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Application of Recycled Plastic Specimens to Enhance Waste Water Treatment Plant Operation for Subterranean Flow Constructed Wetlands

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This study investigates the application of recycled plastic material in Subterranean Flow Constructed Wetlands, which are used for the treatment of pre clarified wastewater in an environmentally sound way inspired by natural biological processes.
The focus of the presented research performed at the Cleanwater Educational Research Facility, located at the New York Village of Monas waste water treatment plant is to investigate the use and application of future growth media made of recycled plastic materials for Subterranean Flow Constructed Wetlands.

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Six recycled plastic materials; Polyethylen-terephthalat, Polyethylene high density, Polyvinyl chloride, Polyethylene low density, Polypropylene, and Polystyrene were used for the growth media experiments in the commercial operated Subterranean Flow Constructed Wetlands.
Testing was conducted during a 5-month period, measuring the test specimens for their biomass growth at a 3-week time interval that allows bacteria to generate a biomass film on the test specimen.
Biomass growth was observed on all types of plastic material at the measuring points. Results show that Polyethylen-terephthalat is the most preferred growth medium for all measuring points followed by Polyethylene low density, Polystyrene and Polyethylene high density as well as Polyvinyl chloride for certain locations.
It is suggested that future research on Subterranean Flow Constructed Wetlands growth media using recycled material should focus on the above recycled plastic types.

Keywords: Bioremediation; contaminants; constructed wetland; recycled plastic material; sewage; subsurface constructed wetland; wastewater.

1. INTRODUCTION

Historically, municipal effluent, agricultural and industrial entities has been discharged into rivers, streams, wetlands and natural water systems with the reliance that nature will clean the discharged Waste Water (WW) [1]. During the industrial revolution this was not enough anymore and in the United States. The increasing problem of water pollution in the United States was first addressed with the River and Harbor Appropriation Act of March 3, 1899, Section 9 & 10, with the goal to ease navigation by limiting the discharge of refuse matter into any kind of navigational waters [2,3]. However, discharge of sewage and industrial effluents into U.S. surface waters was not regulated till June 30, 1948, when the Federal Water Pollution Control Act (FWPCA) was signed into law. [1,2,3,4]. Environmental pollution continued till the U.S. Environmental Protection Agency (USEPA) was established by executive order of President Nixon on December 2, 1970, followed by the Clean Water Act (CWA), signed into law, on October 18, 1972 [5,6] to protect US surface water bodies. Since then, amendments and revisions have been made to the CWA.

As regulatory means involve so do processes that are affected. Today engineers and scientists work constantly on improving existing processes. Results are then implemented in existing processes, which is called upgrading, or implemented as state-of-the-art processes in newly built systems.

Increased environmental awareness in the past decades led to the development of improved and better water treatment technologies by scientists and engineers. To implement these newly developed technologies and upgrade existing water treatment infrastructure in the U.S. an Infrastructure Law was passed by congress and signed into law in 2021 that allows investing more than $50 billion administered by the EPA [7].

For instance, algae growth on a trickling filter can enhance the water treatment capability of a trickling filter as described by Doelle & Watkins [8] in their research which found that over 70% of the phosphorus entering the trickling filter can be removed by the algae layer, and therefore has a positive effect on water quality. Optimizing natural processes inspired by natural biological processes and implementing them in technical solutions is also called biomimicry, which can lead to a more environmentally friendly and sustainable process [1].

Based on this research tests were carried out to further investigate if algae growth would depend on its affinity for a particular carrier medium. Materials such as wood chips, larger blocks as well as cardboard, Styrofoam chips and plastic bags were included in the test series by Doelle and Watkins [9]. Results shown of these tests can be seen in Fig. 1, where Styrofoam peanuts had the highest growth rate with 7.27 g/day followed by plastic bags with 6.19 g/day, softwood wood blocks with 4.26 g/day and sugar maple hardwood wood chips with 2.27 g/day, and cardboard with 0.84 g/day.

The results of this study by Doelle and Watkins lead to the study on an Subterranean Flow Constructed Wetlands (STFCW) which are used at the Minoa Waste Water Treatment Plant (WWTP). Fig. 2 shows the set-up of one of the three constructed wetlands present at the Minoa WWTP.

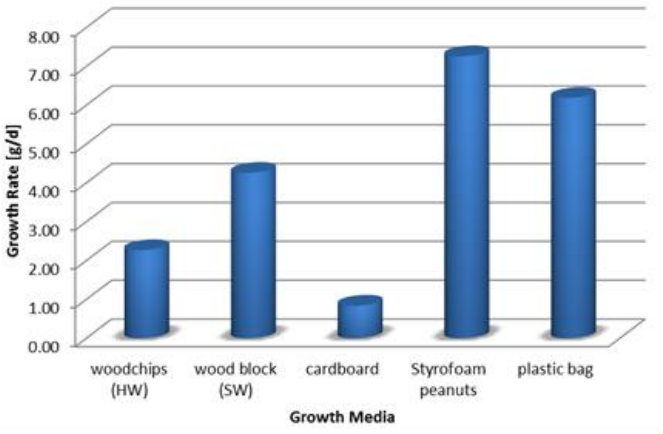

Fig. 1. Support media growth rate [9]

STFCW can be used to treat secondary WW, or are used for polishing off effluent from municipal, agricultural, industrial, and decentralized WWTP before the treated WW is released into the environment.

Fig. 2. Different types of constructed wetland [1]

A STFCW systems, is shown in Fig. 3. The WW is generally treated in three zones embedded in a combined or single zone engineered basins that are sealed off with a geomembrane made either from a clay layer, a High-Density Polyethylene (HDPE) foil, concrete or a combination of the three, in order to prevent environmental contamination by WW seeping in the surrounding environment [10].

A STFCW might contain different Zones as shown in Fig. 3 by Doelle [11]. Treatment Zone 1, 2 and 3 may be filled with gravel or plastic growth media while Zone 2a and b may contain a free water surface which is in most municipal water treatment applications undesirable because it can provide a habitat for mosquitos and rodents as well as a potential safety hazard due to the open water surface.

For the treatment section of the STFCW, smaller rocks such as gravel or crushed stone are used in the treatment zone. The growth material is an important factor for the operation of a STFCW, because it provides sufficient surface area for microbial growth and thus contributes to better filtering harmful particles out of the wastewater [1]. In addition, the growth material serves as anchor element for chosen vegetation (e.g. phragmites, grass etc.) planted on top the STFCW, while the plant roots serve as additional settling and anchor surface for bacteria and microbes.

To control the water level in the STFCW a water level control system such as a weir or wet well is used to adjust the water level, so it stays below the surface of the STFCW [11].

The current used growth media in STFCW is gravel which has a very low porous volume.

In the past gravel, rock, slag and wood were for example used as growth media in trickling filter applications, but these materials were replaced with materials such as Polyvinyl Chloride (PVC) and Polypropylene (PP), because engineered growth media provide a much higher surface area as wood and rock growth media and allow a higher throughput and increased waste water treatment capabilities [12,13,14,15,16].

Testing of recycled plastic material on STFCW was the focus of this research in order to determine its application and use in STFCW. The research was performed at the Minoa WWTP, Clean Water Educational Research Facility CERF under actual STFCW working condition using clarified WW.

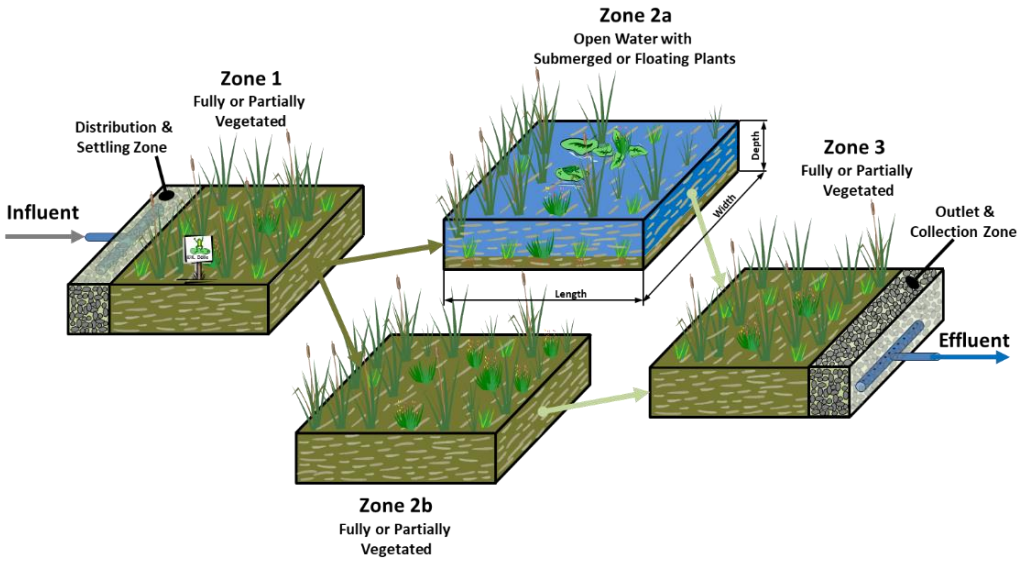

Fig. 3. Surface- and subterranean flow constructed wetland types [1]

2. MATERIAL AND METHODS

The material and methods section describes the materials, system, experimental setup, and the exact procedures and standards necessary to carry out the individual experiments.

2.1 Selection of Plastics

Table 1 provides an overview of the existing recycling number system used in the USA and Europe. Every item made of plastic is always marked with a number that indicates exactly what plastic it is made of for recycling and reuse of the plastic material.

The remaining six types of plastic PET, PE-HD, PVC, PE-LD, PP, and PS, shown in Table 1, are used in the experiments and tested for their suitability as a growth medium in various locations of the WWTP including the plant-based STFCW waste water treatment system.

2.2 Procurement of Materials

Plastic waste generated in U.S. households in the larger Syracuse area is separated and brought to recycling sites. The six different plastic types (PE-HD, PE-LD, PP, PS, PET and PVC) were obtained from a nearby recycling site for the research project.

2.3 Experimental Site

At the Minoa WWTF shown in Fig. 4 as a process sketch, approximately 1.8 million l/d of municipal WW enter the WWTF for treatment through an influent structure at a temperature of approximately 15°C [11] in which a prescreening process removes large impurities via a gravel trap and rake. The removed material is dried disposed of at a landfill [11].

The prescreened sewage leaving the influent structure is split in half. A Sequential Batch Reactor (SBR) receives one half of the prescreened liquid sewage volume (900,000 liters per day). The SBR consists of two alternating parallel tanks that are operated at an alternating 4-hour aeration and settling cycle [Doelle] during which the biological colony in this tank consumes the organic fraction of the wastewater, reducing the Biochemical Oxygen Demand (BOD) and Ammonia (NH_3). After the aeration and settling period, the treated WW is removed with a mechanical decanter and passes a chlorination treatment before it is discharged into a stream. The produced biosolids from bacterial growth also called primary sludge of the SBR are collected in a separate tank adjunct to the treatment tanks [11].

The other half of the prescreened sewage (900,000 liters per day) is pumped to a primary clarifier settling tank where about 30% of the organic substances are removed from the prescreened sewage by sedimentation as primary sludge.

Half of the clarified water, approximately 450,000 liters per day, is directed to the STFCW that currently consists of 3 cells. The first 2 cells

operate on a fill drain cycle, while Cell 3 operates as a through flow cell receiving WW from Cell 1 or Cell 2. All three cells are planted half with grass and the other half with Phragmites. After the STFCW treatment the 450,000 liters per day effluent is redirected into the influent box where it mixes with the other 450,000 liters per day from the primary clarifier. Two trickling filter receive the combined flow of 900,000 liters per day for secondary treatment.

Organic components that leave the Trickling Filter with the treated WW are then settled in the Secondary Clarifiers (SC) and removed as primary sludge.

Primary Sludge removed from the PC, SC and SBR is pumped into an Aeration Tank into which compressed air is supplied. The Aeration tank serves at the same time as a holding tank. During the holding time bacteria break down the pollutants further till the sludge is dewatered with a belt press. The resulting solids are dried in a drying field prior to disposal at a landfill. The removed press water is discharged back into the WWTP influent structure for treatment.

Table 1. Recycling-number code in the USA and Europe

Recycling-Number Code in USA and Europe			
Symbol	**Name**	**Symbol**	**Name**
01 PET	Polyethylene-terephthalat	04 PE-LD	Polyethylene Low Density
02 PE-HD	Polyethylene High Density	05 PP	Polypropylene
03 PVC	Polyvinylchloride	06 PS	Polystyrene

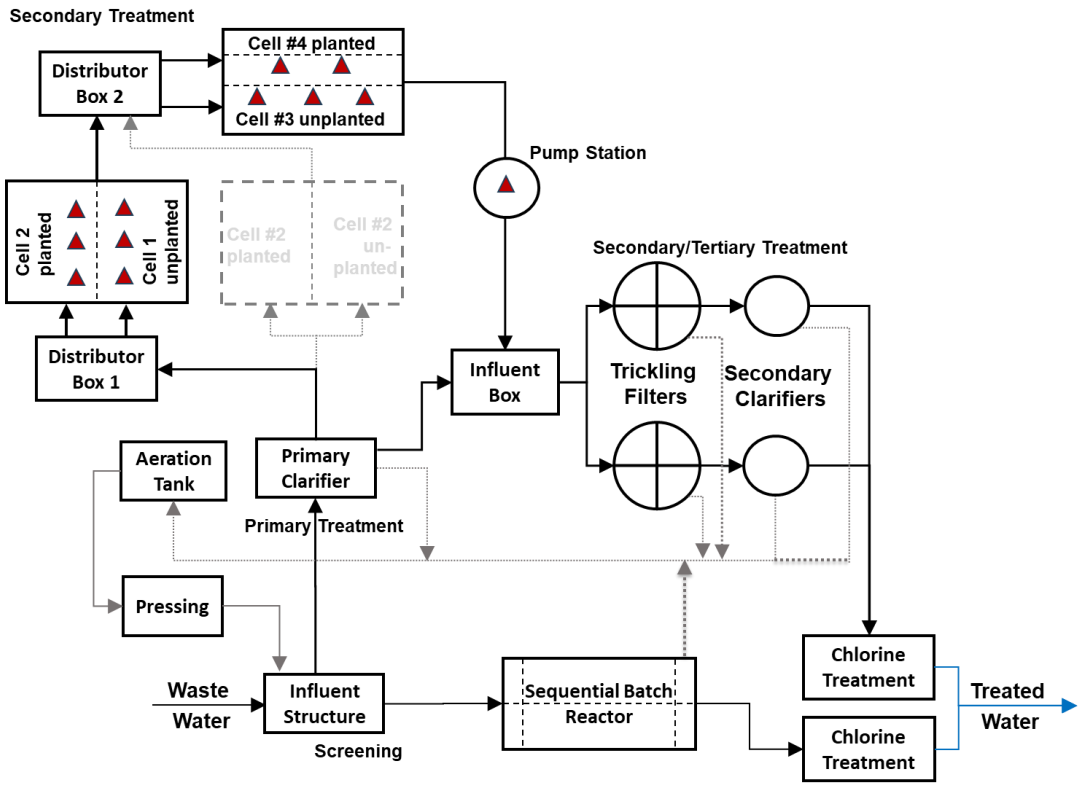

Fig. 4. Waste water treatment plant process sketch [15]

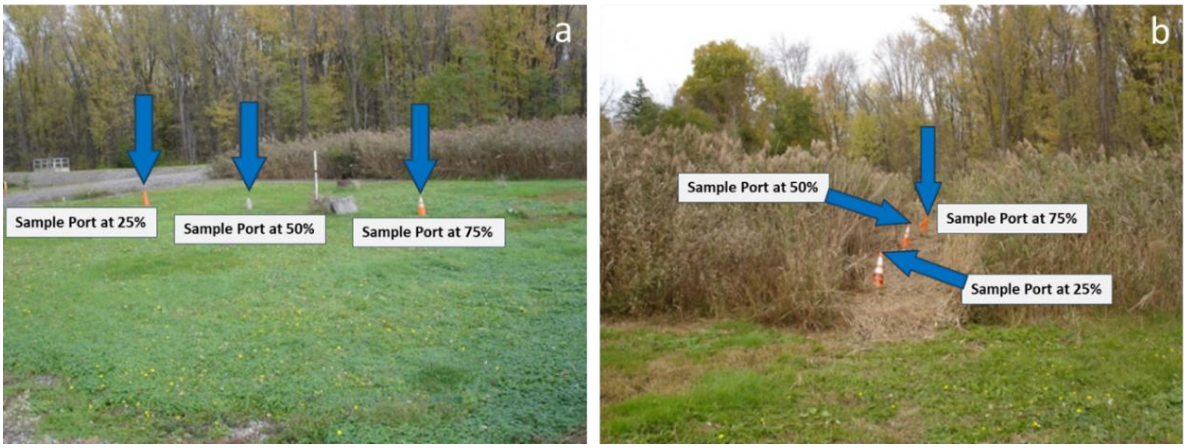

Fig. 5. Sample location a) Cell planted with Grass, b) Cell planted with Phragmites

2.4 Sample Location

For each STFCW cell with a 100 ft long x 200 ft wide footprint with a depth of 12-inch (305 mm) at the beginning and 24-inch (610 mm) at the end with an average depth of 18-inch (458 mm). Half of the STFCW cell (100 ft) are planted with grass and the other 100 ft are planted with phragmites. In each section of the STFCW (Cell 1, 2 &3) three sample points were installed at the 25% (25ft) level, 50% (50ft), and 75% (75 ft) points, see Figs. 5 a & b. Cell 4 contained only 2 sample points at 33% (33 ft) and 66% (66 ft), due to a problem in the STFCW ground that did not allow to install a sample point at the25% (25ft) level, 50% (50ft), and 75% (75 ft) location.

Each sample point, shown in Fig. 6, were made from three 3-inch diameter Polyvinyl chloride (PVC) pipes containing 1-inch holes I the lower half of the pipe that allow the wastewater to flow through the sample pipe.

Fig. 6. Sample point in STFCW

2.5 Construction of the Test Specimens

For testing the bacterial biomass growth with a triplicate test arrangement at the twelve different test location of the STFCW process thirty-six different test arrangements with six test specimens (PE-HD, PE-LD, PP, PS, PET and PVC) each needed to be build. Each biomass growth specimen size was 1.5 cm by 1.5 cm.

In the first step the collected plastic materials were washed first thoroughly to remove any dirt or impurities that may be present so that they do not affect or even distort the measurements later. In a second step the required size of 1.5 cm by 1.5 cm is now drawn on the cleaned plastic types with a ruler and highlighter and then cut out by hand using a scissor. The fourth step consist of weighting and recording the individual test specimens, before they were assembled on the specimen holder in step five which consists of a 3 ft long bronze wire, arranged with approximately 1.5 cm long distance holders in between as shown in Fig. 7.

Fig. 7. Test specimen

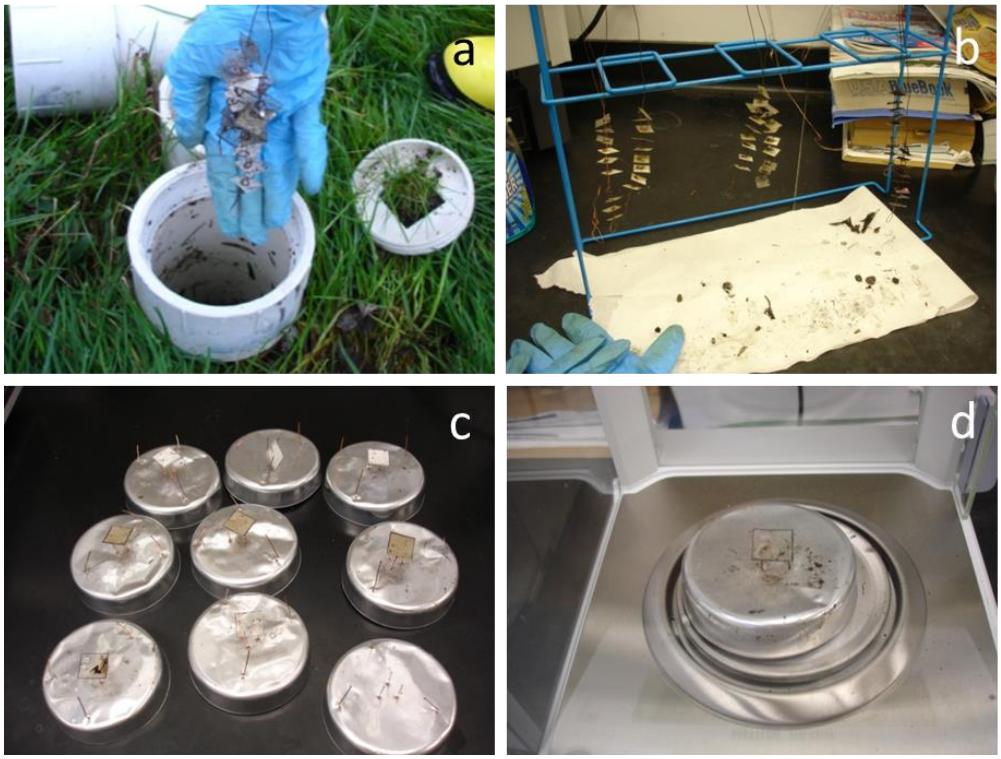

Fig. 8. Test Specimen Examination, a) sample recovery, by drying of samples, c) storage of samples, d) weighting of samples

2.6 Duration of Tests

Testing was conducted starting October 1st with measuring the test specimens for their biomass growth. A 3-week time interval was chosen so that the bacteria generating the biomass fill on the test specimen were given enough opportunity to spread or grow on the respective carrier materials. The last measurement was taken in the 2nd week of February.

2.7 Measurement Procedure

Every 3-weeks, starting in October, the test specimens from the 12 sample locations of the STFCW were examined as shown in Fig. 8. First, the test specimens were removed from the sample location Fig. 8, and brought to the testing laboratory at the WWTP. In a second step the test specimens were hung on a drying rack for 2 hours shown in Fig. 8 b. After drying the test specimens were placed on a pre weight measuring device containing 3 pins for supporting the growth media specimen and not disrupting or damaging the grown biomass. In step four the biomass growth on the specimen was recorded, using a analytical laboratory balance with a 0.0001 g readability. Step five concluded the test specimen evaluation by assembling the specimen holder and placing the specimens back in the respective sample location.

3. RESULTS AND DISCUSSION

The following section describes the results, displayed in Figs. 9 to 20 from the biomass growth study conducted between October and January using six different plastic types (PE-HD, PE-LD, PP, PS, PET and PVC) on biomass growth at the STFCW cell 1 to 4 including the pump station receiving the treated WW.

3.1 Cell 1 and Cell 2

Cell 1 and Cell 2 of the STFCW are operated on a approximately 24-hour fill/drain cycle. As can be seen in Figs. 9 to 14, biomass growth can be observed on all types of plastic material at the measuring points at 25% (25 ft), 50% (50 ft), and 75% (75 ft). The biomass increases in mass steadily until the end of December. However, a significant decline is visible in January, followed by significant growth again in the following month. This fluctuation can be explained by the influence of the seasons and the associated temperature drop occurring in January. The months of October to December were all very

warm and mild, which is why the first continuous increase in mass occurred. However, a rapid drop in temperature followed in January due to the changing weather, including snowfall and frost cooling the WW in the STFCW below the average temperature of 15°C [11]. Consequently, affecting the biomass growth negatively. Bacteria adopt in the system always to environmental influences. In cold temperatures, different microorganisms are used than in warm ones, so there is a slow change in the individual cells. Due to the low activity of the bacteria and the increased water level caused by the snow, no biomass is built up on the carrier media. However, in February there was again a significant increase in the weight on the carrier materials. The reason for this is that the weather has changed again, and temperatures rose above 0°C. This allowed the bacterial activity to regenerate, resulting in increased biomass growth.

The total biomass growth for the 25% (25 ft) measuring point of Cell 1 was 0.0871g for PE-HD, 0.1473g for PE-LD, 0.1302 g for PP, 0.1116g for PS, 0.1555 g for PET and 0.2062 g for PVC during the evaluation period indicating that PE-LD, PET and PVC materials are preferred as biomass growth media.

The samples that were placed in the second measuring point show exactly the same fluctuations, that can also be explained with the above reasons. However, it can be seen here that although an increasing trend in biomass growth can be observed, this is not as pronounced as at the previous measuring point (see Fig. 10). The biomass growth is mainly due to the level of pollution in the water. The higher the pollution of the WW is, the higher is the activity of the microorganisms and subsequently the microorganism growth. Furthermore, the water level in the STFCW cell at 50% (50 ft) is approximately 18-inch (458 mm), which means that different bacteria are present at this point. A higher growth rate can be observed at measuring point one at 25% (25 ft), because the degree of contamination of the water is higher there and because only aerobic bacteria are present there. In contrast, at measuring point two there is already partially purified water as well as a mixture of aerobic and anaerobic microorganisms present [11]. Due to these different circumstances, other plastics materials are also preferred as growth media, such as PE-HD and PP.

The total biomass growth for the 50% (50 ft) measuring point of Cell 1 was 0.0913 g for PE-HD, 0.1214 g for PE-LD, 0.0969 g for PP, 0.1017 g for PS, 0.1026 g for PET and 0.0829 g for PVC during the evaluation period, indicating that PE-LD, PS and PET materials are particularly preferred as biomass growth media.

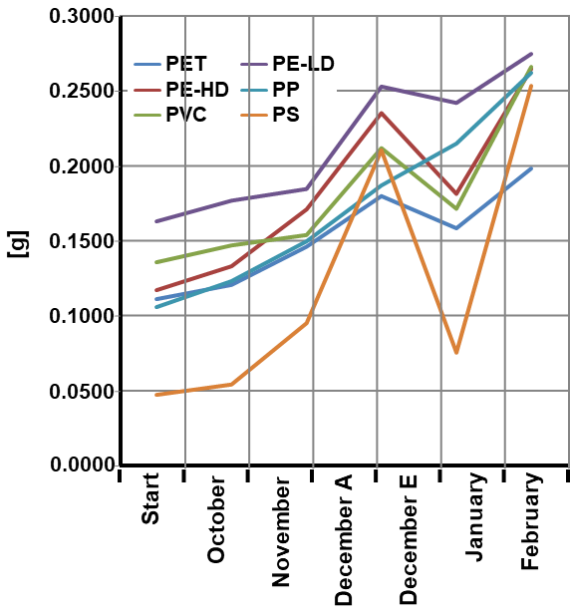

Fig. 9. Cell 1 biomass growth at 25%

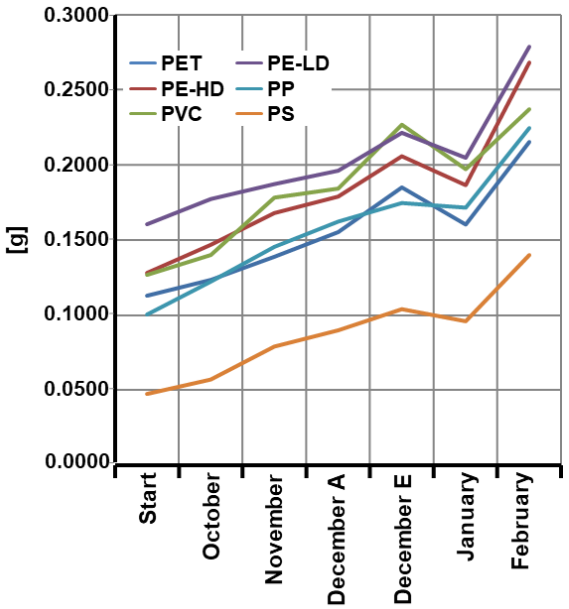

Fig. 10. Cell 1 biomass growth at 50%

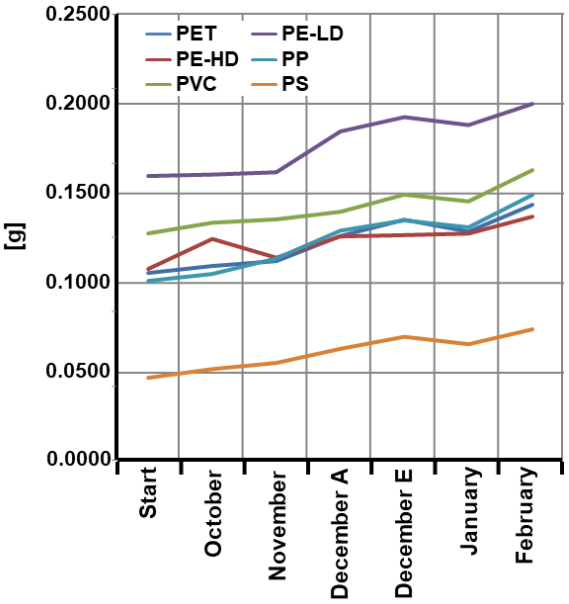

Fig. 11. Cell 1 biomass growth at 75%

When looking at the third sample point at 75% (75 ft) at Cell 1, the influence of the contaminated waste weather no longer plays a significant role as shown in Fig. 11. Here there is only a minimal impact on biomass growth. This can be justified by the fact that at this point the water flows along the foundation of the cell and is therefore almost completely isolated from environmental influences. In addition, only anaerobic bacteria are present here as well as water that has gone through two previous purification steps [14]. This explains the very low biomass growth compared to the previous two measuring points. Measuring point 3 also reveals that the bacteria present and the measured biomass growth does not reveal a preferred plastic material as growth media.

The total biomass growth for the 75% (75 ft) measuring point of Cell 1 was 0.0338g for PE-HD, 0.0126 g for PE-LD, 0.0290 g for PP, 0.0399

g for PS, 0.0442 g for PET and 0.0220 g for PVC during the evaluation period. This indicates that PE-HD, PS and PET materials are preferred as biomass growth media.

Fig. 12 shows the biomass growth of Cell 2 which is identical to Cell 1, except that Cell 2 is planted with phragmites, shows the same large biomass growth continuous increase in biomass at the first measuring point at 25% (25 ft), interrupted by the same fluctuations due to change in in weather conditions in January as well as associated bacterial activity based on temperature and water level.

The total biomass growth for the 25% (25 ft) measuring point of Cell 2 was 0.0663 g for PE-HD, 0.2201 g for PE-LD, 0.0886 g for PP, 0.0450 g for PS, 0.1805 g for PET and 0.1221 g for PVC during the evaluation period. Indicating that plastic types of PE-HD and PET are particularly preferred as biomass growth media.

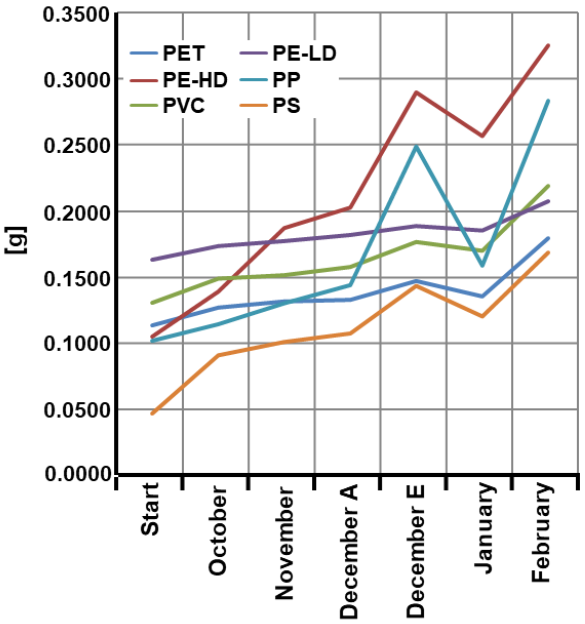

Fig. 12. Cell 2 biomass growth at 25%

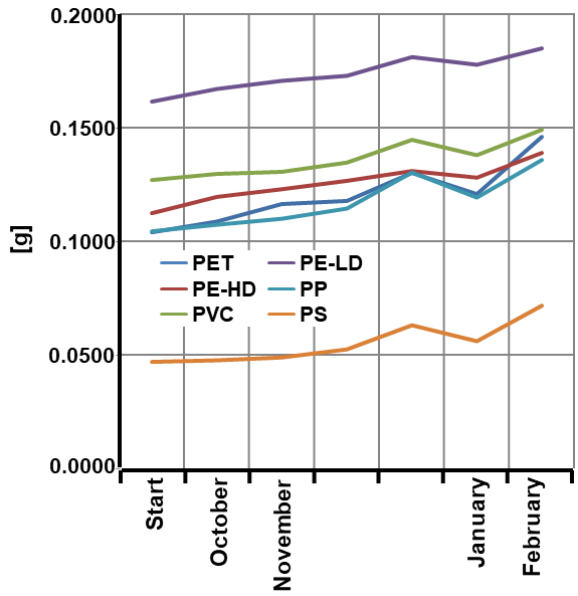

Fig. 13. Cell 2 biomass growth at 50%

As can be seen from the following two Figs. 13 and 14, for the measuring points two at 50% (50 ft), and three at 75% (75 ft), a similar growth rate of the samples is shown. However, they cannot be compared with the increase in biomass growth as shown in measuring point one. It is by far less. It can also be seen here how the influence of the environment (temperatures and seasons) as well as bacteria are present. Measuring point, one has mostly aerobic bacteria present, while at measuring point 2, aerobic and anaerobic microorganisms are present. Measuring point 3 mostly contains anaerobic bacteria [14]. In addition, as the WW makes its way through the STFCW it is purified and less contamination is present at measuring points 2 and 3.

The total biomass growth for the 50% (50 ft) measuring point of Cell 2 was 0.0419 g for PE-HD, 0.0263 g for PE-LD, 0.0217 g for PP, 0.0233 g for PS, 0.0314 g for PET and 0.0248 g for PVC during the evaluation period. Indicating that plastic types of PE-HD and PVC are particularly preferred as biomass growth media.

Based on the above, at the measuring point 3 at 75% (75 ft) in Cell 2, as shown in Fig. 14, it is no longer possible to see exactly which plastic material is preferred for biomass growth. Therefore, due to the level of purified WW at measuring point 3 and its flow along the foundation of the cell, as well as the presence of anaerobic bacteria, it plays no longer a significant role for biomass growth and the preference of the type of plastic material as growth media.

The total biomass growth for the 75% (75 ft) measuring point of Cell 2 was 0.0226 g for PE-HD, 0.0229 g for PE-LD, 0.0166 g for PP, 0.0157 g for PS, 0.0171 g for PET and 0.0153 g for PVC during the evaluation period. Indicating that plastic types of PE-HD and PE-LD are particularly preferred as biomass growth media.

3.2 Cell 3

Cell 3 and 4 operate as a through flow cell to reduce nitrogen in the WW received from Cell 1 or Cell 2 which operate at an approximately 24-hour fill drain cycle.

The biomass growth experiment at Cell 3 and 4 basically show the same continuous increase in biomass, which is interrupted by the same fluctuations due to the same influencing variables (temperature and bacterial activity) as in cells one and two. However, for Cell 3 and 4 an additional factor in cells three and four, was responsible for a low minimal biomass growth in the month of November, see Figs. 15 to 19. In November, Cell 3 and 4 were inexplicably completely flooded due to a severe weather event. This caused too much water mass to affect the system, and the flow rate increased, whereupon some of the biomass on the individual samples might have been removed. However, this problem was solved quickly, and the cells were in perfect use again from December on and the samples gained biomass growth again.

The total biomass growth for the 25% (25 ft) measuring point of Cell 3 was 0.0328 g for PE-HD, 0.0543 g for PE-LD, 0.0525 g for PP, 0.0389 g for PS, 0.0405 g for PET and 0.0290 g for PVC during the evaluation period. This indicates that plastic types of PE-LD, PP and PET are particularly preferred as biomass growth media.

In Fig. 15, it can also be seen that the first measuring point at 25% (25ft) has relatively good biomass growth. However, this growth rate cannot be compared to the measuring points at Cell 1 and 2 at the 25% (25ft) measurement points. from cell one and cell two. An explanation is that the through flow Cell 3 and 4 receive already treated waste water with minimal contamination except with residual ammonium which is converted by nitrifying bacteria present in Cell 3 and 4.

Measuring point 2 at the 50% (50ft) mark shows a similar growth rate of their samples. However, they cannot be compared with the increase in biomass growth as shown in measuring point one. It is significantly lower there.

The total biomass growth for the 50% (50 ft) measuring point of Cell 3 was 0.0250 g for PE-HD, 0.0242 g for PE-LD, 0.0231 g for PP, 0.0205 g for PS, 0.0227 g for PET and 0.0170 g for PVC during the evaluation period, indicating that no specific plastic material is preferred as biomass growth media.

Measuring point 3 at 75% (75 ft) of Cell 3 indicated that there is no longer possible to make a clear statement about which plastic material is actually preferred for biomass growth. All plastic samples gain weight by the same amount and therefore it cannot really be differentiated based on their biomass increase.

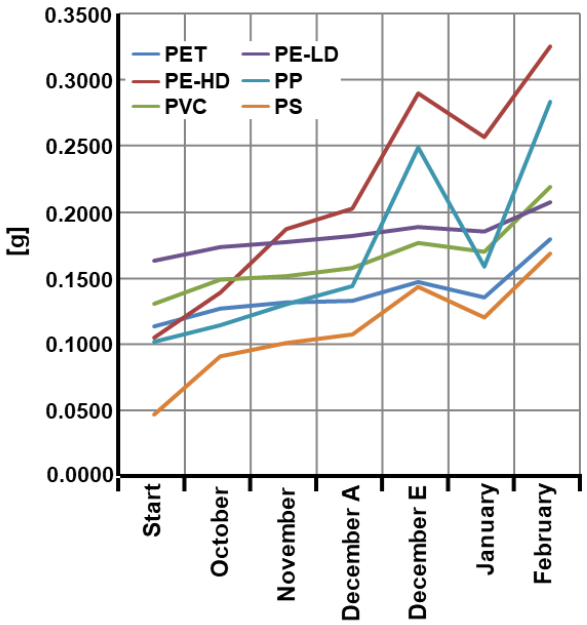

Fig. 14. Cell 2 biomass growth at 75%

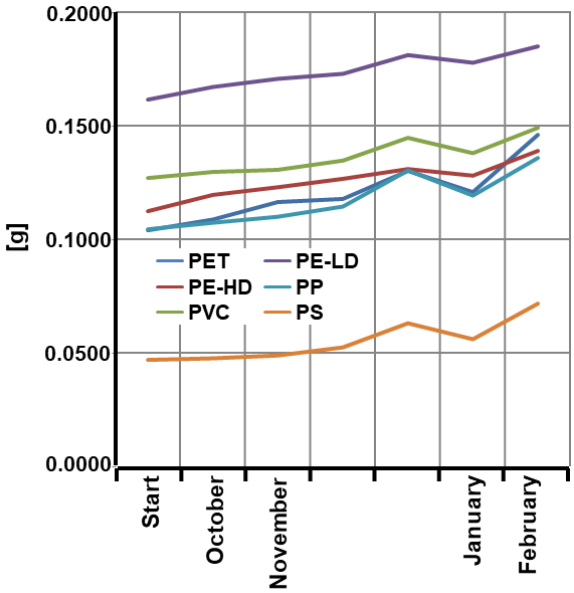

Fig. 15. Cell 3 biomass growth at 25%

The total biomass growth for the 75% (75 ft) measuring point of Cell 3 was 0.0218 g for PE-HD, 0.0206 g for PE-LD, 0.0284 g for PP, 0.0243 g for PS, 0.0285 g for PET and 0.0201 g for PVC during the evaluation period. This indicates that no plastic type tested was particularly preferred as biomass growth media.

Cell 4 is very similar to its partner cell three. The same fluctuations can be observed here too, the flooding causes only a slight initial drop in biomass growth. The only difference is that in Cell 4 there were only two measurement sites at 33% (33ft) and 66% (66 ft) of the cell length. Nevertheless, the same results as in cell three were achieved. Figs. 18 and 16, show that the first measuring point has relatively good biomass growth.

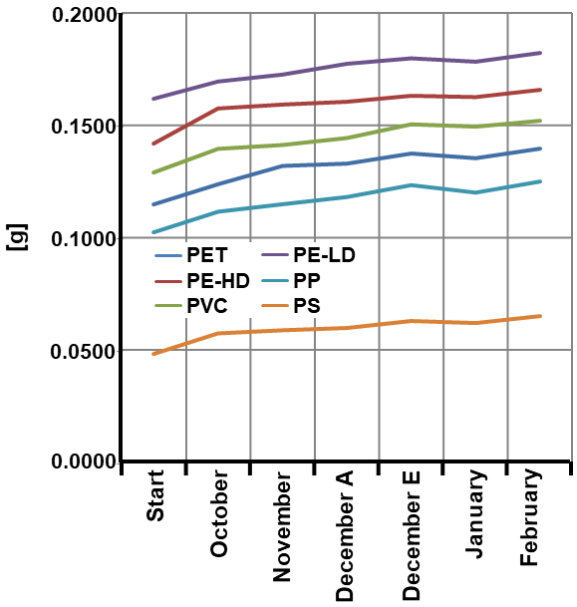

Fig. 16. Cell 3 biomass growth at 50%

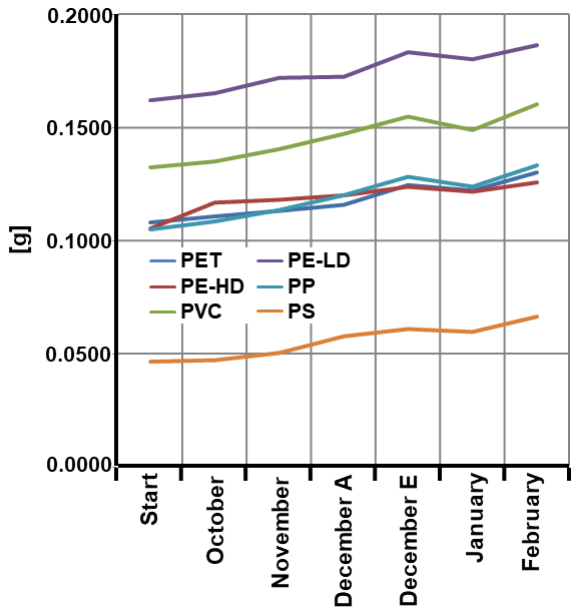

Fig. 17. Cell 3 biomass growth at 75%

The total biomass growth for the 33% (33 ft) measuring point of Cell 4 was 0.0355 g for PE-HD, 0.0407 g for PE-LD, 0.0411 g for PP, 0.0357 g for PS, 0.0387 g for PET and 0.0335 g for PVC during the evaluation period. This indicates that plastic types of PE-LD, PP and PET are particularly preferred as biomass growth media.

The second measurement point at 66% (66 ft), it can also not determine anymore which plastic growth media is preferred for biomass growth. All plastic materials gain weight by almost the same amount and therefore it cannot be differentiated between the plastic growth media.

The total biomass growth for the 66% (66 ft) measuring point of Cell 4 was 0.0172 g for PE-HD, 0.0193 g for PE-LD, 0.0206 g for PP, 0.0213 g for PS, 0.0224 g for PET and 0.0252 g for PVC during the evaluation period. This indicates that plastic types of PS, PET and PVC are particularly preferred as biomass growth media.

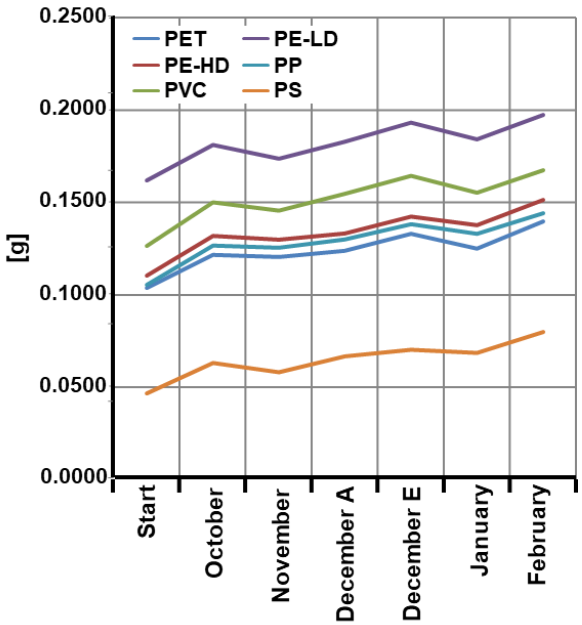

Fig. 18. Cell 4 biomass growth at 33%

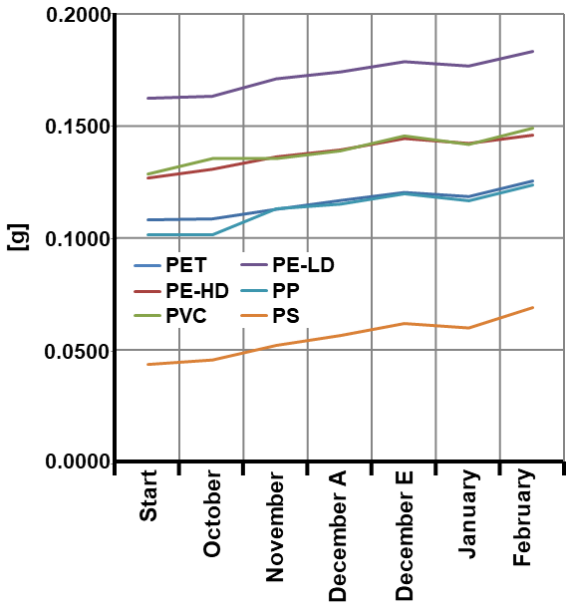

Fig. 19. Cell 4 biomass growth at 66%

3.3 Pump Station

The biomass growth samples placed in the pumping station that receives the effluent of Cell 3 and 4 of the constructed wetlands is not affected by the temperature fluctuations, as can be seen in Fig. 12. This is because this station is not directly connected to the outside environment and is located several feet underground where the treated WW is not influenced by temperature and other environmental factors. As a result, there is a continuous and significant biomass growth on almost all samples except for the PS plastic type.

The total biomass growth for the Pump Station measuring point was 0.0777 g for PE-HD, 0.0728 g for PE-LD, 0.0467 g for PP, 0.0940 g for PS, 0.1040 g for PET and 0.0205 g for PVC during the evaluation period. This indicates that plastic types of PE-HD, PS and PET are particularly preferred as biomass growth media.

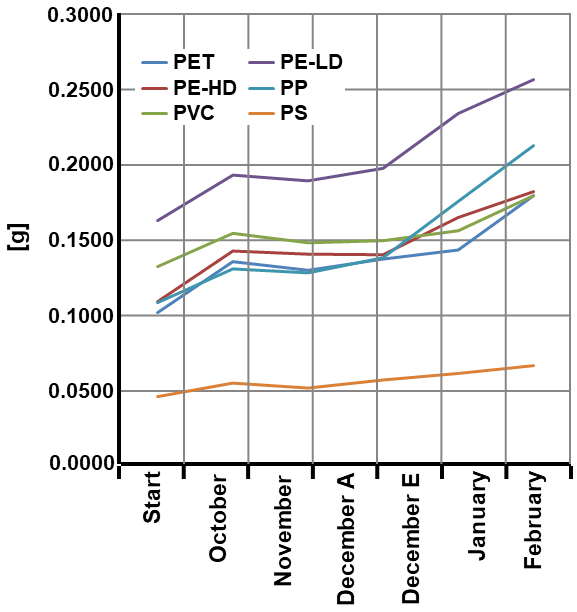

Fig. 20. Pump station biomass growth

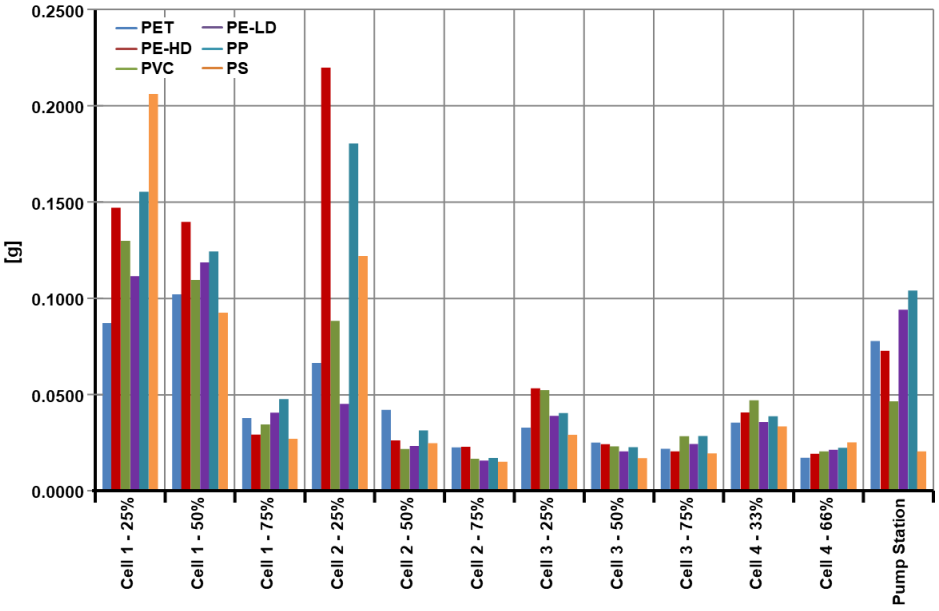

Fig. 21. Combined biomass growth

3.4 Determining Best Growth Media Plastic Material

Fig. 21 shows the tested plastic material PET, PE-HD, PVC, PE-LD, PP, and PS in relation to total biomass growth. It is noticeable that each measuring point prefers a different type of plastic, which in turn is based on the different prevailing conditions. Furthermore, it can be seen in the diagram that the measuring locations of Cell 1 had the most biomass growth at 25% (25ft) and 50% (50ft) and 75% (75ft) location compared to Cell 2, 3 and 4.

The pump station showed a biomass growth on the various plastic materials comparable between the 50% (50ft) and 75% (75 ft) measuring point of Cell 1, but significantly larger then Cell 2, 3 and 4, except for the 25% (25 ft) measuring point of Cell 2.

Table 2. Preferred plastic growth media

Sample Point	Preferred Growth Media; [Biomass Growth in g]
Cell 1 – 25%	PE-LD [0.1473 g], PET [0.1555 g], PVC [0.2062g]
Cell 1 – 50%	PE-LD [0.1214 g], PS [0.1017 g], PET [0.1026 g]
Cell 1 – 75%	PE-HD [0.0338g], PS [0.0399 g], PET [0.0442 g]
Cell 2 – 25%	PE-LD [0.2201 g], PET [0.1805], PVC [0.1221 g]
Cell 2 – 50%	PE-HD [0.0419 g], PE-LD [0.0263 g], PET [0.0314 g]
Cell 2 – 75%	PE-HD [0.0226 g], PE-LD [0.0229 g], PET [0.0171 g]
Cell 3 – 25%	PE-LD [0.0543 g], PP [0.0525], PET [0.0405 g]
Cell 3 – 50%	PE-HD [0.0250 g], PE-LD [0.0242 g], PP [0.0231 g]
Cell 3 – 75%	PP [0.0284 g], PS [0.0243 g], PET [0.0285 g]
Cell 4 – 33%	PE-LD [0.0407 g], PP [0.0411 g], PET [0.0387 g]
Cell 4 – 66%	PS [0.0213 g], PET [0.0244 g], PVC [0.0252 g]
Pump Station	PE-HD [0.0777 g], PS [0.0940 g], PET [0.1040 g]

Table 2 gives the three preferred plastic growth media for the individual measuring points in Cell 1 to 3 and the Pump Station including the measured biomass growth in grams.

Based on the Table 2 PET is the most preferred growth medium for all measuring points followed by PE-LD, PS and PE-HD as well as PVC for certain locations.

4. CONCLUSION

Increased environmental awareness and the need to advance and develop WW treatment processes for future challenges. Implementing and using recycled plastic materials as growth media might be a route to improving already existent technical processes that are inspired by natural biological processes, leading to a more environmentally friendly and sustainable process.

The focus of this research performed at the CERF at the WWTP of the Village of Mona in NY State WWTP under actual operating condition using clarified WW was to suggest future growth media for their STFCW operation.

Six recycled plastic materials; PET, PE-HD, PVC, PE-LD, PP, and PS, were used for the growth media experiments in the commercial operated STFCW.

Testing was conducted starting October 1st with measuring the test specimens for their biomass growth at a 3-week time interval that allows bacteria to generate a biomass film on the test specimen. Testing was concluded in the 2nd week of February.

Biomass growth was observed on all types of plastic material at the measuring points.

Results show that PET is the most preferred growth medium for all measuring points followed by PE-LD, PS and PE-HD as well as PVC for certain locations.

Future research on STFCW using recycled material for biological processes should focus on these recycled plastic types.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Author has declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the author(s) and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by

the producing company rather it was funded by personal efforts of the author(s).

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