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The Wastewater Insight

Environmental Leverage INC.

BENEFICIAL REUSE

BIOAUGMENTATION: THE MATHEMATICS

Operators and managers of industrial wastewater treatment facilities are under increased pressure to meet their effluent quality requirements. This pressure is due to several factors, including environmental restrictions that are tightening allowable final permit levels and increased corporate pressure to maintain total environmental compliance. Many industrial wastewater treatment systems are only marginally capable of meeting the demands under normal or ideal situations. In times of upset conditions, such as high loading or low temperatures, many systems simply cannot provide the desires results without considerable attention and in some cases augmentation with chemical or bacterial additives.

Chemical addition to wastewater systems has been a widely accepted practice for many decades. In some applications, such as oily water clarification and sludge dewatering, ongoing or continuous chemical addition is usually the rule. In areas such as antifoams or secondary clarification polymers, the applications may either be continuous or intermittent.

Over the past twenty years, the addition of selected bacteria to biological treatment systems has become more widely used as a supplement to, or replacement for, many chemical applications. Known as bioaugmentation, this technology offers many benefits, including cost effectiveness, environmental friendliness and an ability to address some problems not solved by chemical addition. Examples of problems not affected by traditional chemical solutions include enhanced soluble Biochemical Oxygen Demand (BOD_5) removal, biological nitrification and recovery of biomass loss due to toxic shocks.

Because the effects of bioaugmentation are sometimes subtle and biological systems are dynamic and ever changing, it has been historically difficult to quantify the impact of bioaugmentation programs. Most documentation of successes utilized before and after data, bestowing some or all of the credit for improvement on the bioaugmentation program. This approach makes for good sales testimonials and case histories, however critics are quick to point out that during many typical bioaugmentation applications, numerous system changes occur (intentional or otherwise) which can also contribute to improvements observed. They also contend that because of a biomass' ability to acclimate to its environment, the indigenous population will eventually optimize itself. A final objective is that the number of bacteria usually applied is not sufficient to have an impact on a system's population. It is this third objection that this article will attempt to address.

In general terms, bioaugmentation applications can be divided into four categories:

1. Rapid building of a biomass during a system start-up or recovery from an upset.
2. Enhancing performance in once-through systems via ongoing supplemental inoculation.
3. Ongoing population enhancement of activated sludge.
4. Solids Reduction

Each of these categories will be discussed in detail and the potential impact of bioaugmentation will be presented in mathematical terms.

RAPID BIOMASS ESTABLISHMENT

Historically, many operators of activated sludge systems have practiced a form of bioaugmentation when they obtain sludge from a neighboring facility with which to seed or re-seed their system. While this is a valid and acceptable approach, the use of commercial cultures can be used in conjunction with or in place of acquired sludge. The use of commercial cultures offers several advantages:

1. The product is readily available and can be kept on hand for quick response. If a plant is geographically isolated, it may be difficult to acquire sludge.

2. The product consistency is assured in terms of concentration of bacteria and types of strains present.

3. No risk of introducing someone else's problems, such as

MYSTERY BUG OF THE MONTH

We started this month out with a new

Mystery Bug of the month!

Check out our website for more photos of our new mystery bug, no he really cannot bite you!!!!
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INSIDE

filamentous or zoogloeal bulking into the system.

4. If properly selected, the commercial cultures provide the rapid growth required to return the system to the desired performance levels.

5. Other advantages include time and labor involved with getting a truck and operators, hauling the sludge from place to place, dumping the sludge and re-cleaning the truck so it can be used for its former job.

Some areas where biomass establishment would be needed include:

1. Start-up of a new plant.
2. Re-start following a shutdown or period of reduced production.
3. Following a loss of biomass due to washout or toxic shock.
4. Following the use of chlorination for control of filamentous bulking.
5. During the winter (colder) months when activity of the biomass slows down due to temperature drops (one log growth for each 10 degrees).
6. With the onset of closed loop systems where water recycle is important,

When comparing the use of commercial cultures with trucked in sludge, one has to compare apples to apples. Because of the concentrated nature of the products, many people fail to recognize or appreciate the numbers of bacteria that can be introduced via bioaugmentation, if properly applied. With trucked in sludge, you get mostly water. Even the solids you receive are relatively low in actual viable bacteria. What about the stage of growth of the bugs, the presence of filaments, the compatibility of the food sources? Plus there is no guarantee that there are no pathogenic bacteria present. With commercial cultures, the products are highly concentrated, stable, and can actually be "grown up" prior to application, which greatly enhances the cost-effectiveness. Figure 1 shows the grow up potential of a typical product used for upset recovery. The mathematics are detailed in the Appendix.

Figure 1. Impact of Bioaugmentation on Plant Effluent BOD Levels

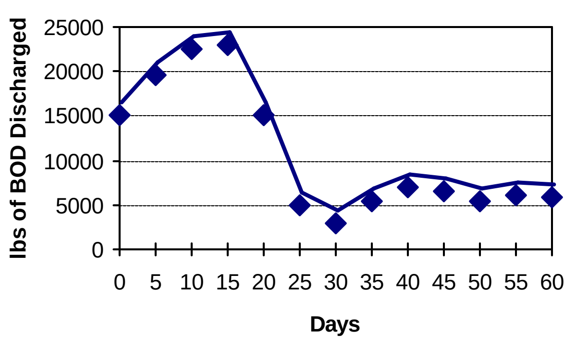


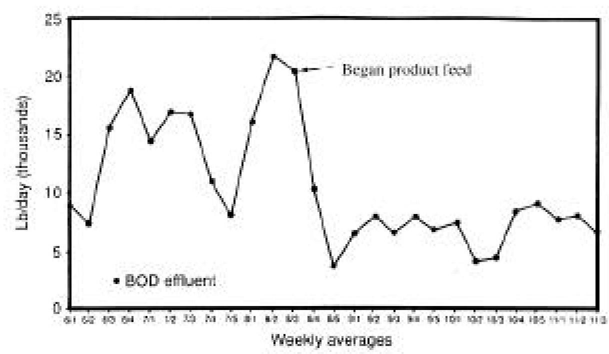
Figure 2 shows how 5-10 pounds of a typical dry commercial blend of bacteria can provide as many bacteria as 4000 gallons of activated sludge. Depending on the situation, commercial bacteria may actually be less expensive than acquiring sludge from another plant. Even if the economics favor trucked in sludge, keeping a supply of bacteria on-site for upsets offers benefits. An improved ability to quickly respond can prevent an upset from escalating into a crisis.

SUPPLEMENTAL INOCULATION OF ONCE-THROUGH SYSTEMS

As the name implies, once through systems have little or no recycle to continuously re-seed the aeration basin with bacteria. The primary source of bacteria is the indigenous bacteria in the product plant effluent to be treated. This indigenous population may vary by as much as two orders of magnitude in terms of numbers of bacteria and may also vary in terms of types of bacteria present.

The lack of sludge recycle and the plug flow configuration of most once-through systems means that the system must rely primarily on the bacteria present in the influent to grow, reproduce and degrade organics compounds in the wastewater stream and insufficient time that the system has to offer without causing TSS or BOD problems in the final effluent

BOD_5 reduction in a once-through system is a function of many factors, including aeration capacity, residence time distribution, nutrient availability and bacterial growth. If the "engineered" aspects of the system, such as flow pattern and aeration capacity are optimized and adequate nutrients are available, then the addition of additional bacteria can boost the bacterial numbers and increase BOD removal across the system. How much additional removal can be obtained will depend on the levels of viable bacteria in the influent, system hydraulic residence time distribution (flow pattern and holding time) and availability of adequate oxygen and nutrients.



While the actual impact of bioaugmentation will vary among different systems, it can be shown that properly applied bioaugmentation cultures can contribute up to an additional 30% to the influent bacteria levels.

Figure 4 in the appendix shows how bioaugmentation can enhance the performance of a system by increasing the number of bacteria available to degrade the various wastewater constituents as well as the types present.

Supplemental bioaugmentation in once-through systems differs from the upset recovery type approach. In once through systems, the bioaugmentation program usually needs to be continued on a regular basis. With no sludge recycle, there is no means for the population to sustain itself and therefore, bioaugmentation may be routinely required to make the process capable. In some cases, the use may be seasonal to address performance problems during winter months or lower effluent BOD permit levels in summer months. There may be TSS problems in once-through during summer months, algae problems or D.O. loss during summer months.

ONGOING POPULATION ENHANCEMENT OF ACTIVATED SLUDGE

The practice of ongoing bioaugmentation in activated sludge processes relies on a simple premise. Even though many strains or species of bacteria can accomplish a given task, they vary in efficiency and speeds with which they degrade various compounds. The goal of ongoing bioaugmentation is to provide additional organisms that are more efficient or effective than the indigenous bacteria at degrading the various organic compounds and producing a settleable biomass. They are usually selected strains that are healthier, sturdier, and more able to withstand shocks better.

Figure 2. Impact of Bioaugmentation on Plant TSS Effluent Levels

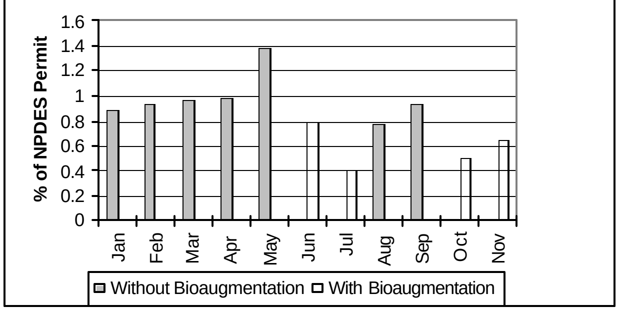


Figure 5 conceptually categorizes the biomass into Population A (desired indigenous microorganisms), population B (other filler, less active or undesirable indigenous microorganisms) and Population C (selected bioaugmentation organisms). The goal of bioaugmentation program is to enhance the growth of Population A, establish the selected microorganisms of Population C and minimize Population B.

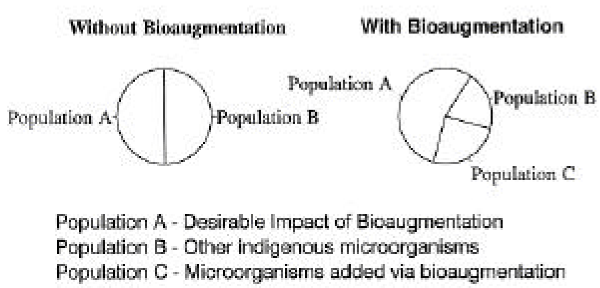
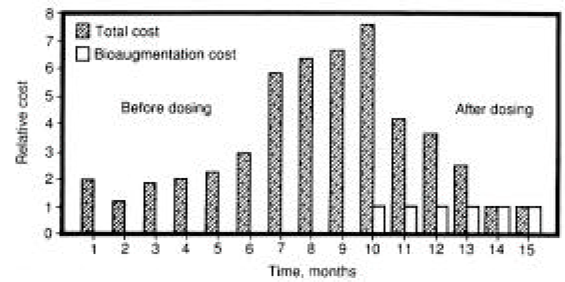


Figure 5: Conceptual Impact of Bioaugmentation on Bacterial Population in an Activated Sludge System

There is the question of why bioaugmentation products must be fed continuously after initial dosing of product in an activated sludge plant. An activated sludge plant is a dynamic system, where bacteria are routinely removed through wasting and additional indigenous bacteria are constantly being introduced via the influent and other sources. Due to system upsets and influent composition changes, a maintenance dosage is required to maintain the desired population diversity.

Ongoing product requirements of "biomass maintenance" dosages are targeted to maintain bacteria at a pre-determined level. Proper monitoring of the system using statistical process control, combined with microbiological analyses techniques will provide the information needed to maintain the desired population. By using microscopic analyses and advanced plating techniques, one can correlate bacterial population characteristics with plant performance for a particular waste treatment system. Because every system is unique, the optimum population will vary from plant to plant.



Impact of Bioaugmentation on Total Chemical costs

SUMMARY

While the acceptance of bioaugmentation continues to grow, there are those that remain skeptical regarding the scientific validity of this approach. The mathematical examples in this article are not intended to provided definitive proof of the effectiveness or legitimacy of bioaugmentation. Rather, they were developed to provide the reader with a new and different perspective of the technology.

Explaining why a biological system performance varies from day to day can be as difficult as trying to explain why a particular sports team wins or loses. In both cases, there are numerous factors that effect the final outcome, and many of those factors are not fully understood or appreciated. Bioaugmentation should be applied in only those cases where it is a technically correct approach. It is critical to keep both the potential benefits and the limitations of bioaugmentation in perspective when applying this technology. If this perspective is maintained, than bioaugmentation can help provide solutions to many wastewater treatment problems.

Appendix

IMPACT OF FEEDING ONGOING BIOAUGMENTATION TO A ONCE-THROUGH LAGOON: THE ARITHEMETIC

Assumption: 40 MGD flow
Adequate aeration and holding time
Essentially plug flow
10 lbs/day Biological product (70 growth factor/ 6 x 109 cfu/g average count)

Case 1: Influent TVC of 1 x 107 cfu/ml
Daily innoculation of indigenous organisms = 1.5 x 1 18 cfu
Additional bacteria due to Biological product feed = 1.9 x 1015 cfu
Minimum contribution of Biological product = 0.13%

Case 2: Influent TVC of 1 x 105 cfu/ml
Daily innoculation of indigenous organisms = 1.5 x 1 17 cfu
Additional bacteria due to Biological product feed = 1.9 x 1015 cfu
Minimum contribution of Biological product product = 12.7%

RANGE OF POPULATION CONTRIBUTION OF BIOLOGICAL PRODUCT IN A ONCE-THROUGH LAGOON SYSTEM

Assumptions: 10 MGD flow
5 lb/day Biological product feed

Range of Indigenous Inoculations: 3.785×10^{15} - 3.785×10^{17} cfu/day

Range of Biological product innoculation 5.675×10^{14} - 1.43×10^{15} cfu/day

Minimum Contribution of Biological product 0.14%

Median Contribution of Biological product 2.6%

Maximum Contribution of Biological product 38%

COMPARISON OF RESEEDING WITH Biological product VS TRUCKING IN SLUDGE: THE ARITHEMETIC

1 truck load of Activated Sludge = 4000 gallons

(4000 gals/truck) (3785 ml/gal) (5 x 107 cfu/ml) = 7.57 x 1014 cfu/truck

typical

Biological product in Biofeeder

A) No Grow up
(1 lb Biological product) (454 grams/lb) (5 x 109 cfu/gram) = 2.27 x 1013 cfu/lb
grow up product specification

= 333 lbs Biological product = 1 truck

B) Using Biological products and with an 8 hour grow up time period
(1 lb Biological product) (10) (454 grams/lb) (5 x 109 cfu/gram) = 2.27 x 1013 cfu/lb
grow up product specification

(7.57 x 1014) ÷ (2.27 x 1013) = 33 lbs Biological product C = 1 truck

C)Using Biological products and with a 16- 24 hour grow up time period (1.5 logs)

(1 lb Biological products) (50 growth factor)(454 grams/lb)(5 x 109 cfu/gram) = 1.135 x 1014 cfu/lb
grow up product specification

(7.57 x 1014) cfu/truck ÷ (1.135 x 1014) cfu/lb = 6.7 lbs Biological product = 1 truck

IMPACT OF FEEDING BIOAUGMENTATION TO AN ACTIVATED SLUDEGE SYSTEM: THE ARITHEMETIC

Assumptions: 1 mgd flow w/0.5 mgd recycle
1 mgv under aeration
5 x 107 cfu/ml TOC in AB
2 lb/day Biological product feed

Approach 1: Relative to biomass in basin

(1 mgv) (3785 ml/gal) (5 x 107 cfu/gram) = 1.9 x 1017 cfu
2 lb Biological product = 2.27 x 1014 cfu or 0.1 % of biomass (1000 ppm)

Approach 2: Relative to recycle

(0.5 mgd) (3785 ml/gal) (1 x 108 cfu/gram) = 1.9 x 1017 cfu
2 lb Biological product = 2.27 x 1014 cfu or 0.1 % of biomass (1000 ppm)

Approach 3: Relative to influent innoculation

(1 mgd) (3785 ml/gal) (1 x 106 cfu/gram) = 3.785 x 1015 cfu
2 lb Biological product = 2.27 x 1014 cfu or 6.0 % of daily innoculation

Summer Activity

Ever wonder why your clarifier looks like a bubbling volcano in the summer?

Did you know that in the summer the biological activity is significantly higher than in the winter, therefore you need to carry less MLSS in your system. For every 10 degree F change in temperature, the activity of the bacteria increase one log's growth.
That means when it is 45-50°F you need to carry more MLSS than when it is 80-90°F in the summer.

Since the activity is higher in the summer, it takes less bacteria to do the same amount of work. Another thing to keep in mind also is that oxygen transfer changes in the summer. Less oxygen will stay in the water in the summer verses the winter months with higher temperatures in the water, so you will run out of air quicker in the clarifier with higher activity and lower oxygen transfer. Make sure to only keep the solids as long as necessary in the clarifier in the summer, or you will get gassing, septicity and growth of filaments that can cause problems with bulking and increase dewatering costs.

Misc. websites

Department of Homeland Security Funds Creation of Process Control Systems Forum

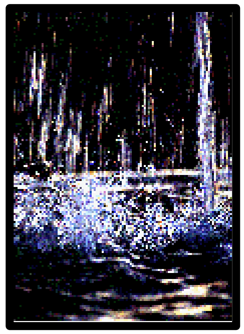
Protecting our nation's power and energy systems, refineries, water management, and factory automation from a devastating cyber attack is critical for homeland security.

Many of our most vital infrastructure assets are operated by computerized automated control systems such as Process Control Systems (PCS) and Supervisory Control and Data Acquisition (SCADA) systems. Adoption of PCS and SCADA technology has allowed for great improvements in efficiency, safety, and response to market forces. However, there is increasing concern that this has come at the price of increased vulnerability to network attacks. To address this concern, the

Department of Homeland Security (DHS) has funded the establishment of the ***Process Control Systems Forum (PCSF)***.

The goal of the PCSF is to protect our nation by developing next-generation core architecture that offers security, reliability, resiliency, and continuity in the face of disruptions and major incidents.

https://www.pcsforum.org/faqs.php



Environmental Leverage Inc. offers consulting services, beneficial reuse, training and bioaugmentation programs that can help reduce your surcharges.

Contact our office today to find out how your can start saving money and become more efficient at your plant!!!

Many times we have suggested articles for the next months issues. Sometimes we change what we will be featuring based upon critical issues that surface during our contacts with our customers. We hope this does not inconvenience you. If you have a specific topic you are interested and do not want to wait to see if it shows up in our newsletters, call us direct. We do have over 20 gigabytes of information on file on every subject around on water and waste issues.

The new model SID-10200 from Raven Environmental Products is a portable handheld instrument that accurately determines the sludge blanket solid/liquid interface depth in primary tanks, clarifiers, sedimentation basins and a wide variety of sludge settling tanks.

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