Environmental Microbiology Seminar 14.11.16

Explain the difference between the classical plume and the 'plume fringe concept'. Give your opinion which theory fits better and why?

With the plume fringe concept, the main degradation process takes place at the fringe of the plume. However, with the classical plume, the degradation occurs within different zones along the plume. The redox zonation concept follows the redox tower. There is no transversal dispersion of processes within the plume. The plume fringe concept can explain why contaminant degradation is limited in the center of a plume because the dissolved electron acceptors are depleted.

What happens with the O_2 and H_2S concentration in a sediment after cutting the cable bacteria?

- The O_2 consumption goes down
- Sulfide concentration goes up 10 mm (due to diffusion)
- The curved radiant went straight
- The long distance electron transfer is not working anymore

How is an increase of the pH in the oxic zone of the sediment connected to the metabolism of cable bacteria? (remember the redox reaction)

Oxygen reduction: $2O_2 + 8e^- + 8H^+ \rightarrow 4H_2O$

Sulfide oxidation: $HS^- + 4H_2O \rightarrow SO_4^{2-} + 8e^- + 9H^+$

An increase of the pH is a consequence of the oxygen reduction in the area close to the surface. The sulfide oxidation leads to a decreased pH.

What is long distance electron transfer and how is it used in cable bacteria?

LDET is used by cable bacteria to provide or better transport electrons from cell to cell. This is necessary, because their redox half reactions take place in spatially separated cells. The electrons are transported through filamentious connections between those cells. So, this property or ability makes it possible to reduce oxygen and oxidize sulfide in different cells.

What does BTEX stand for and why are they important in groundwater control?

It is a group of aromatic hydrocarbons (benzene, toluene, ethylbenzene, xylene). These compounds account for about half of the contaminations.

1. Is biodegradation activity mostly controlled by the availability of specific electron acceptors or thermodynamics? Why the microorganisms would choose one of these ways?

Solution: In hydrocarbon contaminated aquifers biodegradation is mostly limited by electron acceptor availability. As long as enough electron donor is present (usually hydrocarbons are present in excess) it is expected that all respiratory processes take place simultaneously. Thus, they are availability limited. Only in systems with limited supply of electron donor (e.g. pristine aquifers) a real thermodynamic control takes place.

2. what advantage do Cable bacteria take from the spatial separation of the redox half-reactions, when it comes to the competition with other microorganism?

Solution: Cable Bacteria are able to outcompete other microorganisms by reducing compounds at one depths of the sediments and transport the electrons to the upper part of sediments where competition for oxidation are favorable. Other organisms must perform both oxidation and reduction processes in the same spot and cannot compete with the cable bacs that can bridge a zone where none of the reactants is present.

3. outline the plume fringe concept

Solution 1: Higher technology has shown that the classical redox zonation theory is not correct. The plume fringe concept changes the order how the electron acceptor is used, pointing out that electron acceptor that are already depleted in the source zone, can not be available downstream of the plume.

Solution 2: Reactions are limited by diffusion or dispersion which determines degradation. Bioavailability is determined by the transport. Redox reactions takes place at the fringe of the plume with redox reactions from the outside to the inside of the plume determined by dispersion.

5. Explain why small organisms like bacteria do not need a blood circulation system and make assumptions on how the human anatomy would need to change in order to survive without a heart.

Solution: Bacteria do not need a blood circulatory system because diffusion is enough for them. Since they are very small organisms, diffusion is the fastest possible transport process. Some bacteria can also do long distance electron transport. In humans, transport distances are far too big and transport by diffusion would take years. Thus, an active blood transport system is needed.

Which organism can live on diffusion?

> Only microorganisms are able to do this, as they are small enough. Diffusion is very fast on micrometer scales but very slow on larger scales of mm and higher.

- Explain one of the characteristics of cable bacteria. Why is it important?

> Cable bacteria are the only organisms which can separate the two parts of the redox reaction. They can do the oxidation and the reduction on different ends of a cellular filament. This allows them to live in habitats where electron donor and acceptor are spatially separated. This is a great advantage, as no other organism can do this.

- What are the advantages of the plume fringe concept over the redox zonation concept?

> The plume fringe concept accounts for the dispersive mixing in groundwater and also is able to predict that electron acceptors are depleted in the centre of contamination plumes. It also has the advantage of explaining which processes take place at certain locations

- Describe the redox zonation concept.

> Contrary to the plume fringe concept, in the redox zone concept there are dedicated zones where just one specific electron acceptor is used. For example in the area right around the contamination zone, primarily methanogenesis used and then sulfate reduction in the next zone. However, this doesn't make sence as the electron acceptor sulfate should have been depleted before methanogenesis takes place.

1) How does cable bacteria conserve energy? Explain briefly the mechanism involved.

Cable bacteria oxidize sulfide in deeper layers of the sediment and reduce oxygen in upper layers. The electrons are transported along the filaments by long distance electron transport.

2) Why can´t a bacterial cell grow big like an elephant?

Bacteria is unicellur and elephants are multicellular. The more cells an organism has the bigger it can grow. Moreover, bacteria does not possess a blood system and oxygen transport only through diffusion is limiting size. An organism of the size of an elephant cannot be life without active transport through a blood circulation system which a unicellular organism could not provide.

3) Explain what the redox tower represents.

It shows the redox potentials of different redox pairs. Due to the position in the tower one can determine which half reaction-partner is oxidized and which one is reduced. Half reactions with a lower potential will be oxidized by redoxpartners with a more positive potential.

5) For what do we need an Isotope Analysis (e.g. Toluene, sulfate) to confirm the plume fringe concept? What does this Isotope Analysis show? (Why isotopes are used (Interaction of Microorganisms and isotope)?

Isotopes are occuring naturally with certain abundances. Degradation of compounds such as toluene leads to an enrichment of heavy toluene (^{13}C, i.e isotopes of low natural abundance incorporated) in the residual substrate fraction which allows for determination of degradation. The high sensitivity of

stable isotope analytics allows for the analysis and determinations of the isotopic ratios. Thus, we can detect where in the plume degradation takes place.