FATS, OILS and GREASES: (FOG)

Keith Davis - An Opinion and some facts

Treatment in 'Grease Converters" using Bioadditives

September 2013

BACKGROUND

From 1994 until final retirement in December 2012 the writer was the technical adviser to a community liaison group of local residents that may have been adversely affected by the building of Wellington's Moa Point Wastewater Treatment Plant. The treatment plant came into operation late in 1998 and whilst there were some teething problems the major one was related to the discharge of odours. In 2008-09 a problem began to appear with FOG build up in the wet well of the treatment plant's inlet pumping station. Not only was there a problem with the build up of odorous FOG that had to be physically tankered away but there was also interference with the station's pump control systems. Having been associated with early experiments on 'bioaugmentation' back in 1973 whilst working for Ministry of Works and Development at the Wastewater Treatment Plant Operator Training School at Trentham the writer undertook a review of the likely cause of the increase in FOG levels being found in the wet well of the Moa Point inlet Pumping Station. The following has been written as a technical narrative suitable for general consumption.

INTRODUCTION

Fats, oils and greases (FOG) have been a major problem for sanitary service providers since the advent of piped waste disposal systems. The first FOG trap was patented by Whiting in California at the end of the nineteenth century. The trap was a simple tank with a pipe inlet and outlet and has remained unchanged for over a hundred years even though the makeup of FOG has changed from being basically made up of fats that were solid at room temperature, to a multiplicity of both solid fats, and now oils that remained liquid at all temperatures.

Today's modern living, together with changes in eating habits has produced a multitude of efficacy problems with traps based on the original Whiting design. To overcome the problems there have been a variety of inlet and outlet structures devised and baffles inserted but still the problems continue. In the USA it has been noted that about 50% of sewer network blockages can be attributed to FOG accumulating in pipelines and at pumping station wet wells. The term grease trap has now been superseded by the term FOG Interceptor (FOGI).

A perusal of various reports and newspaper articles the FOG problem can be attributed to a number of reasons including the belief that FOG dissolve in hot water and that interceptors only require emptying or have any maintenance carried out a couple of times a year. Some early workers even claimed that FOGI did not need cleaning at all.

This review looks at one particular method of FOG disposal based on bioaugmentation.

BIOADDITIVES and BIOAUGMENTATION

- Bioadditives can be best described as a mixture of bacterial cultures together with a range of nutrients plus lipase. The essential element of the bioadditives mixture is lipase that is also produced by the bacterial cultures in the bioadditives. The process is also referred to as bioaugmentation and the process carried out in a tank generally referred to as a 'grease converter'.

- Lipase is triacylglycerol lipase, an enzyme (or more exactly a group of enzymes) belonging to the esterases that hydrolyse fat (present in ester form, such as glycerides) yielding fatty acids and glycerol. Optimum temperature for enzyme action is between 35ºC and 37ºC and at pH 5-6. Preferably closer to 6.0.

- Short-chain volatile fatty acids (VFA) due to the fact that they are miscible (mix with water as the molecules remain intact and fit between the molecules of water) can be separated by distillation and are therefore readily identifiable. Alternative methods are required for total fatty acid determinations.

- Short-chain fatty acids that are miscible with water have unpleasant odours. Long-chain fatty acids, such as stearic acid found in animal fats, are solid and most have little or no odour although souring can occur on the surface if left to stand.

- Those marketing bioadditives throughout the world claim that by their use, there is a substantial decrease in carbonaceous biochemical oxygen demand ($cBOD_5$). This may be the recorded value of a sample but it is not the true picture as the same samples chemical oxygen demand (COD) is substantially increased. This COD can be considered as the $cBOD_5$ in disguise as, in the wastewater treatment system, as a result of further bacterial and enzyme action in an aerobic environment much of the COD, can now be measured as $cBOD_5$. Low effluent $cBOD_5$ values being due to the fact that the pH value of the effluent is sufficiently low so as to bring about the denaturing of most of the living organisms in the effluent stream.

- There are some forty FOG trap formulations on the market many of which can be added directly to the waste flow as well as be used in a FOG interceptor or 'grease converter' as they are sometimes termed. These include Ecolab Actizyme, Actazyme, Eco-Green, Fat-Bio, Grease-Eater, Grease-Grabber, Grease Express, Russel Reid Hungry Bugs, NuTech Bio, EnviroClear, Grease Guzzler® in UK, Swish Grease Trap

Cleaner and many more. Nearly all claim the bioadditives consist of lipase and selected bacterial cultures along with nutrients and other additives including fillers.

- Most companies claim carbon dioxide and water to be the end products *in situ* with the liberation of heat energy. See p 11 for one patent application and the probable reasons why such claims are being made. A couple cite the need for oxygen to achieve complete breakdown of FOG to carbon dioxide and water, whilst one acknowledged that the addition of bicarbonate to maintain a 'good' pH did more harm than good as it encouraged the production of methane that in turn caused a small explosion when a cast-iron manhole was being removed from the FOG interceptor. These comments suggest that many commercial firms have a lack of understanding of the biochemical processes involved with the use of bioadditives.

- One firm is now marketing a mini-moving bed bioreactor with bio-additives and aeration using compressed air but at significant cost (aeration diffuser US $895.00, compressor US $395.00, odour control US $350.00, hoses and pipe work US $75.00) in addition to the cost of the various bioadditive options available which range up to US $465.00 for a 10L pail and considerable electrical energy costs.

- Figs 1 and 2, page 9 shows how some 'grease converter' effluent $cBOD_5$ results may be misleading. The accompanying high COD value is most likely to be made up mainly of fatty acids and glycerol that in turn can add to the organic load on a wastewater treatment plant. It should be noted that the COD value is the sum total of all the fatty acids, glycerol, residual FOG and any extraneous organic matter that may be present.

- Glycerol may not be attacked readily biologically in a grease converter. There is little degradation under non-controlled anaerobic conditions that prevail at most times. Under aerobic conditions, glycerol is readily decomposed by Aerobacter and *E.coli.* Glycerol is also readily fermented by *Enterobacteriaceae.* With *E.coli* the end products are mainly alcohol, and carbon dioxide; with Aerobacter (requiring oxygen) they are mainly alcohol and acetic acid. As neither group of bacteria is present in a kitchen waste stream any such fermentation is unlikely to take place in a 'grease converter'. Fermentation can occur in the sewer network and at a treatment works where faecal matter is present and where acclimatised aerobic conditions prevail. Glycerol therefore, also becomes part of the potential $cBOD_5$.

- Where high sulphates or seawater are contained, such as in the normal waste stream, as occurs in Wellington, fatty acids increase levels of hydrogen sulphide being produced in the wastewater disposal system especially in the summer months. The complex biochemistry is not expanded on here but a simple FOG degradation pathways diagram is shown on p10. In simple form the basic equation for hydrogen sulphide production in the presence of sulphate and volatile fatty acids can be summarised as follows;

$$CH_3COOH + Na_2SO_4 = Na_2CO_3 + H_2S + CO_2 + H_2O$$

- In this simple equation acetic acid is the organic donor of hydrogen for the reduction of sodium sulphate to produce sodium carbonate, hydrogen sulphide, carbon dioxide and water. A portion of the hydrogen sulphide can then be oxidised by further bacterial action to sulphuric acid. Both hydrogen sulphide and sulphuric acid are then considered to be the major corrosion causing agents in any wastewater disposal system.

- FOG itself has no measurable $cBOD_5$ as it separates from water and is not available for microbiological attack. If a value is desired it best be established using the COD test.

- During a literature research on the use of bio-additives one interesting paper was found entitled "Grease biodegradation: Is bioaugumentation more effective than populations for start-up?" Mendoza-Espinosa, Tom Stephenson, School of Water Sciences, Cranfield University, Bedford, UK 1999. They determined that, under optimum conditions, normal activated sludge was able to degrade FOG at nearly the same rate as a bioadditives solution. Moreover, the bioadditives and the activated sludge reactors had very similar kinetics of COD removal under different FOG concentrations. It was concluded that the use of natural activated sludge microorganisms was sufficient to acclimatise biological processes to removing FOG.

IMPLICATIONS OF cBIOCHEMICAL OXYGEN DEMAND$_5$ TEST RESULTS

- The $cBOD_5$ test, although used as a quantitative test, is actually a qualitative test with a narrow range of variations that allows it to assume semi-quantitative proportions. It is not an absolute test and may face legal challenge at any time and in particular with industrial discharges. The prime factor in the $cBOD_5$ test is the presence of the appropriate microorganisms in the wastewater itself. Secondary factors include any elements or compounds that act as bacterial inhibitors. These would include heavy metals, acids and alkalis, disinfectants such as phenol and cresol and chlorine

- Variations in the initial bacterial populations may influence the result of a $cBOD_5$ test. Low initial bacterial populations can delay growth quite considerably. This in turn retards protozoa growth resulting in a net reduction of oxygen uptake at the end of 5 days. If the bacteria are not adapted to the waste under test, they will decrease in number until they die or adapt to the substrate. The result is that there is a lag that may exceed the normal duration time of the test resulting low results.

- Where unusual wastes or trade effluents are being dealt with, a suitably acclimatised seed must be used to obtain a true (more accurate) $cBOD_5$. This can be achieved by aerating a mixture of the waste or effluent with settled wastewater until a floc is formed. This may take several days or even weeks to achieve. Many analysts take the easy option of using settled wastewater as seed material but this does not solve the problem with some specific trade effluents and the 'grease converter' is no exception. Once a floc is formed it denotes that microorganisms present have become acclimatised to the waste and can be used as a seed. Trial and error may be needed to develop an appropriate floc or as noted earlier an activated sludge floc (liquor in this case) may be used.

- Mass action laws apply to the test and sufficient dilutions should be used to ensure that there is sufficient dissolved oxygen left at the end of the 5 day test. At least 3mg/L of oxygen should be used and not less than 3mg/L should remain. With an initial DO of 9mg/L this give a 3mg/L working range. With the appropriate seed being use and a range of dilutions used a value within the 3mg-6mg/L range should be found and used for calculating the $cBOD_5$. Experience will determine the number of dilutions required for a particular effluent if tests are being carried out on a regular basis.

- Once it has been established that the COD of the effluent is basically the $cBOD_5$ there is no need to carry out the test again. The COD should by agreement be considered to be all biochemically degradable once the right environment is reached. Return supernatant liquor from a biosolids plant is likely to provide ideal seed material if the biosolids is producing methane under controlled conditions. Treatment plants using Moving Bed Reactors will require additional air (oxygen) and this in turn will require additional energy and operating costs.

- Effluent values; pH 4.5- 5.5 VFA 1,000 -2,800 mg/L COD 2,300 – 3,700 mg/L but numbers depend on the type of bioadditive product being used and the particular FOG makeup.

- The impact of FOG degradation by-products on a treatment plant using diffused air or fine bubble aeration for secondary treatment can be roughly calculated. An example:

  Say COD of effluent 3,000 mg/L = (3.0g/L)

  Daily flow 500L = (0.5 m^3)

  Total COD/d = 3.0 x 500 ÷ 1000 = 1.5 kg.

  Number of units in use = 300.

Total kilograms COD per day = 1.5 x 300 = 450 kg.

Assuming true ($cBOD_5$) = say approx 70%* of COD = 450 x 0.7 = 315 kg.

Power requirements based on kg $cBOD_5$ removed/kWh say 1.0**, power required = 315 kWh.

* It should be noted that the three likely main products will be VFAs, solid fatty acids and glycerol, all of which are readily degradable under aerobic conditions so the value of 70% may be low even though normal $cBOD_5$ is taken as ± 65% of the measured COD.

**The value of 1.0 is approximate only and varies from plant to plant and averaged from a number of plants operating in the UK. These comments about the shortcomings of the BOD test apply to all organic trade wastes and not only to FOG.

- It is considered desirable to ensure that the size of the interceptor chosen will allow a retention time of at least 30 minutes at peak flow rates**.** This should ensure that at least 90% of the incoming FOG is retained in the interceptor. It is, however, acknowledged that many overseas authorities require a one-hour retention time at peak flow. An issue that needs to be looked at by territorial authorities

- FOG removal rates are best achieved at near room temperatures. The use of hot water to disperse solid FOG wastes should be discouraged. The higher the temperature the smaller the globules of FOG.

- Colloidal systems involving the dispersion of one liquid into another are known as emulsions. Both must be immiscible in each other. With regard to FOG, water is the second component with a third component the emulsifying agent to keep the emulsion stable. Destabilization of emulsions or salting out can occur in a wastewater system and in particular if seawater or salts of calcium, magnesium, etc are present giving rise as FOG-like matter that may adhere to the walls of pipes and wet wells of pump stations.

- The high level of VFA and the low pH values in samples of effluent clearly demonstrate that carbon dioxide and water are not the end products of ‘bioaugmentation’ in ‘grease converters’. The measured $cBOD_5$ is likely to be only a fraction of the true $cBOD_5$ that in turn has the potential to place an additional organic load on any treatment works having to deal with large quantities of such wastes.

SOME IMPORTANT ISSUES ARISING FROM THE FOREGOING DISCUSSION

pH Value contravening N Z Trade Waste Bylaws

- It has been brought to the writer's attention that a number of local authorities are concerned with the low pH values in effluents from FOGIs and 'grease converters' and what controls or treatment should be imposed on the discharger.
- The VFAs are miscible with water and are weakly dissociated. They show up as pH values as low as about 4.5 and being so weak they are unlikely to present any problems in terms of corrosion in the sewer network.
- The author firmly believes that trade waste officers or councils have three options open them.
    1. Simply ignore low pH values where there is substantial flow in sewer.
    2. Amend bylaws to exempt FOGIs and grease converters from pH control.
    3. Require neutralisation of the effluent prior to discharge.
- The author is of the view that #2 – amending the bylaw to exempt FOGIs and 'grease converters' is the most practical means of dealing with the problem. Once the effluent is mixed with the main-stream waste flow there should be sufficient buffer available to accommodate the discharge from a FOGI or a 'grease converter'. (Model TW Bylaws in need of review in the author's opinion anyway).
- If neutralisation is to be preferred then the cheapest and safest agent would be sodium bicarbonate but this introduces another cost, management and maintenance element. Bicarbonate would not cause 'salting out' a term referred to in earlier discussion.

Can the 'grease converter' performance be improved upon?

- The key to the success of bioaugmentation, at least to the end of the hydrolysis stage of treatment, is the keeping of the organisms lipase mixture in contact with the FOG at all times. This is best done by some form of mechanical mixing but would be impractical in most cases from an operational point of view.
- It has been noted that patent applications for one set of bioadditives used operated under constant temperature, continuous mixing and oxygenation to achieve the desired results but have not been matched on a practical scale. With the two mediums water and FOG having different densities, under quiescent conditions, their separation is inevitable and within a relatively short time probably a few minutes.

- It is understood that some improvements to tank design have been made over the last year or two these changes may not be enough to maintain continuous contact between the bioadditives and the FOG. This is the key to the success of the process. Just get the FOG completely hydrolysed and not worry about anything else.

- It is strongly recommended that commercial entities give serious thought to looking into this aspect of the treatment process to improve hydrolysis of FOG.

Additional uses for bioadditives and bioaugmentation

- Bioadditives have a role to play in the clearing of blocked drains and for general purpose cleaning of sewers and pump station wet wells provided that the intimate contact problems can be overcome.

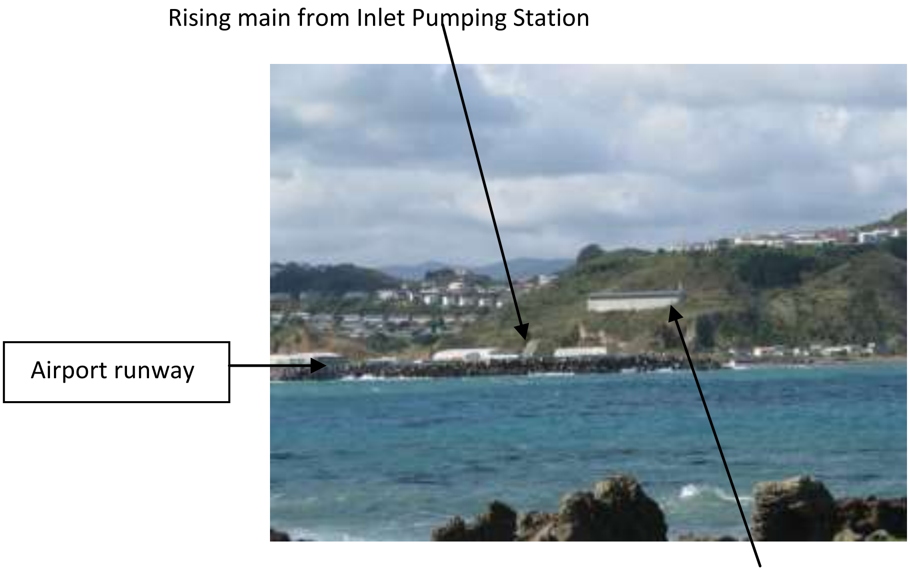
- Used prudently the bioadditives may minimise the risk of future blockages in wastewater treatment systems or as a clean-up tool involving FOG spillages that cannot be dealt with by any other means.

- The writer firmly believes that a technical group should be set up to further enhance FOGI design and operation as well as bioaugmentation.

- Added Sept 2017. Noted 'bioadditive sticks' available for home use to keep drains clean. Conversion of FOG to glycerol and fatty acids is all that is needed.

Outcome

No new grease converters to be used in the Wellington Region. Existing 250 units in use to be modified to improve efficacy.



Moa Point Wastewater Treatment Plant (krd 2009)

$cBOD_5$: COD RELATIONSHIP IN 'GREASE CONVERTER' EFFLUENTS

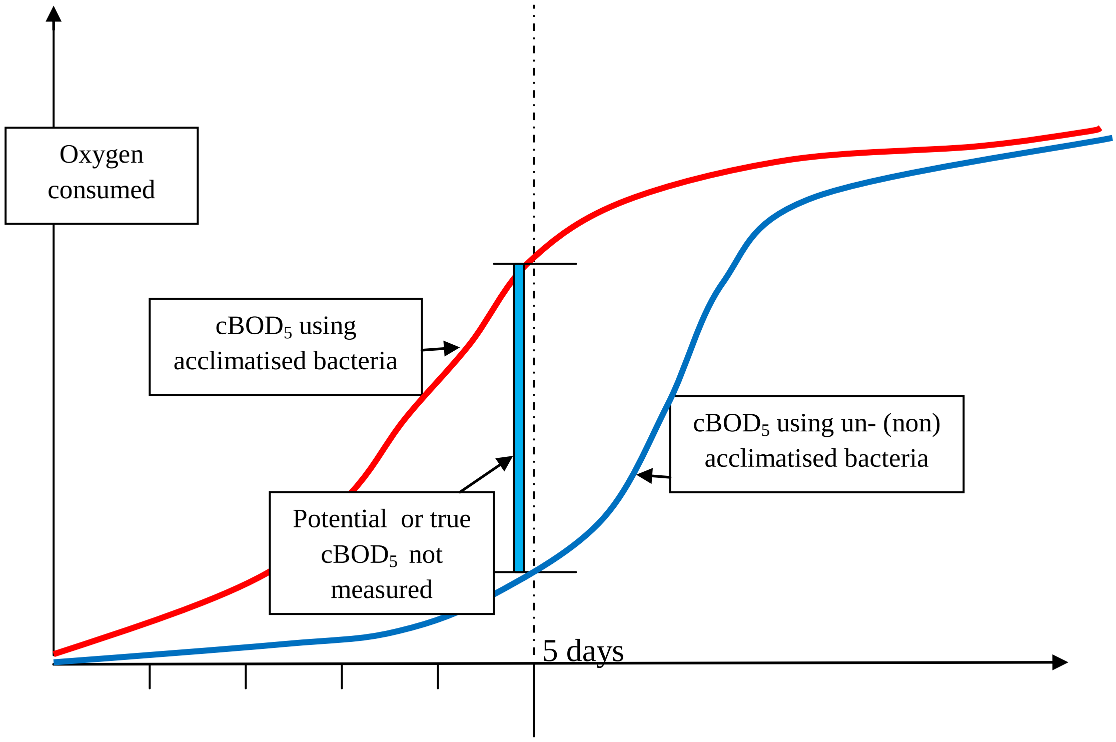


Fig 1 Effect of acclimatised seed vs. un-acclimatised seed on $cBOD_5$ test results (not to scale)

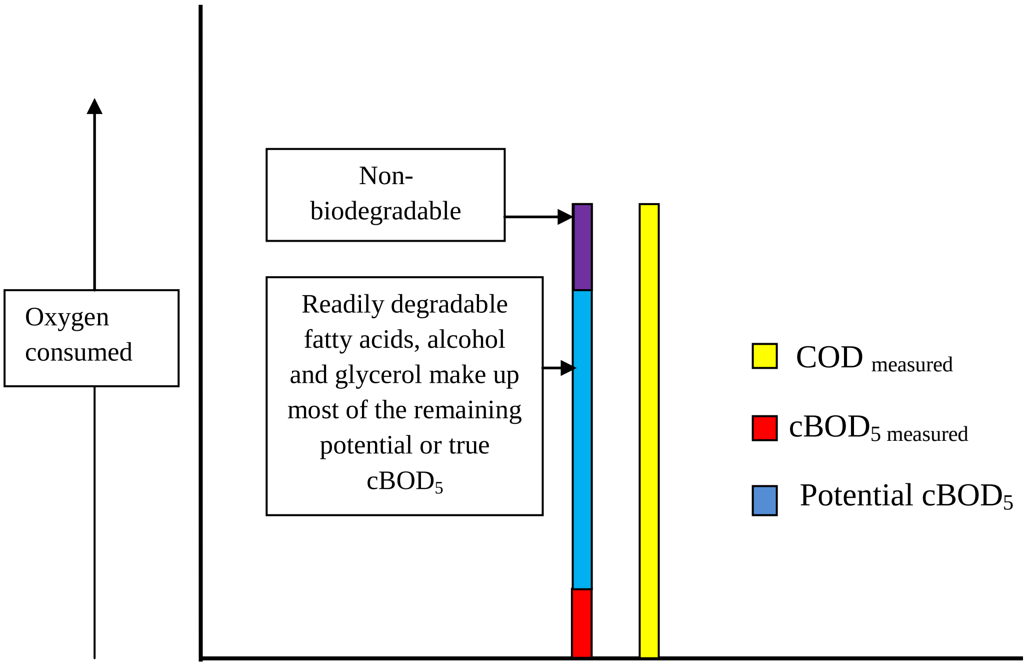
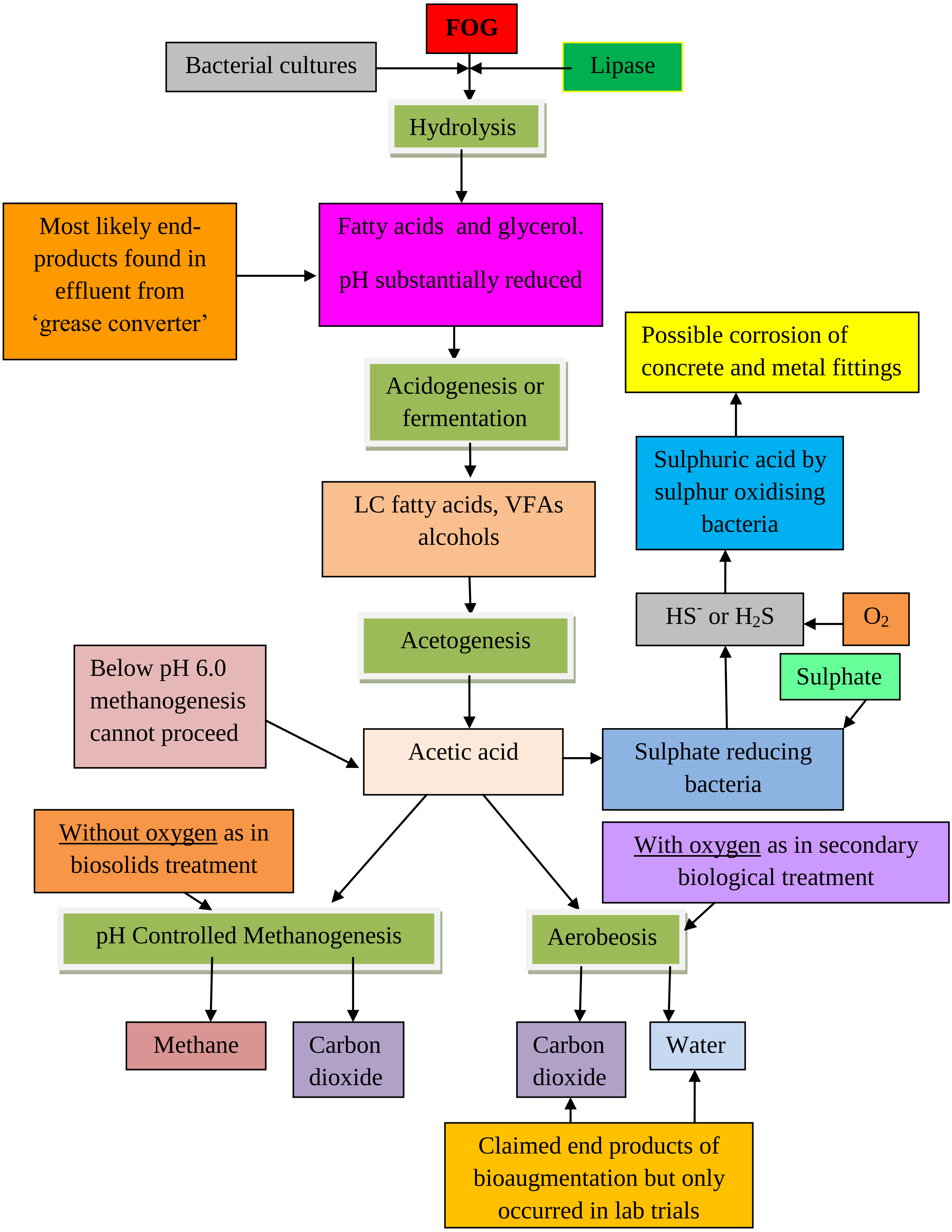


Fig 2 COD vs. $cBOD_5$ in effluent from 'grease converter' (not to scale)

SIMPLIFIED PATHWAYS FOR FOG DEGRADATION USING BIOADDITIVES



Note: Wellington City has seawater intrusion problems. Hence sulphate reduction mentioned.

Grease Converter Patent Application studied

Patent number US 6,818,211 B2 Nov 2004 Just one of a number of patents

- *The invention discloses a Gram-positive microorganism, **Bacillus megatarium** that effectively and efficiently degrades fats, oils and grease. A composition comprising said microorganism and a method of degrading fatty acids and grease are also disclosed. Availability of glycerol to the biodegrading organism was discovered to enhance biodegradation.* (Bioaugmentation)
- Tests used an AER-200 Respirometer.
- Sterile samples prepared for laboratory trials.
- Nutrients and other enhancers used
- Conditions controlled for experiments.
- Temp constant 25 degrees C
- Mixing continuous. pH value consistent and within the range of 6.8 – 7.2 at end of experiments.
- **Oxygen available and uptake rates were measured to demonstrate the efficacy of the process. An aerobic process. Desired result achieved. End products assumed to be carbon dioxide and water.**

Commercial Claims in 2008

- Commercial claims based around patent claims. The claims include the bacterial degradation of FOG into water, carbon dioxide with the liberation of heat (energy).

What was found in 2009

- Temperature is not controlled. Generally lower than test temp.
- There was no continuous mixing meaning that the added bacterial cultures could not be dispersed in the floating FOG layer in the grease converter.
- There was some action at the FOG bacterial interface producing fatty acids and glycerol with a substantial lowering of the pH vale in some cases to below 5.0. Low pH lowers the rates of any microbiological activity.
- With no mixing and no oxygen transfer possible from the air to the contents of the grease converter conditions quickly become anaerobic.
- **End products appeared to be an increase in fatty acids and glycerol and an increase in effluent BOD and COD rather than the production of carbon dioxide and water as claimed.**
- Some of the FOG retained but much lost from the grease converter.
- The lab trial test procedures are therefore not being matched in commerce. (Since grease converters used in Wellington City substantial increase in FOG as found at the Moa Point Inlet Pumping Station).
- **Claims should read – a method of converting insoluble FOG into miscible with water ('soluble') products (fatty acids and glycerol) that can be disposed of into a sewer and dealt with by normal treatment means. Potential to increase BOD_5 load on treatment plant.**