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Is there an effective way of treating the fatberg crisis occurring in our sewer systems?

Abstract:

Fatbergs are the product of fat, oil and grease being thrown the drain as well as other things which don't break down in water (e.g. wet wipes, syringes, sanitary products). This is due to an increase in population leading to an increase in restaurants and as there aren't good regulations which forcibly make these restaurants install proper grease traps it causes these fatberg appearances to increase. The same applies to companies who produce 'flushable' wet wipes as these wet wipes are not actually flushable which also causes these fatbergs to build up. To combat this problem we have looked at the different methods at solving this problem but focused mainly on how we can engineer bacteria to break down the fatberg and have it act as a long term solution. However, along with this solution the best way, we found, to prevent fatberg formation is public awareness.

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Introduction:

Fatbergs are accumulated, congealed masses of fat, oil and grease (known as FOGs), which clog up our sewer systems causing blockages in these systems preventing water to flow in this system. If this blockage continues to build up, then it would lead to a serious issue where sewage would have nowhere to go and in the worst-case-scenario sewage will start flowing back up pipes. One main contributor to the formation of fatbergs are wet wipes, these (along with the oil and grease from restaurants and homes) are flushed down the toilet and most of them are creating fatbergs as it helps the fat and oils in the sewers to condense into one solid mass. This is because most wet wipes that are labelled as flushable aren't actually flushable meaning that they don't dissolve in water. These are wet wipes made of polypropylene, which means they don't dissolve/break down in water. One company who created one particular set of "flushable" wipes said, '…the reason we originally stated flushable was because the wipes were small enough to flow through the system without causing blockages in the home.' (1) This indicates how the biggest cause of fatbergs is being uneducated about the issue.

As cities expand so does the population of that city, as a consequence of this, more and more FOGs are being dumped into the sewer system leading to more fatbergs being formed. Currently, fatbergs are being formed in cities all over the world however in just London alone there were at least five fatbergs of notable size (2), and the most notable one found was the one in Whitechapel where a 250 metre long, 130 tonne fatberg was found and each day 20-30,000kg was removed (3). It cost Thames Water £1 million a month in order to unblock the sewers and from it, 10,000 litres of biodiesel could be produced (4).

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Fatberg Formation:

The main reason for the formation of fatbergs in sewer systems is that fatty acids, formed from the hydrolysis of triglycerides in the FOGs undergo a saponification process (conversion into soap) along with calcium from the eroded concrete that the sewers are made out of. This causes the formation of fatberg soaps which is the main culprit for the fatberg forming. Embedded within these fatberg soaps are wet wipes, used needles, diapers, etc. which altogether creates the fatberg problem [5].

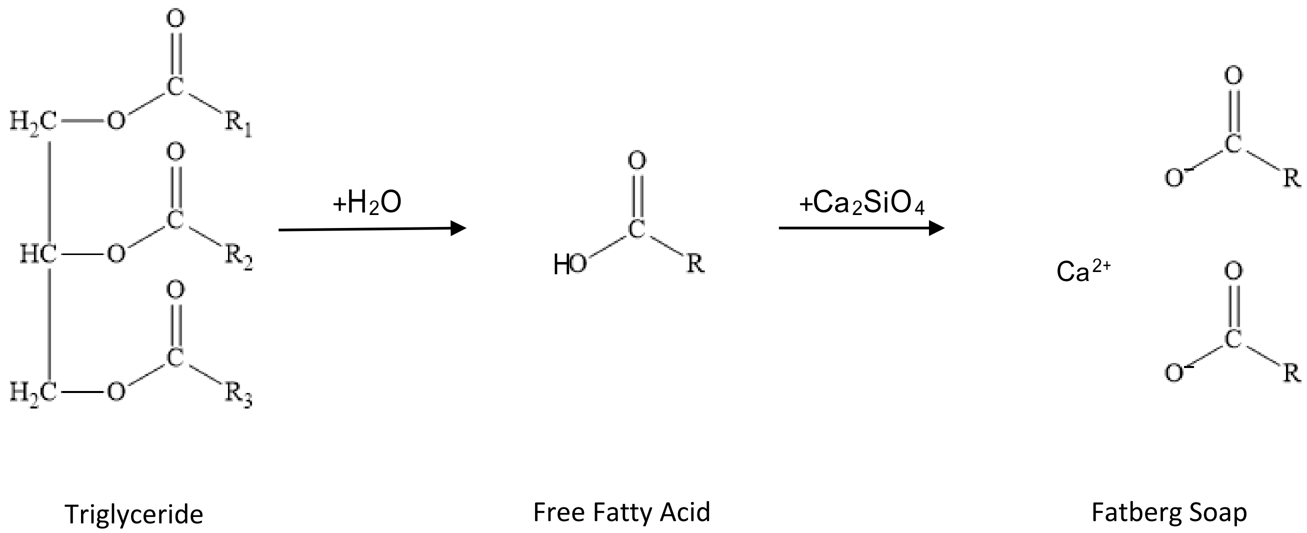

Figure 1. The chemical process of fatberg formation (saponification)

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Fatberg Composition: [6]

Cranfield University analysed the contents of a fatberg sample from the Whitechapel fatberg. It was first dried at 105°C to remove any water present and afterwards it was placed in an oven at 550°C to get rid of any volatile substances within it. After the analysis, these were the results obtained:

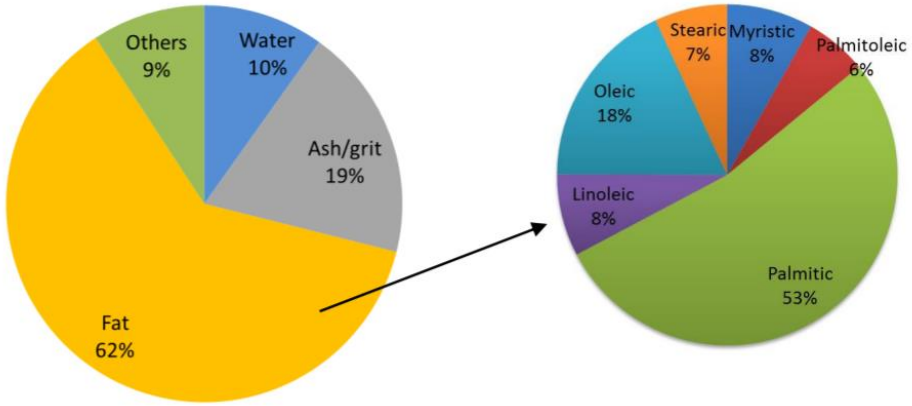
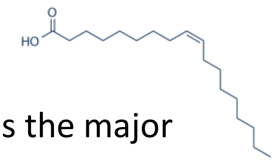


Figure 2. On the left is the composition of the Whitechapel sample received, on the right is the specific fatty acids that were found within the portion of fat found within the sample.

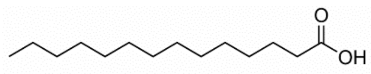
Breakdown of the fatty acids found:

- 53% of the fat was Palmitic acid ($CH_3(CH_2)_{14}COOH$), this is a saturated fat typically found mainly in palm and olive oils as well as butter, cheese, milk and meat.

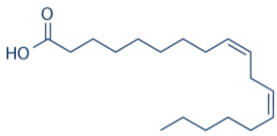
- 18% of the fat was Oleic acid ($CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$), this is an unsaturated fat and is the most abundant fatty acid in nature, and is the major part of plant oils such as olive oil and almond oil.



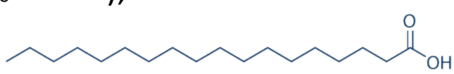
- 8% of the fat was Myristic acid ($CH_3(CH_2)_{12}COOH$), this is a saturated fat found mainly in palm, nutmeg and coconut oils, used in soap and cosmetics.



- 8% of the fat was Linoleic acid ($CH_3(CH_2)_4CH{=}CH(CH_2)CH{=}CH(CH_2)_7COOH$), this is a polyunsaturated fat found mostly in plant oils.



- 7% of the fat was Stearic acid ($CH_3(CH_2)_{16}COOH$), this is a saturated fat found in animal and plant fats and used primarily in cocoa and shea butter.



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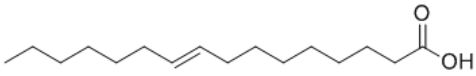
- 6% of the fat was Palmitoleic acid ($CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$), this is an unsaturated fat found in macadamia and Sea Buckthorn oil and used for lubricants.



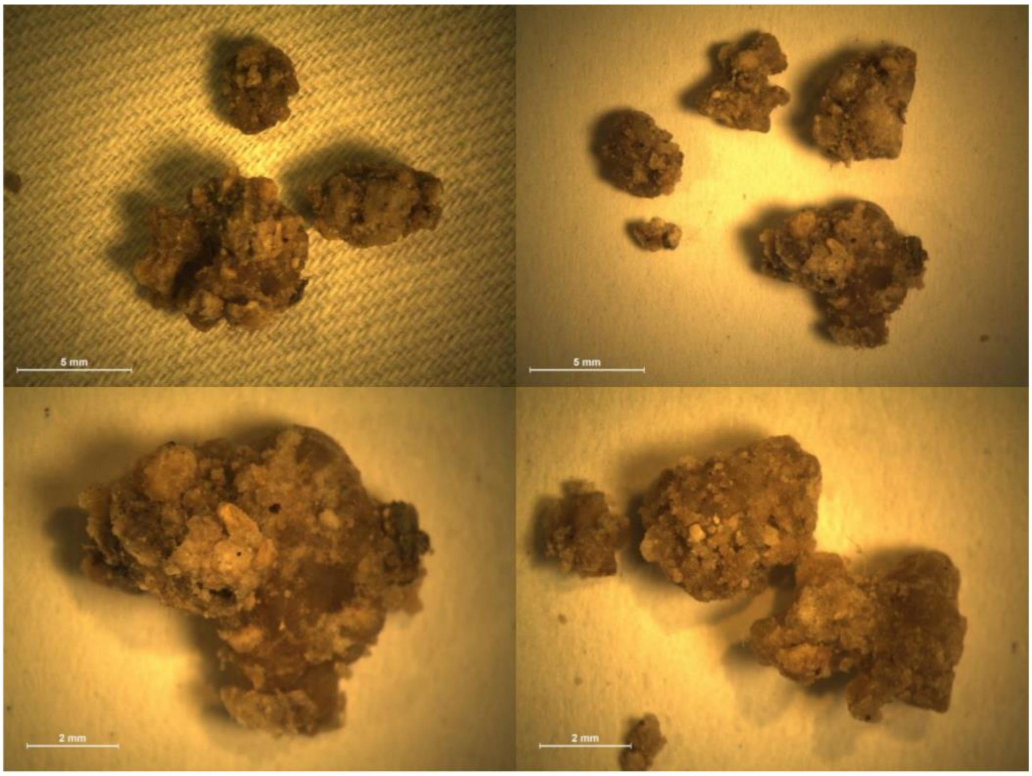


Figure 3. The fatberg sample under an optical microscope

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Possible Methods to remove fatbergs:

There are three possible routes that can be taken in order to remove fatbergs: the mechanical method; the chemical method and the biological method.

Mechanical:

One company called Hydro Cleansing uses water jets in order to physically break down the fatbergs. They have two high-powered tankers (called Megatron and Terminator) which are able to break down fatberg and solid concrete and can remove the smaller chunks without the need of anyone going down into the sewers [(7)], this is useful as within these sewers deadly H_2S gas builds up which is toxic to humans [(1)]. Furthermore, Megatron has a recycling system on it which can filter out water which is then re-used for jetting. However, for fatbergs that have grown to a substantial size, they use super combination tankers which have UHPWJ (ultra high-pressure water jetting), this can spray water out at 4000psi (27.6MPa) [(7)].

Chemical:

One method proposed to break down the fatberg chemically is to: 'heat the fatty deposits up to temperatures between 90 and 110 degrees Celsius… and mix in hydrogen peroxide, which kickstarts the breakdown process.'[(8)] .This only breaks down the fat in the fatberg, leaving the wet wipes and other things to be drained down the sewer. However, when the water and the hydrogen peroxide mix, it forms a weakly acidic solution which creates a different problem.

Biological:

This is the method we focused on in our project, this involved engineering bacteria (specifically E. coli) to have an up-regulated form of the lipase gene which is able to break down fats into triglycerides however this could also be problematic as these triglycerides can undergo saponification as long as there are high calcium levels within the sewers which remake a fatberg. The lipase would catalyse an esterification which combines the triglycerides with ethanol, this also means that the bacteria need to have a gene which allows them to survive within the ethanol.

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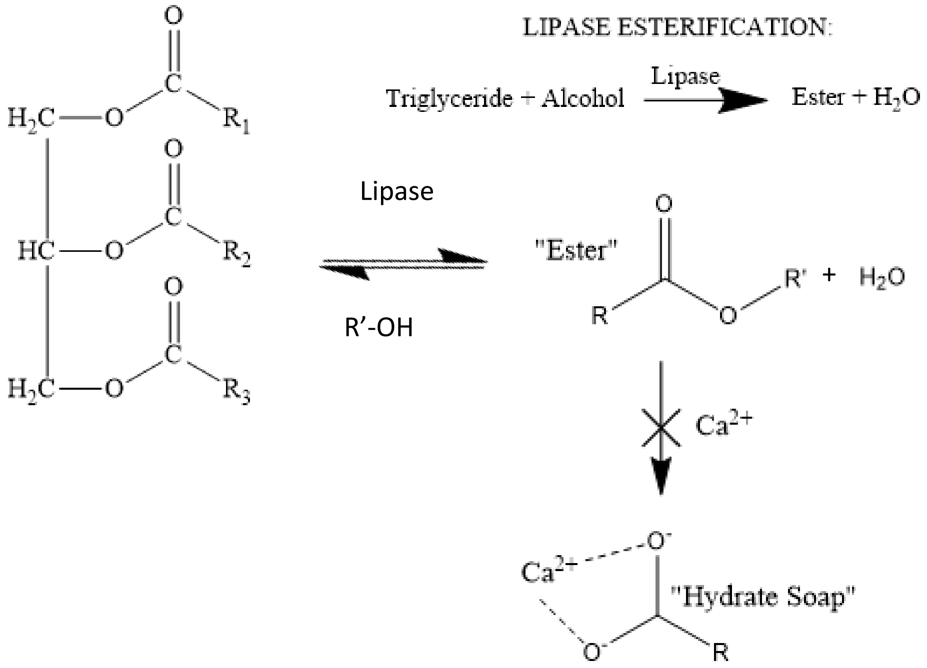

Figure 4. The chemical process of the lipase breakdown of the triglycerides, what we are trying to prevent in this process is the production of the 'Hydrate Soap'

Another method of using bacteria is to instead target the cellulose that makes up most of the wet wipes within the fatberg rather than the triglycerides. This has its own advantages and disadvantages, especially since there wouldn't be a need to pour ethanol into the sewer system and there wouldn't be the fear of the fatberg reforming.

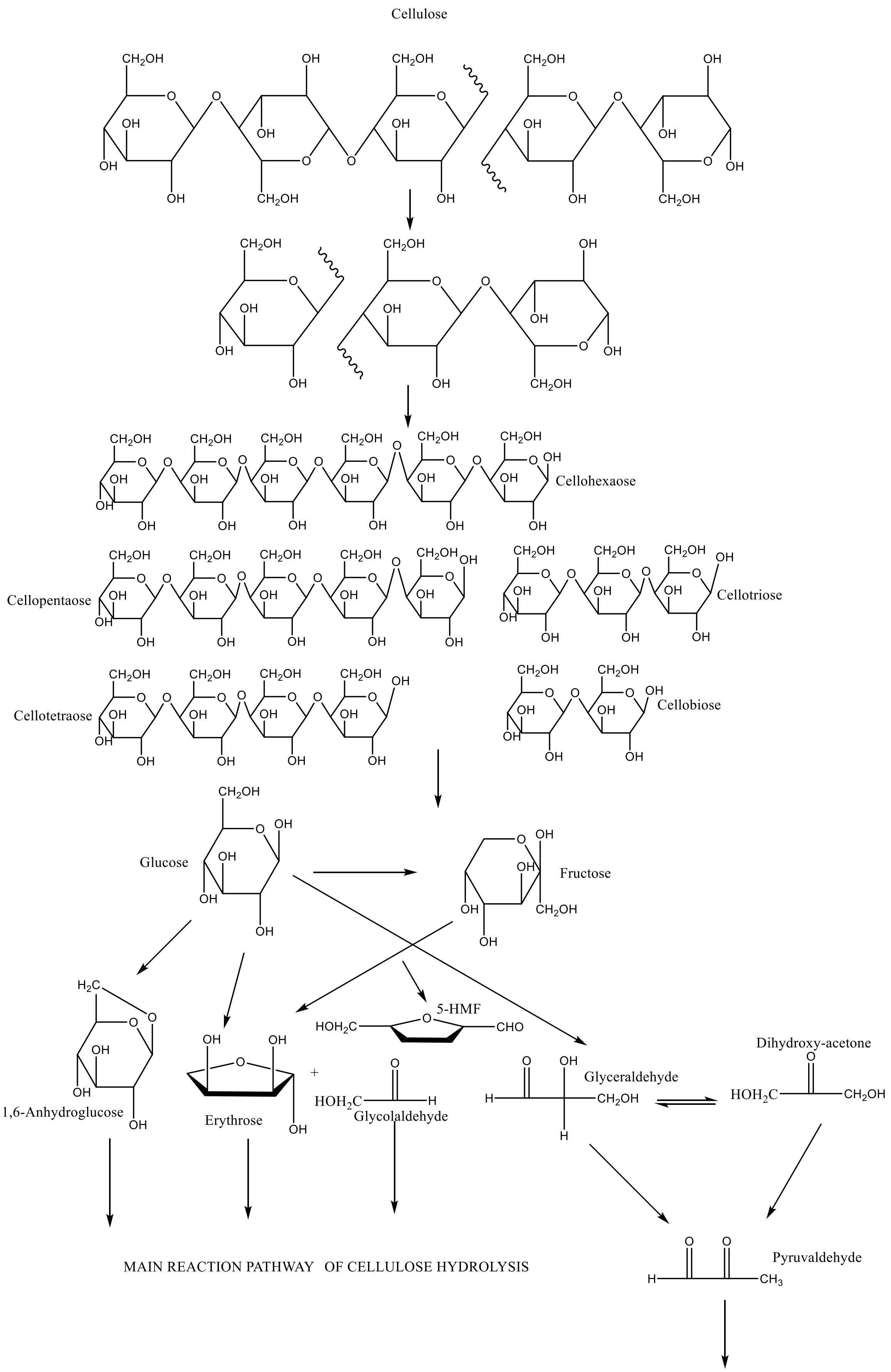

Figure 5. The chemical process of the cellulose breakdown

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Labs:

In the labs, tested whether the bacteria could survive under high concentrations of oil to replicate the conditions found in the sewers. First, we made a 10% triton/oil stock. This was done by adding 10ml of Triton to 90ml of sterilised water into a conical flask, which was then incubated at 37°C 150rpm until it solubilised. The 10% solution was then sterilise filtered and oil was added in a 2:1 solution so for a 90ml stock, 45ml oil is added. This was then incubated at 37°C 150rpm until it solubilised. Then, in pre-labelled bottles form concentrations of oil agar of 0.5%, 1%, 5% and 10%. See table below for volumes of each solution. Then, for each concentration, six plates were produced which had 25ml of the solution in them. The E. coli was then spread on five of the six plates and one was left empty, this was done for each concentration.

Table 1. Volumes of stock solution and LB-a needed to make the different concentrated solutions

Concentration of Solution/%	Volume of stock solution/ml	Volume of LB-a/ml
0.5	2.25	147.75
1.0	4.50	145.50
5.0	22.5	127.5
10	45.0	105.00

Results:

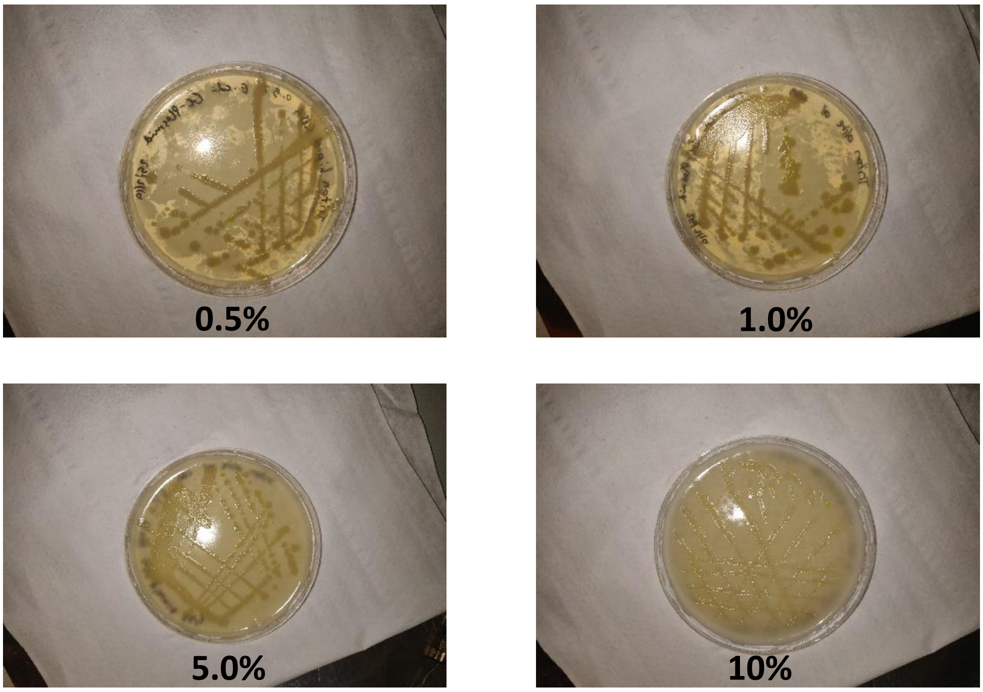

Figure 6. Photos of the plates with the concentration used underneath each photo

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From these photos you can see that even at 10% concentration, the bacteria still grew and multiplied, and as these are similar to the conditions in sewers. This means that these bacteria are ideal for use in the sewers as they won't die out due to high oil concentration.

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Conclusion:

In conclusion, we have found that the biological method is the most optimum if the bacteria correctly expresses the lipase/cellulase gene as this doesn’t require constantly having to deploy machines or to release chemicals into our sewer systems and causing them to become acidic. These bacteria are able to survive in these oily conditions as shown by the plate experiment so E. coli are a good carrier of the enzyme gene. Also, there are many different types of E. coli available which all have different purposes so this makes it versatile as there are some which can express the genes within their plasmids better, which is ideal for this project. There is a risk of saponification if the lipase route is taken, which makes the cellulase method a lot more viable as wet wipes make up a lot of the fatberg, however, there are certain types of wet wipes where it’s made out of non-cellulose material such as polypropylene.

Even with all these methods, the best way to stop fatbergs is public awareness. This is because the public isn’t aware of what’s being formed underneath them as well as the fact that they trust companies who make ‘flushable’ wet wipes and they aren’t going to test whether these wet wipes are actually flushable or not. So a good start would be to tell the public that flushing wet wipes as well as pouring oil down the sink is very bad and showing them what it’s causing and what it could lead to would be very useful. Also, regulations need to set in place to prevent restaurants from tipping their used oil into the drain, this can be done by enforcing a law where all restaurants need to install a grease trap, maintain and be inspected every year.

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References:

(1) – 'Fatberg Autopsy: Secrets of the Sewers' Presented by Rick Edwards (2018) https://www.channel4.com/programmes/fatberg-autopsy-secrets-of-the-sewers/on-demand/67354-001

(2) – Fatberg (Last edited 22/07/2019) https://en.wikipedia.org/wiki/Fatberg

(3) – "'Monster' fatberg found blocking east London sewer" (12/09/2017) https://www.bbc.co.uk/news/uk-england-london-41238272

(4) – 'Fatbergs: 90% of London restaurants are contributing problems' Chris Johnston (11/10/2017) https://www.bbc.co.uk/news/uk-england-london-41238272

(5) – 'Fats, oils & grease (fog) waste monitoring in sewer networks using sensor technology' Conor R. Broderick, Thomas P. Curran (2018) https://www.researchgate.net/profile/Wen_Hao_Su2/publication/328049145_DISCRIMINATION_OF_ORGANIC_WHEAT_FLOUR_FROM_OTHER_FLOUR_VARIETIES_BY_NEAR-INFRARED_NIR_HYPERSPECTRAL_IMAGING/links/5bb4e371a6fdccd3cb84fe95/DISCRIMINATION-OF-ORGANIC-WHEAT-FLOUR-FROM-OTHER-FLOUR-VARIETIES-BY-NEAR-INFRARED-NIR-HYPERSPECTRAL-IMAGING.pdf#page=194

(6) – Cranfield Water Fatberg Analysis

(7) – 'Fatberg Removal Services' Hydro Cleansing https://hydro-cleansing.com/services/fatberg-removal.php

(8) – "The Monstrous 'Fatbergs' Lurking Below Cities Might Have a Surprisingly Important Benefit" Peter Dockrill (24/08/2018) https://www.sciencealert.com/monster-fatbergs-clogging-sewers-valuable-source-biofuel-methane-bacteria

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