# Bioaugmentation and the use of biocultures: applied industrial microbiology in coal substrates

The need to find viable energy alternatives, combat climate change, and secure an energy future is essential for all sectors today. There are many proven solutions in renewable energy being implemented, such as wind, solar, and wave energy. Numerous research projects are underway in establishments around the world on topics ranging from new ideas in renewable energy to finding alternate uses for current energy resources such as oil and coal. One such project on alternative energy is currently ongoing in Queensland, Australia.

The research has developed microbe formulations that are expected to promote the production of methane gas in commercially relevant quantities when coupled with standard wastewater treatment technology for treating coal (above ground and below), coal seam gas wells, shale oil, and other associated coal waste streams. Essentially, a wastewater treatment system is a condensed form of the natural ecosystem's ability to assimilate waste. Nature simply cannot deal with the quantities and concentrations of waste emitted by business, manufacturing, and industry today, requiring specialized wastewater treatment plants to reduce the impact on the environment and reduce pollution.

### Reliance on bacteria and enzymes

An essential part of the treatment process involves bacteria, enzymes, and nutrients within the system. Each species of bacteria has a specific role to play in breaking down waste until the resulting effluent can be introduced to the environment with as little impact as possible. Bacteria are single-celled forms of life, and some species are more resilient than others. The most abundant species are not necessarily the most efficient at breaking down waste streams. Our research has shown that certain types of bacteria that may not be abundant naturally can be artificially increased. As these colonies increase over time, they take over the more indigenous populations and potentially make the process perform more efficiently. This has the benefit of being able to increase recoverable by-products and produce a far cleaner final discharge than the more indigenous population of bacteria.

These single-celled organisms grow and, after reaching a certain size, they divide into two. This is termed "reproduction by binary fission," with both of the new cells adapting to the physical properties of the substrate being treated and becoming identical to each other. Every time a cell splits into two, we have a new generation. If an adequate food supply is present, the cells will keep dividing and growing.

As the population of bacteria grows, producing enzymes, the cells adapt to the waste stream in which they have been introduced. The actual bacteria do not change, but their enzymes adapt to suit the waste. This means that after introducing bacteria specific for the substrate, they will become better at digesting the waste with time.

Research has confirmed this process on mined coal in a laboratory under controlled conditions. Studies on methane-producing bacteria within coal seams is occurring worldwide, and the leaders appear to be private-sector enterprises in the USA. The duplication of research programs in different countries may be unnecessary since microbes available for purchase and approved by regulatory authorities can be combined to create gas from coal. The fundamental disconnect in conventional research on microbial energy-producing processes occurs because the microbe consortia essentially "cannibalize" and successively "eat" each other, leaving only the methanogens that are last in the chain. These methanogens are "starved" and need organic acids produced from long-chain hydrocarbons such as coal to continue making methane effectively.

### Lateral transfers of knowledge

By concentrating on the upstream, facultative bacteria that produce methanogen "food," current research requires only minimal capital and few scientific staff. Progress occurred primarily because of lateral transfers of knowledge gained from decades of work in wastewater treatment. A low-risk process has been developed to show that methane can be produced in coal subjected to conventional wastewater treatment technology. Although a pilot plant has not yet been built, the process should produce high-quality biogas, a solid high in carbon (plus other minerals in the waste stream not biodegradable), and recyclable water suitable for onsite purposes. Figure 1 outlines results from preliminary testing performed in relation to the calorific values of the coal substrate prior and after digestion testing.

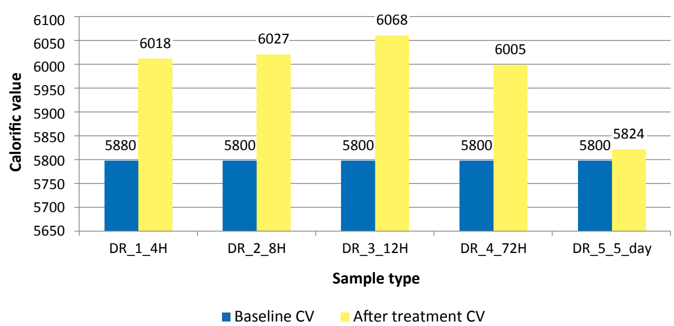


**Figure 1.** Calorific value (CV) of coal substrate before and after digestion treatment.

The process incorporates two conventional strategies in wastewater treatment: an enhanced two-phase biological treatment process; and bioaugmentation, which is the introduction of natural microbial strains to treat contaminated soil or water using biocultures. When combined, the biogenic process of some elements within a coal substrate and methanogenesis can potentially be enhanced, producing intermediary material that will be digested by methanogenic bacteria to form biogas.

Success has been achieved by working with various designs for wastewater treatment and different strains and formulations of bacteria (bioaugmentation) in different waste (from animal manure to food-processing waste to pharmaceutical and chemical waste streams). The results show that by applying different phases of bacterial growth and discovering how different elements of waste are broken down, there is potential to improve the overall performance of treatment systems, producing recoverable by-products such as biogas, a cleaner substrate, and recoverable water.

These two basic principles have been adapted to treat coal. Researchers are applying wastewater treatment principles and bioaugmentation to two types of coal substrate, washed bituminous coal and brown coal. Results have varied and raised questions on the design and application of the process, as well as on the bacterial blends used so far. Further testing is underway.

**How the process works**

The process is derived from wastewater treatment methods that have been used successfully for decades. These same methods can be used to break down any organic-derived substrate to produce by-products such as biogas, biosolids, and recyclable water on a commercial scale. Research involving small-scale testing parameters indicated that the organic content of coal substrates was digested, biogas was produced, and mass reduction or digestion of the substrate occurred.

The adaptation of wastewater treatment principles is the key to the success of biogas production from hydrocarbon sources. Biogenic biogas is produced in a four-step process consisting of hydrolysis, acidogenesis, acetogenesis, and methanogenesis. In conventional anaerobic digestion, the four steps occur within the same space. However, the first three steps are performed at a pH different from that in the fourth and final stage, as illustrated in Figure 2.

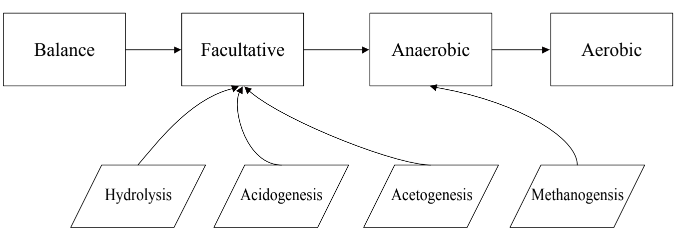


**Figure 2.** Simple illustration of the separation of stages. The first three stages occur in the facultative tank, and the fourth stage occurs in an anaerobic reactor.

This causes the different species of bacteria associated with each stage to fight each other, which naturally creates a less efficient ecosystem. The adapted process separates the first three stages of the anaerobic process into hydrolysis, acidogenesis, and acetogenesis. This is advantageous for two main reasons: 1) the facultative anaerobes that are present in the first three stages no longer have to compete for space with the fourth-stage methanogen bacteria and therefore react far more efficiently and effectively; and 2) the process yields more by-products.

**Conclusion**

Further research on the viability of coal substrate digestion is ongoing. The next phase will be to refine the process and then build a pilot-scale treatment plant to find the most effective, efficient means to digest coal substrates and obtain viable by-products that can be sold on a commercial scale. On completion of the pilot tests, it is hoped that a method for producing gas from coal and cleaning coal substrates to reduce the carbon footprint of burning them can be adapted worldwide for any coal-based deposits.

*Jonathan Evers has 25 years' experience in the environmental field and applying microbial solutions to waste management problems. His expertise covers such areas as identifying and formulating microbial formulations for waste management, applied industrial microbiology, carbon accounting, greenhouse gas emissions, sustainability, climate change, resource recovery, eco-efficiency, energy use, renewable energy, waste management, and more recently ecological economics. He has a BA in Environmental Management majoring in sustainable development and an MA in Environmental Law. His work in ecological economics of coal seam gas/water disposal coupled with extensive experience in waste management led to his pioneering breakthrough in coal digestion yielding viable by-products. Evers has been a guest speaker for the APO at conferences focusing on technology for mitigating climate change. He is a part-time lecturer at the University of Queensland, Griffith University, and Bond University on climate change, renewable energy technology, and eco-efficiency.*