# Washington State Ferry Biodiesel Research & Demonstration Project

## Final Report Executive Summary

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## Executive Summary

The Washington State Ferry (WSF) system conducted a pilot biodiesel fuel test in 2004 over a period of four months using a B20 biodiesel blend (20% soy biodiesel and 80% low sulfur diesel) in three vessels. This pilot program experienced challenges due to excessive clogging problems in the ferries' centrifugal fuel purifiers and plugging of fuel filters during the test. While these operational issues were challenging, the test was successful in that the ferry system learned important information that would assist in their 2008 Biodiesel Research and Demonstration Project. This Demonstration Project was important as WSF vessels burn approximately 18,000,000 gallons of diesel fuel per year. Diesel particulate emissions have been identified as the most significant airborne health risk in the Puget Sound region. The Environmental Protection Agency projects that using a B20 fuel is expected to reduce diesel particulate by approximately 10%, carbon monoxide by 11% and hydrocarbon emissions by 21%

The U.S. Department of Energy (DOE) awarded a grant to Puget Sound Clean Air Agency (PSCAA) to perform a scientific study to determine appropriate fuel specifications, fuel handling procedures, and conduct a fuel trial using biodiesel blended fuels in WSF operations.

Washington State University (WSU) was selected to lead the research project team conducting the two-year project. The team members included the University of Idaho (UI), Imperium Renewables, Inc. (IRI), and The Glosten Associates.

The goals of the project were (1) to test current fuel specifications for biodiesel and biodiesel blended fuels, (2) to develop biodiesel product handling guidelines for use in a marine environment, and (3) to demonstrate that biodiesel blended fuels can be successfully used in marine applications in the Pacific Northwest. The fuel test work plan was designed to test the use of biodiesel on three WSF vessels during normal vessel operations. The vessels and routes selected were the same vessels and routes used in the 2004 pilot test. All three vessels were run on B20, which was the highest biodiesel blend used in the ferry tests.

Biodiesel from different feedstock sources were tested in each vessel, including canola-based biodiesel, soy-based biodiesel, and biodiesel with a high cloud point. All biodiesel used met the most current version of the ASTM D6751 specification. The fuel blends tested were incrementally raised from 5% to 20%, with samples being taken at critical junctures to ensure fuel quality.

Excess sludge buildup formed in the fuel purifier of one of the vessels after one month of operation, which was similar to the problem experienced in the 2004 pilot test. The research team performed extensive research to find causes of the problem. The sludge samples studied contained metal (~11% ash), water (11-17%), major fractions of organic materials including 8-octadecenoic acid methyl ester from canola biodiesel, and bacteria. WSU researchers found active bacteria were present in the sludge samples from the

purifier, and the bacteria played a key role in the sludge formation. Microbial growth in the ferry system was one of the major causes for excessive sludge formation that resulted in filter clogging. Discussions with WSF operators indicated that sludge formation from microbial growth has been encountered with conventional diesel fuel also. The excessive sludge problem was solved by the application of biocide in the fuel during the studied period. Biocide application is strongly recommended when biodiesel blend fuels are used in marine applications.

This project demonstrated the viability of using B20 biodiesel in year round marine conditions. The results obtained from this project are expected to be directly transferable to other marine applications, as well as being beneficial to land-based end-users. The key lessons learned from these test are as follows:

a) ASTM biodiesel fuel standards provided adequate safeguards to ensure high product quality.
b) Fuel quality was not affected by biodiesel feedstock (i.e. soy, canola, and high cloud point fuel).
c) The percentage of biodiesel (B5 – B20) used in the fuel did not impact vessel operations.
d) Use of biocides is recommended in all future testing with biodiesel. Although comparisons of sludge formation between conventional diesel fuel and biodiesel were primarily anecdotal, vessel operations using biodiesel may require increased maintenance of fuel filtration systems.
e) The high humidity of marine environments appears to promote microbial growth.

## Conclusions and Recommendations

The biodiesel fuel demonstration showed that biodiesel blended fuels can be used in marine applications. Problems such as filter clogging may arise unless preventative measures are taken. The conclusions and recommendations for biodiesel applications resulting from study are listed below.

1) Biodiesel fuels that meet the current ASTM 6751 specifications can be used at the level of B20 for marine application.
2) Fuel quality was not affected by feedstocks from which the biodiesel was derived, either soy, canola, high cloud point (i.e. restaurant oil, or animal fat).
3) Fuel tanks on board marine vessels will benefit from cleaning prior to introducing biodiesel blends.
4) Microbial growth in the ferry system was identified as the major cause for sludge formation resulting in filter clogging / fuel purifier sludge problems observed in the WSF biodiesel test vessels.
5) Vessel operations using biodiesel may require increased maintenance of fuel filtration systems.
6) The percentage of biodiesel (B5 – B20) used in the fuel did not impact vessel operations or maintenance of machinery.
7) Bacteria obtained from sludge can be grown in the presence of biodiesel blends and water in anaerobic and aerobic conditions.

8) The bacteria in the sludge could contain several strains. Five bacterial strains which could be dominant in the sludge sample were obtained.
9) Three bacteria of the five dominant strains were identified as *Staphylococcus epidermidis*, *Klebsiella oxytoca,* and a potentially novel strain of *Klebsilla*.
10) Viscous polysaccharides dissolved in the water of the purifier could be produced by the bacteria.
11) The sludge samples obtained from this test contained metal, microbes, water, and oil fractions (such as 8-octadecenoic acid methyl ester) from canola biodiesel and light compounds that were possibly from diesel.
12) The excessive sludge problem was solved by application of biocide in the fuel.
13) Biocide application is strongly recommended when biodiesel blends are used in marine conditions. The biocides can inhibit the growth of microbes over long periods of time in very low concentrations. The presence of the biocide does not interfere with engine operation. Biocide products are typically pesticides. Detailed information about the mechanism of sludge formation is still unclear. Further research requires understanding the relationship between bacteria and other components in the sludge.
14) Further investigation is needed to identify the remaining bacterial strains and microbial population in the sludge.
15) More information is needed about biocide function in the microbial growth, such as interaction between biocide and specific microbial species. This information would be useful to screen better biocides in terms of higher performance and lower cost.
16) It is recommended to conduct a pilot demonstration test using biodiesel fuel for a longer term, such as 3-5 years. Several other factors that were not included in this test should be considered. These include engine performance, engine longevity, fuel efficiency, exhaust gas emissions, fuel system injectors, and conditions of hoses and seals.