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Wastewater Treatment Fatty Acids for Biodiesel Production

Zachary Christman
University of Nebraska-Lincoln

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Abstract

Wastewater scum is the thick oily substance that floats on top of the primary and secondary tanks within a wastewater treatment plant. Scum has a 30% to 60% lipid content making it an excellent resource for the biodiesel industry. Also the use of scum would reduce the cost of current management practices such as landfill disposal or incineration. In this article there is an overview of lipid byproducts currently being produced at wastewater treatment plants today. This is followed by a presentation showing a full length process for turning wastewater scum into biodiesel raw material.

Introduction

Biodiesel is Fatty Acid Methyl Esters (FAME) that are produced by the acid or alkali catalyzed transesterfication of lipids such as oil, fat or grease. A saponifiable lipid is the main requirement as a raw material. Saponifiable lipids are those with an ester functional group that can be hydrolyzed under reactor conditions. Biodiesel is a good supplement to the world's energy supply because it is: [4]

- Renewable and biodegradable
- Less toxic than petroleum diesel
- Lower emission profile than petroleum diesel
- Excellent lubricant properties
- Provides generally the same energy content as petroleum diesel
- It can be used in current diesel engines without modification
- Biodiesel can use current vehicle fueling stations

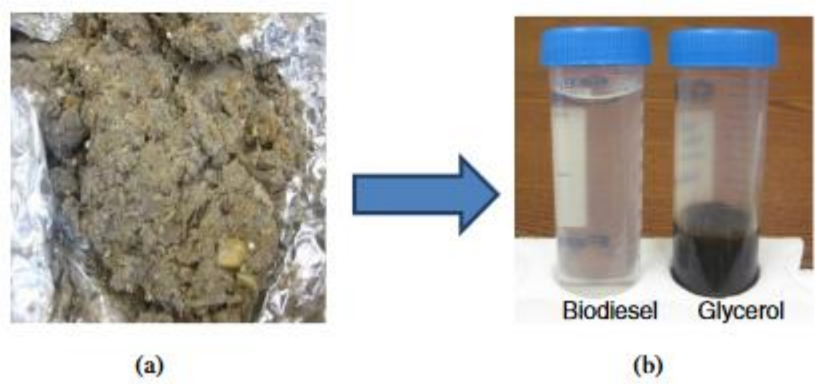

FIGURE 1. (a) Wastewater scum from the St. Paul, Minnesota Wastewater Treatment (Metro Plant). [3] **(b)** The clear liquid is scum biodiesel. The black liquid is glycerol formed as a waste product.

The producing biodiesel is largely based on the raw material cost ranging from 70 to 85% of the final cost. Seeds with high oil content like palm kernel and soybean as well as animal fat is the raw material biodiesel is currently made from. However, these raw materials are highly expensive and would not be able to economically compete with petroleum fuel. A competition between fuel and food for agricultural space would increase the price for both. Another issue is that any sustainable fuel needs to consider the amount of energy needed for all processing to take place to produce the fuel. This would include the energy cost of machinery, fertilizer and other chemicals, harvesting, extraction of oil and finally the production of the fuel. Therefore, generating fuel from the waste products of other industries is of great interest.[4]

The lipids found in wastewater provide a possible raw material for biodiesel production. This raw material would not compete for agricultural land or food products. [4]

Primary sludge is the grease and organic matter within untreated wastewater. This type of sludge has the highest amount of lipids present. [4]

Secondary (Activated) sludge is composed of microbial cells and suspended solids produced from aerobic biological treatment of wastewater after primary sludge has been extracted. [4]

Blended sludge is a mixture of thickened primary and secondary sludge. [4]

Stabilized sludge comes from a microbial digestion process where the organic matter in a sludge source is mineralized. Stabilized sludge has a high level of nonsaponifiable material that cannot be used for biodiesel.[4]

Scum is the thick material that floats on top of the primary and secondary water treatment tanks. It is mainly composed of grease, digested food and organic matter. Scum is skimmed off the top of the tanks to prevent clogging of pipes.[5]

All types of wastewater lipid byproducts have significant amounts of palmitic acid (C16:0), stearic acid (C18:0) oleic acid (18:1), and linoleic acid (C18:2) as can be seen in Figure 2 and 3 below.[4]

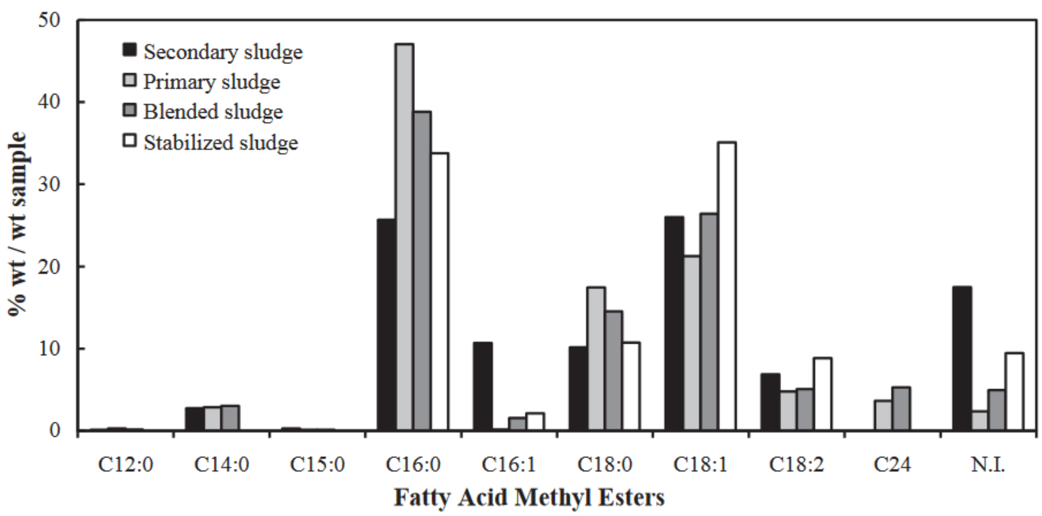

FIGURE 2. Fatty Acid Composition of Different Wastewater Sludges.[4]

One of the main differences that can be seen is the higher level of palmitoleic acid (C16:1) found in secondary sludge (11%) than in primary sludge (0.2%). Also, there is no sign of lignoceric acid (C24:0) in the profile for secondary sludge. linoleic acid (C18:2) is common in oils derived from vegetables. The presence of linoleic acid and other polyunsaturated fatty acids needs to be monitored due to its ability to auto-oxidize and therefore destabilize the properties of the biodiesel. The presence of 5% polyunsaturated fatty acids in wastewater primary sludge is more favorable for oxidation stability than 61% polyunsaturated fatty acids that is found in soybean biodiesel.[4]

Wastewater scum is composed of mainly oleic methyl ester (C18:1) at 39.4% and methyl palmitate (C16:1) at 24.3%. The level of saturated fatty acids was 59.3% and unsaturated fatty acids 40.7%. These results are reviewed in Figure 3.[2]

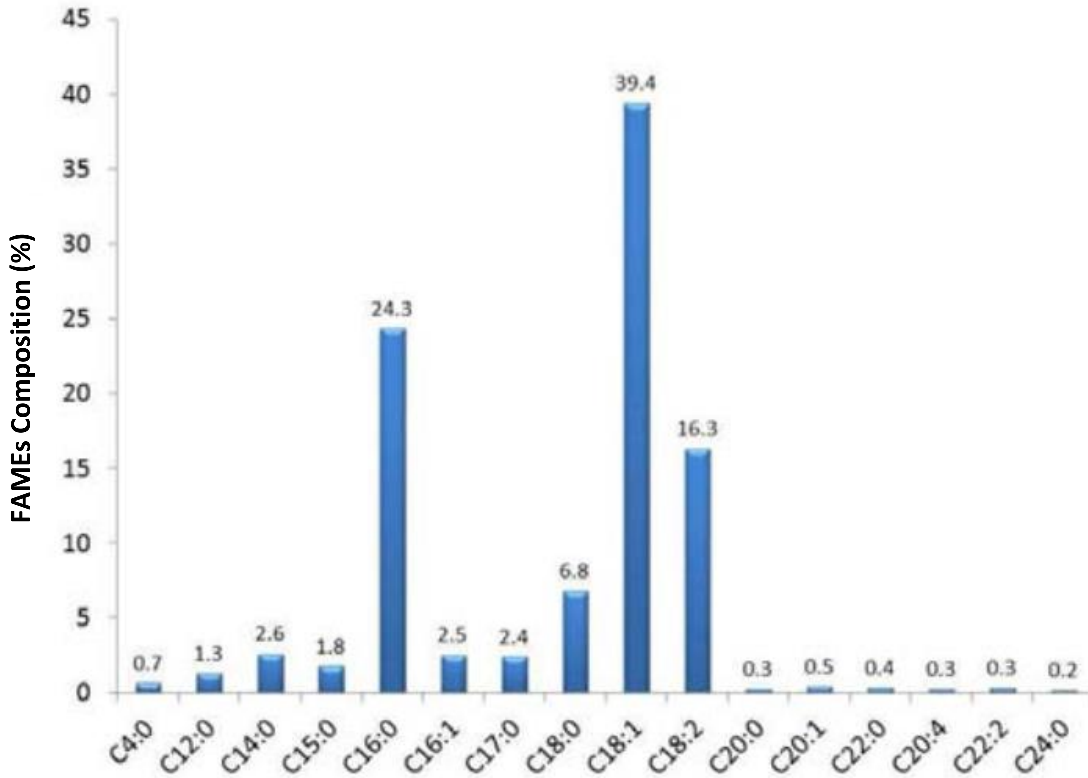

FIGURE 3. The fatty acid profile of wastewater scum.[2]

For comparison, lard has a saturated fatty acid content of 50%, while soybean has 16% saturated fatty acid. Saturated fatty acids increase the stability of biodiesel to oxidation. However, high levels of saturated fatty acids decrease the cold flow property of the fuel. Cold flow property is the temperature in which the biodiesel will become cloudy as the saturated fatty acids congeal; this is followed by the material turning more into a thick gel. The differences and similarities of primary sludge, soybean and lard can be viewed in Figure 4.[4]

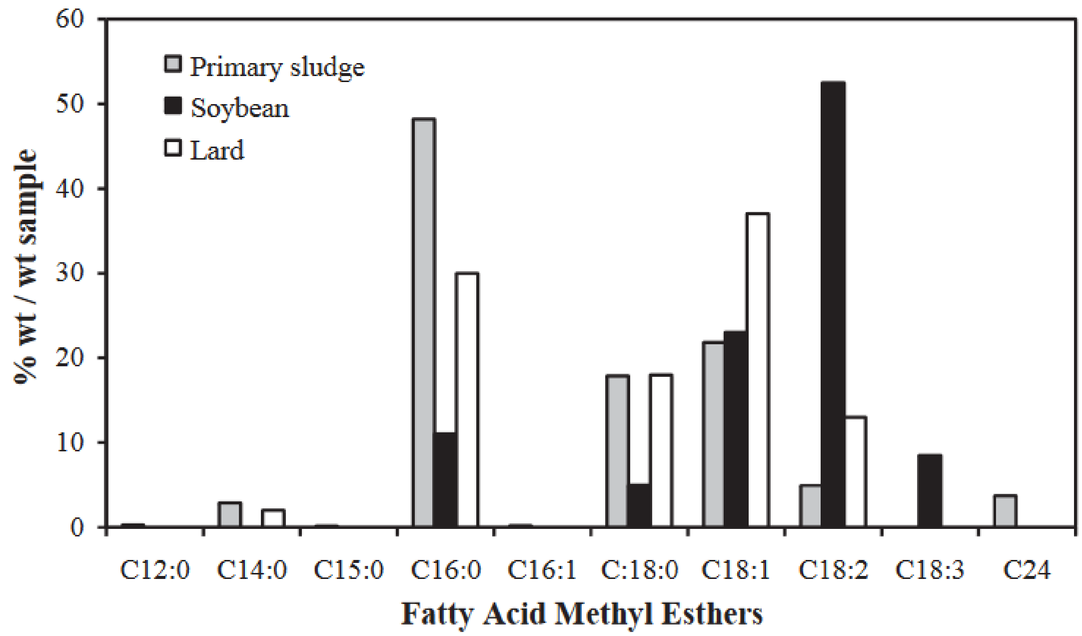

FIGURE 4. Comparison of Oils from Different Sources.[4]

A study was conducted by Febrian Rizkianto, et al. in 2019 on the lipid extraction from three Japanese wastewater treatment plants. The pretreatment used hydrochloric acid on dewatered sludge. The lipid extraction was done using hexane with a Soxhlet apparatus. Their work can be seen in Table 1 and Figure 3.[5]

TABLE 1.
Three Different Wastewater Treatment Plants in Japan. [5]

WWTP	Capacity (m^3/day)	Sewage Collection System	Wastewater treatment process	Sludge digestion system
A	552,780	Combined	Primary sedimentation, multi stage nitrification and denitrification with step inflow	A part of primary sludge
B	17,580	Separated	Primary sedimentation, conventional activated sludge treatment	All sludge
C	52,500	Separated	Primary sedimentation, multi stage nitrification and denitrification with step inflow and coagulant addition	No digestion

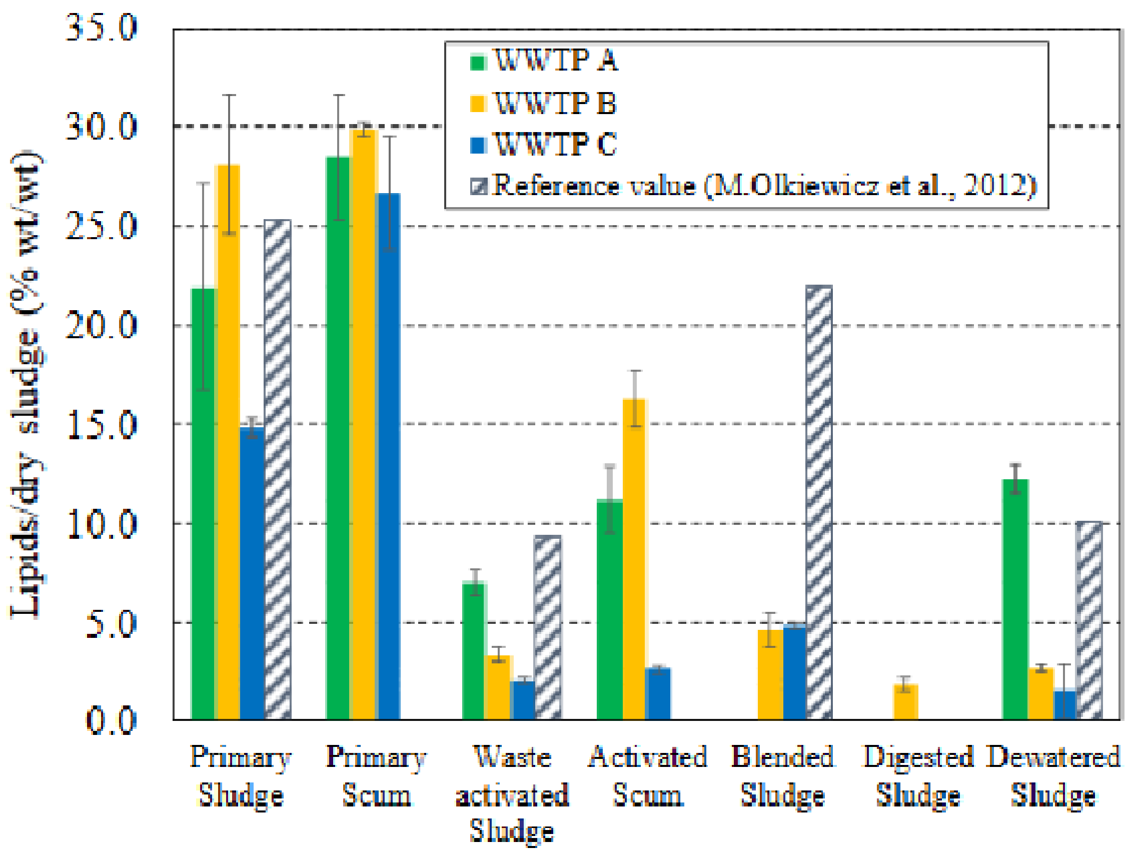

FIGURE 5. Lipid yield from three different Japanese Wastewater Treatment Plants.[5]

The majority of wastewater scum is disposed in landfills. This process is not only expensive; in addition, it has many environmental consequences. For example, the wastewater treatment plant in St. Paul, Minnesota (Metro Plant) spends $100,000 a year just for landfilling scum. In addition to this, the leachate from the scum pollutes local water resources.[1]

Lipid Extraction From Wastewater Scum Method
Author: Samir N. Hag Ibrahim

1. Collection of wastewater scum from screening chambers.
2. Scum kept in plastic bottles while on ice for transport.
3. Samples sieved through a less than 2 mm mesh.
4. Gravitational settling of samples at 5^{o}C for 12 hours.
5. The supernatant was removed. Then 2 rounds of centrifugation at 3000 rpm for 10 minutes for further dewatering.

6. The thickened sludge samples were frozen at -20°C and freeze dried for 5 days.
7. The scum lipids were extracted. The best results were found to be a solvent of methanol and hexane in a ratio of 40 percent. The solvent to scum ratio of 40 ml per gram is used. The optimum temperature was found to be 90°C. The extraction time is 6 hours.
8. After extraction the material was filtered through a Buchner funnel with Whatman paper number 1 and water aspirator to remove remaining solvent.
9. The filtrates were further concentrated using a rotatory evaporator at 40°C.
10. The remaining material was dried to a constant mass with a vacuum desiccator.

The lipid material is now ready to begin the steps in making biodiesel. The biodiesel can be produced on-site or shipped to a separate facility.

Conclusion

The cost of the raw material is 70 to 80% of the final cost of biodiesel. Therefore, it is important to find sources of lipids that would produce high quality biodiesel yet be economically favorable. Scum is the thick oily material that floats on top of the primary and secondary tanks within a wastewater treatment plant. Scum must be removed otherwise it will clog pipes and cause other mechanical issues. The majority of scum is managed by expensive landfilling. For example the St. Paul, Minnesota wastewater treatment metro plant pays $100,000 a year to manage their scum. The use of scum for biodiesel would add a valuable fuel to the energy market while improving the economics of wastewater treatment plants. Scum is not a food source of lipids such as soybean or palm kernel so it will not result in an increase in food prices. Also, the use of scum will not need agricultural land to be assigned for production.

References

1. Bi, Chong-hao, et al. "Process development for scum to biodiesel conversion." Bioresource technology 185 (2015): 185-193. https://www.researchgate.net/profile/Min_Min13/publication/278327838_Bi-Scum_converstion_paper/links/557f1f2708aeb61eae261461.pdf

2. Ibrahim, Samir N. Hag. "Statistical Optimization of Lipid Extraction from Wastewater Scum Sludge and Saponifiable Lipids Composition Analysis." Science 5.2 (2017): 48-57.

3. Mu, Dongyan, et al. "A life cycle assessment and economic analysis of the Scum-to-Biodiesel technology in wastewater treatment plants." Bioresource technology 204 (2016): 89-97.

4. Olkiewicz, Magdalena, et al. "Evaluation of different sludges from WWTP as a potential source for biodiesel production." Procedia Engineering 42 (2012): 634-643. https://www.sciencedirect.com/science/article/pii/S1877705812028561/pdf?md5=5e42df9e6aee1126c66c7dcdb2a8eeb1&pid=1-s2.0-S1877705812028561-main.pdf&_valck=1

5. Rizkianto, Febrian, et al. "Evaluation of Different Sewage Sludges as a Potential of Biodiesel Source in Japan." http://www.technobiz.org/3R-2019-Abstracts/Poster-session/P3-1%20Febrian%20Rizkianto-poster.pdf