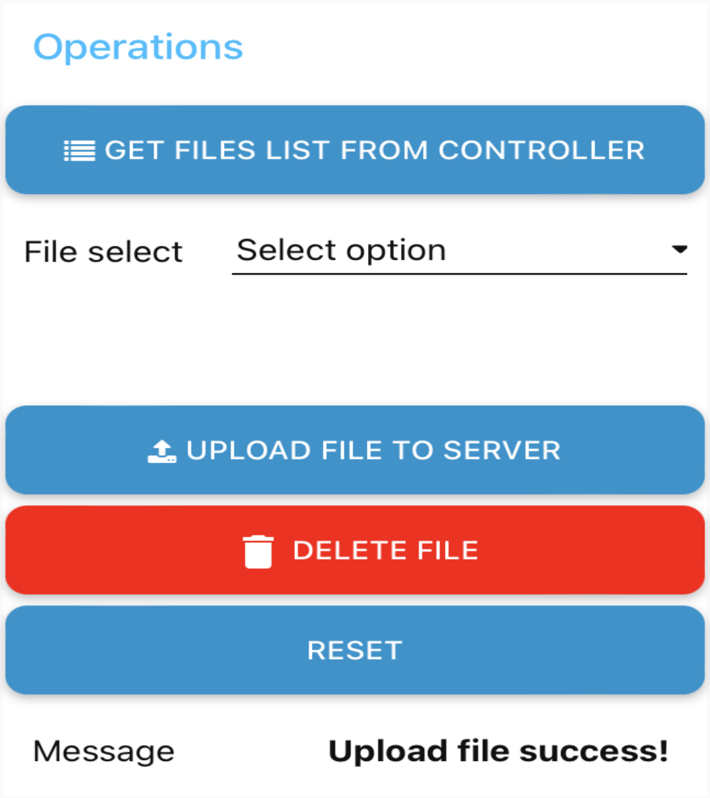

Electronic devices
(mobile phone, iPad)
internet
System Components in Smart Fish
Communication
protocol: MQTT
System details in Server
SIM card
4G router
Main Server:
Raspberry Pi 5
Camera
Raspberry Pi 4
Node-red
Serial port
Mosquitto
Arduino mega
ftp
Sample
collection
MQTT: Massage Queuing Telemetry Transport



Control the operational status in the Smart Fish (controller) and the backend server

FTP To Server

FTP is to transfer the image captured in the Smart Fish (controller) and send to the server.



Server Image Viewer

Operation

DOWNLOAD | DELETE

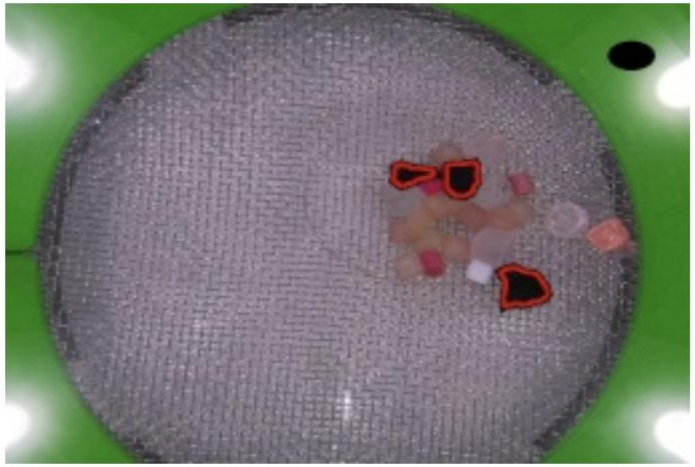
ANALYSIS

REFRESH

Name	Size
20241128-165406.jpg	302730
20241128-165406_black_re...	101930
20241129-100014.jpg	305998
20241129-100014_black_re...	103238
20241129-100133.jpg	313456
20241220-104800-1_black...	101379
20241220-104800-1_black...	25433
20241220-104800-1_black...	6668
20241220-104800.jpg	303280
20241220-104800_black_r...	101019
20241220-104800_black_r...	25266
20241224-090222.jpg	214283
20250221-144047.jpg	96305
20250221-144047_black_re...	37275

First Prev 1 Next Last

Result **Black object count: 3**



Users can retrieve the selected image from the list and perform analysis individually. Both the selected image and the results are shown on the screen. Users can download the images and results to their own devices.

Appendix V

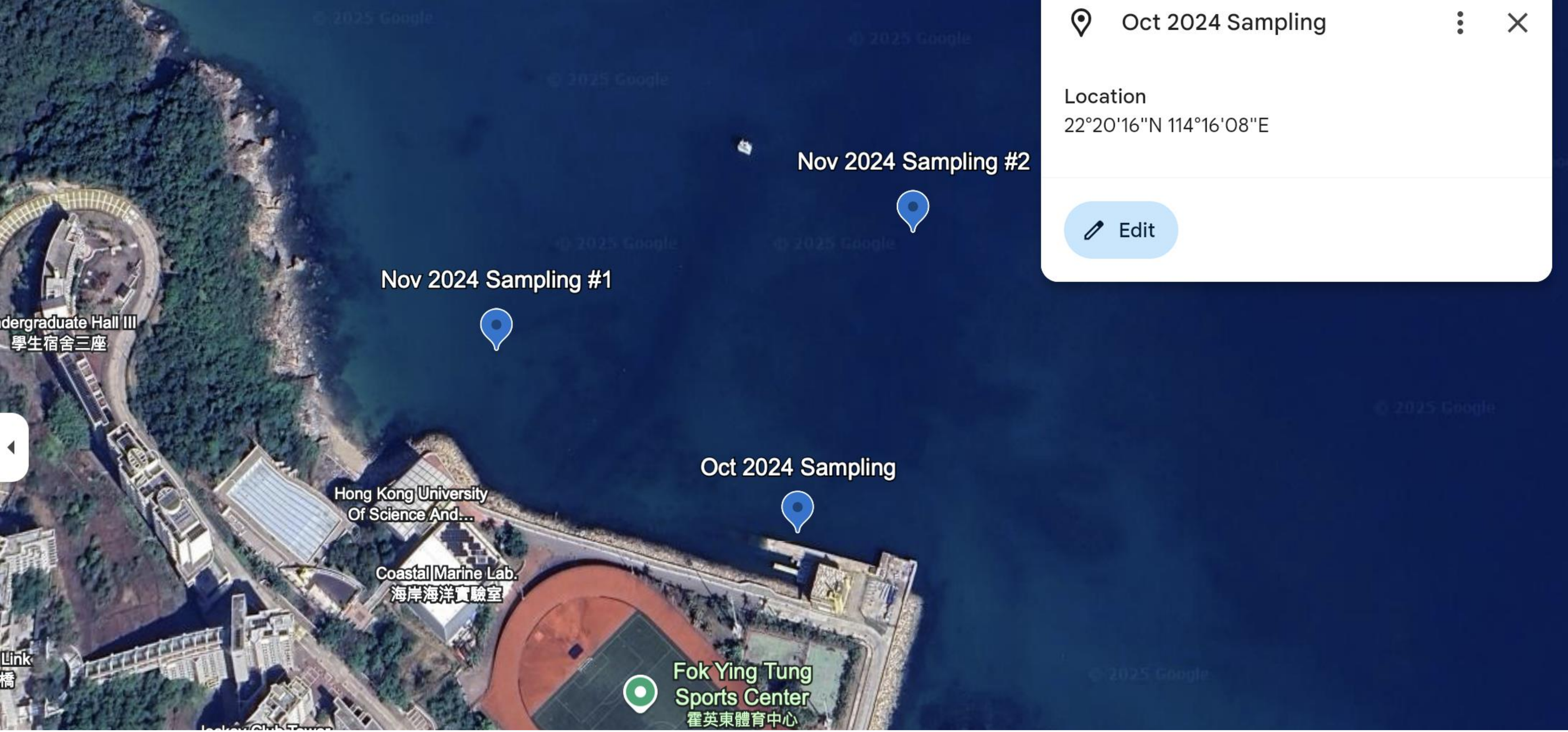
Water Test at HKUST Pier on 29 November 2024

(original plan of water test was cancelled on 25 October 2024 due to typhoon/ strong wind)

Appendix VI

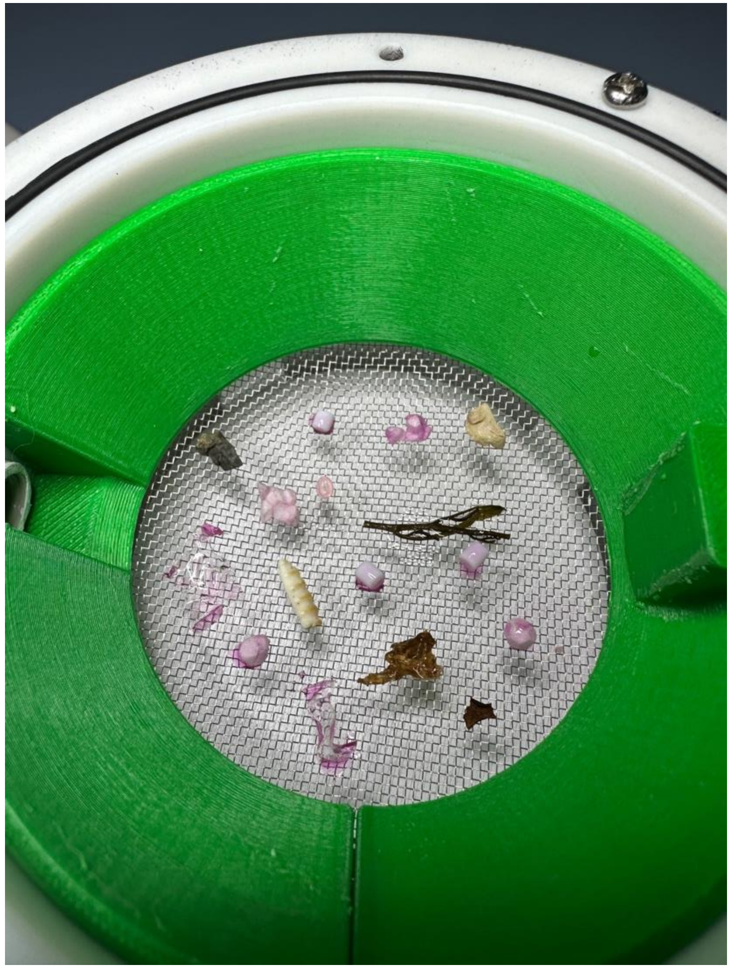
	Sampling #1	Sampling #2	Sampling #3	Sampling #4	Sampling #5	Sampling #6	Sampling #7	Sampling #8	Sampling #9
Sampling Date	18 Oct 2024	29 Nov 2024		24 Dec 2024		27 Jan 2025		15 Feb 2025	
Sampling Location	HKUST Pier 22º20’16’’N 114º16’08’’E	HKUST Pier #1 22º20’19’’N 114º16’03’’E	HKUST Pier #2 22º20’21’’N 114º16’10’’E	HK Airport #1 22º18’31’’N 113º52’54’’E	HK Airport #2 22º17’39’’N 113º52’53’’E	Tung Chung Pier #1 22º17’39’’N 113º56’22’’E	Tung Chung Pier #2 22º17’41’’N 113º56’31’’E	Tung Chung Bay #1 22º17’15’’N 113º56’01’’E	Tung Chung Bay #2 22º17’19’’N 113º55’39’’E
Types & Number of Plastics (in %)									
Polystyrene (PS)	4 (25%)	3 (27.27%)	2 (22.22%)	3 (18.75%)	2 (16.67%)	2 (12.5%)	2 (18.18%)	2 (20%)	2 (25%)
Polyethylene (PE)	2 (12.5%)	1 (9.09%)	1 (11.11%)	2 (12.5%)	2 (16.67%)	1 (6.25%)	2 (18.18%)	1 (10%)	2 (25%)
Polyvinyl chloride (PVC)	0	0	1 (11.11%)	1 (6.25%)	0	1 (6.25%)	0	0	0
Polyethylene terephthalate (PET)	3 (18.75%)	2 (18.18%)	1 (11.11%)	1 (6.25%)	1 (8.33%)	2 (12.5%)	1 (9.09%)	1 (10%)	1 (12.5%)
Polyamide 6 (PA6)	0	0	0	0	0	0	0	0	0
Polyamide 66 (PA66)	1 (6.25%)	0	1 (11.11%)	2 (12.5%)	1 (8.33%)	2 (12.5%)	1 (9.09%)	0	0
Poly(methyl methacrylate) (PMMA)	0	0	0	0	0	0	0	1 (10%)	0
Rubber tire particles	0	1 (9.09%)	0	1 (6.25%)	2 (16.67%)	3 (18.75%)	2 (18.18%)	1 (10%)	0
Non-plastic items	6 (37.5%)	4 (36.36%)	3 (27.27%)	6 (37.5%)	4 (33.33%	5 (31.25%)	3 (27.27%)	4 (40%)	3 (37.5%)
Total	16	11	9	16	12	16	11	10	8

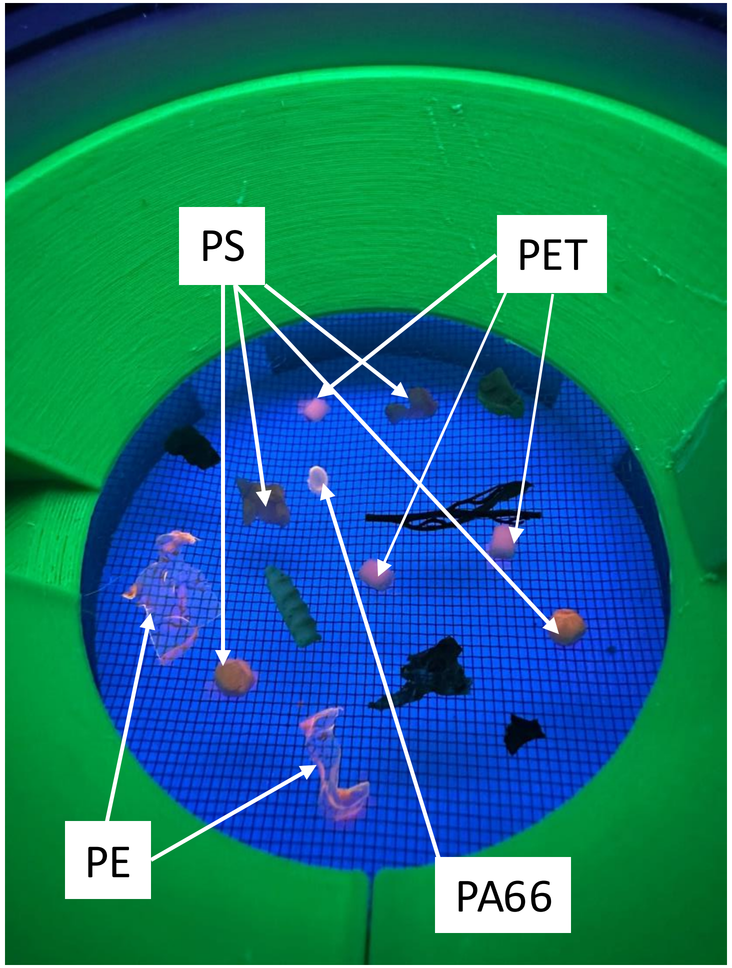
Overview of HKUST boulder shore (which is close to the pier). Picture was taken after typhoon hit Hong Kong on 27 Nov 2024.

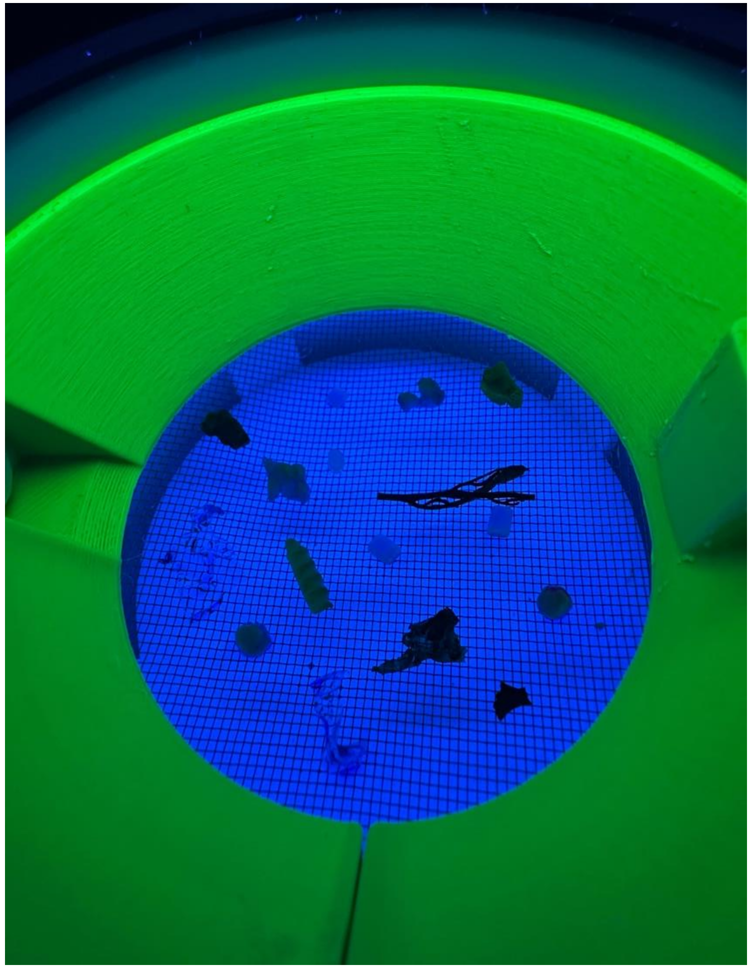


Oct 2024 Sampling @HKUST Pier

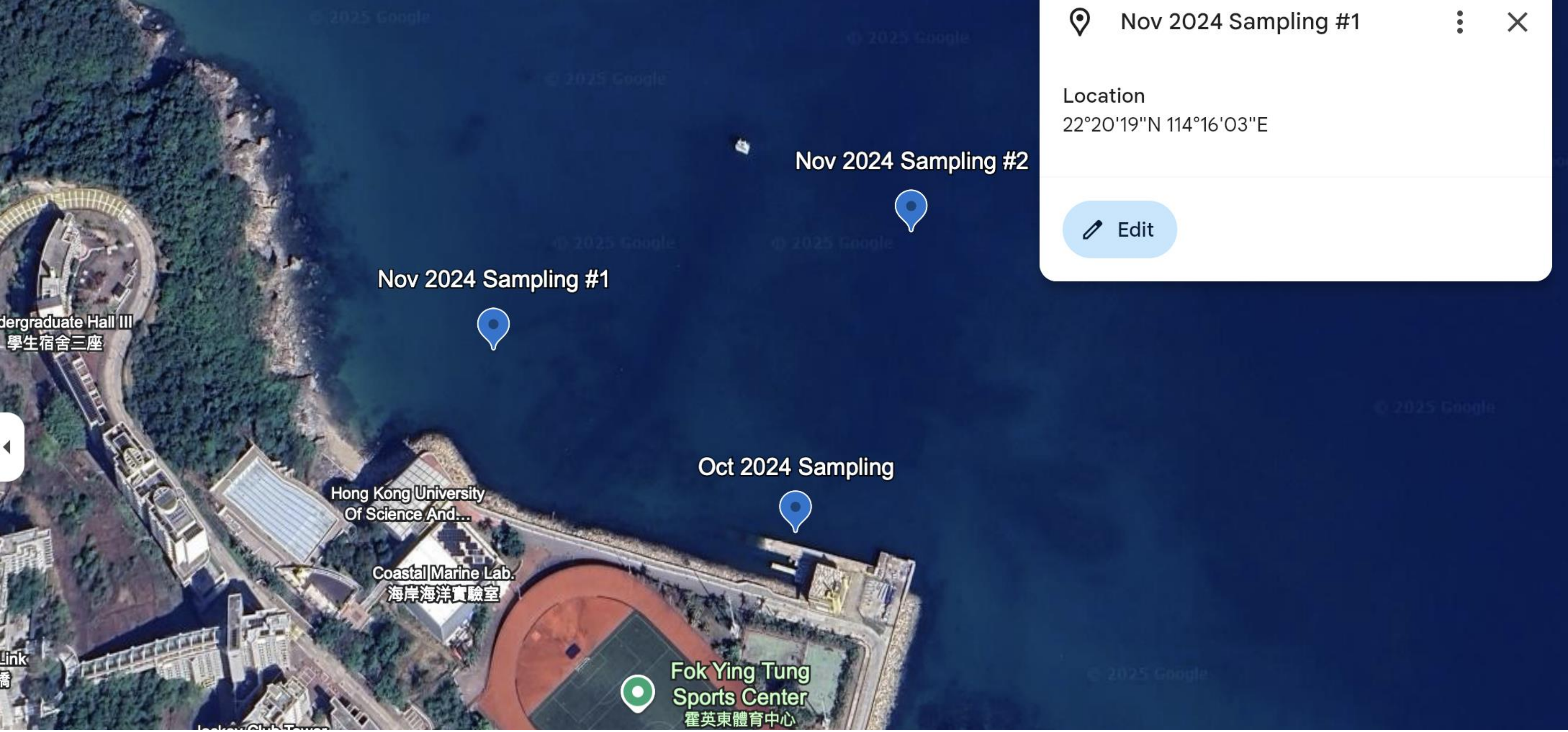
Results of Sampling in Oct 2024





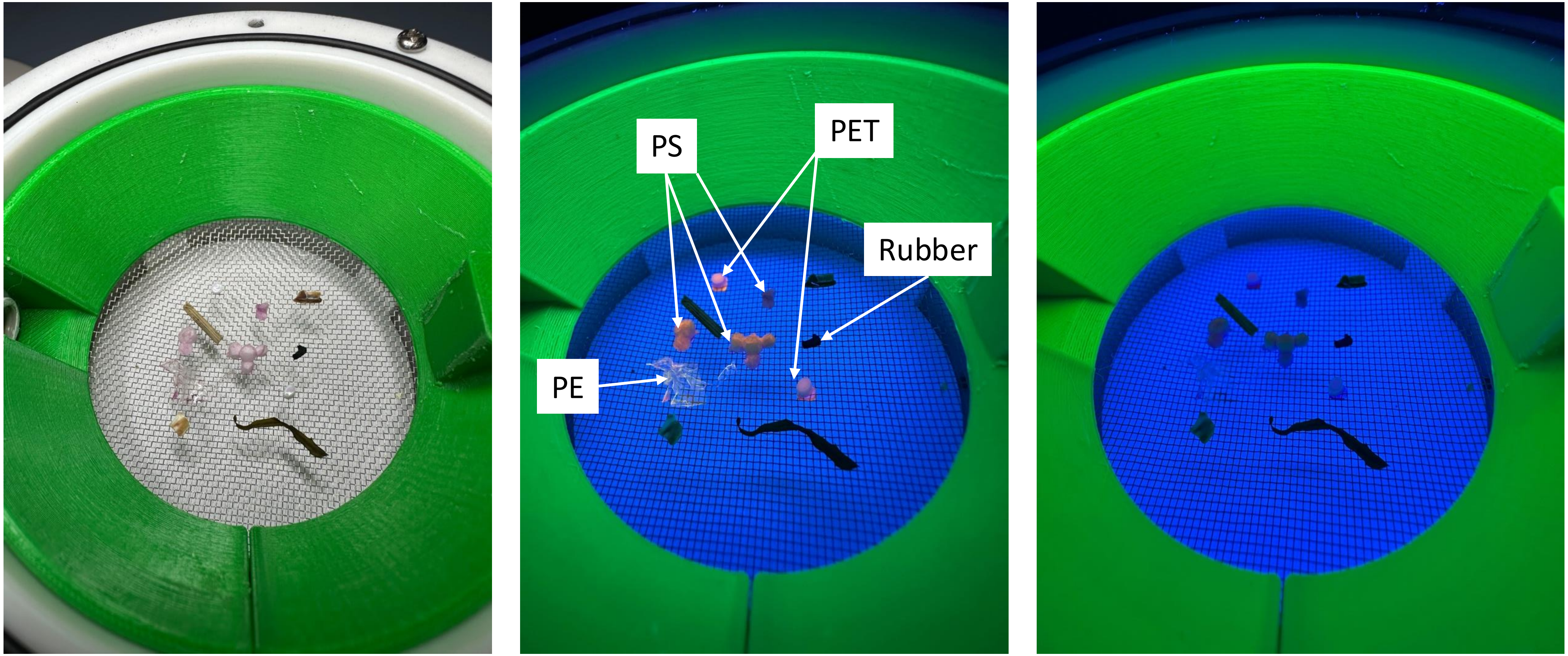


Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.

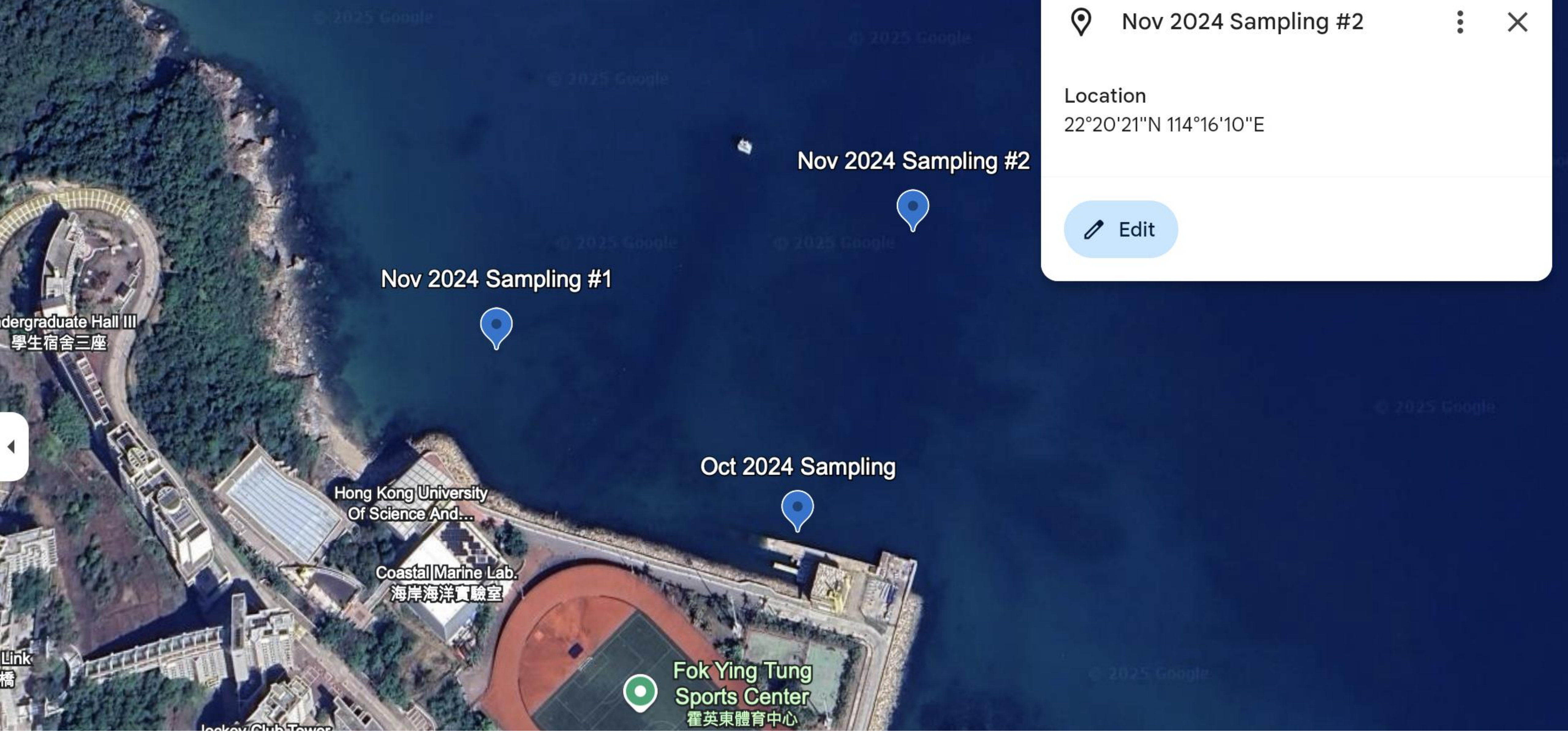


Nov 2024 Sampling #1 @HKUST Pier

Results of Sampling #1 in November 2024

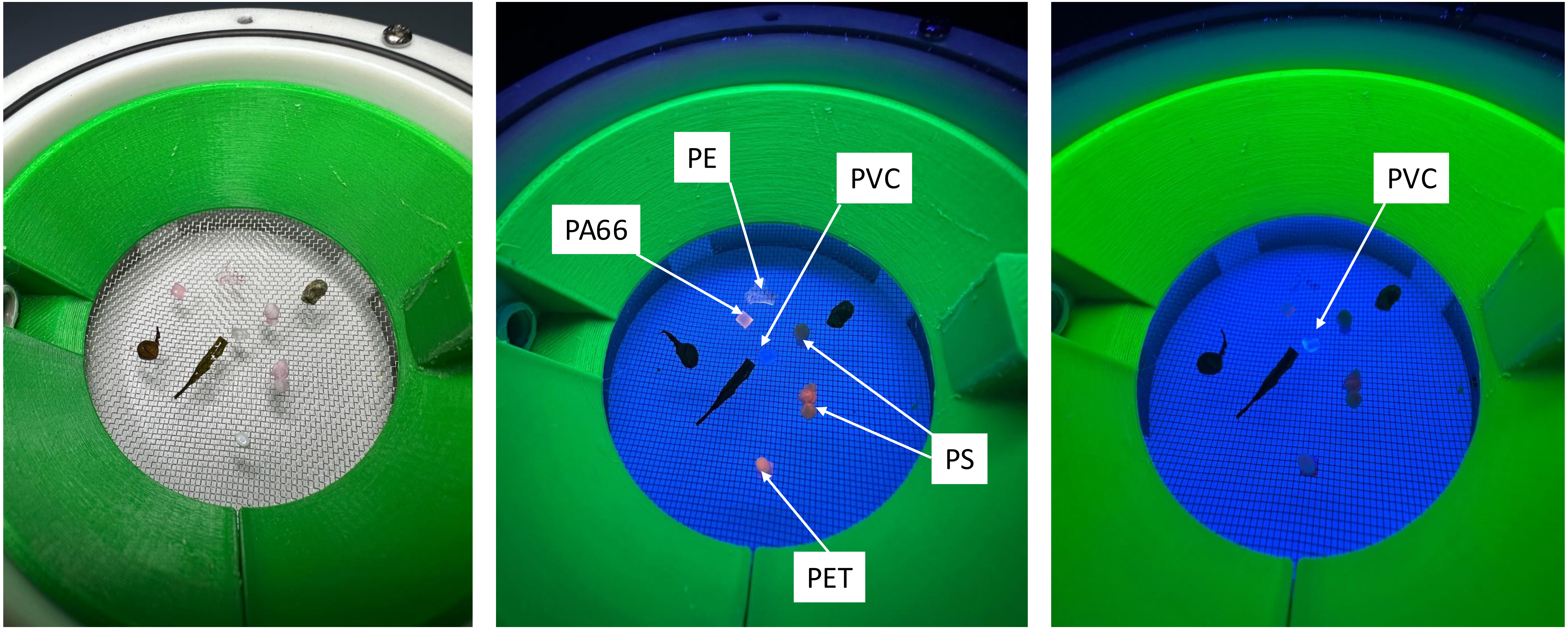


Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.

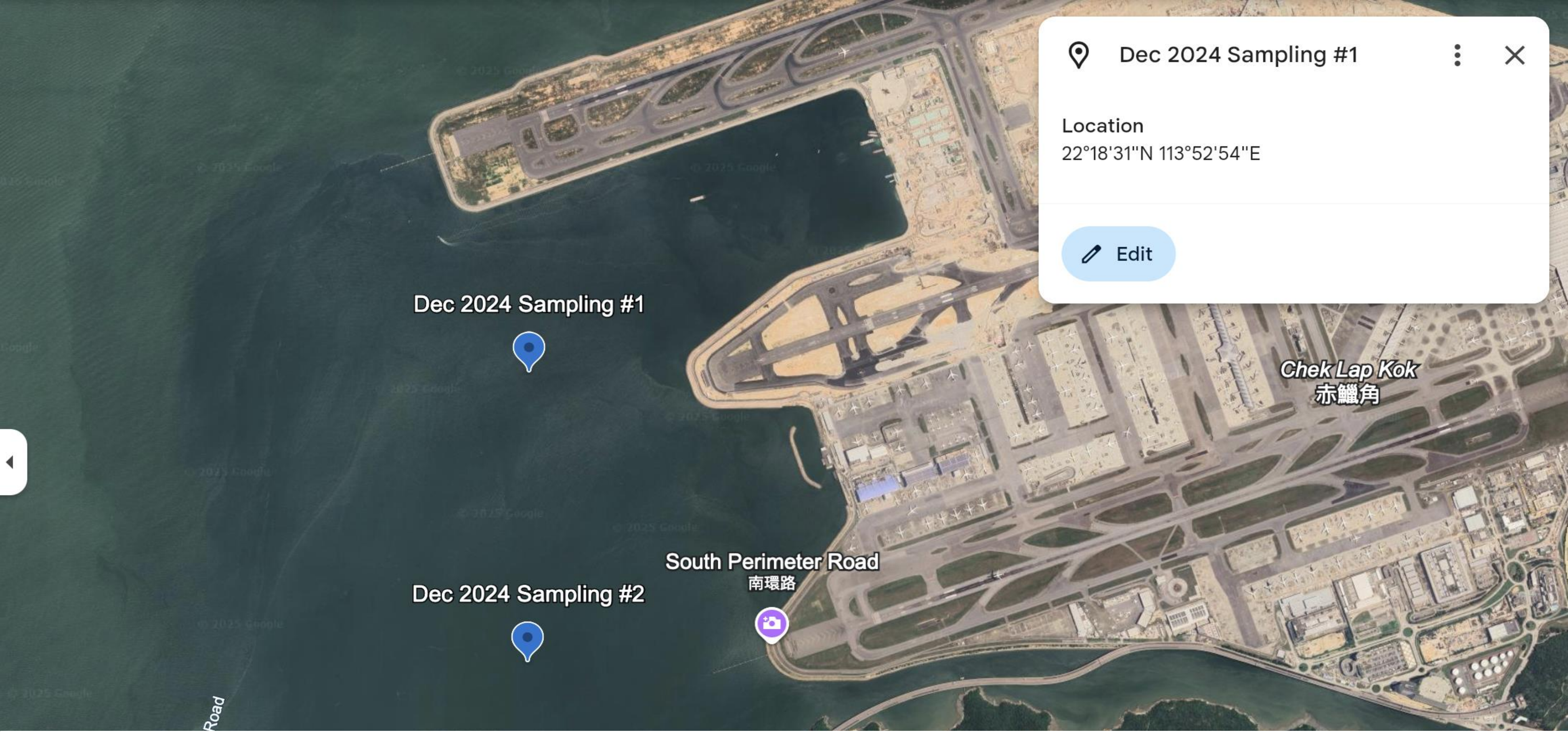


Nov 2024 Sampling #2 @HKUST Pier

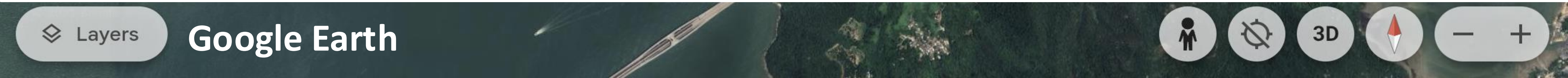
Results of Sampling #2 in November 2024



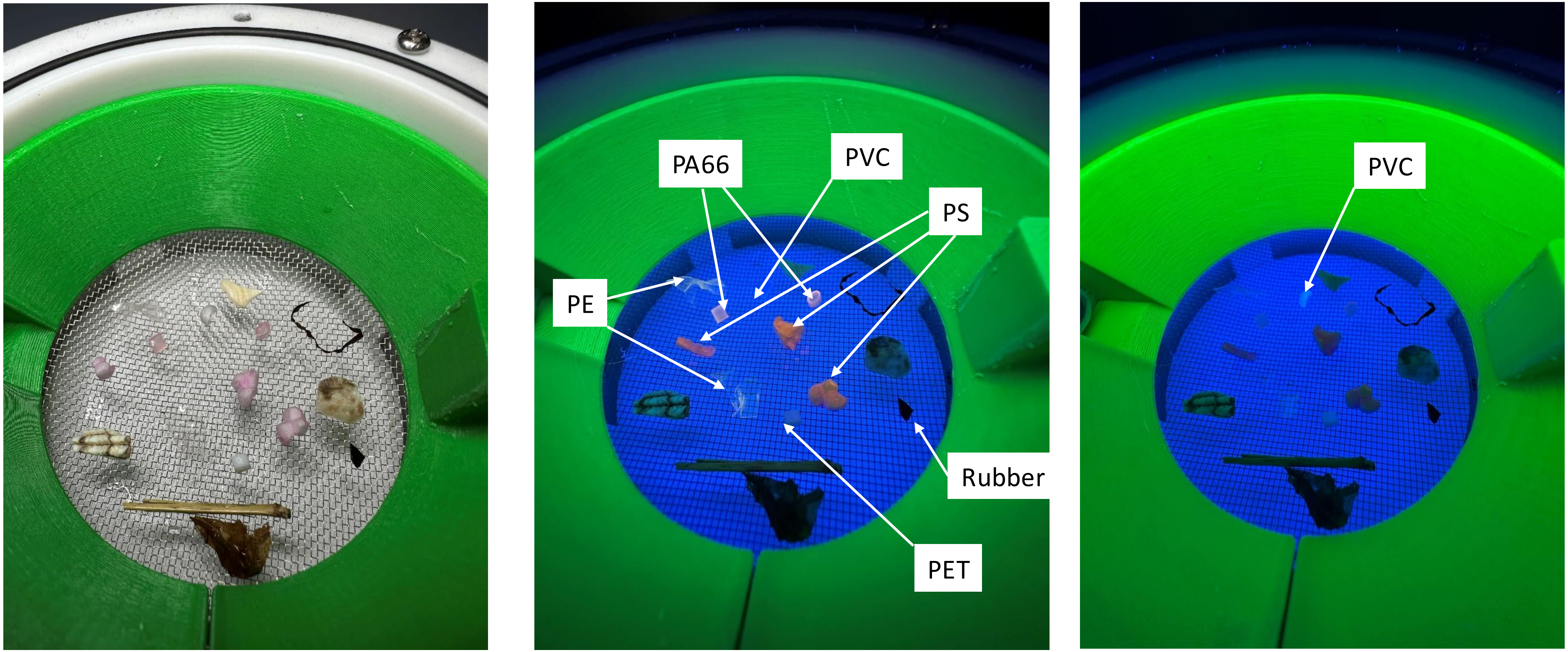
Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.



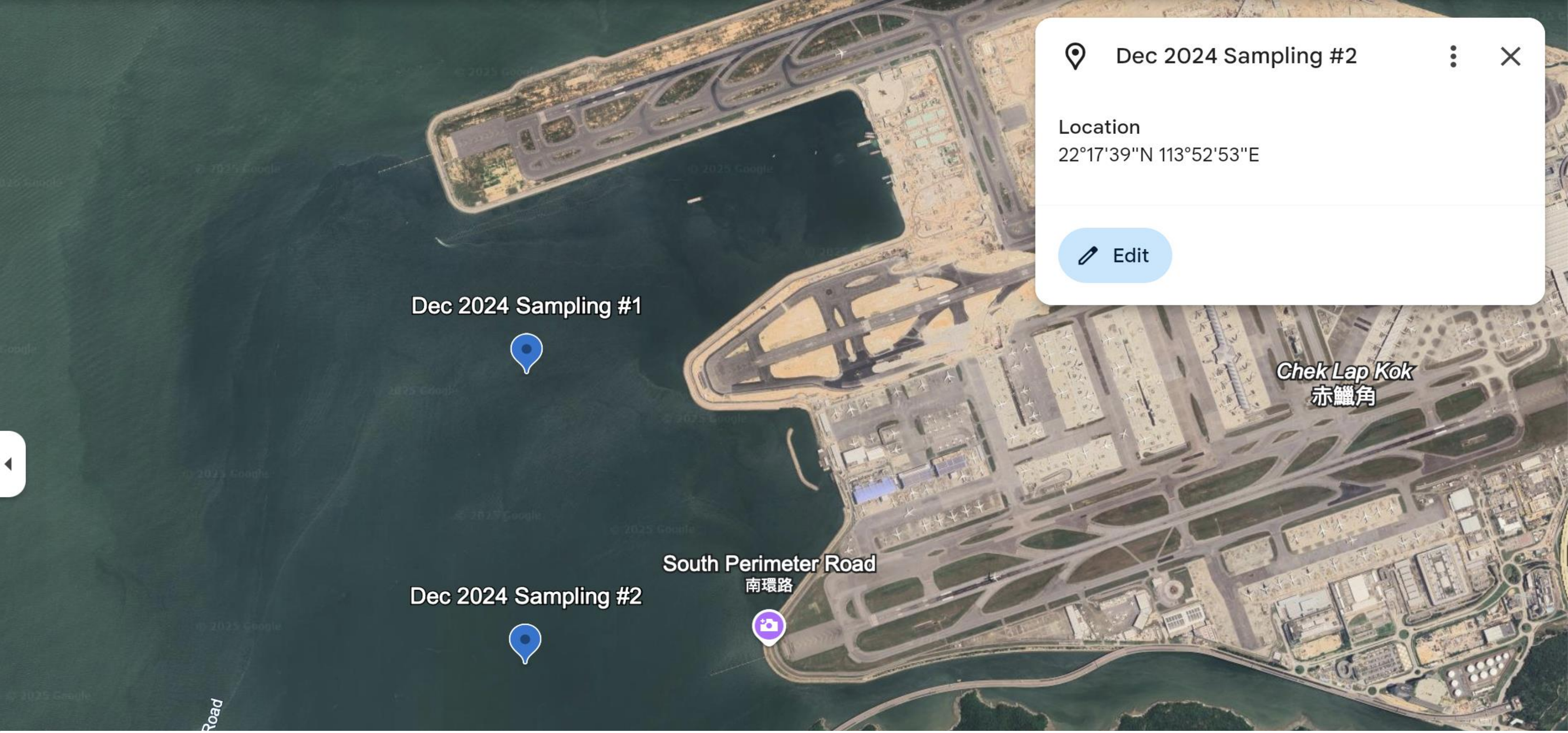
Dec 2024 Sampling #1 @HK Airport



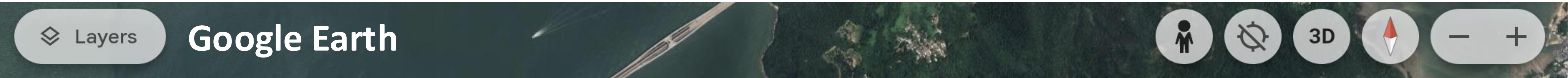
Results of Sampling #1 in December 2024



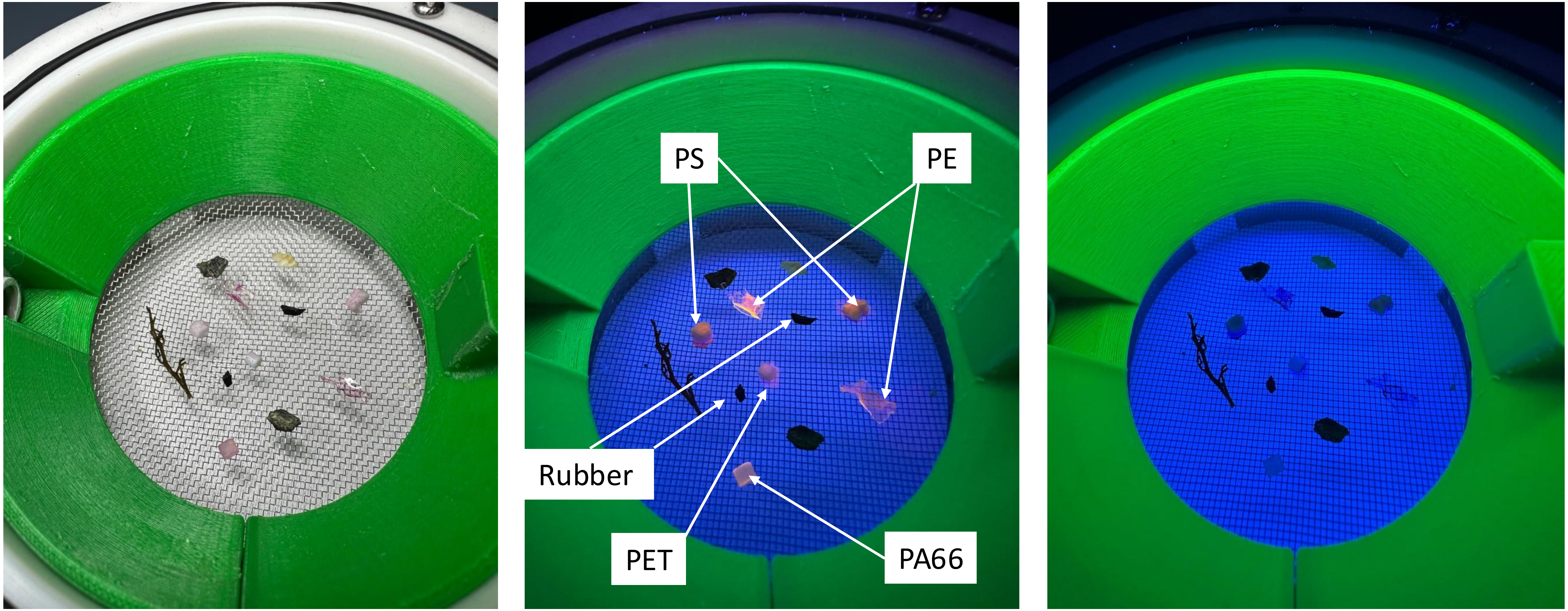
Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.



Dec 2024 Sampling #2 @HK Airport

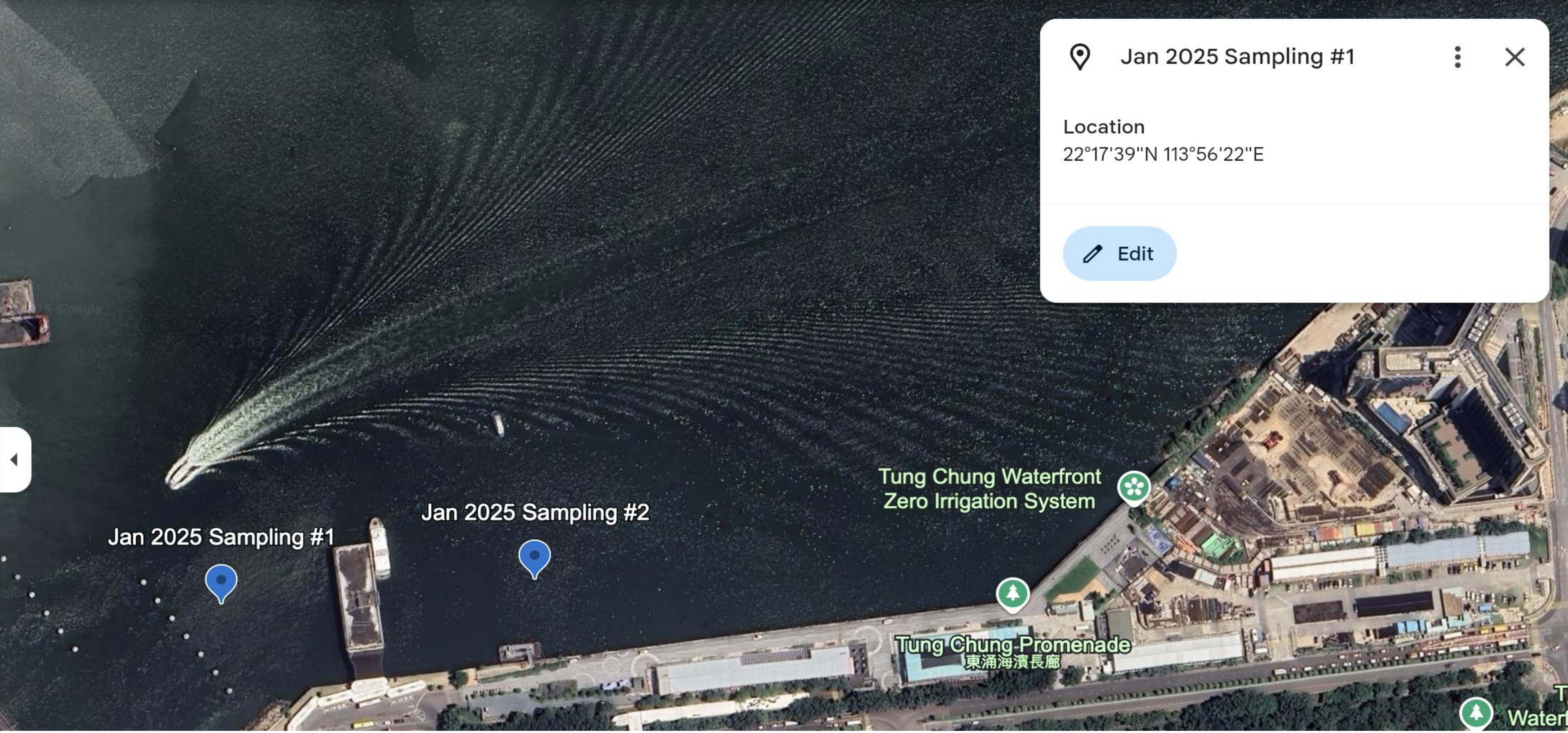


Results of Sampling #2 in December 2024



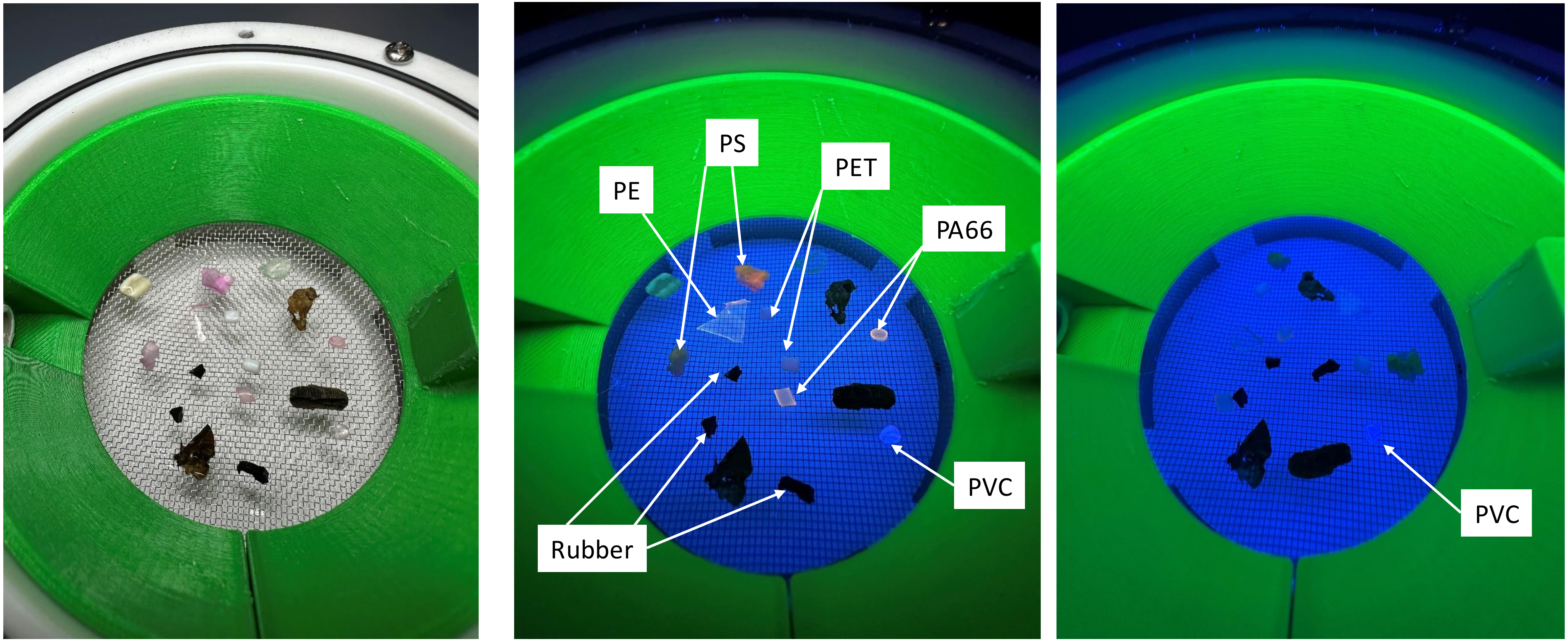
Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.

Tires Used by the Ferry

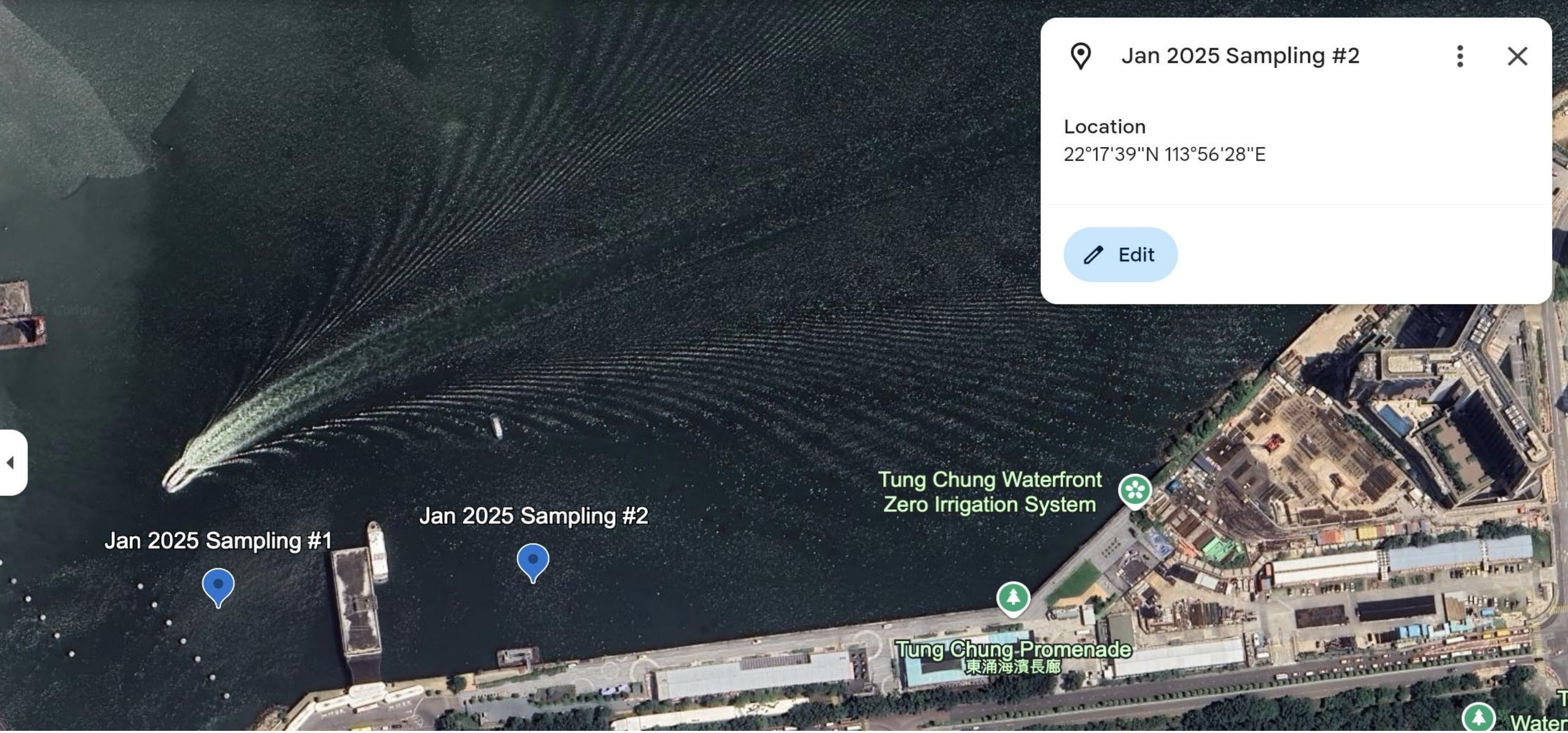


Jan 2025 Sampling #1 @Tung Chung Pier

Results of Sampling #1 in January 2025

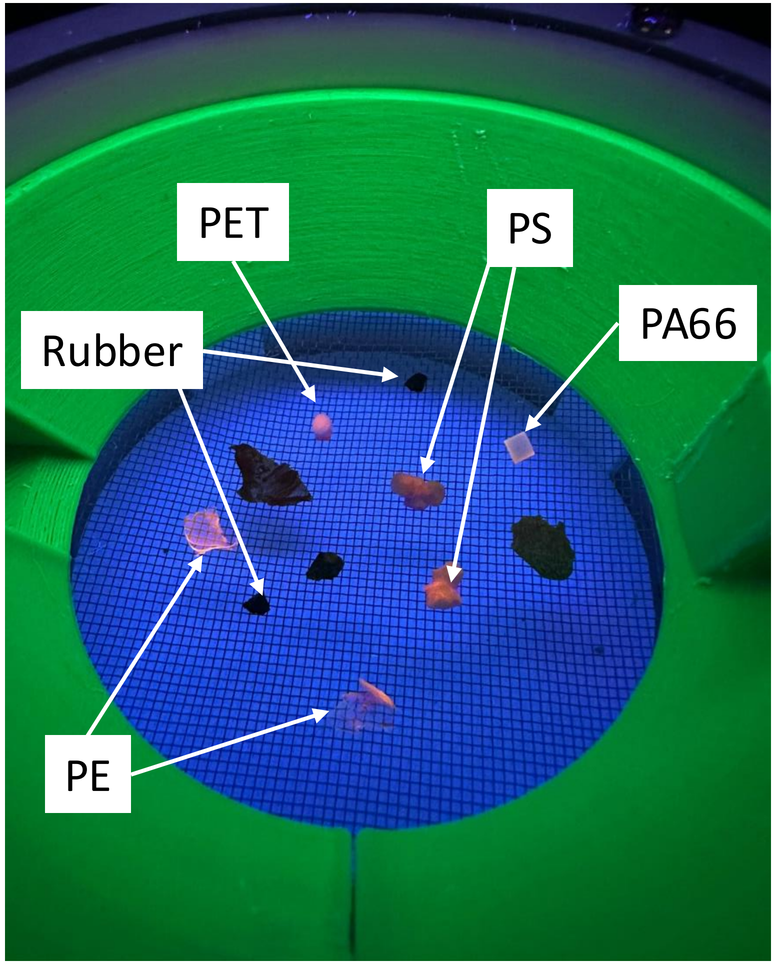


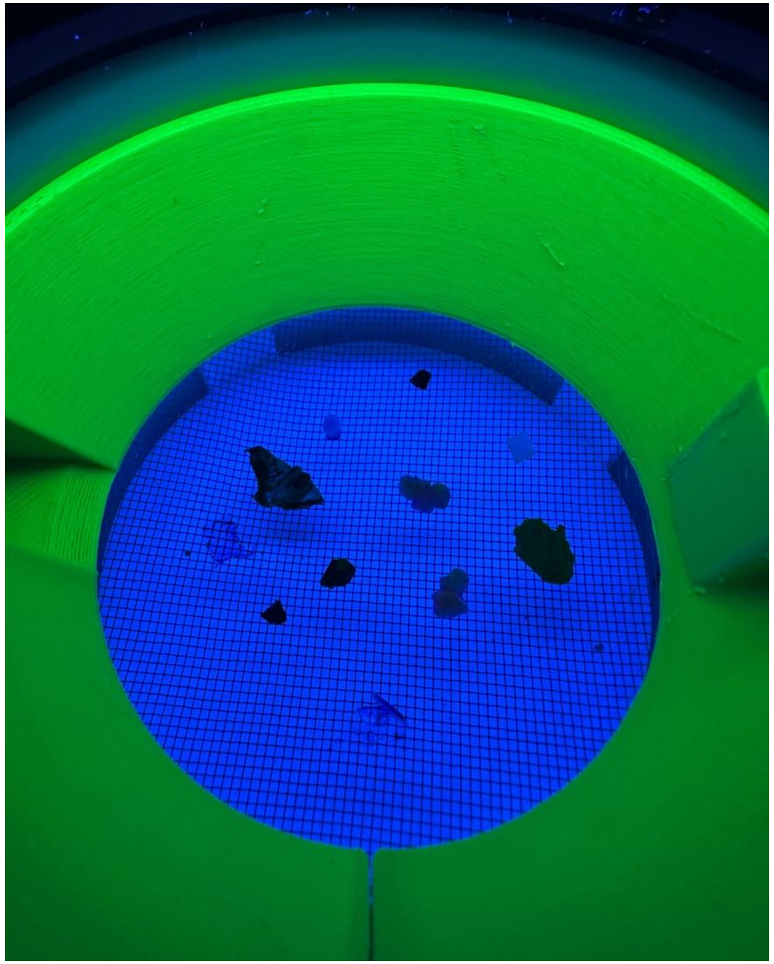
Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.



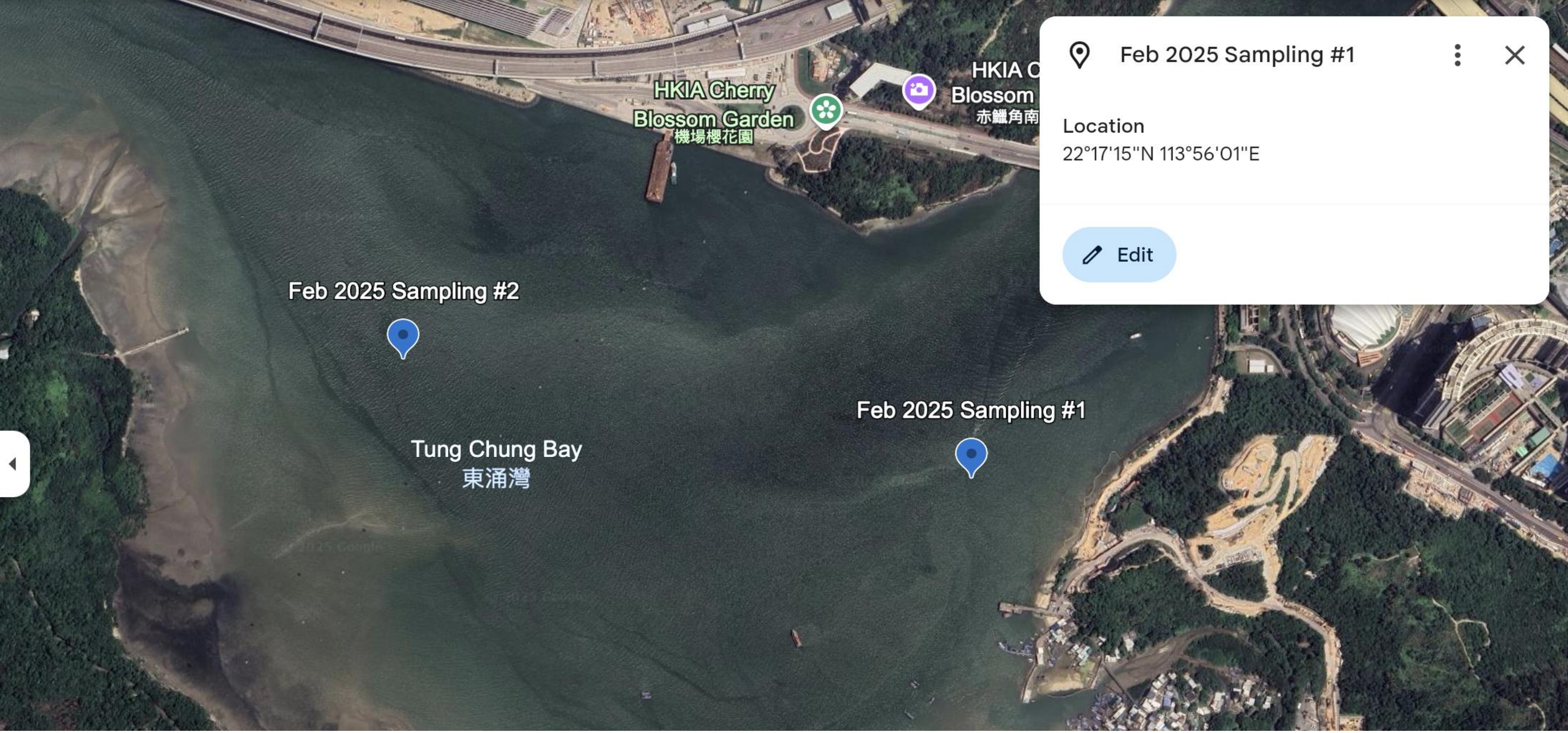
Jan 2025 Sampling #2 @Tung Chung Pier

Results of Sampling #2 in January 2025



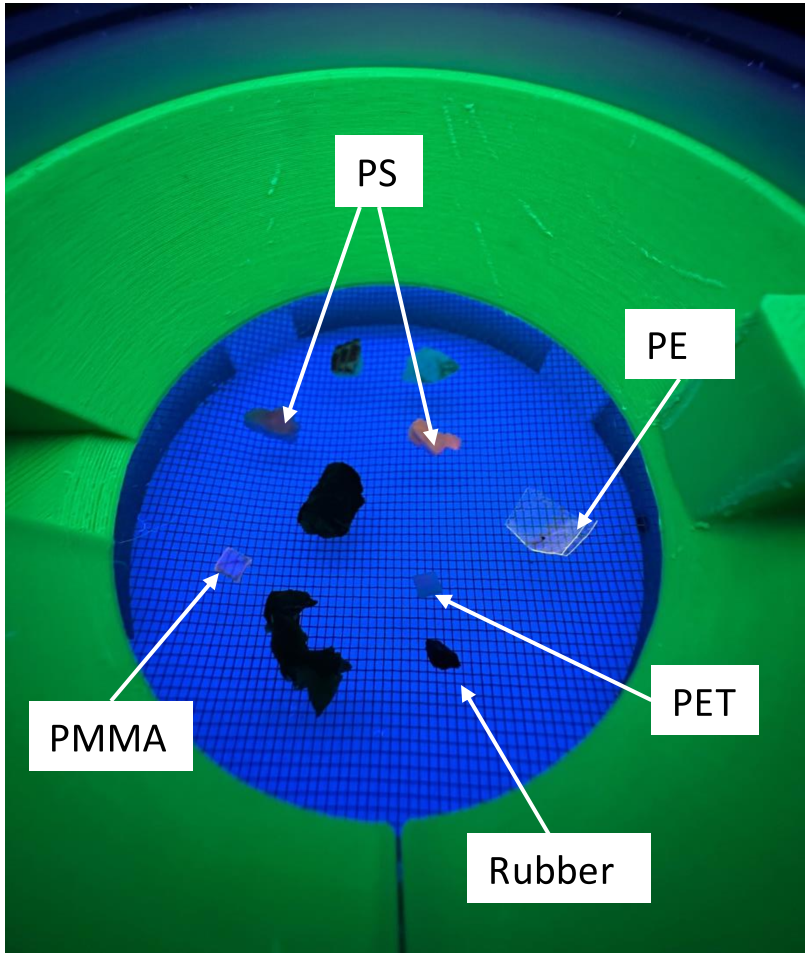


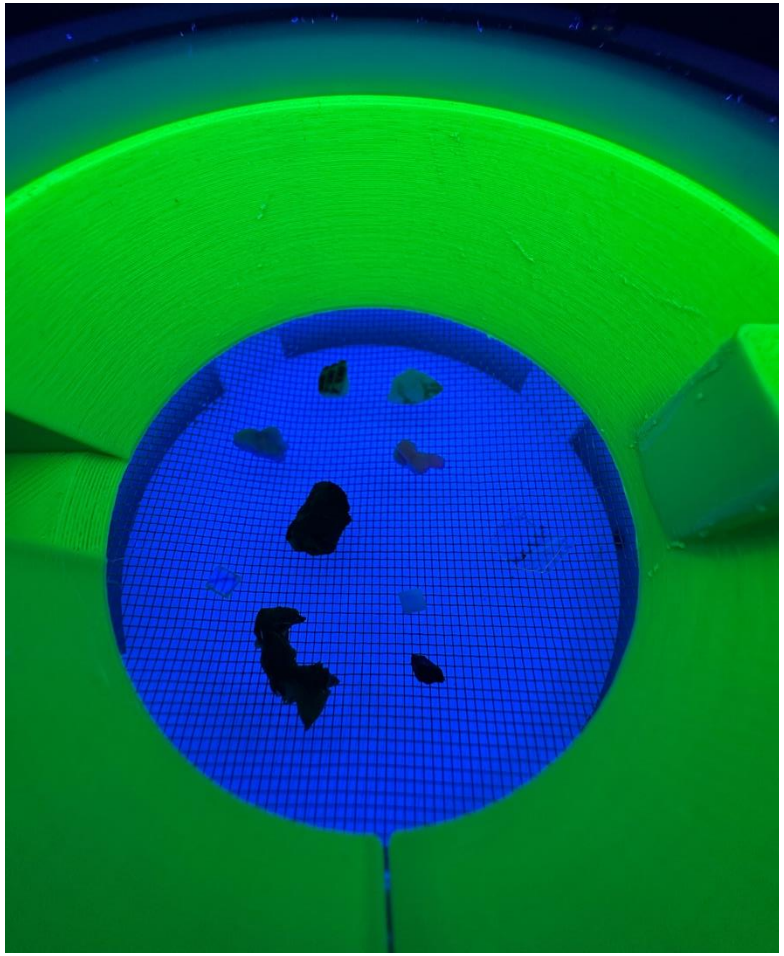
Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.



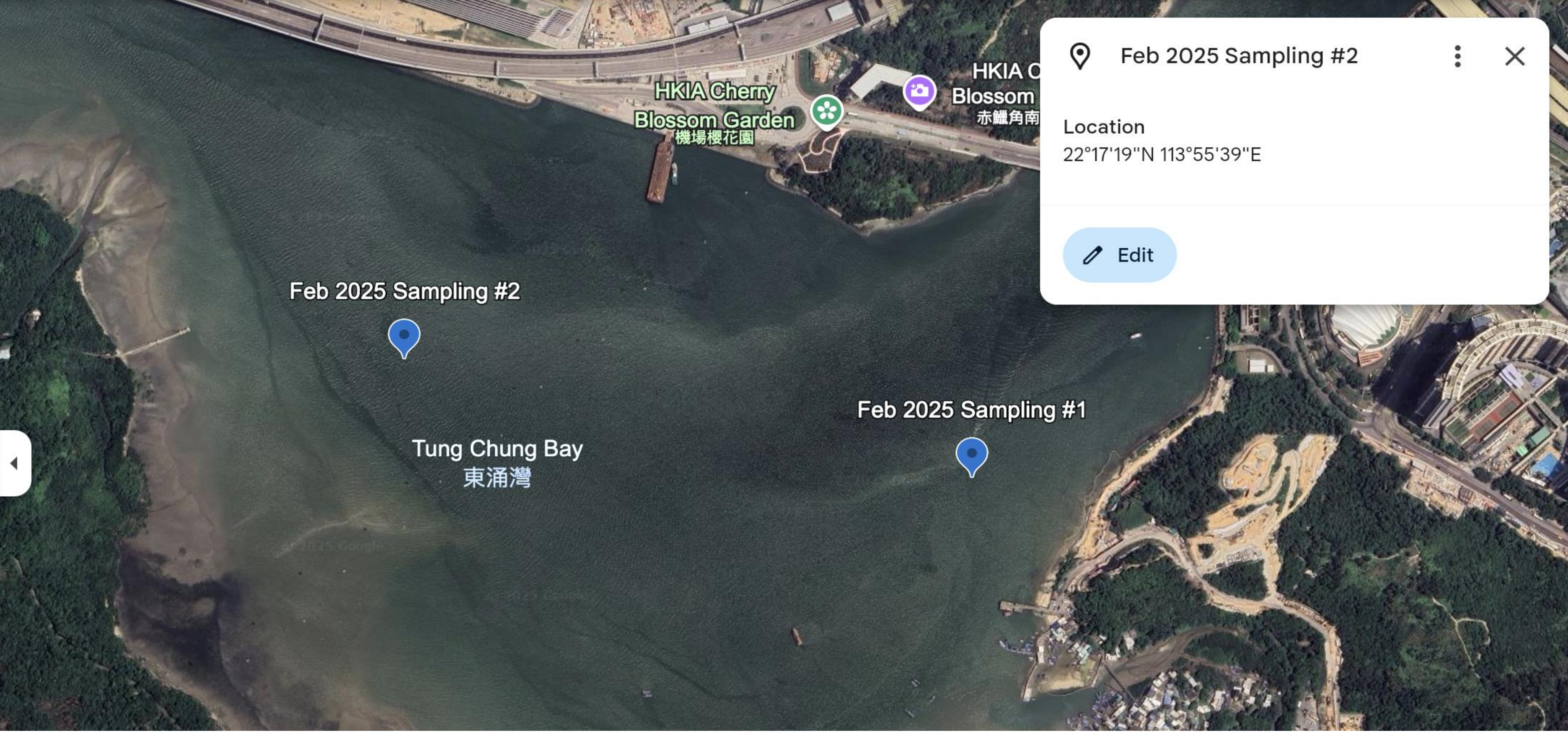
Feb 2025 Sampling #1 @Tung Chung Bay

Results of Sampling #1 in February 2025



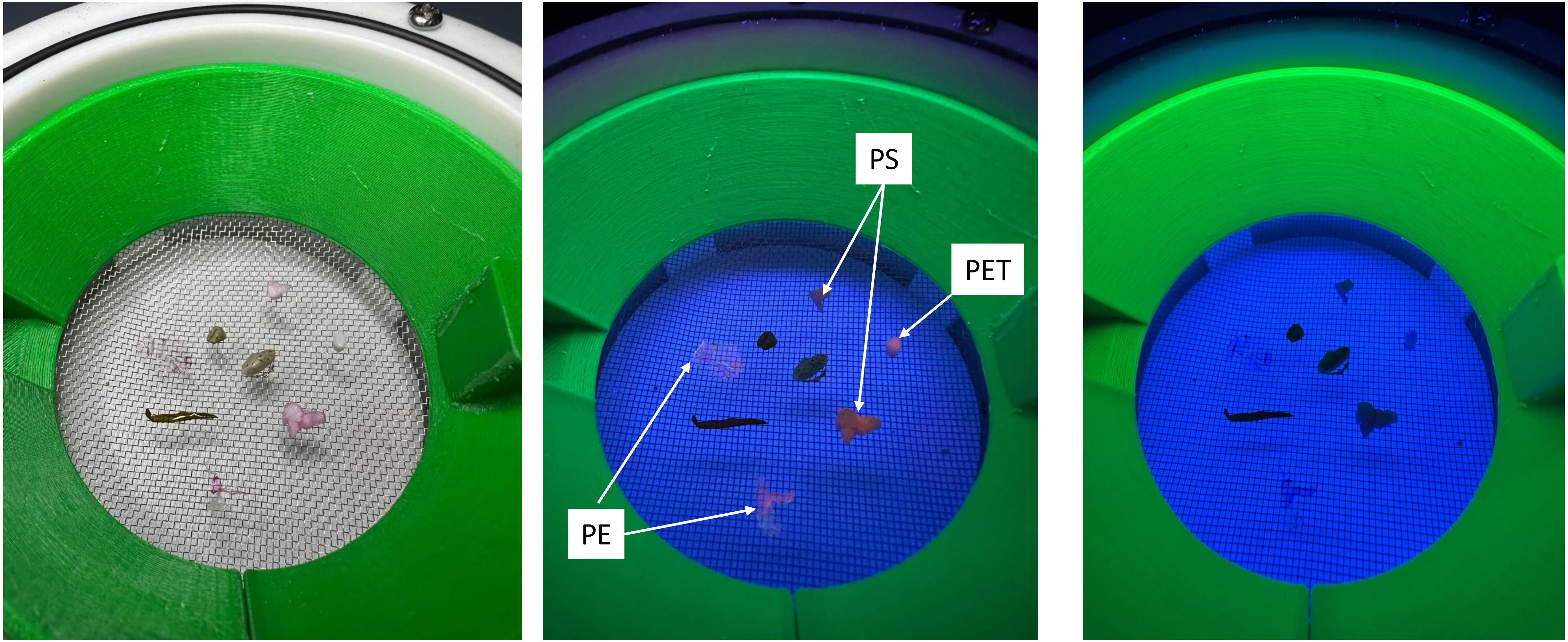


Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.



Feb 2025 Sampling #2 @Tung Chung Bay

Results of Sampling #2 in February 2025



Pictures showing water samples after staining with a composite dye under white light (left), 254 nm UV illumination (middle) and 365 nm UV illumination (right). Non-labelled items in the photo are non-plastic items.

Appendix VII

Project website: https://hkust-smartfish.com

Background
背景

Microplastic contamination in natural water bodies, which results from the disintegration of plastic waste, has raised public concern due to the high level of fragmentation and disturbance in the ecosystem. The associated problem will significantly affect the sustainability of aquatic animals and human beings.

Tire Wear Road Particles account for a large proportion of microplastics in the environment. Previous studies showed that the emission of tire wear particles is nearly 100,000 tons per year in Germany. The friction between the tire and the pavement during driving, speeding up and braking causes particles to be worn out from the car tires. Similar problems may arise from aircraft tires. However, there is not much research focused on real-time detection and removal of tire wear particles in coastal waters in Hong Kong.

近年來，海洋微塑膠污染的問題逐漸引起公眾的關注。塑膠物料在自然環境下（包括風、海浪沖刷和紫外線等因素）分解成塑膠碎片或更細小的微塑膠粒，這不僅影響海洋生態，也間接影響人類健康。輪胎磨損產生的微塑膠粒在環境中所佔比例很大。例如，過去研究顯示德國每年輪胎磨損產生的微塑膠粒排放量接近10萬噸。車輛在行駛、加速和煞車過程中，輪胎與路面間的摩擦會產生大量微塑膠粒。飛機輪胎也存在同樣問題，由於這方面的研究數據有限，我們希望通過研發智能檢塑魚從而了解這方面海洋污染問題。

Project Objectives

Our project would fill up the information gap by developing a prototype device to provide real-time sampling, detection, and degradation of tire wear particles (TWP) in the coastal area of Lantau Island near Hong Kong International Airport. The prototype combines autonomous sampling, real-time detection of microplastics, and aircraft tire wear particles with a treatment unit to address and mitigate the problem in the region.

The prototype includes the following components:

- a sampling unit
- a filtration unit
- two staining chambers for microplastics and tire wear particles
- a capturing system using a digital camera
- a user-friendly mobile app to visualize the data
- a treatment unit to remove microplastics and tire wear particles

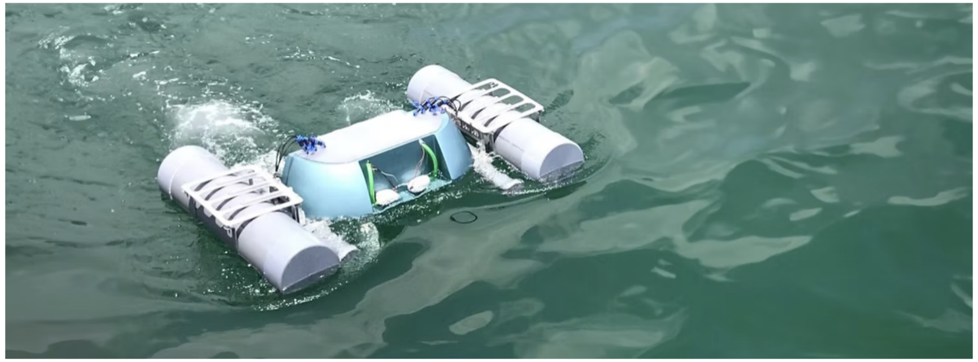
Computer programs will control the operation of the prototype. Solar panels will be installed on top of it for sustainable energy production and consumption.

Development of Smart Fish Prototype

開發智能檢塑魚

Being inspired by the appearance of a stingray, the smart fish is designed in a streamlined model swimming continuously to filter and record microplastics and other physical parameters in seawater. With numerous components installed inside the fish, aluminum, and glass fiber are used to build the framework due to lightweight and durable to resist strong waves and water currents. The outer layer of the fish is cast by glass fiber as it can bend a curved surface on the aluminum frame. The model is tightly sealed to avoid water penetration and cause electric outages when operating in the sea.

受魔鬼魚外型啟發，智能檢塑魚設計成流線型，能持續游動以過濾和記錄海水中的微塑膠及其他物理參數。魚體內裝有眾多組件，選用輕質且耐用的鋁材和玻璃纖維作為框架材料，以抵抗強烈波浪和水流。魚的外層由玻璃纖維製成，它能在鋁框上形成彎曲的表面。魚體嚴密密封，在海上操作時避免海水滲透，導致電力中斷。

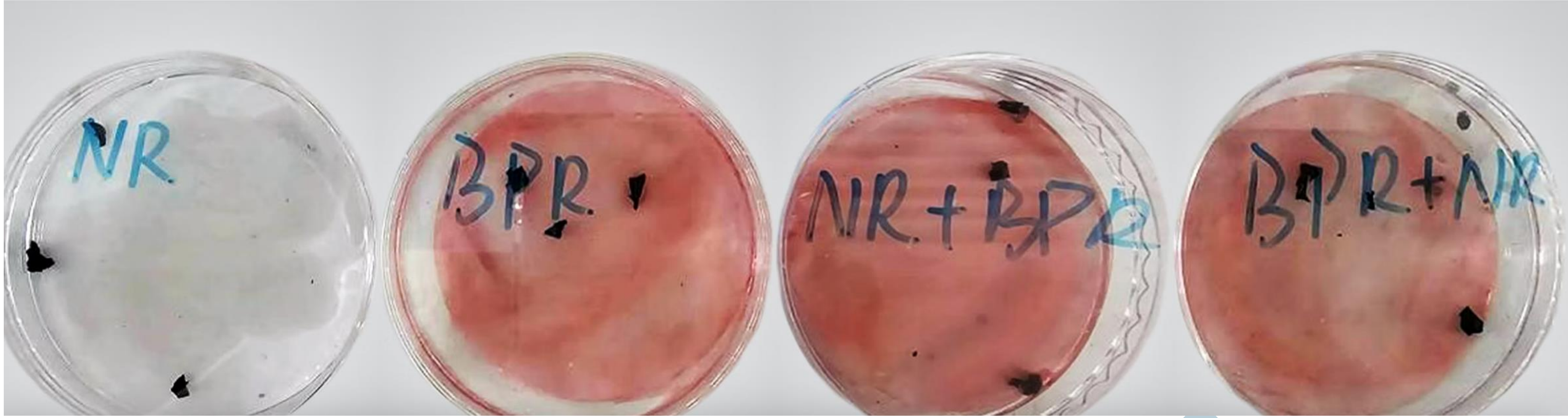


Staining Method

染色方法

Samples are firstly soaked in Nile Red and shined under UV light for microplastics detection, and then soaked in Oralith Brilliant Pink R and shined under UV light for tire wear particles detection. This method is highly accurate and precise to different types of plastics and rubbers.

樣本首先使用尼羅紅染劑 (Nile Red) 進行浸泡， 然後在紫外光下照射以檢測微塑膠。同一樣本隨後使用還原桃紅R染劑 (Oralith Brilliant Pink R) 進行浸泡， 在紫外線照射後檢測輪胎磨損產生的微塑膠粒。此方法對不同類型的塑膠和橡膠具有高度的準確性和精確性。



Past Seminars

過往講座

Jan 23

Seminar

海洋微塑膠講座
Seminar on Ocean Microplastics

Jan 13

Seminar

海洋微塑膠講座
Seminar on Ocean Microplastics

Nov 25, 2024

Seminar

海洋微塑膠講座
Seminar on Ocean Microplastics

Nov 20, 2024

Seminar

微塑膠的處理講座
Seminar on Treatment of…

Nov 8, 2024

Seminar

Oct 30, 2024

Seminar

Oct 6, 2024

Seminar

Aug 6, 2024

Seminar

Resources

資料庫

Leaflet

小冊子

香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

海洋科學系 DEPARTMENT OF OCEAN SCIENCE

DEPARTMENT OF CHEMICAL AND BIOLOGICAL ENGINEERING 化學及生物工程學系

資助機構 Marine Ecology & Fisheries Enhancement Funds Trustee Limited 改善海洋生態及漁業提升基金信託有限公司

智能檢塑魚

用於消滅沿海地區海洋微塑膠

自然水體中的微塑膠污染，由塑膠廢物分解而成。微塑膠因其高度碎片化，科學家研究發現它對海洋生物的健康造成負面影響。相關問題將對水生動物及人類的可持續性產生重大影響，引起了公眾關注。

我們的創新技術

即時檢測各類塑膠

與傳統方法相比，智能檢塑魚可即時檢測和識別主要塑膠類型（例如 PP、PE、PET、PVC），速度只需 15-20 分鐘。

去除地表水中的微塑膠

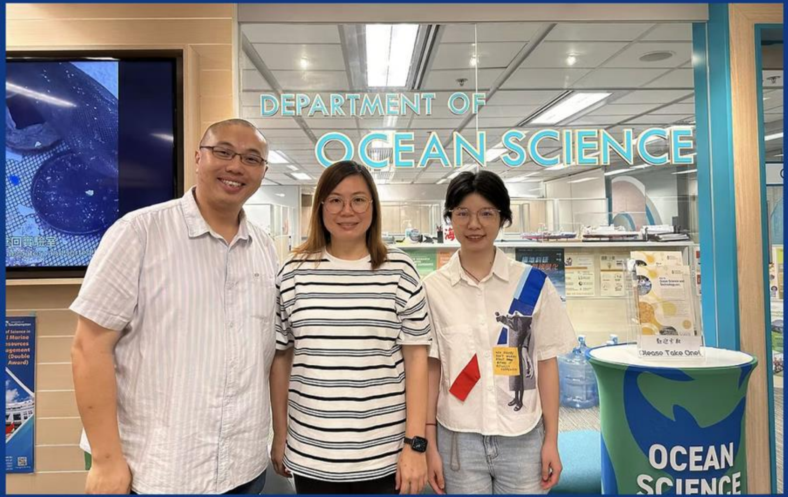
智能檢塑魚將過濾約 10-15 公升水樣本，檢測後將收集微塑膠以供實驗室進一步分析。

海洋感測器檢測水參數

About Us
關於我們

This innovative research project is a collaborative work between the Department of Ocean Science and the Department of Chemical and Biological Engineering at HKUST. With funding support from Marine Ecology & Fisheries Enhancement Funds Trustee Limited, we share the same mission and vision of protecting the marine environment and marine life from emerging man-made pollutants.

是次研究項目是由香港科技大學海洋科學系與化學及生物工程系的研究團隊合作進行。在海洋生態及漁業改善基金信托有限公司的資助下，我們共同致力於保護海洋環境和海洋生物免受人造污染物的侵害。



Acknowledgements:

海洋科學系
DEPARTMENT OF OCEAN SCIENCE

DEPARTMENT OF CHEMICAL AND BIOLOGICAL ENGINEERING
化學及生物工程學系

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Funding Organization
資助機構

Marine Ecology & Fisheries Enhancement Funds Trustee Limited
改善海洋生態及漁業提升基金信託有限公司

Appendix VIII

Outlook

Re: Invitation for seminar on aircraft tires

From
Date
To
Cc

Dear Bridgestone Aircraft Tire Team,

Greetings.

We are writing to you as the Project Managers in the project 'Smart Fish for Oceanic Microplastics Degradation in the Coastal Area' which is funded by the Marine Ecology Enhancement Fund (MEEF). The fund is established as part of the Third Runway Project at the Hong Kong International Airport. This initiative is committed to enhancing marine ecology and supporting sustainable fishing practices in the region, particularly in response to concerns around microplastics contamination.

Our work includes exploring the environmental impact of various pollutants, including aircraft tire wear particles (ATWP), which contribute to microplastics in our water bodies. Given Bridgestone's leadership in aircraft tire technology, we would be honored to have an expert from your team present at our upcoming public education seminar in summer 2024. In the seminar, we are particularly interested in learning about the structure of airplane tires and car tires, production of ATWP during landing on the runway. Bridgestone's innovative approaches to minimizing environmental impacts, and any studies your team has conducted related to the release of microplastics. This information will greatly benefit our ongoing research and the broader community, contributing to a more informed discussion on sustainable practice in aviation and marine ecology sectors.

Meanwhile, the seminar will be an excellent opportunity to showcase Bridgestone's commitments to sustainability and innovation, engaging with a diverse audience that includes environmental experts, researchers, and the general public. We believe your expert's insights will be incredibly valuable to our understanding and efforts in combating microplastic pollution.

Please let us know your availability for this event and any requirements your might have for the presentation. We are egar to facilitate meaningful exchange of knowledge and are flexible with the arrangements to accommodate your team's needs.

Thank you for considering this invitation. We look forward to the possibility of welcoming Bridgestone at our seminar and to a fruitful collaboration.

Warm regards,

Department of Ocean Science/ Department of Chemical and Biological Engineering,
The Hong Kong University of Science and Technology, HKSAR, China

Thank you for your inquiry

?

Sun 02/06/2024 23:41

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Depending on the question, it may take some time to respond.
We highly appreciate your understanding.

Consumer Tire Product Dept.
THE YOKOHAMA RUBBER CO.,LTD
Terms of service: I have read and agreed to the Privacy Policy

Reply Forward

Ocean Microplastics Seminar Feedback Survey

Thank you for attending our seminar! We value your feedback and invite you to share your thoughts so we can improve future events and better communicate our mission.

Section 1: Participant Background

1. **Educational Level**
   - What is your current level of study?
     ☐ Primary School
     ☐ Secondary School
     ☐ University
     ☐ Other (please specify): ___________

Section 2: Seminar Content and Delivery

2. **Overall Seminar Experience**
   - How would you rate the overall seminar?
     ☐ Excellent
     ☐ Good
     ☐ Average
     ☐ Poor
3. **Clarity of Presentation**
   - The information presented was clear and easy to understand.
     ☐ Strongly agree
     ☐ Agree
     ☐ Neutral
     ☐ Disagree
     ☐ Strongly disagree
4. **Duration of the Seminar**
   - Was the length of the seminar (approximately one hour) appropriate?
     ☐ Too short
     ☐ Just right
     ☐ Too long

Section 3: Awareness and Impact on Understanding Microplastics

5. **Awareness Post-Seminar**
   - After attending the seminar, how would you rate your understanding of the impact of microplastics (including vehicle tire wear particles) on the marine environment?
     ☐ Significantly increased

☐ Moderately increased
☐ Slightly increased
☐ No change

6. **Interest in the Issue**
   - How likely are you to explore more about marine microplastics and related environmental issues?
     ☐ Very likely
     ☐ Likely
     ☐ Unsure
     ☐ Unlikely
     ☐ Very unlikely

Section 4: Smart Fish Project Introduction

7. **Perceived Innovation**
   - How innovative do you find the concept of a robotic fish for microplastics sampling?
     ☐ Extremely innovative
     ☐ Quite innovative
     ☐ Moderately innovative
     ☐ Not very innovative
8. **Interest in Involvement**
   - Would you be interested in learning more about or getting involved with projects like Smart Fish in the future?
     ☐ Yes
     ☐ No
     ☐ Maybe
9. **Feedback on Smart Fish**
   - What are your thoughts or suggestions regarding the Smart Fish project?
     [Open-ended response]

Appendix X

Schedule of Seminars

Seminar	Topic	Date	Presenter	Target Audience
1	Ocean microplastics	4 Jul 2024	Dr. Cindy Lam	40 secondary school students
2	Ocean microplastics	17 Jul 2024*	Dr. Cindy Lam	40 secondary school students
3	Treatment of microplastics	6 Aug 2024	Dr. Frank Lam	30 secondary school students
4	Ocean microplastics	6 Oct 2024	Dr. Cindy Lam	30 general public
5	Treatment of microplastics	30 Oct 2024	Dr. Frank Lam	40 university students
6	Ocean microplastics	8 Nov 2024	Dr. Cindy Lam	50 university students
7	Treatment of microplastics	20 Nov 2024	Dr. Frank Lam	60 university students
8	Ocean microplastics	25 Nov 2024	Dr. Cindy Lam	30 university students
9	Ocean microplastics	13 Jan 2025	Dr. Frank Lam	~200 primary school students
10	Ocean microplastics	23 Jan 2025	Dr. Frank Lam	~300 primary school students

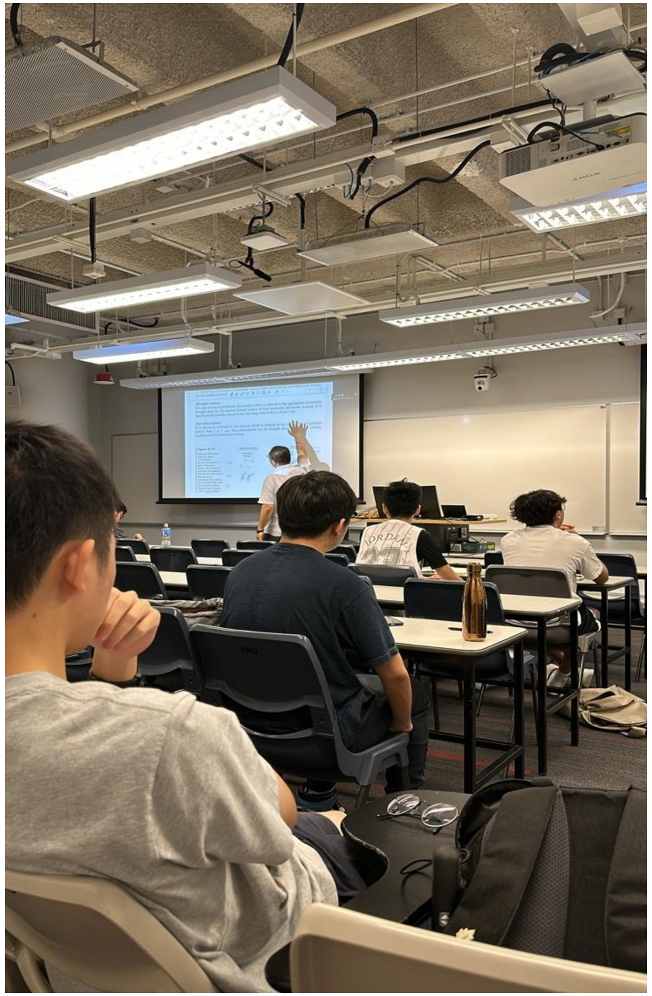
* Seminar and workshop were organized on the same day.

Event Photos – Seminars in July 2024

4 Jul 2024 Seminar on ocean microplastics at HKUST

17 Jul 2024 Seminar on ocean microplastics at HKUST

Event Photos – Seminars in August 2024



6 Aug 2024 Seminar on treatment of microplastics at HKUST

Event Photos – Seminars in October 2024

Oct 6 – Seminar on ocean microplastics

Oct 30 – Seminar on treatment of microplastics

Event Photos – Seminars in November 2024

Nov 8 – Seminar on ocean microplastics

Nov 25 – Seminar on ocean microplastics

Event Photos– Seminars in November 2024

Nov 20 – Seminar on treatment of microplastics

Event Photos – Seminars in January 2025

13 Jan 2025 Jordan Road Government Primary School

23 Jan 2025 Sau Mau Ping Catholic Primary School

Leaflets

E-version is available under project website

香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

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Funding organization Marine Ecology & Fisheries Enhancement Funds Trustee Limited 改善海洋生態及漁業提升基金信託有限公司

SMART FISH

FOR OCEANIC MICROPLASTICS DEGRADATION IN THE COASTAL AREA

Microplastics contamination in the natural water bodies, which are resulted from disintegration from plastic waste, has raised public concern due to high level of fragmentation and disturbance in ecosystem. The associated problem will significantly affect the sustainability of aquatic animals and human beings. Scientists are concerned about microplastics as they are found to pose negative impacts on the health of marine organisms.

OUR INNOVATION

REAL-TIME DETECTION OF VARIOUS TYPES PLASTICS

The autonomous device speeds up detection time and identificaiton of major plastic types (e.g. PP, PE, PET, PVC) in 15-20 min compared to conventional method.

REMOVAL OF MICROPLASTICS IN SURFACE WATERS

Around 10-15 L of water samples will be filtered in the Smart Fish prototype. Microplastics will be collected for further analysis in laboratory after detection.

OCEAN SENSOR DETECTING WATER PARAMETERS

Our Smart Fish prototype equips with sensors measuring other water parameters (e.g. water temperature, pH) which may affect microplastics aunadance in close proximity.

ABOUT US

This innovative research project is a collaborative work between the Department of Ocean Science and the Department of Chemical and Biological Engineering at HKUST. With funding support from Marine Ecology & Fisheries Enhancement Funds Trustee Limited, we share the same mission and vision of protecting the marine environment and marine life from emerging man-made pollutants.

https://www.hkust-smartfish.com/ envscindy@ust.hk kefrank@ust.hk

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智能檢塑魚

用於消滅沿海地區海洋微塑膠

自然水體中的微塑膠污染，由塑膠廢物分解而成。微塑膠因其高度碎片化，科學家研究發現它對海洋生物的健康造成負面影響。相關問題將對水生動物及人類的可持續性產生重大影響，引起了公眾關注。

我們的創新技術

即時檢測各類塑膠

與傳統方法相比，智能檢塑魚可即時檢測和識別主要塑膠類型（例如 PP、PE、PET、PVC），速度只需 15-20 分鐘。

去除地表水中的微塑膠

智能檢塑魚將過濾約 10-15 公升水樣本，檢測後將收集微塑膠以供實驗室進一步分析。

海洋感測器檢測水參數

智能檢塑魚配備了感測器，用於測量水參數（例如水溫、pH 值），這些參數可能會影響附近的微塑膠豐度。

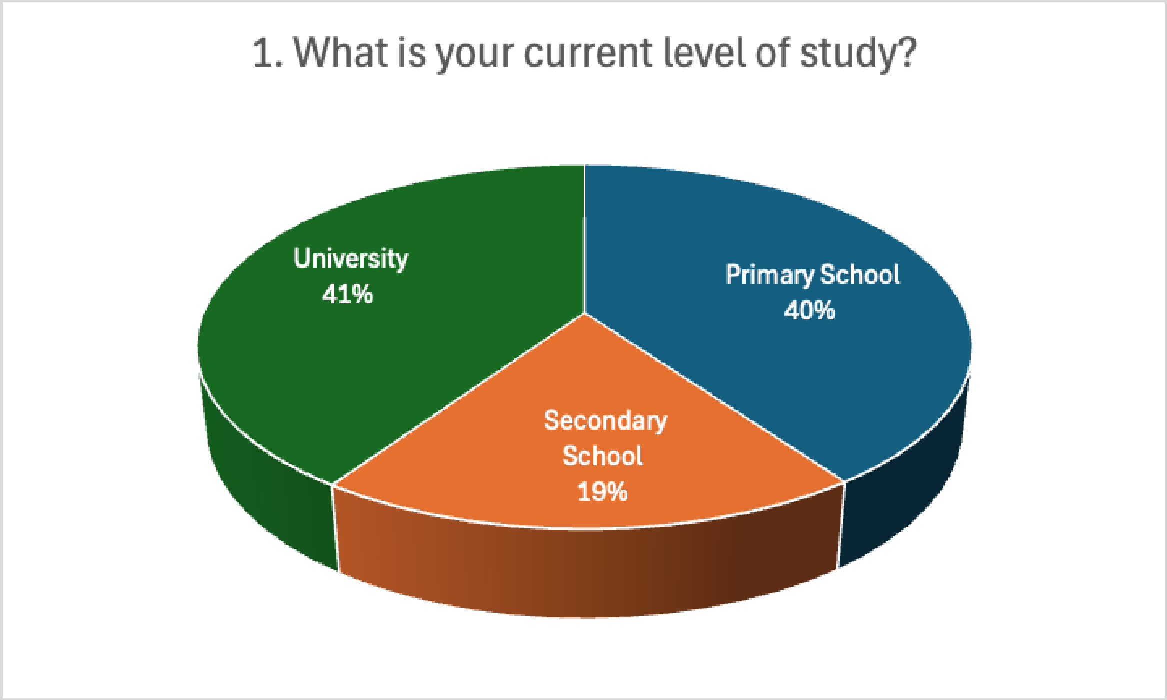
關於我們

是次研究項目是由香港科技大學海洋科學系與化學及生物工程系的研究團隊合作進行。在海洋生態及漁業改善基金信托有限公司的資助下，我們共同致力於保護海洋環境和海洋生物免受人造污染物的侵害。

https://www.hkust-smartfish.com/ envscindy@ust.hk kefrank@ust.hk

Results of Survey - Seminars

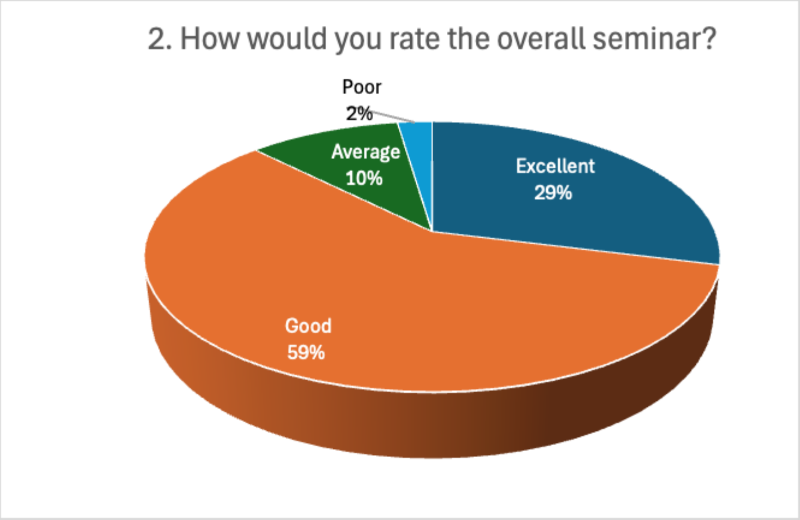
Section 1: Participant Background



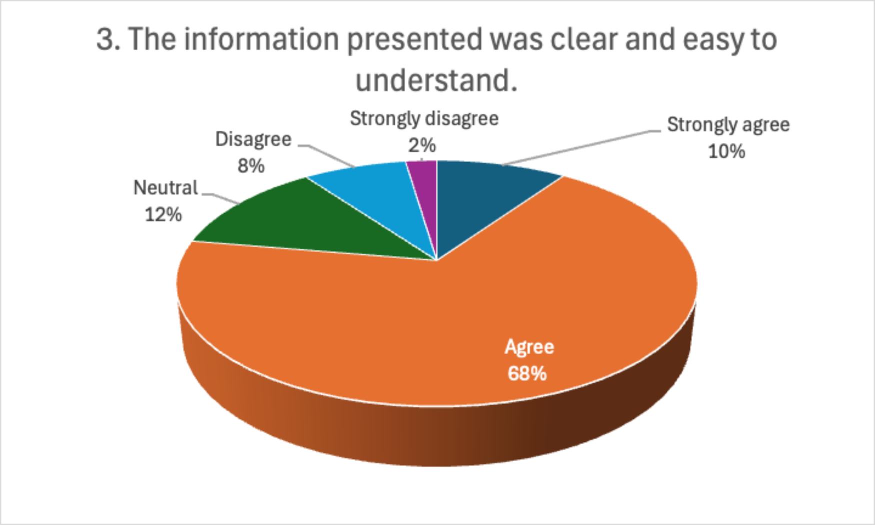
Number of response: 560

Section 2: Seminar Content & Delivery

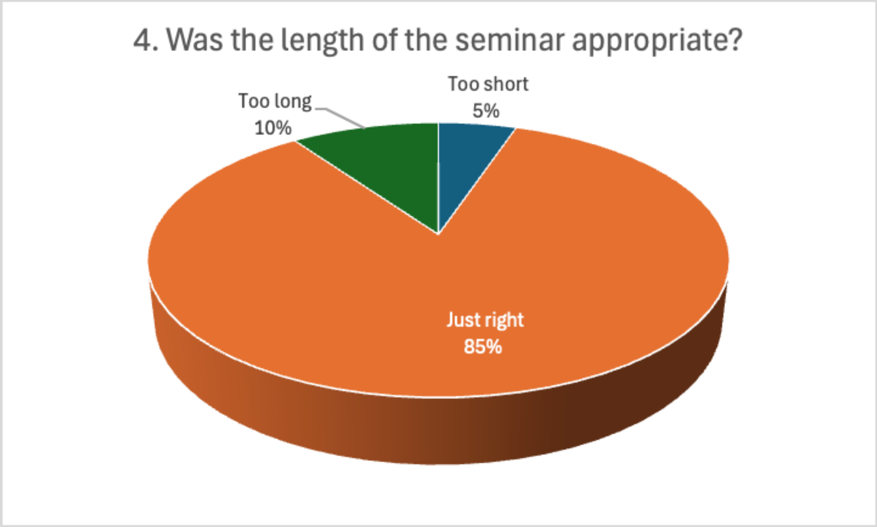
Overall Seminar Experience



Clarity of Presentation

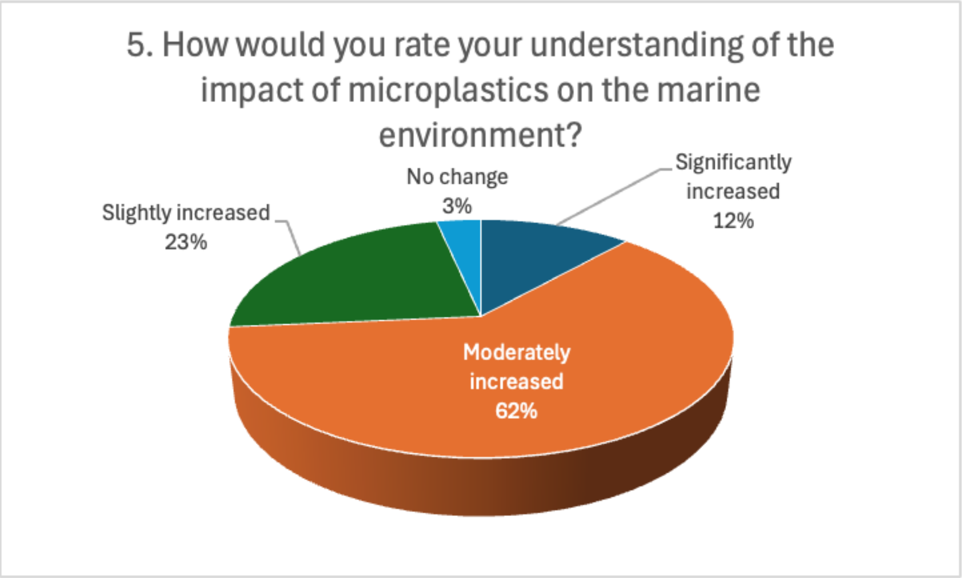


Duration of Seminar

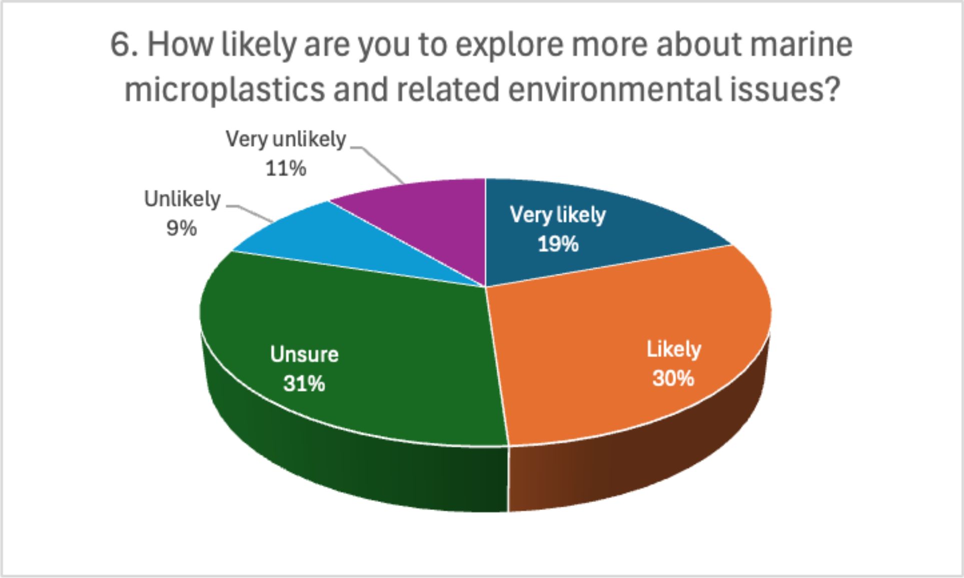


Section 3: Awareness and Impact on Understanding Microplastics

Awareness of Post-Seminar

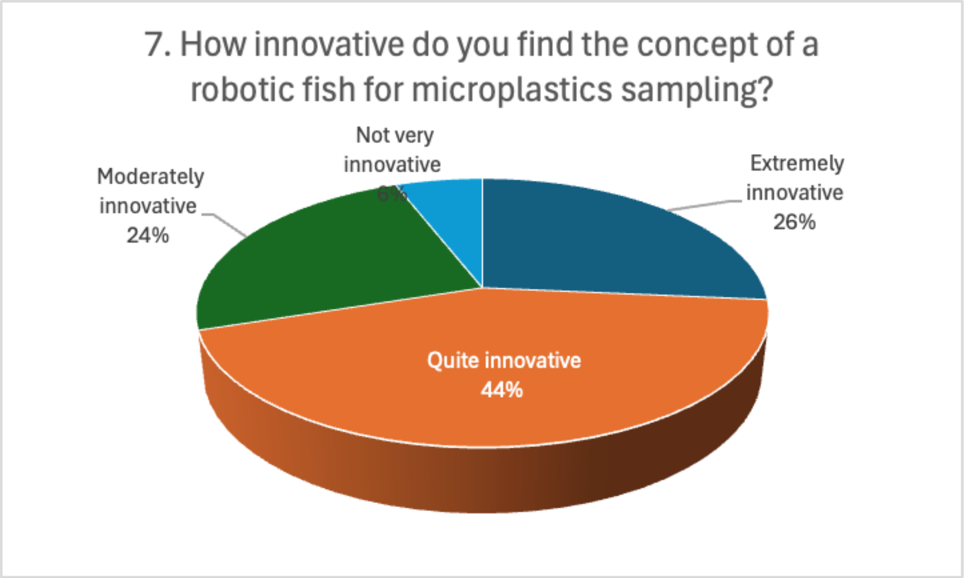


Interests in the Issue

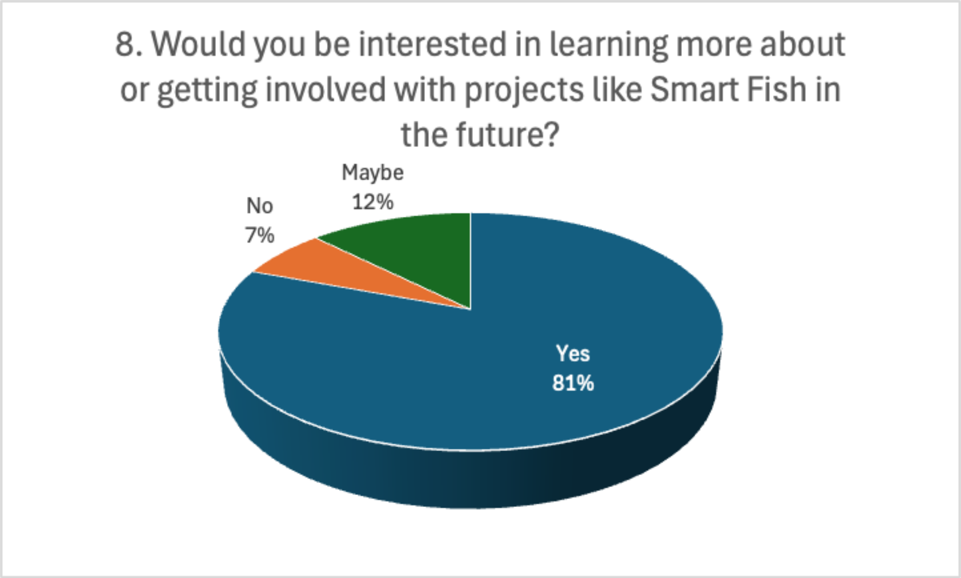


Section 4: Smart Fish Project Introduction

Perceived Innovation



Interest in Involvement



Detection of Microplastics on HKUST Boulder Shore

Marine litter and microplastics found along the upper shore area on the HKUST boulder shore.

Sample collection and preparation:

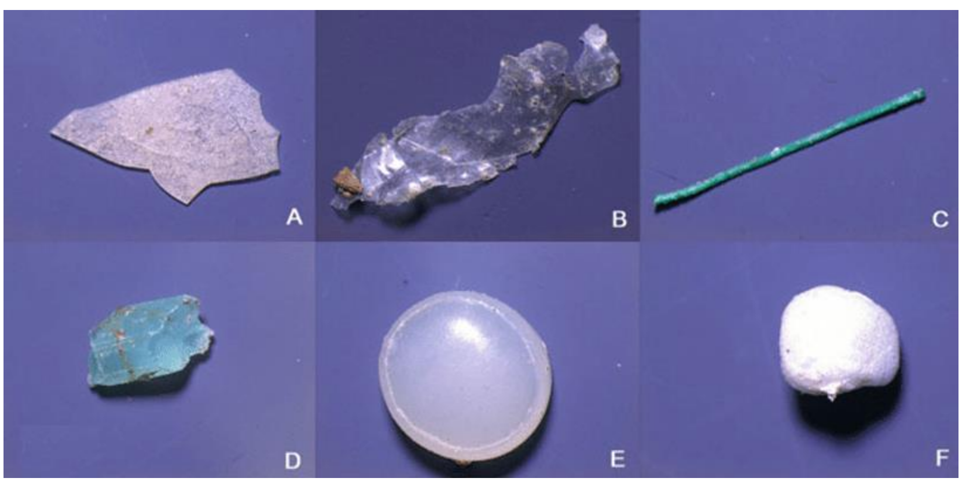
1. Collect around 10 g of litter sample from the HKUST boulder shore using trowel provided.
2. Remove large non-plastic items using a 2 mm metal sieve in the laboratory.
3. Place the sample on a petri dish and identify the microplastics at low magnification under the stereomicroscope.
4. Record the number and shape of microplastics under the stereomicroscope on the data record sheet.

Density separation of sediment samples:

1. Transfer around 10 g of sample onto the filter funnel of the density separation setup (see photo on the right).
2. Fill the filter funnel with concentrated sugar solution and cover the density separation setup with aluminium foil. Allow the samples to settle for at least 1 hour.
   Remove the settled substances and only collect the floating portion (the upper part). Rinse the funnel with water several times to ensure the procedure is complete.

Visualization of microplastics under fluorescent microscope:

1. Filter the sample collected after density separation with 50 µm mesh.
2. Transfer the residue into the filtration setup.
3. Filter the solution with 0.2 µm polycarbonate membrane.
4. Incubate the sample with 10 mL of Nile Red working solution (1 mg/ L in MeOH) for 20 minutes.
5. Remove the dye and visualize the microplastics on the membrane at wavelength of 365 nm under UV illumination box. Take a photo of your sample using your mobile phone.
6. Record the number and shape of microplastics found on the data record sheet below.



Shapes of typical microplastics found in the environment.

Data Record Sheet

Number of microplastics (under steromicroscope)						
Type	Film	Fiber	Fragment	Pellet	Foam	**Total**
Number						
Number of microplastics (under fluorescent microscope)						
Type	Film	Fiber	Fragment	Pellet	Foam	**Total**
Number						

Follow-up questions:

1. Have you encountered any difficulties when identifying microplastics under the stereomicroscope?
2. What are the occurrence and ecological impacts of microplastics in the marine ecosystem?
3. Suggest an effective way to remove microplastics in the marine environment.

Acknowledgement:

Organizers:

香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

海洋科學系 DEPARTMENT OF OCEAN SCIENCE

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Funding Organization:

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Ocean Microplastics Workshop Feedback Survey

Thank you for participating in our workshop! Your feedback is important to help us enhance future workshop experiences and educational activities.

Section 1: Participant Background

1. **Educational Level**
    - What is your current level of study?
      ☐ Primary School
      ☐ Secondary School
      ☐ University

2. **Prior Knowledge & Experience**
    - How familiar were you with microplastics and laboratory procedures before this workshop?
      ☐ Not at all familiar
      ☐ Slightly familiar
      ☐ Moderately familiar
      ☐ Very familiar
    - Have you participated in a similar hands-on lab activity before?
      ☐ Yes
      ☐ No

Section 2: Workshop Content and Organization

3. **Workshop Structure and Timing**
    - Was the two-hour duration sufficient for the activities?
      ☐ Too short
      ☐ Just right
      ☐ Too long
    - How would you rate the overall organization and flow of the workshop?
      ☐ Excellent
      ☐ Good
      ☐ Average
      ☐ Poor

4. **Lab Activity Effectiveness**
    - How effective were the hands-on activities in helping you understand microplastics identification in environmental samples?
      ☐ Extremely effective
      ☐ Quite effective
      ☐ Moderately effective

☐ Slightly effective
☐ Not effective

Section 3: Smart Fish Demonstration

5. **Innovation Perception**
   - How innovative do you find the concept of using a robotic fish for microplastics sampling?
     ☐ Extremely innovative
     ☐ Quite innovative
     ☐ Moderately innovative
     ☐ Not very innovative

6. **Interest in the Technology**
   - Would you be interested in learning more about or participating in projects like Smart Fish in the future?
     ☐ Yes
     ☐ No
     ☐ Maybe

7. **Feedback on the Demonstration**
   - What aspects of the Smart Fish demonstration did you find most impressive or inspiring?
     [Open-ended response]

Section 4: Overall Workshop Feedback

8. **Overall Experience**
   - How would you rate your overall workshop experience?
     ☐ Excellent
     ☐ Good
     ☐ Average
     ☐ Poor

9. **Knowledge Gain**
   - To what extent has this workshop increased your awareness and understanding of marine microplastics?
     ☐ Significantly increased
     ☐ Moderately increased
     ☐ Slightly increased
     ☐ No change

10. **Suggestions for Improvement**
    - What improvements would you suggest for future workshops on this topic?
      [Open-ended response]

Appendix XIII

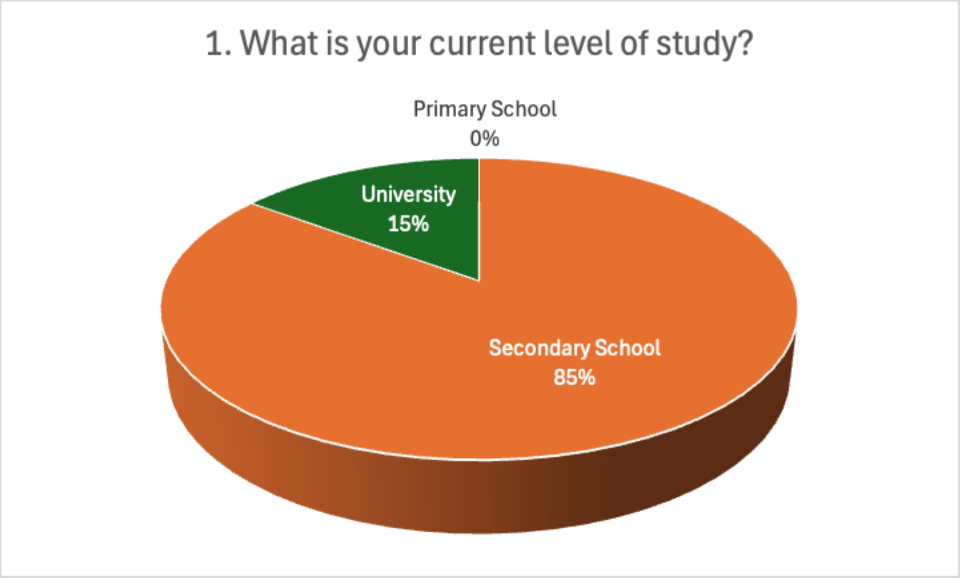
Schedule of Workshops

Workshop	Topic	Date	Presenter	Target Audience
1	Identification and characterization of microplastics in laboratory + Smart Fish demonstration	17 Jul 2024*	Dr. Cindy Lam, Dr. Frank Lam	40 secondary school students
2	Identification and characterization of microplastics in laboratory + Smart Fish demonstration	7 Aug 2024	Dr. Cindy Lam, Dr. Frank Lam	36 secondary school and university students

* Seminar and workshop were organized on the same day.

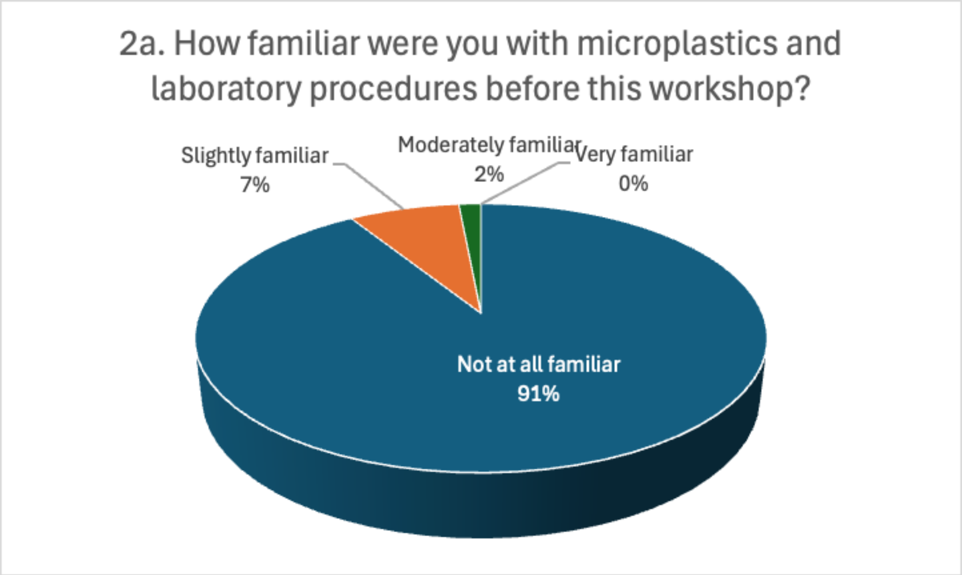
Event Photos - Workshops

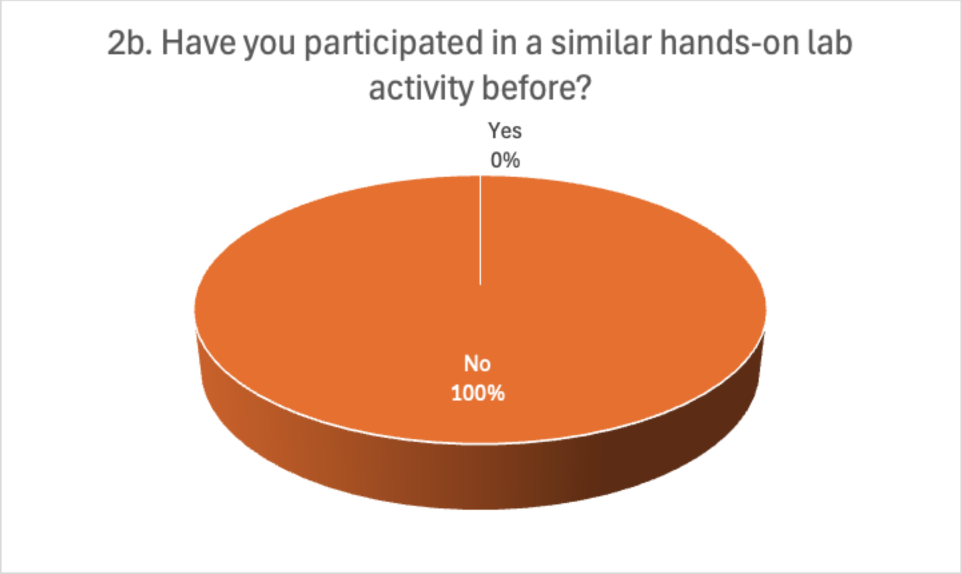
Section 1: Participant Background



Number of response: 67

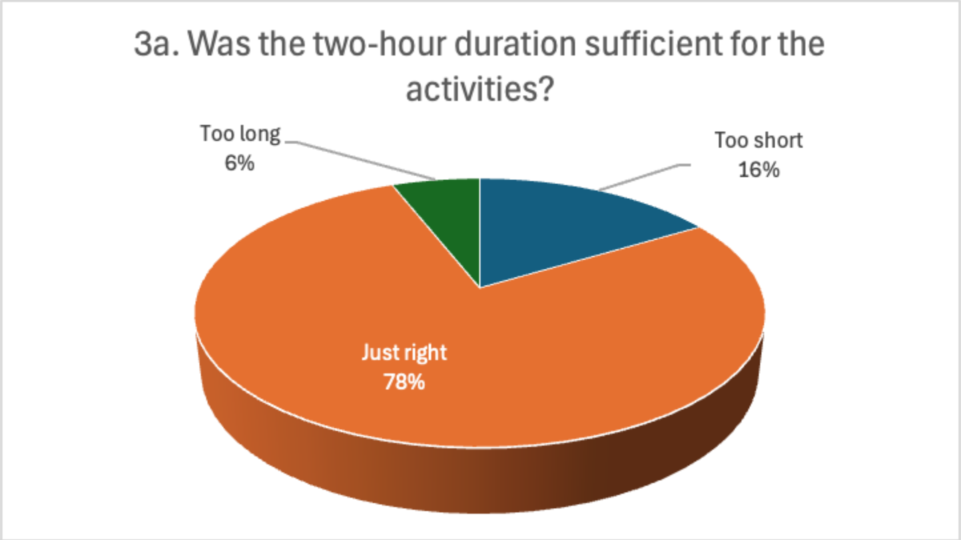
Prior Knowledge and Experience

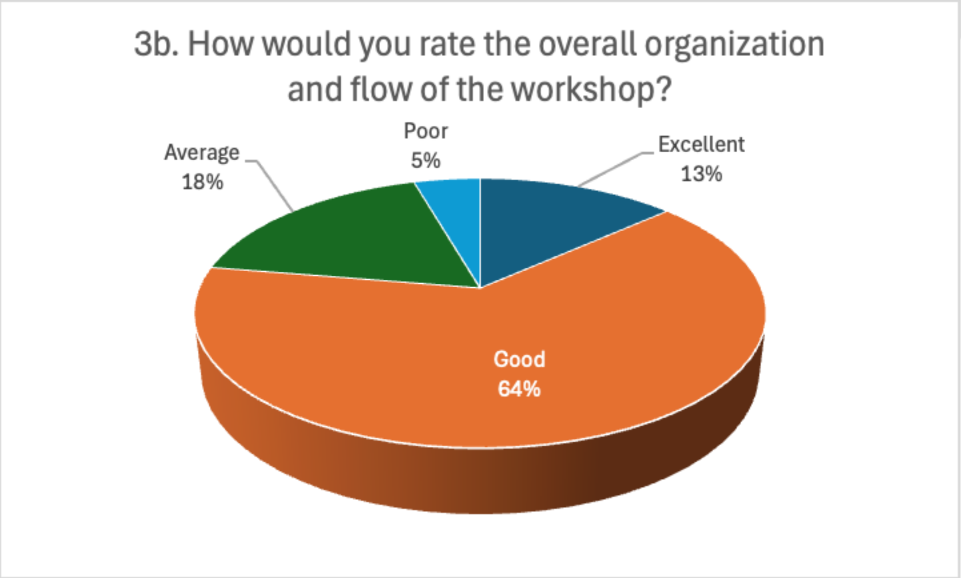




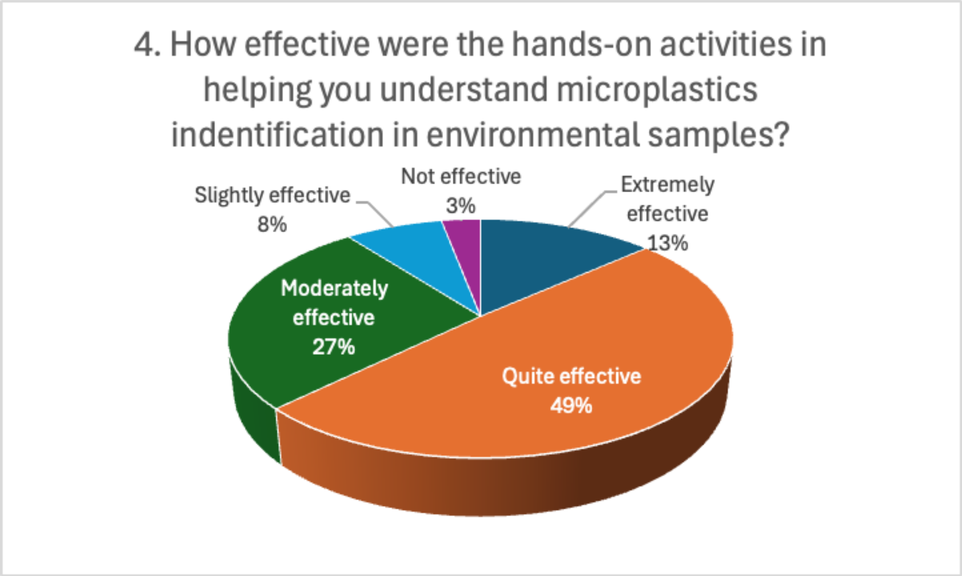
Section 2 – Workshop Content & Organization

Workshop Structure and Timing



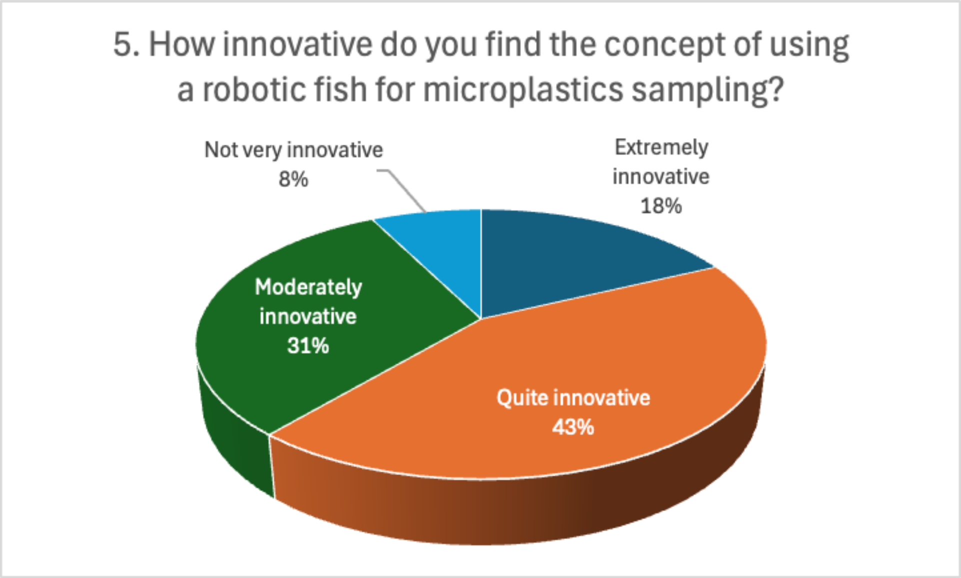


Lab Activity Effectiveness

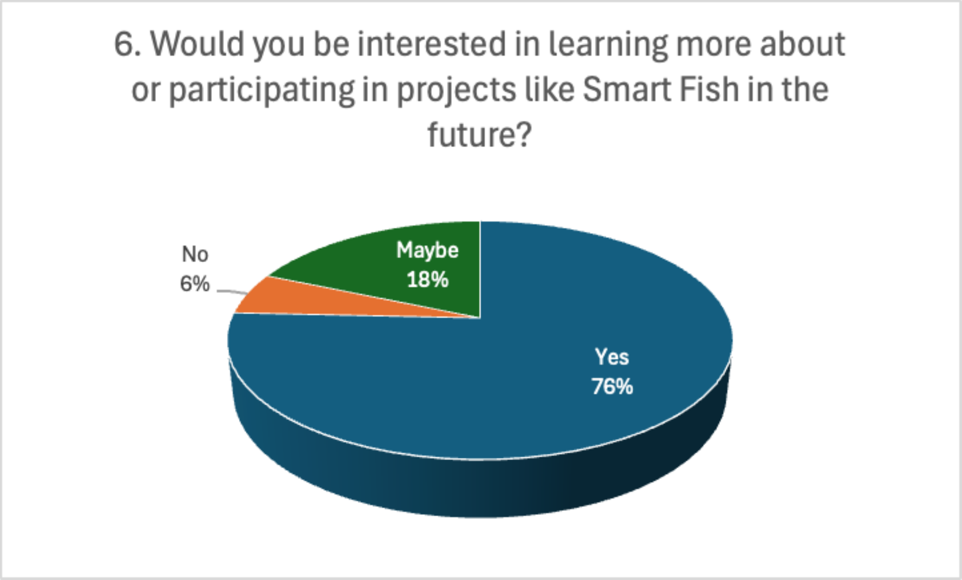


Section 3 – Smart Fish Demonstration

Innovation Perception



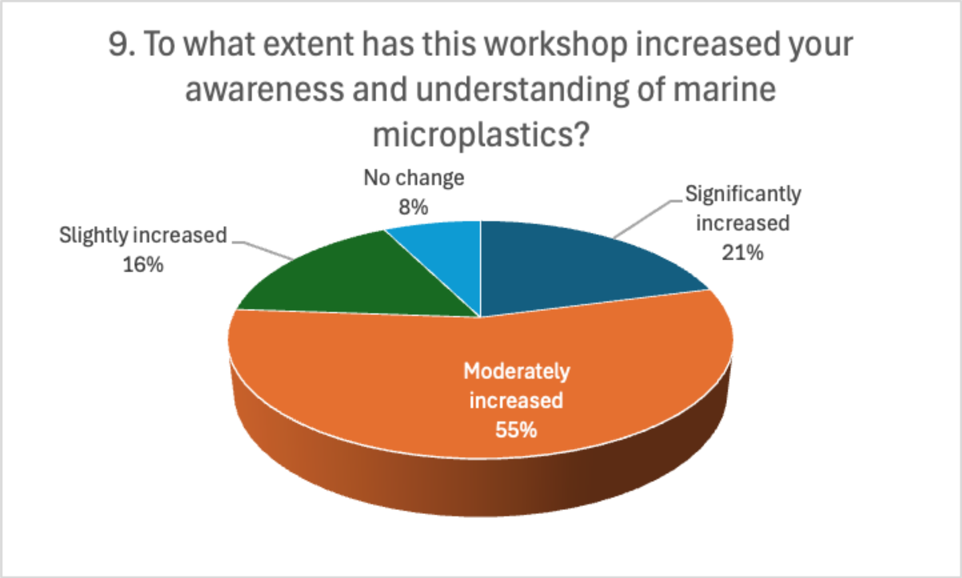
Interest in Technology



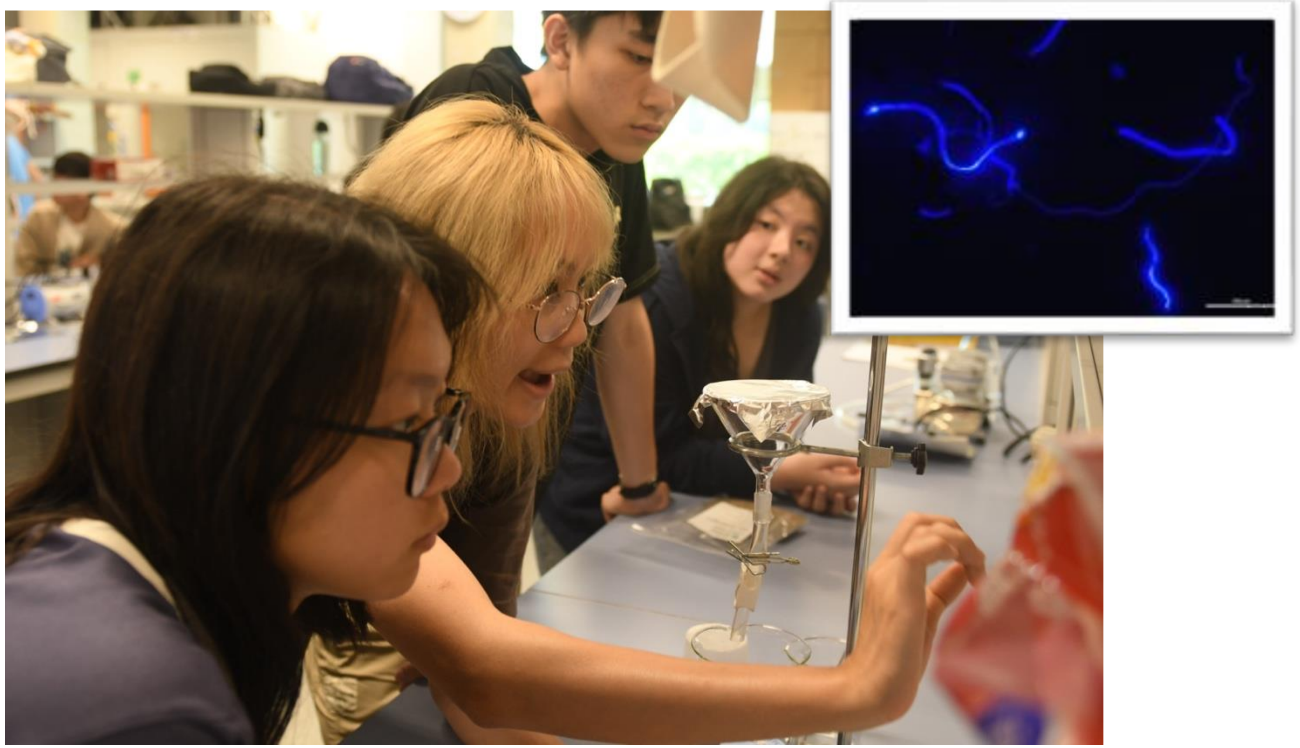
Section 4 – Overall Workshop Feedback

Overall Experience

Knowledge Gain



Event Photos – Workshop in July 2024



Workshop on 17 July 2024 – participants were collecting environmental samples followed by conducting density separation method in laboratory. A photo showing microfibers in the sample under UV illumination (top right).

Event Photos – Workshop in August 2024

Workshop on 7 August 2024 – (left) Demonstration of microplastics treatment process in laboratory. (right) Demonstration of first generation of Smart Fish in the mechanical workshop.

Degradation Efficiencies

Objectives

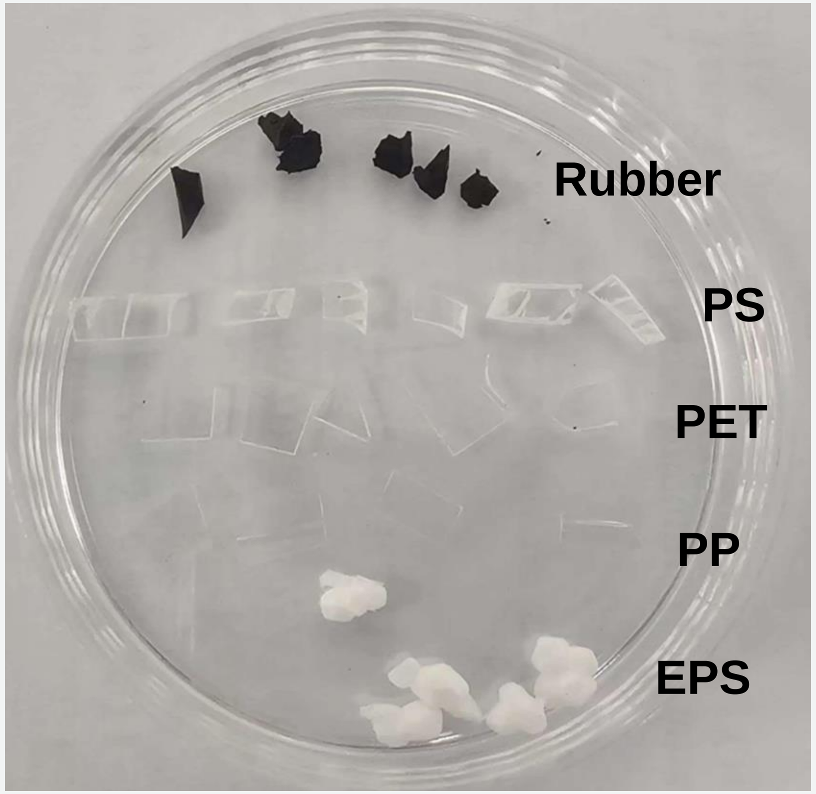
- To study the degradation rate of plastics using different concentration of Fenton's reagents
- Fenton reactions:

$$Fe^{2+}\ (aq) + H^{+}\ (aq) + H_2O_2\ (l) = Fe^{3+}(aq) + H_2O\ (l) + {}^{\bullet}OH$$

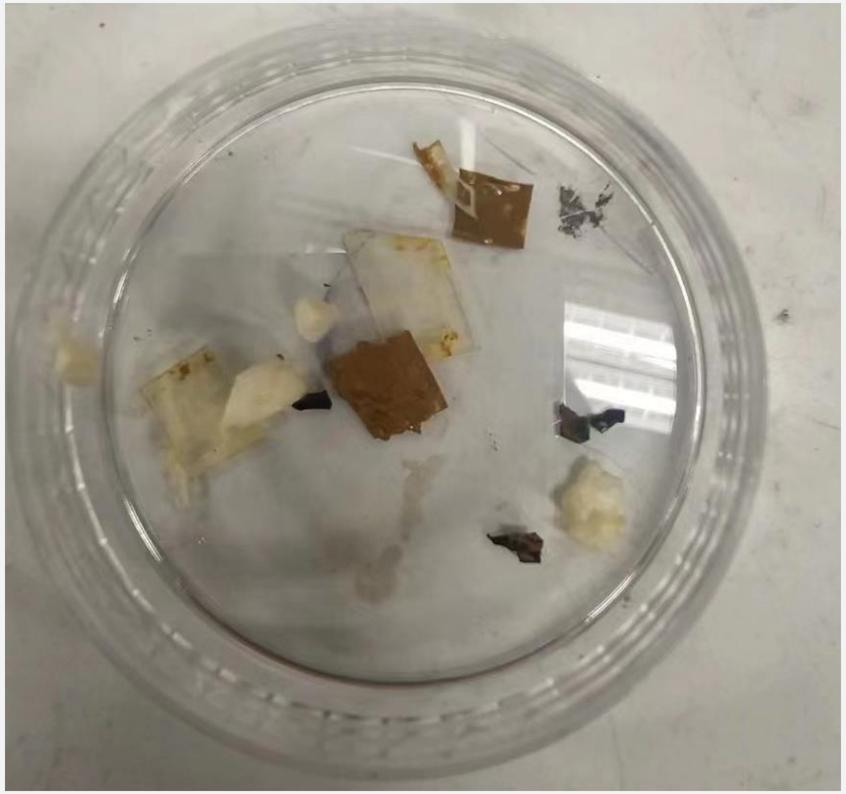
$$PET\ /PP\ /PS\ /EPS\ (plastics) + {}^{\bullet}OH \rightarrow CO_2\ (g) + H_2O\ (l)$$

Condition of Fenton's reaction: Temperature at 40℃, pH:2.5-3.5, reaction time: 3h

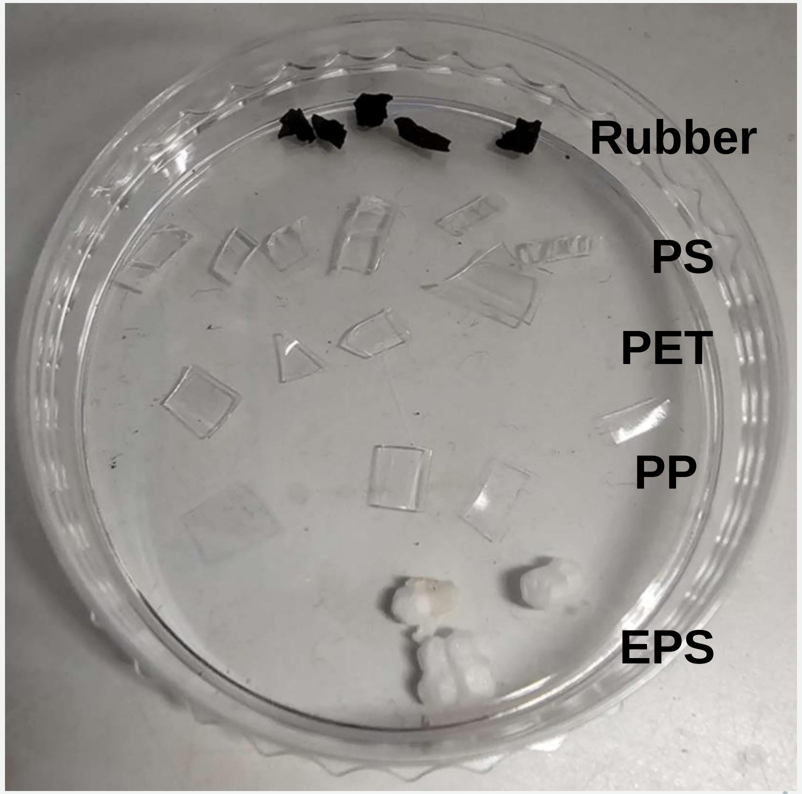
Samples Selection for Degradation



Samples before Fenton's reaction



Samples after Fenton's reaction



Samples after Fenton's reaction with HCl cleaning (remove iron metals on surface)

Sample's Weight Before and After Degradation

PS: polystyrene; PET: polyethylene terephthalate

Condition 1: $[Fe^{2+}]$=0.0334mol/L, $[H_2O_2]$=1.58 X 10^{-3}mol/L

	Sample dry weight before reaction (g)	Sample dry weight after reaction (g)	Degradation efficiency (%)
Rubber tires	0.0487	0.0248	49.076
PET	0.0404	0.0313	22.525
PS	0.0564	0.0392	30.497
PP	0.0056	0.0043	23.214
Styrofoam (EPS)	0.0039	0.0025	35.897

Total organic carbon (TOC): 0.163 mg/L (before the reaction) and 0.729 mg/L (after the reaction)

Condition 2: $[Fe^{2+}]=0.0493 mol/L$, $[H_2O_2]=1.90 \times 10^{-3} mol/L$

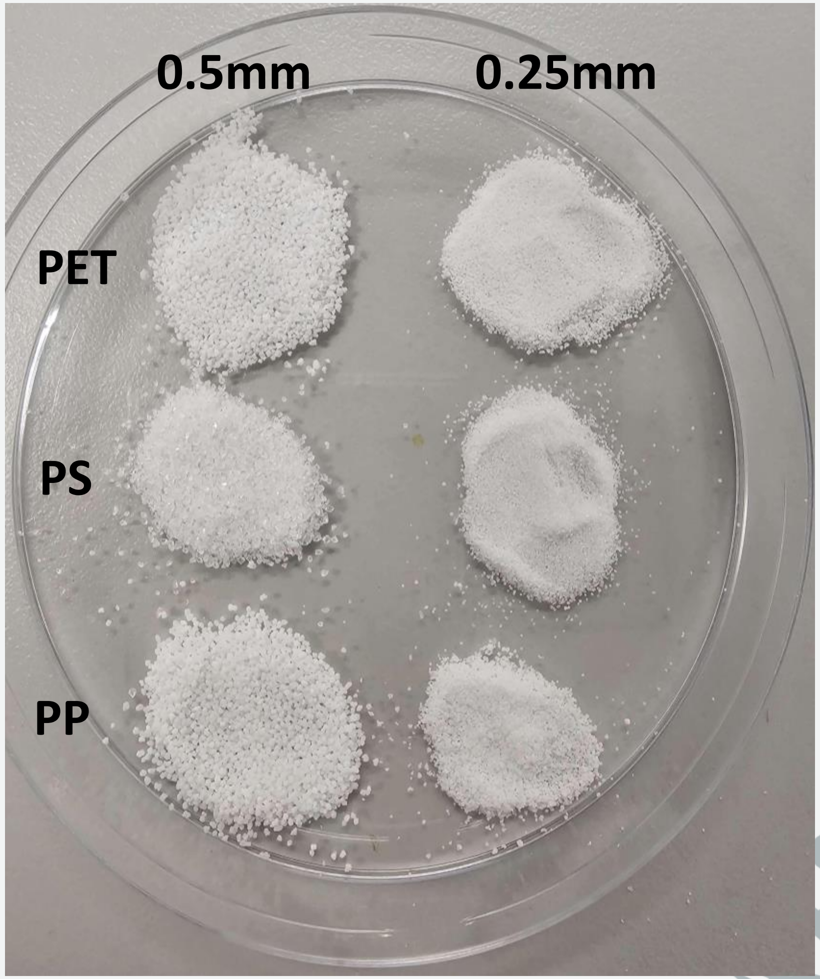
	Sample dry weight before reaction (g)	Sample dry weight after reaction (g)	Degradation efficiency (%)
Rubber	0.0573	0.0564	1.5707
PET	0.0339	0.0304	10.325
PS	0.0549	0.0415	24.408
PP	0.0421	0.0401	4.751
Styrofoam (EPS)	0.0033	0.0030	9.091

**Due to technical errors, total organic carbon of this condition was not measurable.*

Degradation Efficiencies of Microplastics with Sizes

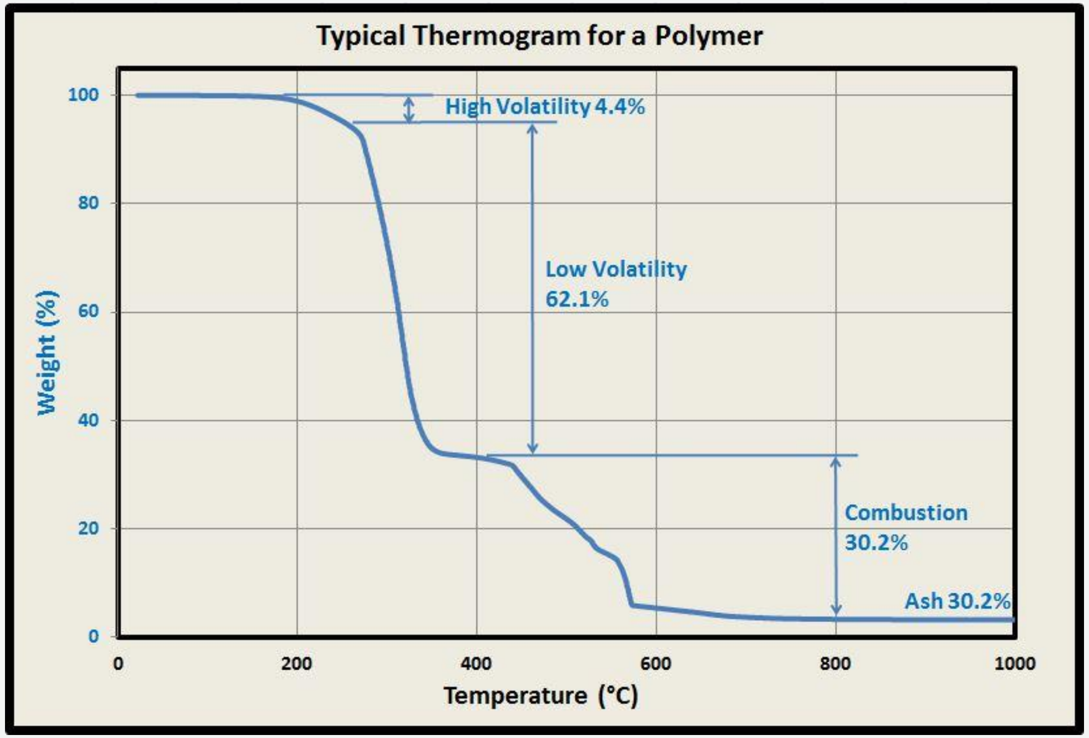
Condition 1: $[Fe^{2+}]$=0.0334mol/L,$[H_2O_2]$=1.58 X 10^{-3}mol/L

Types of mircoplastics	Degradation efficiencies of microplastics Size	
	0.25 mm	0.5 mm
PET	13.94	6.56
PS	17.62	9.37
PP	9.03	4.38



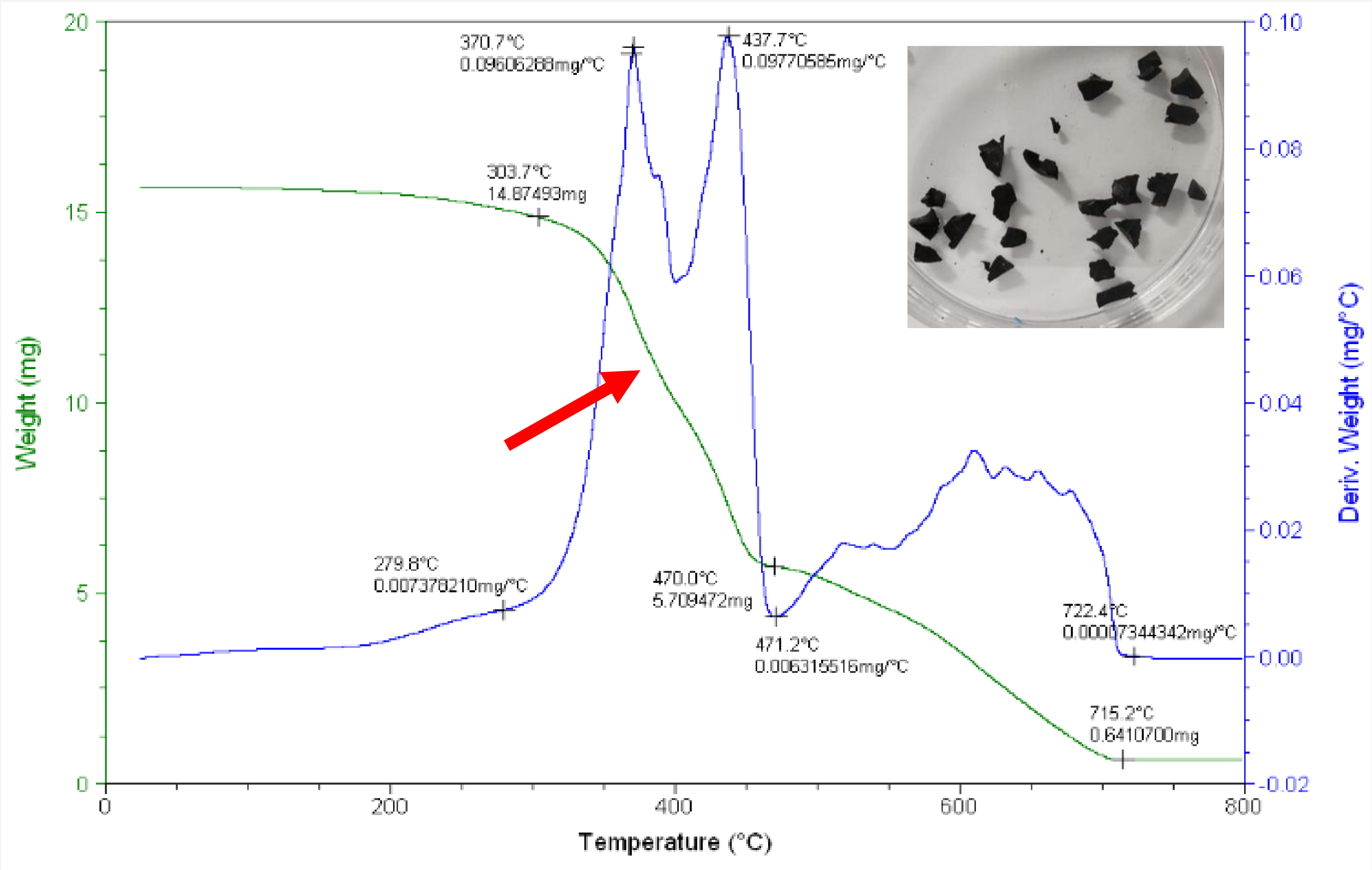
Thermogravimetric Analysis (TGA)

- Common thermal analysis technique to study the mass change of materials during the heating process
- Sample is placed in a weighing bottle then heated
- During the heating process, the sample undergoes **thermal decomposition**, **evaporation**, **combustion** and other reactions
- TGA instrument measures changes in sample mass in real time and plot them as TGA curve

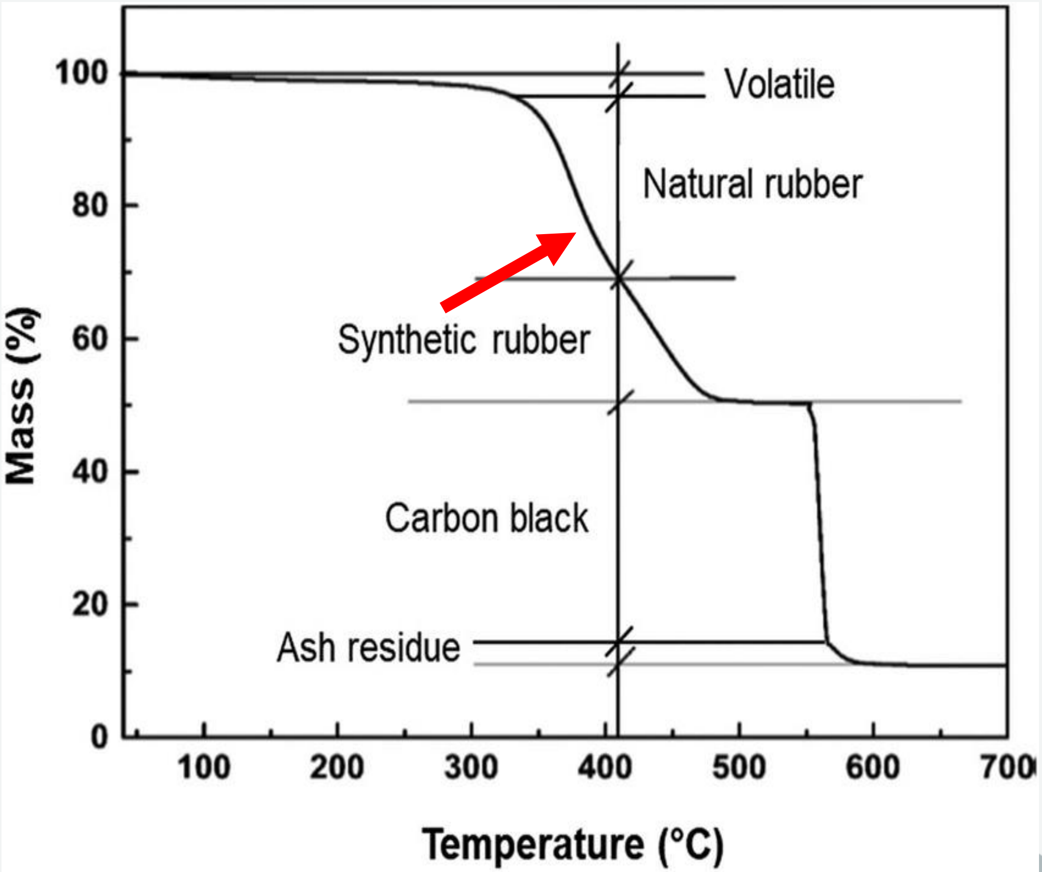


Schematic TGA curve (Source: LPD Lab Service, UK)

TGA Curve of Rubber Tire

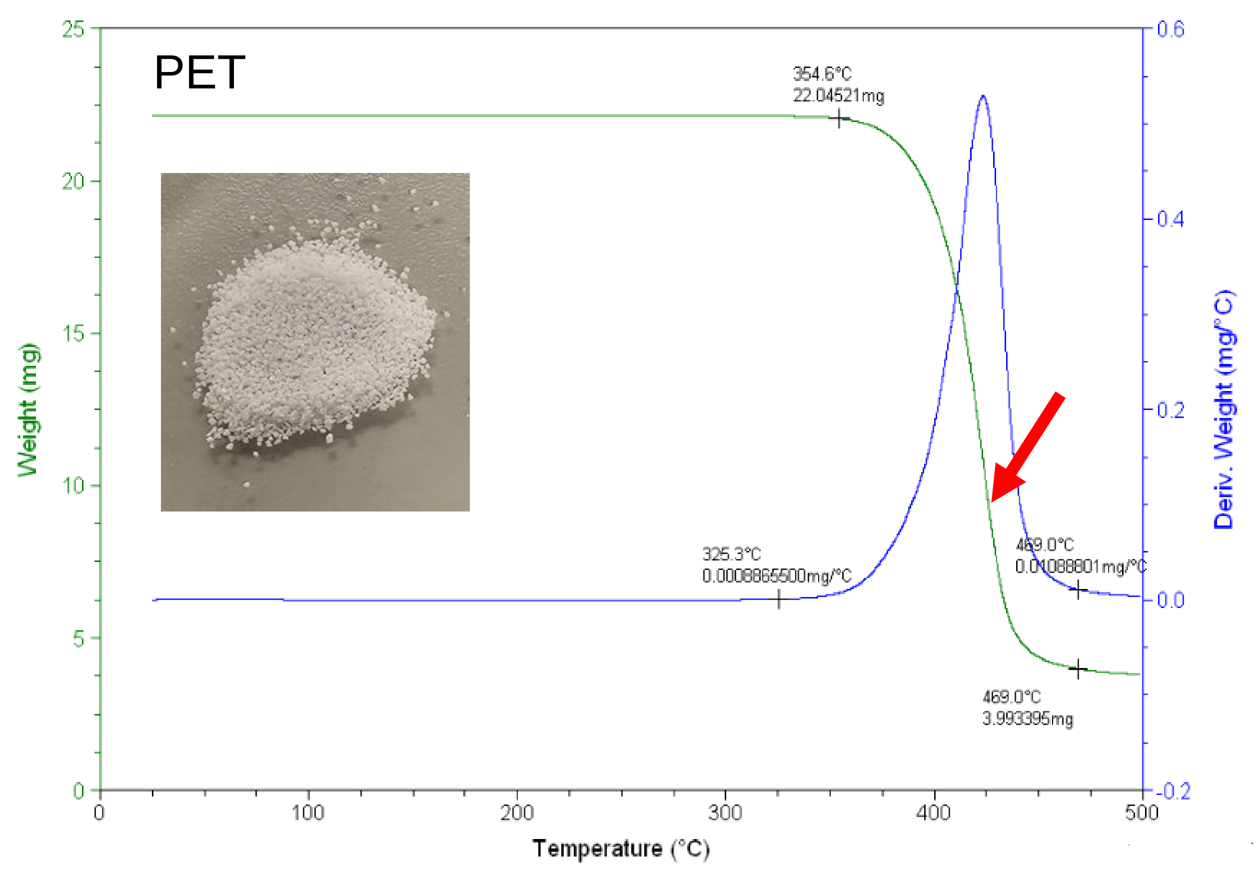


Sample: Rubber Tire

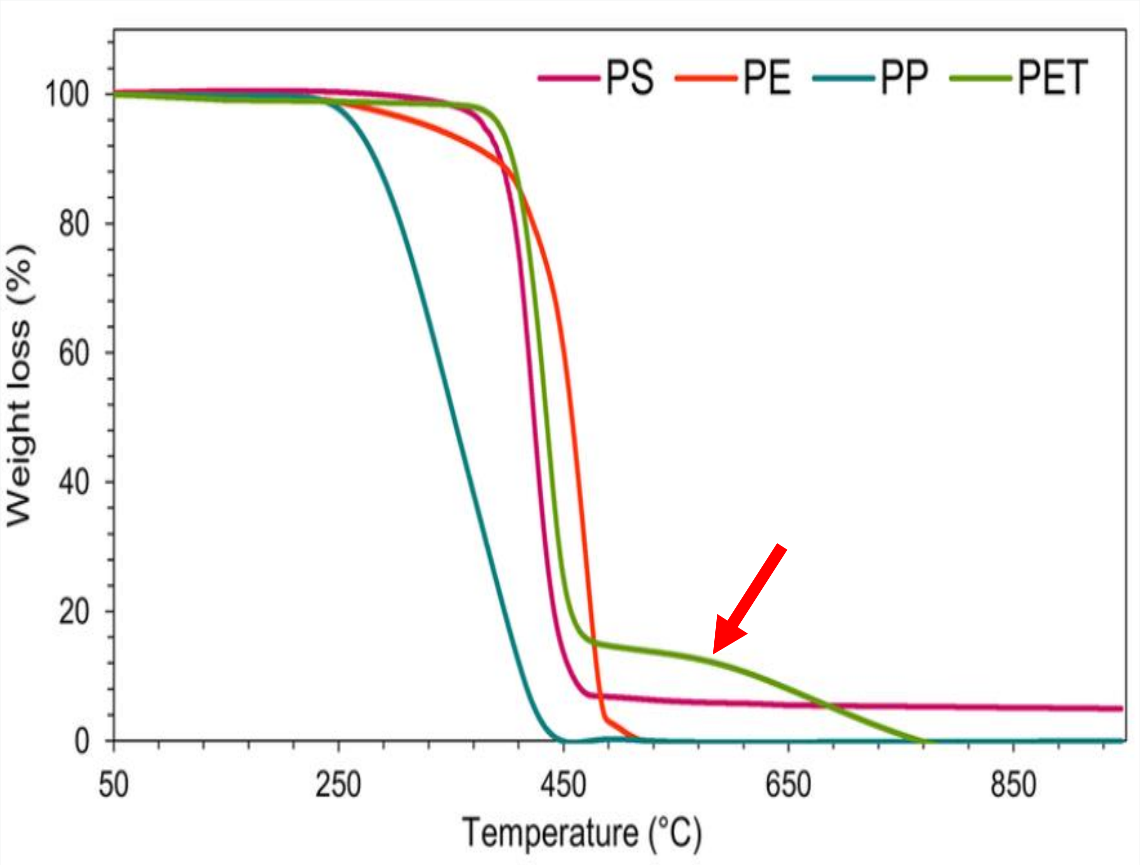


TGA Schematic curve of rubber

TGA curve of PET microplastics

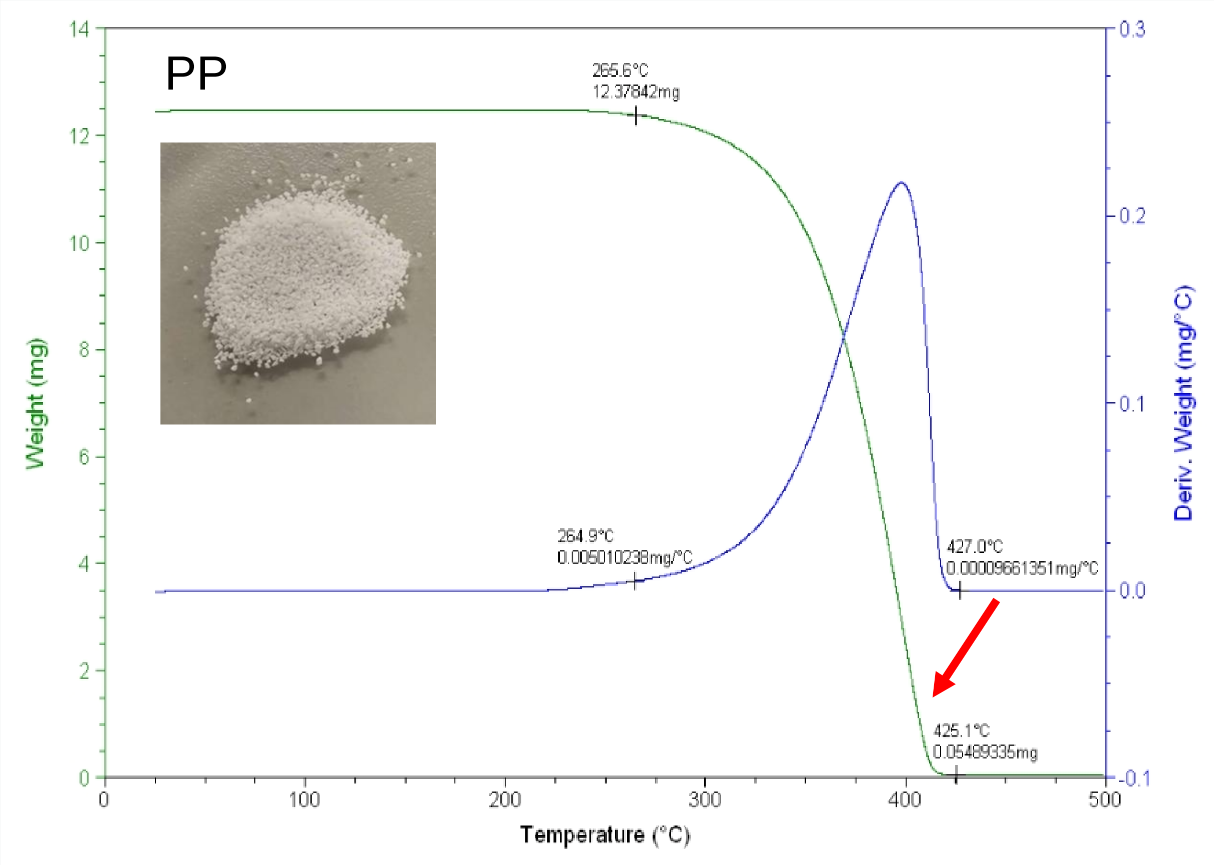


Sample: PET microplastics

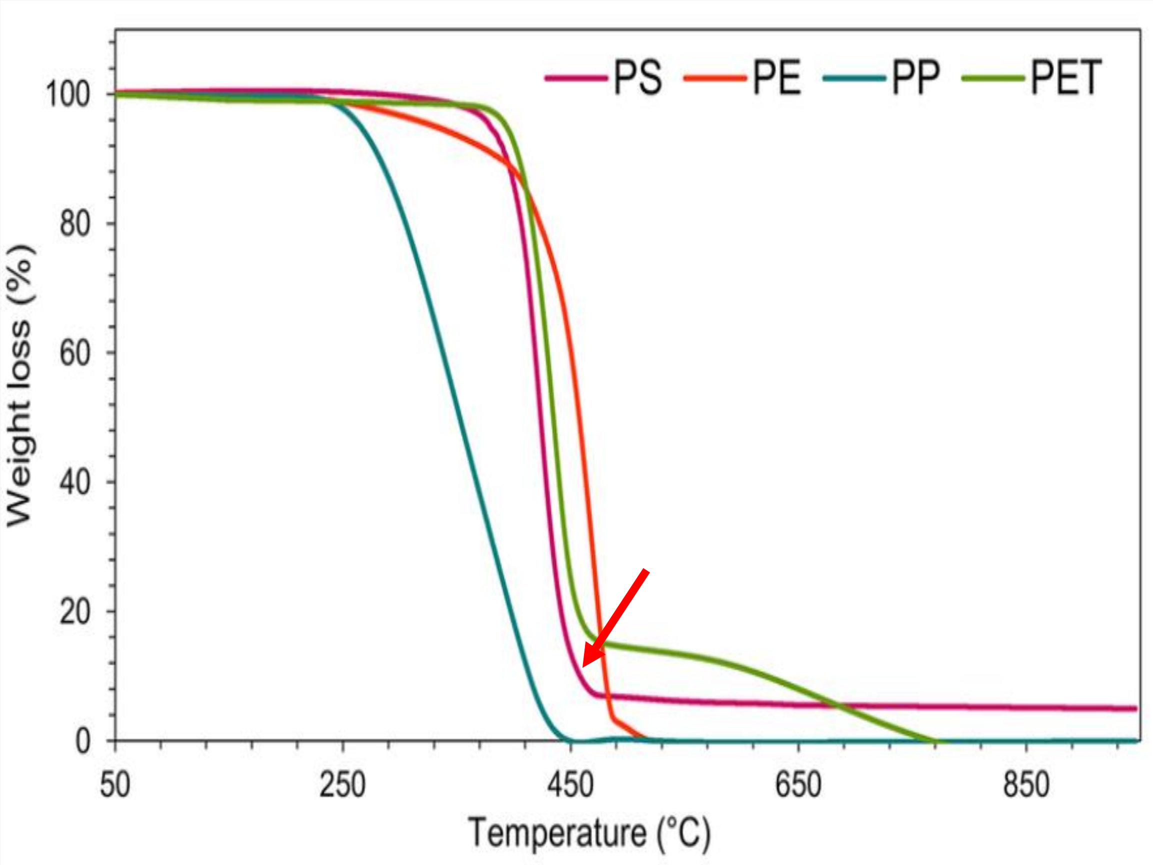


TGA Schematic curve of PET plastics

TGA Curve of PP microplastics

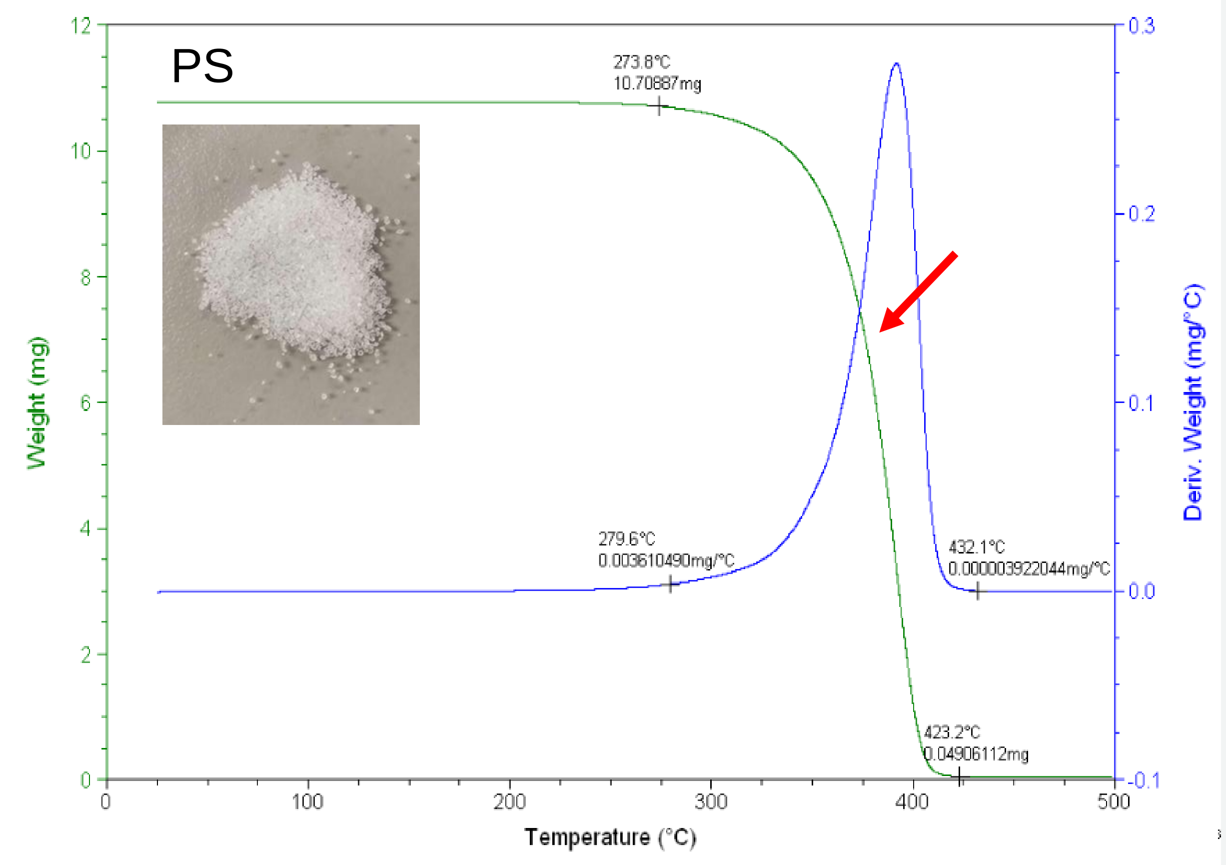


Sample: PP microplastics

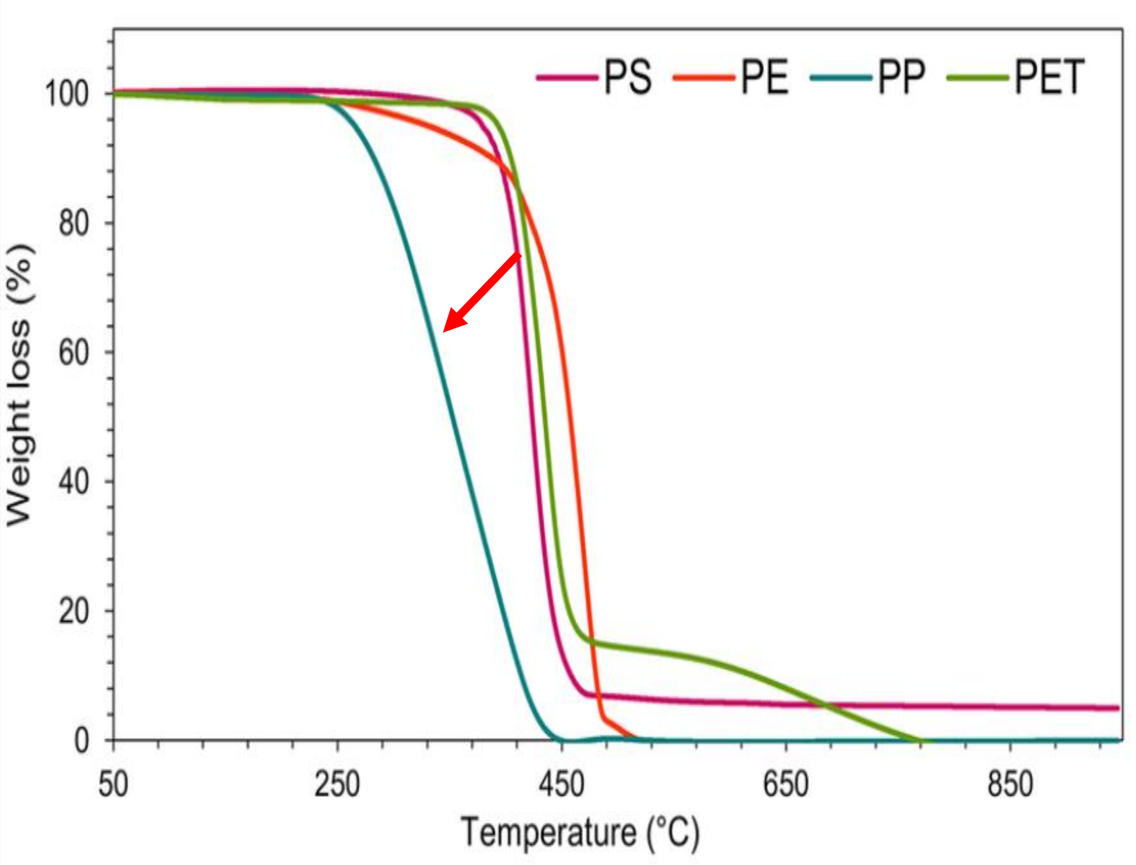


TGA Schematic curve of PP plastics

TGA Curve of PS microplastics



Sample: PS microplastics



TGA Schematic curve of PS plastics

Summary

- Microplastics and rubber tires can be degraded into carbon dioxide and organic compound by Fenton's reaction
- Significant degradation of microplastics and rubber tires using Fenton's reagents of ferrous solution and hydrogen peroxide at 0.0334 mol/L and 1.58 X 10^{-3} mol/L respectively
- Smaller sizes of microplastics have greater degradation efficiencies than larger sizes of microplastics
- TGA analysis confirming our samples are highly similar to the original types of microplastics and rubber materials