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Quantification of Microplastic in Domestic Greywater Using Image Processing and Machine Learning at Microscopic Level

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Abstract -
Washing processes of synthetic textiles has recently been assessed as one of the main sources of primary microplastics in the oceans. Plastic microplastics (microbeads, fragments and fibres) pass directly from household water into wastewater systems and are too small to be retained by the standard filters used at wastewater treatment plants. Every day, the water treatment plant discharges 160 trillion litres of water effluents with 8 trillion plastic particles into the aquatic ecosystem. Microplastics are ingested by aquatic creatures such as fish and different crustaceans, and finally, people ingest them at the tertiary level of the food chain. Therefore, to reduce existing quantities of microplastics released in the marine environment, there is a need for innovative methods for detection of microplastics. The aim of our project is to create a prototype for Real-Time monitoring of Microplastics in the greywater released from household washing machines. This includes monitoring using a camera, analysing and storing data in the cloud. Computer Vision and Machine Learning will be used for detection of microplastic in the images from the camera. It would also include a system for logging and monitoring of microplastics in the greywater. This prototype can be used by the government to govern the amount and type of microplastic released by various types of clothes.

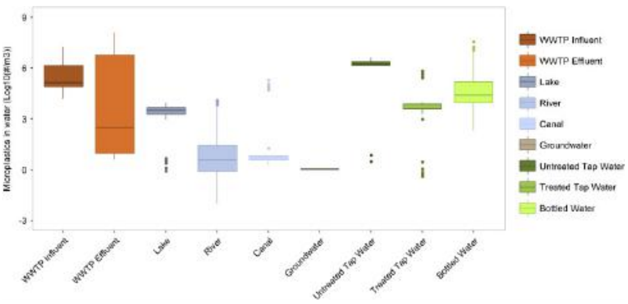
Keywords- **Microplastic, Water Pollution, Computer Vision, Microscopic imaging, Micro-level Reflection of laser, Domestic water pollution, Grey water, Microplastic in sewage, Microfebric.**

1. Introduction:

When I talk about plastics, I usually think about food wrappers, beverage bottles, straws, cups and plates dumped carelessly into the ocean. But what about the fragments of plastic, hardly visible to the human eye?

particle counts in individual samples from 0 to 10 000 particles/L and mean values from 10-3 to 1000 particles/L.The global release of primary microplastics into the ocean was estimated at a startling 1.5 million tons per year

In recent years, Microplastics in aquatic ecosystems have become a major environmental concern. Inadequate detection methods and slow disposal rate of microplastics has made it ubiquitous in the environment. Freshwater studies, reported microplastic particle counts ranged from around 0 to 1000 particles/L. These studies reported



What is microplastic?

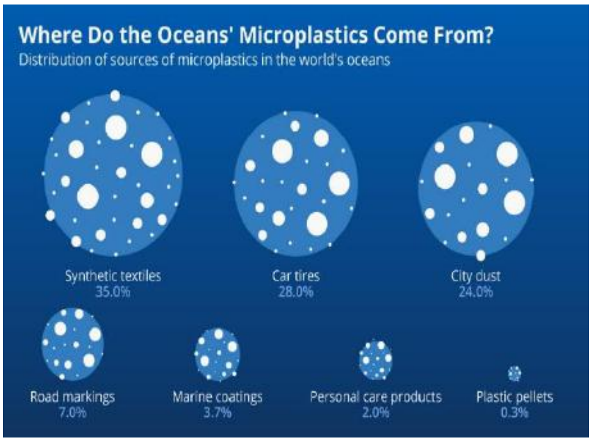
Plastic is the most prevalent type of marine debris found in our ocean and Great Lakes. Plastic debris can come in all shape

s and sizes, but those that are less than five millimetres in length (or about the size of a sesame seed) are called "microplastics."

Microplastics come from a variety of sources, including from larger plastic debris that degrades into smaller and smaller pieces. In addition, microbeads, a type of microplastic, are very tiny pieces of manufactured polyethylene plastic that are added as exfoliants to health and beauty products, such as some cleansers and toothpastes. These tiny particles easily pass through water filtration systems and end up in the ocean and Great Lakes, posing a potential threat to aquatic life.

Where does it come from?

Adequate measures to curb microplastic pollution may lead us to the principal source:abrasion of synthetic textiles during washing.During a wash, the fibres of synthetic clothes undergo significant stress.The fibres of these clothes ,thus, detach from the yarn that constitutes the textile.Recent estimations[1] have assessed that synthetic clothes contributes by about 35% to the global release of primary microplastics to the world oceans, thus becoming the main source of microplastics. This estimation is not surprising considering that synthetic fibres represent almost ~~the~~ 60% of the annual global consumption of fibres, that is 69.7 Mt, used in the apparel industry[1] and that, globally, more than 840 million domestic washing machines are used, consuming annually around 20 km3 of water and 100 TWh of energy[10]. In such a scenario, it is of striking importance to evaluate the real environmental impact of washing processes of synthetic clothes, starting from quantifying microplastics that can be released during a wash and identifying possible parameters of influence on the release.



What are its effects?
Microplastics can carry a range of contaminants such as trace metals and some potentially harmful organic chemicals.
These chemicals can leach from the plastic surface once in the body, increasing the potential for toxic effects. Microplastics can have carcinogenic properties, meaning they potentially cause cancer. They can also be mutagenic, meaning they can damage DNA.

Microplastic in homes
According to a study done in Australia, People spend up to 90% of their time indoors and therefore the greatest risk of exposure to microplastics is in the home.
Their study was the first to examine how much microplastic people are exposed to in Australian homes. They have analysed dust deposited from indoor air in 32 homes across Sydney over a one-month period in 2019.

I found 39% of the deposited dust particles were microplastics; 42% were natural fibres such as cotton, hair and wool; and 18% were transformed natural-based fibres such as viscose and cellophane. The remaining 1% were film and fragments consisting of various materials.

Between 22 and 6,169 microfibres were deposited as dust per square metre, each day.

Homes with carpet as the main floor covering had nearly double the number of petrochemical-based fibres than homes without carpeted floors.

Conversely, polyvinyl fibres (synthetic fibres made of vinyl chloride) were two times more prevalent in homes without carpet. This is because the coating applied to hard flooring degrades over time, producing polyvinyl fibres in house dust.

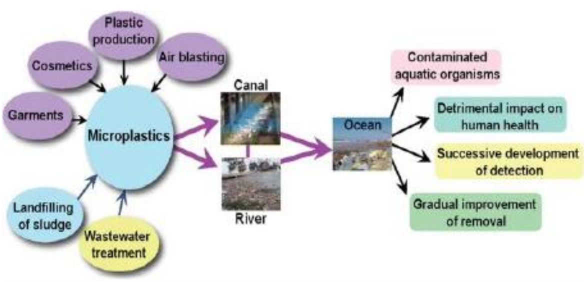
Effect of microplastics on marine life:

1) Because of increasing microplastics in marine life, we find microplastics in the tissue of aquatic life. These enter their bodies either from ingestion or respiration.
2) It is contributing to the cancer in all the species related to oceans including humans as humans consume seafood infected with microplastic
3) Many of its adverse effects are still unclear as it is in microscopic level but it is merging into the marine food circle

2. LITERATURE REVIEW

1. Dey, T.K., Uddin, M.E. & Jamal, M. **Detection and removal of microplastics in wastewater: evolution and impact.** *Environ Sci Pollut Res* 28, 16925–16947 (2021).

This analysis provides a complete understanding of entire strategies for detecting and removing microplastics and their associated issues to ensure a waste discharge standard to minimise the ultimate potential impact in aquatic environments.



In this research work, researchers have worked thoroughly on the flow of the microplastic and its path to the ocean. They have concluded that the domestic and industrial textile waste water is the biggest contributor to the microplastic release in the ocean. It contributes to the total of 35% microplastic present in the ocean.

2. Z. Chaczko, P. Wajs-Chaczko, D. Tien and Y. Haidar, "**Detection of Microplastics Using Machine Learning**," *2019 International Conference on Machine Learning and Cybernetics (ICMLC)*, 2019, pp. 1-8, doi: 10.1109/ICMLC48188.2019.8949221.

This paper presents results of the work related to exploration of methods and techniques useful for detecting suspicious objects in their respective ecosystem captured in hyperspectral images and then classifying these objects with the use of Neural Networks technique. This solution provides a really nice classification of various different sizes of microplastics and their structure. They have designed a very smart and accurate machine learning model using neural networks which provides really accurate results in detecting the microplastic in the sample image of water.

3. **Microplastics removal in wastewater treatment plants: a critical review**, P. U. Iyare, S. K. Ouki and T. Bond, *Environ. Sci.: Water Res. Technol.*, 2020, **6**, 2664 **DOI:** 10.1039/D0EW00397B

Wastewater treatment plants (WWTPs) are an important route for microplastics to enter aquatic environments..This paper talks about the amount of microplastics that are removed from the wastewater as it passes through these plants.The aim of this study was to examine and quantify the removal efficacy of microplastics by WWTPs. Experimental methods employed in sampling, analysis and quantification of microplastics vary widely between studies. Microplastic removal rates in 21 studies were compared. Secondary and tertiary WWTPs removed an average of 88% and 94% of microplastics, respectively. The majority of microplastics, 72% on average, were removed during preliminary and primary treatment. Calculations of the settling/floating velocities of commonly used polymers indicate that primary sedimentation removes spherical particles >27–149 μm in diameter, depending on the polymer in question. Thus, the majority of microplastics removed during wastewater treatment are likely to be present in sewage sludge. Although the removal of microplastics is high, WWTPs are still an important entry point into aquatic and terrestrial systems, given the high volumes involved and the amount of sludge reused *via* land application. The major concerns are with small particles (especially <~150 µm) in discharged wastewater effluent and the impact that particles which accumulate in sewage sludge may have on terrestrial ecosystems.

4. Government Policies and Acts:

Plastic Waste Management Amendment Rules, 2021.

Thickness of plastic carry bags increased from 50 to 75 microns from 30th September, 2021 and to 120 microns with effect from the 31st December, 2022.

In the 4th United Nations Environment Assembly held in 2019, India had piloted a resolution on addressing single-use plastic products pollution, recognizing the urgent need for the global community to focus on this very important issue. The adoption of this resolution at UNEA 4 was a significant step.

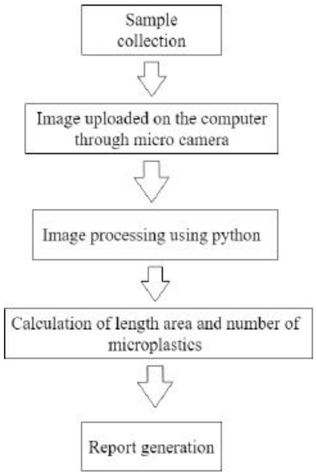
The manufacture, import, stocking, distribution, sale and use of following single-use plastic, including polystyrene and expanded polystyrene, commodities shall be prohibited with effect from the 1st July, 2022:-

a. earbuds with plastic sticks, plastic sticks for balloons, plastic flags, candy sticks, ice-cream sticks, polystyrene [Thermocol] for decoration;
b. plates, cups, glasses, cutlery such as forks, spoons, knives, straw, trays, wrapping or packaging films around sweet boxes, invitation cards, and cigarette packets, plastic or PVC banners less than 100 micron, stirrers.

In order to stop littering due to light weight plastic carry bags, with effect from 30th September, 2021, the thickness of plastic carry bags has been increased from fifty microns to seventy five microns and to one hundred and twenty microns with effect from the 31st December, 2022. This will also allow reuse of plastic carry due to increase in thickness.

The plastic packaging waste, which is not covered under the phase out of identified single use plastic items, shall be collected and managed in an environmentally sustainable way through the Extended Producer Responsibility of the Producer, importer and Brand owner (PIBO), as per Plastic Waste Management Rules, 2016. For effective implementation of Extended Producer Responsibility the Guidelines for Extended Producer Responsibility being brought out have been given legal force through Plastic Waste Management Amendment Rules, 2021.

3. Our Solution

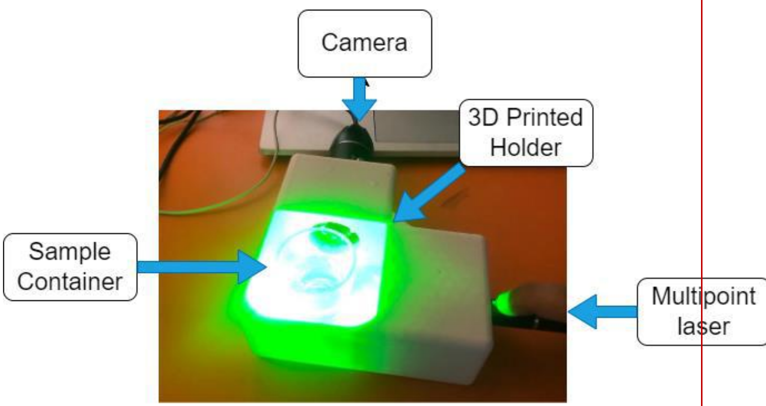


Our Solution is handy, easy to use, and built on practicability. The simple mechanism of a microcamera and image processing tools/code
enable us to get accurate data at a domestic level.The code implemented uses technology to ensure that the margin of error remains minimal.
It is a small experimentation tool kit which includes a multi-point green laser light, a microscopic camera, a smartphone and a holder.It costs less than 3500 INR and could be used to perform thousands of tests

The tool has a camera in the front which captures the image of the water sample and then applies the machine learning algorithm to detect microplastics by canny edge detection.

The average area occupied is calculated along with its length. It can also calculate the total individual microfibers present in the water sample.

Prototype:
We have made a 3D printed holder with 2 holes at the angle of 90 degree directly facing the sample in the middle of the holder. On one side laser can be fit and on the other side we can fit the camera as you can see in the picture:



1. Micro-camera:

We have used a 1000X zoom microscope camera to click the picture of the contaminated water. I had to click the microscopic image and this camera is providing us a very magnified image of the area of 1 mm^2. With the resolution of 1600X1200.

2. Multipoint Green laser:

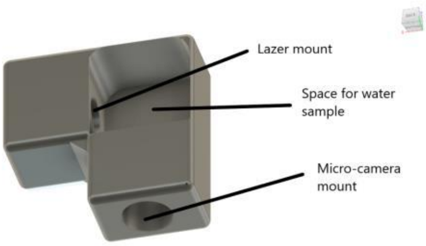
We have used a 500nm high intensity multi point laser to make the microplastic visible to the microscopic camera. This laser shoots multiple green laser lights inside the glass of sample water and then the microplastic in the water cuts the path of the laser and starts glowing which makes it visible to the microscopic camera at 1000x zoom

3. Camera and laser holder

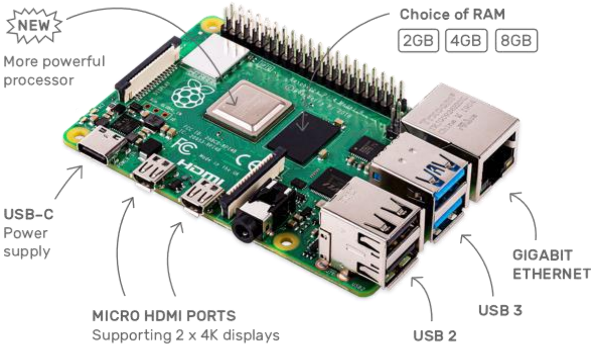
We have made a special 3D Printed holder which combines all the components like camera, laser and the sample container into a single unit. This is a L shaped block which can hold the camera on one side and the laser on the other side so that both of them point directly to the water sample container at the angle of 90 degree.

CAD design :

I have specially designed a holder for the prototype.
I have used fusion 360 software to make the real size 3D model of the holder. This holder has a 20mm wide opening in one end as seen in the picture below. Which holds the laser light and a 32mm opening in the other side at the angle of 90 degree

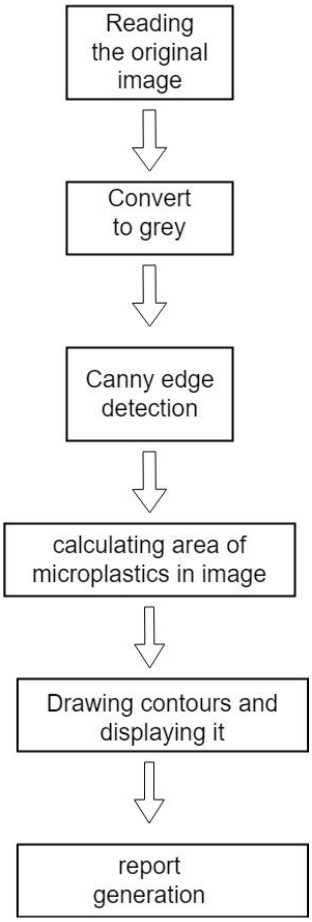


4. Raspberry Pi 4:



I am using the Raspberry Pi4 as the main computer of the robot . It is the latest and the fastest model available for making smart computer based projects. It helps in making the prototype compact and really portable

Code :



CV2 is a python library known for its code readability and simplicity. We use CV2 for converting image to grey and specifying thresholds for canny edge detection

Numpy: All of the images are stored in the form of numpy arrays. This helps us to implement machine learning models which take input in height width and channel format

Fpdf: we use fpdf for report generation

```
import cv2
import numpy as np
from PIL import Image
import pandas as pd
import fpdf
from fpdf import FPDF

# Read the original image
x=0
y=0
img = cv2.imread(r"C:\Users\prana\100063.jpg")


#convert colour to grey
img_gray = cv2.cvtColor(img,
cv2.COLOR_BGR2GRAY)

#canny edge detection and defining thresholds
max_area=0
edges = cv2.Canny(image=img_gray,
threshold1=50, threshold2=150)
contours,_=cv2.findContours(edges,cv2.RETR_T
REE,cv2.CHAIN_APPROX_SIMPLE)
for cnt in contours:
    area1=cv2.contourArea(cnt)

    (x,y,w,h)=cv2.boundingRect(cnt)
    cv2.drawContours(img,[cnt],-1,(0,0,255),4)
    max_area += cv2.contourArea(cnt)
    print(max_area)


# Display Canny Edge Detection Image
print("contors:",len(contours))

print(max_area)
ratio_brown =
cv2.countNonZero(edges)/(img.size/3)
#area
print('brown pixel percentage:',
np.round(ratio_brown*100, 2))

#showing image with image processing
```

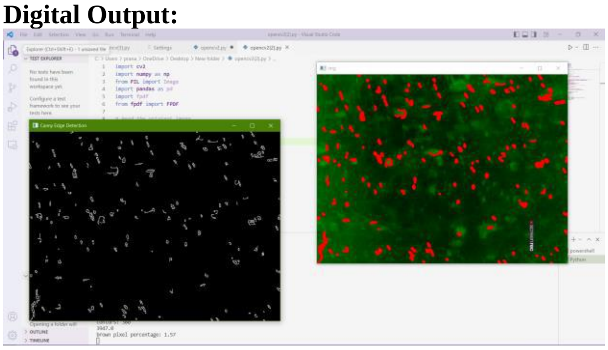
```
cv2.imshow('Canny Edge Detection', edges)
cv2.imshow("img",img)
cv2.imwrite("final.jpg",img)
cv2.waitKey(0)
cv2.destroyAllWindows()
#report generation
pdf = FPDF('P', 'mm', 'A4')
pdf.add_page()
pdf.set_margins(0, 0, 0)
pdf.set_font('Arial', size= 14)
pdf.cell(200,20,txt="percentage of microplastic",ln=2,align="C")
pdf.set_font('Arial', size= 10)
pdf.image('final.jpg',50,50)
pdf.output("sample.pdf")
#code to convert video to individual photos that can be used for image processing
import cv2
import numpy as np
vid=cv2.VideoCapture(r"C:\Users\prana\Downloads\WIN_20220322_16_21_37_Pro.mp4")
c=100000
while True:
    ret,frame=vid.read()
    if ret==True:
        cv2.imwrite(str(c)+".jpg",frame)
        c+=1
        print("imgsaved",c)
    else:
        break
```

4. Testing the Prototype:

Initial testing:

During the journey of the project I have tested our solution many times**.** We started with a phone camera and realised that the resolution was not enough to capture tiny microplastics suspended in the water. This led us to buy a micro-camera for testing. During our analysis we realised that the camera which we held in our hand was cumbersome to hold and did not give clear images. This prompted us to design a 3d printed plastic holder for better testing.

Digital Output:



On the left, we can see the contours detected from the image. Right,we mark the detected microplastic on the original image with red.

We have tested our prototype on multiple different types of clothes and found following results:

Cotton Kitchen cloth:
Quantity - 1625 microplastics per litre
Average size - 33 Micrometre

Cotton T-shirt:
Quantity - 400 Microfibres per litre
Average size - 80 Micrometre

Woollen Clothes:
Quantity - 2336 microplastics per litre
Average size - 57 Micrometre

Synthetic Cloth - 3211 microplastics per litre
Average size - 42 Micrometre

5. Future Scope:

Our Solution is right now at its initial testing stage. I have made a small and very promising prototype which is very simple and easy to use. It provides very good quality images to do the analysis and gives very good results. In the near future I will be starting field testing. Till now I have used it at personal level and tested it for its accuracy and consistency. My next step will be to use it at multiple places like in societies to collect the data at a larger level. I am also going to make it portable by converting it into a very small device using raspberry pi. SO that it can be used anywhere. This solution has a great potential in revolutionising the awareness about the water pollution and contribution of microplastic in it.

6. Conclusion:

This project is more research-oriented which can help tremendously in understanding the individual's contribution to water pollution. This information can help us solve the water pollution problem at the very beginning. We may not be able to end the water pollution but using this solution we can decrease the individual's contribution by making them aware,

I will also specifically research each material and obtain data on which fabric releases the most microplastics.This may help us in identifying the source and subsequently implementing necessary actions to curb the release.

Consumers and brands can use this data to make informed decisions and be more environmentally conscious.

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