

## **BIOLOGICAL CLEANING FOR ORGANIC COATINGS**

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Biological cleaning integrates two proven technologies: emulsion cleaning and bioremediation. This process has the advantage that the removed oils and greases are digested by the microbial action rejuvenating the cleaner and extending its life. Biological cleaners have been used effectively in many metal working and metal finishing industries during the last twenty years. Recently a major new area has opened up for this technology in the preparation of metal surfaces for organic coatings. This paper will review the background and industrial experience of biological cleaning for organic coatings, especially in the area of powder coatings

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## INTRODUCTION

Biological cleaning is based on the simultaneous use of **surface cleaning** and **bioremediation**. The cleaning actually takes place in two consecutive steps. When parts come in contact with the solution, the oil and impurities are emulsified into micro-particulates. The particulates are then consumed by microorganisms, which are present in the bath or spray. The microbes consume the oil present in the bath, as their food source. This process has the advantage that the removed oils and greases are digested by the microbial action rejuvenating the cleaner and extending its life.

While microorganisms have been used for many years to digest oil from wastes and spills, the integration of biodegradation with aqueous cleaning for industrial cleaning applications is a relatively recent process. Most of the conventional cleaners will not allow the survival of oil consuming microbes due to high operating pH and temperatures. By formulating a mild alkaline emulsifying cleaner that operates at relatively low temperatures it is possible to integrate the removal of oil and particulates with the biological digestion of the residues. The system is essentially self-regulating, since the microbial activity will adjust itself to the amount of oil present in the system.

The present biological cleaning process employs an alkaline cleaning solution that operates at relatively low temperatures (104°F - 131°F) (40°C - 55°C) and a pH range of 8.8 - 9.2, which is a viable habitat for these microorganisms.

The cleaning solutions from the cleaning baths are pumped continuously into a separator/control module then pumped back into the processing tank. This operation is run in a continuous mode without interruptions for solution dumping and new solution make-up. As a result of the dynamics of the process and the recirculation of the bath solution, the consumption of oil by the microbes occurs throughout the biological degreasing system. For an efficient operation the oil must be emulsified and oil must be present at all times to keep an active population of microorganisms. In the case of a longer interruption that may be conducive to the total depletion of the oil present in the system, to keep the microbes alive it is necessary to render them dormant by increasing the pH to 10.5 or alternatively, to feed them with small amounts of oil during the down time.

The principles and major industrial applications of biological cleaning can be found in the paper presented at SUR/FIN 2002 (J.Hajdu, Advances in Biological Cleaning, AESF SUR/FIN 2002, Chicago). Also a comprehensive description of biological cleaning is available at the Environmental Protection Agency's website, under the Environmental Technology Verification Reports ("Evaluation of BioClean USA, LLC Biological Degreasing System for the Recycling of Alkaline Cleaners"). This investigation was originally presented at the 22<sup>nd</sup> Annual AESF/EPA Conference on Pollution Prevention and Control for the Surface Finishing Industry, January 29-31, 2001, in Orlando, FL.

Recently an in-depth study of the biodegradation process has been completed by Prof. Thomas K. Wood and Sachiyo Iwashita of the Department of

Chemical Engineering & Molecular & Cell Biology of the University of Connecticut. Observing the biodegradation of a widely used commercial lubricant containing naphthenic petroleum oil and extreme pressure additives, they found that a naturally occurring microbial consortium was responsible for the degradation of the lubricant and that the process was conducive to the complete mineralization of the lubricant. The active bacteria for the degradation process were identified as *Bacillus licheniformis*, responsible for the degradation when high concentrations of lubricant are present. At lower concentrations, *Bacillus cereus*, *Pseudomonas aeruginosa*, *Rhizobiaceae str. M100*, and *Achromobacter sp. LMG 5431* were also found active. In addition, Wood and Iwashita found that at pH 9 the rate of heterotrophic biodegradation of the lubricant was significantly higher than the rate degradation of the surfactants present in the biological cleaner while at lower pH values (pH 7) the rate of surfactant degradation increases. These results confirm the empirical observation that biological cleaners should be operated between pH 8.8 and pH 9.2. The methodology and quantitative results of this work will be published in the near future in the Journal of Applied Microbiology and Biotechnology.

## **BIOLOGICAL CLEANING FOR ORGANIC COATINGS.**

The main markets for biological cleaning are in the metal working and metal finishing industries. Case histories of these applications were presented during 22<sup>nd</sup> Annual AESF/EPA Conference, January 29-31, 2001, Orlando, FL under the title “*Field Experience with an Integrated Biological Degreasing System*”. In addition, successful applications were developed for painting and powder coating from the early days of biological cleaning. One of the first installation to use biological cleaning was the ESCP Corporation in their Minneapolis and Moline plants that manufactures powder coated automotive racks. In both production lines the mildly alkaline biological cleaner is used by spray, followed by a simple rinse. A thin organic film is left on the parts, that protects the parts from rusting and assists in the adhesion of the powder coating. The biological cleaning solutions are over five years old and have never been dumped.

Biological cleaning is also used as the first step in multi-stage surface preparation systems for electrocoating in conjunction with iron or zinc phosphating. In case of electrocoating the presence in the line of a cleaning tank containing microorganisms was of a great concern, since the soluble resins used in electrocoating are sensitive to microbial contaminations. For this reason, the supplier of the electrophoretic paint established a severe microbial control of the paint. While microbes were found in the paint, it was concluded that these

microbes were indigenous to the paint, and not carried over from the biological cleaning step.

As mentioned before, in these coating operations the standard mild alkaline cleaner is used. One of our customers (KVF Quad Corporation, East Moline, IL) was using successfully the biological cleaner as the first stage of a five stage spray iron phosphating line prior powder coating, and requested a biological product that could be used in a three stage spray line to replace the cleaning iron phosphate in use. In this kind of process the degreasing and the conversion coating are carried out simultaneously in a single step, and for that reason the solution will become contaminated with the removed oils. At KVF the cleaning iron phosphate solution required periodic disposal due to the heavy build up of oils, and at the same time required significant attention in order to consistently achieve coating weight and adhesion specifications. In theory, a biological cleaning phosphate offered the potential of an extended life and a steady state activity due to the continuous rejuvenation of the solution.

The initial indications about the success in developing this type of product were not excessively promising. Iron phosphates work at acid pH ranges (pH 3.5-5.0) and the literature indicated that at pH values under pH 5 the biodegradation process would slow down considerably. Also the iron phosphate formulations include accelerators, and most of these materials are incompatible with bacterial growth. Still, experimentally it was found that adequate bacterial activity could be found in the range of pH 4.5 to 5.5, with the added advantage that in this pH range

the heterotrophic microbial digestion was inclined towards the degradation of the lubricants, protecting the surfactants present in the system. This experience is similar to the microbial activities observed with the mildly alkaline cleaners at pH 7 and 9.

Following these experimental indications, it was possible to formulate an iron phosphate with biological cleaning properties. The inorganic components, accelerators and surfactants are biocompatible and the operational variables can be controlled using the same standard control module that is used for biological cleaning. The control and maintenance of the biological cleaning phosphate (P4 System) is similar to the alkaline biological cleaner (P5 System), as shown in Table 1. This product has been running efficiently for more than two years without the need of dumps, allowing KVF Quad Corporation to meet and exceed the specifications of coating weights and salt spray resistance (Figures 1 and 2). Compared with the previous phosphating system, the new biological cleaning phosphate process has operated as a steady state mode, as a result of the continuous rejuvenation of the solution. Also, thanks to its extended life, the new process has generated savings in chemicals, water usage and waste

**Controls for P4 System**

pH: 8.8 to 9.2

% Solution: 2.0 +/- .4

Conductivity: < 2000 mS/m

Microbes: >10\*3, <10\*8

Surface Tension: <33 mN/m

Temperature: 105 F to 135 F

Temperature: 42.0 C to 52.0 C

Module: 230 Gal.

Stage 1 P4 Volume: 1,100 Gal.

P4 Total Volume: 1,330 Gal.

P4 1% Solution: 13.3 Gal.

**Controls for P5 System**

pH: 5.0 to 5.5

% Solution: 2.0 +/- .4

Conductivity: < 2000 mS/m

Microbes: >10\*3, <10\*8

Surface Tension: <33 mN/m

Temperature: 105 F to 135 F

Temperature: 42.0 C to 52.0 C

Module: 230 Gal.

Stage 1 P5 Volume: 942 Gal.

P5 Total Volume: 1,172 Gal.

P5 1% Solution: 11.2 Gal.

**DAILY MAINTENANCE (P4 and P5)**

1. Check Function of Airing Blower
2. Check circulation from stage 1 through Module (Pump Functional)
3. Check feed lines for placement into pH buffers (5 gallon containers)
4. Check supply of pH buffers (> 4" from bottom ok, < 4" from bottom replace)
5. Verify pH reading on controller with calibrated hand held pH meter.
6. Verify temperature  
 Any conditions other than normal for items 1 through 7 above, notify the Plant Manager or QP&P

**WEEKLY MAINTENANCE (P4 and P5)**

1. Check module liquid level
2. Clean pH probe
3. Remove 1 to 2 gallons from sump (sludge)  
 Any conditions other than normal for items 1 through 7 above, notify the Plant Manager or QP&P

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Table 1

### Resistance To Salt Fog Exposure (Adhesion)

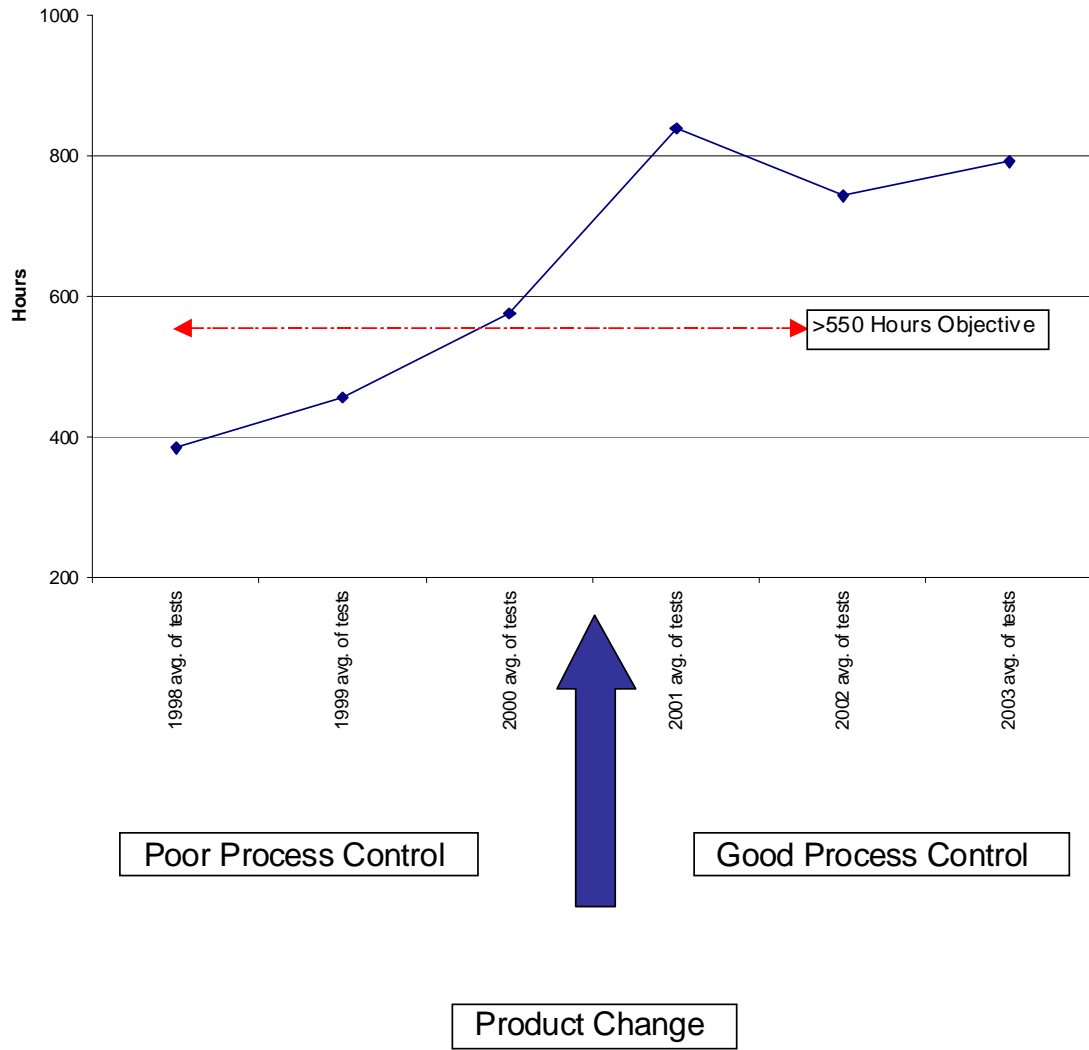


Figure 1

### Coating Weights (measured in mg/square foot surface)

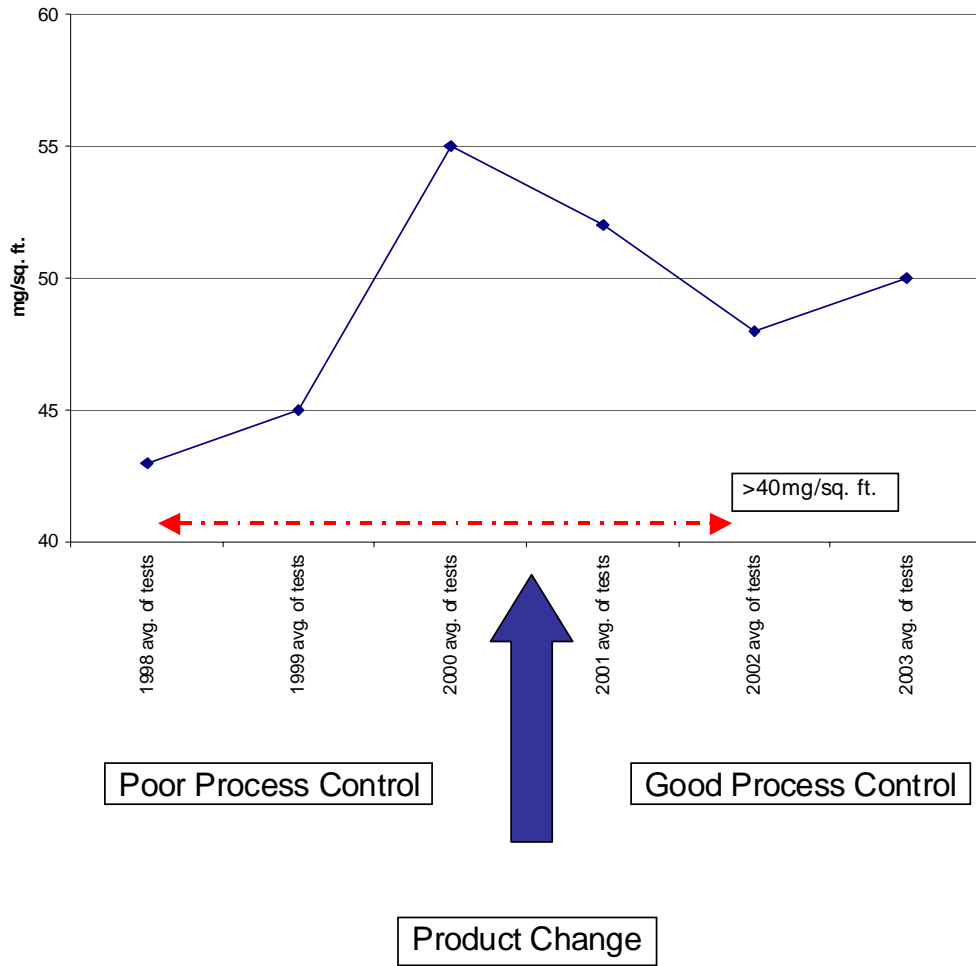


Figure 2