Self Selecting BioReactors

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Bioreactors 101: What is a bioreactor?

Simply put, a place where biologically catalyzed reactions occur producing useful, or at least non toxic, products.

Unintentional: Nature, in an open system, is self selecting but deterministic towards reproduction and the generation of environments that increase survival.

Intentional: A bioreactor is an embodiment that grows life for the generation of environments and products that increase human and ecological survival.

These systems host one or many (homogeneous/heterogeneous) microbial species in their biofilm form. Over all known as ecology. So a bioreactor is an ecological form that does predictable and reproducible work.

Examples of bioreactors, specific and by-proxy

MRUs/PermaCyclers,

methane digesters, composting toilets

reclamation ponds,

fish tanks,

gardens,

space stations,

waste treatment plants,

people, plants, my dog River...

What is biofilm?

- A generally heterogenous mix of microbes adapted to a particular niche so that the biofilm remains generally stable in its biomass and biodiversity.
- As opposed to planctonic cells, which are free floating and not producing EPS
    - Extrapolysaccharidal matrix (the film).
- This film provides an enormous amount of protection to the biofilm bound cells over their planctonic phylogeny. Up to 1000x greater resistance to abiotic factors like antibiotics
    - Also provide chemical signaling, structural support, refuge, desiccation protection, limited UV protection, catalyze a host of redox reactions.

What is a bioreactor?

- A place where biological catalyzation of inputs results in outputs which are in part derived/determined by growth and reproduction of the working/growing biofilm,
    - Don’t forget conservation of mass and energy! Stoichiometry and Enthalpy
    - This change in products and energy is “work” and is measurable and well understood.
    - A good microbial biofilm class, mixed with limnology, strikes the closest to this discipline at the undergrad level.

(constant state of flux by predictable and stabilized biofilm).

Parts of a bioreactor: 4 major components

1) A generally constrained space for work to happen within.
    a. Cell membrane, nuclear membrane, organelle membranes
    b. Or the Outside of a plastic box and internal structures.
2. The biology within. The biofilm is the primary catalyst of reactions which would otherwise not occur at rates useful or practical for work.
3. Growth matrix. The surface area upon/within which the biofilm grows. Generally, the more surface area the better, to a point.
4. The influent products to be remediated.

Feedback loops and steady state

1. Positive Feedback Loop:
   - a "disturbance in the force" that impacts a niche's biological steady state to the point where biodiversity shifts to a new steady state. Antibiotics, sedimentation, lack of O2/C source
2. Negative Feedback Loop:
   - an "attenuation factor" that allows for a disturbed ecosystem to return to the existing biological steady state, therefore not undergoing a permanent shift.
   - Homeostasis is a good example of an ecology (human) preserving a steady state. White blood cells and disease fighting are examples of negative feedback loops preserving the steady state.

So what about geo-chem-electric...?

The geology, chemistry, electric, ORP, solute diversity and concentrations all affect and are affected by the biology, which modify its environment to better survive.

Without the biology, the other factors combined are not capable of useful work at the existing conditions. The biofilm is the catalyst to get the work done, so the emphasis on bio-reactor

Side note: abiogenesis

Metabolic Pathways: Bill and “TED’s” Herbal “TEA”

- Terminal Electron Acceptors: from most energetic to least energetic, O2, Nitrate, MnOx, Fe3 oxides and oxyhydroxides, Sulfate, Methane...
- Some are lost to volitization, but others, like MnOx are redissolved as a solute and can be lost down stream.

- Terminal Electron Donors: the carbon and/or energy source,
  - Lots of these, near endless, glucose, Fe2, methane, sunlight (technically)...
- The source of TED’s TEA determines the kind of metabolic pathways that can exist in a bioreactor.

Diversity of Metabolic Pathways

Many pathways can exist within very tight confines, sometimes no more than the thickness of a cell wall.

Chemo - autotroph/heterotroph

Photo - auto/hetero

Litho - auto/hetero

I'm missing some, but you get the idea...

Open Environments, the only constant is change

- An open environment is constantly changing, and products of one metabolic pathway are biological necessities for another.
- This flux (succession) of material, energy, and living organisms provides the ability, and stability, of a self selecting biofilm reactor (or wetland) to not only remediate a large number of products, but can sequester or volitize them in stable niches that can then be collected for use.
- Think of it as biological heterogeneous distillation of many products
    - though not like alcohol, with is another example of a homogeneous bioreactor favoring one species for one product.
    - Or, like a (bio) schenk line

Primary Indicators and Manipulations

Major simple things to monitor or manipulate for increased performance.

RedOx with and ORP probe

Flow

pH

Temp

Biological Engine

Since the bioreactor is doing work, it can be measured in its efficiency of biological conversion.

The Prime Manipulations will indicate the stability of a specific environment and the products on the basis of amount removed/converted per cubic meter per day, or the work efficiency.

An engine must be fine tuned to get the best performance.

55 mph is the best rate over distance traveled to acheive the best gas efficiency for most vehicles.   A bioreactor has a best rate too.

The MRU/PermaCycler

In order to take full advantage of successional bioredox reclamation, a bioreactor must be used that can run fast, be cleaned out easily, and easily manipulated to select for different TEDs TEA .

The MRU is a scaleable and modular bioreactor and can be adapted to infinite flows and concentrations by changing the arrangement of the MRUs to provide enough surface area and retention to remediate the entire load.

Load = concentration x volume (or rate)

Run ‘em faster. Gets you more bang for your buck

Depending on the TEA and its energetic potential, the biodiversity in an open, self selecting environment will select the best energy providing couplet of TED’s TEA until one or the other of the couplet is depleted and succession selects for the next most energetic couplet.

For example. Aerobic macros will thrive in moving water with lots of DO and fully oxidized acceptors and donors. When Dissolved Oxygen is consumed by BOD and COD, the next best TEA (nitrate) will be utilized, till its gone, then MnOx…. Down the ladder

Manipulations and Reclamation

The energetic availability from each stoichiometrically balanced redox couplet is predictable by its energy availability and can be manipulated to remove different products at different times, intelligently using self selection to remove all TEDs and TEAs to low concentration or background levels, considered safe or clean.