Assessment of the Microbiological Treatment Process for the Oxidation of Fats, Oils, and Greases in Albuquerque Area Wastewater Traps

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Abstract

The disposal of wastewater discharged from kitchens, restaurants and the food preparation industry containing high levels of fat, oil, and grease to treatment facilities is problematic. Waste traps are typically installed before the raw wastewater is introduced into sanitary sewers to collect and retain the fat, oil, and grease. Usually the lipid materials are removed from the wastewater trap by pumping or skimming, but an alternative microbiological method is also used. The microbiological method utilizes aerobic microorganisms with known fat, oil, and grease degradation capability. Despite wide use of the process, an assessment of the environmental variables affecting process performance has not been conducted. To that end, the dissolved oxygen concentration, bulk temperature, and pH of wastewater trap contents at ten sites across Albuquerque, New Mexico were measured, and the bioavailability of fats, oils, and grease was assessed based on observation. The measurements and assessments are reported and potential method improvements suggested.

1. Introduction

Wastewater discharged from kitchens, restaurants and the food preparation industry includes high levels of lipid materials such as, fat, oil, and grease. The disposal of these materials is treatment facilities is problematic because they have a high biochemical oxygen demand (BOD), clog wastewater pipes, and degrade the efficiency of wastewater activated sludge treatment. To mitigate these problems, waste traps are typically installed before the raw wastewater is introduced into sanitary sewers and the main treatment system. The trap is a 30 to 1500 gallon (112 to 5700 liter) tank located inside or outside the waste generating facility that receives all wastewater coming from the kitchen drains and sinks. The wastewater entering the trap passes through a number of baffled compartments. The baffles increase retention time causing the fat, oil, and grease lipids to separate from the wastewater. Once released, the low specific gravity lipids float to the top, and accumulate until removed.

Usually the lipid materials are removed from the wastewater trap by pumping or skimming, but an alternative microbiological method is also used. The microbiological method utilizes aerobic microorganisms with known fat, oil, and grease degradation capability to completely mineralize the lipids to carbon dioxide and water. However, despite wide use of the process, overall effectiveness in reducing total lipid content and BOD values of water introduced into the sanitary sewer system is considered inadequate. Optimization of the microbiological lipid degradation process is dependent on many factors, but especially bioavailability, dissolved oxygen concentration, bulk temperature, and pH.

For this study, the dissolved oxygen concentration, bulk temperature, and pH of wastewater trap contents at ten sites across Albuquerque, New Mexico were measured, and the bioavailability of fats, oils, and grease was assessed based on observation. The measurements and assessments are reported and potential method improvements suggested.

2. Methods and materials

Ten sites throughout Albuquerque, New Mexico with commercial kitchen wastewater traps were selected for dissolved oxygen concentration, bulk temperature, and pH measurement and bioavailability assessment. The sites were selected to provide a range of lipid sources, trap sizes, and locations. The selected sites and characteristics are presented in Table 1.

Dissolved oxygen (DO) concentration was measured with a dissolved oxygen meter utilizing a remote polarographic dissolved oxygen sensor (EXTECH Instruments Model 407510, Waltham, MA). The measurable DO range was 0.0 to 19.9 mg/l with a resolution of 0.1 mg/l and an accuracy of $\pm$0.4 mg/l. Calibration was accomplished by setting the meter reading to 0.0% with the DO sensor disconnected and setting the meter reading to 20.9% with the sensor connected while the measurement switch was at the O_2 air position. All measurements were automatically altitude compensated to 1600 meters MSL. Dissolved oxygen measurements were made by placing the DO probe tip 6 to 8 cm into wastewater trap contents, swirling until the reading stabilized, and recording.

Bulk temperature and pH were measured with a combination temperature/pH meter utilizing an RTD temperature probe and standard pH electrode (EXTECH Instruments Model 407227, Waltham, MA). The measurable temperature range was 0.0 to 50.0^{o}C with a resolution of 0.1^{o}C and an accuracy of $\pm$1.0^{o}C, and the measurable pH range was 0.00 to 14.00 pH with a resolution of 0.01 pH and an accuracy of $\pm$0.03 pH. Calibration of the temperature probe was accomplished by setting the meter temperature reading to 0.0^{o}C with the temperature probe placed in an ice/water slurry. A single point calibration of the pH electrode was accomplished by setting the meter pH reading to 7.00 with the pH electrode submersed in a pH 7.00 buffer solution. Bulk temperature and pH measurements were made by placing the temperature probe and pH electrode tip 6 to 8 cm into wastewater trap contents and recording meter readings after stabilization.

Bioavailability assessment was subjective rather than objective because of analytical capability constraints. Lipid bioavailability is dependent on solubility and can be subjectively assessed by examination of lipid to water partitioning in the wastewater system. The assessment examination consisted of estimation of surface crust depth and observation of fat, oil, and grease partitioning extent.

Dissolved oxygen concentration, bulk temperature, and pH measurements and bioavailability assessments were made at five locations (Albuquerque Grill, Burger King, Century Rio 24 Theater, La Mantanita Co-Op, and Manor Care) prior to microbiological treatment, and at five additional locations (JB's Restaurant, Madstone Theater, Manzano del Sol, Taco Bell, and Twisters Restaurant) prior to and after microbiological treatment. Microbiological treatment consisted of removal of organic solids, addition of sodium bicarbonate and microbial spores, and mixing by water agitation. The measurements were made after treatment to assess the affect of treatment on system DO and pH.

3. Results

The environmental variables measured and observed in the Manzano del Sol wastewater trap before treatment were ideal for aerobic microbiological metabolic activity. Dissolved oxygen was measured at 5.1 mg/l, temperature was 33.3^{o}C, pH was 7.6, and limited crust and lipid layers were observed. Following treatment the DO was reduced to 3.4 mg/l and the pH fell to 6.52. Minimal crust and lipid layers were noted at the facility.

Dissolved oxygen in all other wastewater traps (n=9) before treatment ranged from 0.5 to 1.2 mg/l with an average value of 0.76 mg/l (±0.26) with temperatures ranging widely from 26.8 to 36.6°C. Measured pH values for the same traps were relatively similar ranging from 4.46 to 5.33 with an average value of 4.90 (±0.32).

Following system treatment, dissolved oxygen in the anoxic wastewater traps ranged from 1.7 to 3.0 mg/l with an average (n=4) value of 2.32 mg/l (±0.72) for an average increase of 1.43 mg/l after treatment. Measured pH values for the same traps ranged from 5.32 to 6.73 with an average value of 6.10 (±0.64) for an average increase of 1.18 for the four measured traps after treatment. Water agitation and mixing broke up crustal layers and dispersed the lipid layer throughout the wastewater volume.

The pre- and post-treatment dissolved oxygen concentration, bulk temperature, and pH measurement and bioavailability assessment data are presented in Table 2 for all locations.

4. Discussion

All wastewater traps evaluated were working as designed, that is, the trap baffles increased retention time causing the fat, oil, and grease lipids to separate from the wastewater and accumulate at the surface. Pumping or skimming was the original design intent for removal of surface organic crusts and lipid layers. However, the wastewater trap fat, oil, and grease removal design under investigation in this study is aerobic microbiological metabolic mineralization of lipids and crustal organic matter to carbon dioxide and water.

Dissolved Oxygen

The optimal dissolved oxygen concentration for aerobic metabolic activity is saturation or approximately 6.0 mg/l O_2 under the environmental conditions encountered in this study (1600 meters MSL and 28^{o}C). At dissolved oxygen concentrations below 2.0 mg/l, aerobic metabolic activity is dramatically reduced and virtually ceases below 1.0 mg/l (Leahy and Olsen, 1997; Bonin and Bertrand, 2000).

Because of the high organic loading in the wastewater traps, aerobic microbiological metabolic activity will rapidly consume the available oxygen and drive DO levels below 1.0 mg/l. The only mechanisms available for replenishment of dissolved oxygen to sustain a vigorous metabolic activity in the wastewater trap are introduction of oxygenated water and dissolution of atmospheric oxygen at the wastewater atmosphere interface. Any dissolved oxygen provided by introduction of oxygenated wastewater will reinvigorate aerobic metabolic activity, but only for a short time before the limited oxygen supply is again depleted. The only mechanism for sustained introduction of oxygen is dissolution of atmospheric oxygen at the wastewater atmosphere interface.

As stated earlier, all wastewater traps evaluated were working as designed. The fat, oil, and grease lipids, as well as other organic matter, were separated from the wastewater and partitioned at the surface. However, the lipid and organic crustal layers effectively form a barrier to dissolution of atmospheric oxygen effectively limiting aerobic metabolic activity as the available dissolved oxygen is rapidly depleted.

The partitioning of lipid and other organic matter in the evaluated systems was readily observed and the affect on dissolved oxygen content verified by measurement. The measured DO values at all traps, but one, were near or below 1.0 mg/l which indicates minimal if any aerobic metabolic activity was occurring. Following system treatment, introduction of oxygenated water and system agitation, the average dissolved oxygen in the wastewater traps increased from 0.9 mg/l to 2.32 mg/l which will increase metabolic activity. However, the environment is organic matter rich and the system will rapidly return to the anoxic state with no sustained increase in oxygen level.

Bioavailalbility

Only organic matter in solution is metabolized. The partitioning of organic matter at the wastewater/organic matter interface limits the surface area available for dissolution. Limiting the surface area results in a reduced solvation rate and consequently reduces metabolic activity. The observed lipid and crustal layers at the evaluated sites were sufficient to limit solvation and reduce microbiological activity.

pH

Another factor influencing microbiological metabolic activity and growth is pH. Although microorganisms will grow over wide pH ranges, there are tolerance limits. Fat, oil, and grease degrading organisms have optimum growth between pH 5.5 and 8.0 with maximization at 7.5 (Lefebvre, *et al*., 1998). The pH at all, but one, wastewater trap was below 5.5 creating an environmental condition conducive to bacterial cell death. Sustained low pH is another indicator of minimal metabolic activity and limited effective microbiological removal of organic material.

The measured pH following addition of sodium bicarbonate increased from an average of 4.93 to 6.11indicating improvement in the pH environment for microbiological activity.

Bulk Temperature

Bulk environmental temperature profoundly affects microorganisms. The most important influence temperature has on activity and growth is the temperature sensitivity of enzyme-catalyzed reactions. Wakelin and Forster (1997) demonstrated microbiological removal of fats, oils, and greases by a mixed microbial culture at 28^{o}C and 30^{o}C. A typical temperature range for enzymatic activity is $\pm$5^{o}C from the optimal temperature, or in this instance 23^{o}C to 35^{o}C. All wastewater bulk temperatures, but one, fell within this range, and the only outlier was close enough based on assumptions of optimal temperature made here.

5. Conclusions and Recommendations

Based on measurements and observations collected for this assessment, it appears that the process of microbiological removal of fats, oils, and grease from commercial kitchen wastewater traps in the Albuquerque, New Mexico area is relatively ineffective. Any benefit gained from the treatment process, as currently implemented, is expected to be transitory. The following recommendations are suggested to improve the performance of the process using the existing wastewater traps whose operational design is actually detrimental to the microbiological treatment process. Recommendations in order of potential impact are:

1. Pump or skim organic crust and lipid layer from the wastewater surface to improve oxygen transfer to wastewater.

2. Add surfactants to disperse and emulsify the lipids, potassium hydroxide to saponify lipids (Lefebvre, *et al*., 1998), or enzymes to bio-catalyze lipid metabolic activity (Gary and Sneddon, 1998). These additions improve lipid bioavailability and potassium hydroxide also increases pH.
3. Continuously mix the wastewater by mechanical agitation to improve atmospheric oxygen transfer and solvation rate. Be aware, this process negates the original design goals of the trap and will possibly allow more organic loading (BOD) to reach the sanitary sewer system.
4. Actively aerate the wastewater by introducing air through a pressure manifold, or pump and spray the wastewater mixture into the trap air space to improve dissolved oxygen concentration.
5. Adjust pH to 7.5 by addition of disodium carbonate (soda ash).
6. Add supplemental nutrients, such as, nitrogen, phosphorous, and trace elements (Nakano and Matsumura, 2001) to mitigate limiting nutrient growth deficiencies.
7. Promote better housekeeping at source to minimize organic matter of all types into wastewater system.

References

Bonin, P and JC Bertrand. 2000. Influence of oxygen supply on heptadecane mineralization by *Pseudomonas nautica*. *Chemosphere*. 41:1321-1326.

Gary, E and J Sneddon. 1999. Determination of the effect of enzymes in a grease trap. *Microchemical Journal*. 61:53-57.

Leahy, JG and RH Olsen. 1997. Kinetics of toluene degradation by toluene-oxidizing bacteria as a function of oxygen concentration, and effect of nitrate. *FEMS Microbiology Ecology*. 23:23-30.

Lefebvre, X, E Paul, M Mauret, P Baptiste, and B Capdeville. 1998. Kinetic characterization of saponified domestic lipid residues aerobic biodegradation. *Water Research*. 32(10):3031-3038.

Nakano, K and M Matsumura. 2001. Improvement of treatment efficiency of thermophillic oxic process for highly concentrated lipid wastes by nutrient supplementation. Journal of Bioscience and Bioengineering. 92(6):532-538.

Wakelin, NG and CF Forster. 1997. An investigation into microbial removal of fats, oils, and greases. *Bioresource Technology*. 59:37-43.

Table 1. Selected sites and characteristics.

Site	Type	Location	Trap Size (gallon)
Albuquerque Grill	traditional restaurant	Rio Grande - I40	1500
Burger King	fast food restaurant	Carlisle -I40	1000
Century Rio 24 Theater	movie theater kitchen	Jefferson – I25	40
JB's Restaurant	traditional restaurant	Rio Rancho	1000
La Mantanita Co-Op	natural food deli	Carlisle - Central	50
Madstone Theater	movie theater kitchen	San Mateo – I25	30
Manor Care	elder care kitchen	Constitution - Pennsylvania	100
Manzano del Sol	elder care kitchen	San Mateo - Roma	50
Taco Bell	fast food restaurant	Eubank - Copper	1000
Twisters Restaurant	traditional restaurant	San Mateo - Menaul	500

Table 2. Selected site DO, temperature, and pH measurements and bioavailability assessment.

Site	Dissolved Oxygen (mg/l)		Temperature (^oC)		pH		Bioavailability
	Pre-	Post-	Pre-	Post-	Pre-	Post-	
Albuquerque Grill	0.5	-	36.6	-	5.13	-	Limited 1-2 cm crust 1-2 cm lipid
Burger King	0.6	-	28.1	-	5.04	-	Negligible 10-15 cm crust 2-3 cm lipid
Century Rio 24 Theater	0.5	-	26.8	-	4.52	_	Limited 1-2 cm crust 1-2 cm lipid
JB's Restaurant	0.6	1.7	28.1	26.8	4.46	5.32	Limited 2-3 cm crust 1-2 cm lipid
La Mantanita Co-Op	0.7	-	27.8	-	4.63	-	Limited 1-2 cm crust 2-3 cm lipid
Madstone Theater	1.1	2.9	28.6	30.5	5.20	5.85	Minimal <1 cm crust 1 cm lipid
Manor Care	0.9	-	31.8	-	5.07	-	Limited 1-2 cm crust 5-6 cm lipid
Manzano del Sol	5.1	3.4	33.3	29.2	7.60	6.52	Moderate <1 cm crust <0.5 cm lipid
Taco Bell	0.7	1.7	28.5	23.0	4.71	5.85	Negligible 5-6 cm crust 8-10 cm lipid
Twisters Restaurant	1.2	3.0	28.6	30.5	5.33	6.73	Limited 1-2 cm crust 1-2 cm lipid