CTB3365x – Introduction to Water Treatment

W5a1 – Nitrogen cycle

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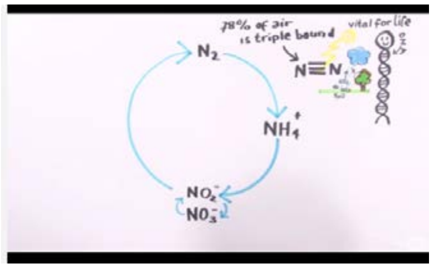
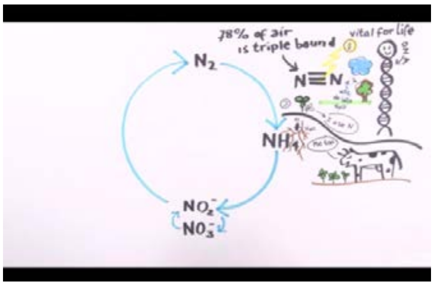
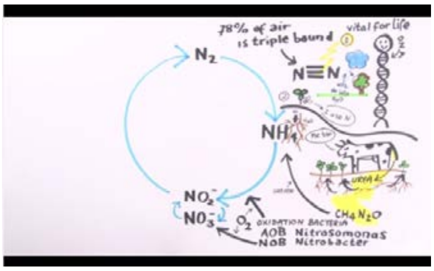


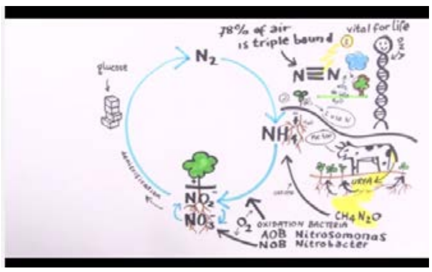
Besides the famous carbon cycle, we have another elemental loop on earth: the nitrogen cycle. 78% of the air consists of nitrogen, a stable molecule due to its triple bond that requires a lot of energy to break. This atmospheric nitrogen is the largest pool on earth, but turnover is very low. Still, nitrogen is vital to life. Nitrogen is present in amino acids, proteins, DNA, RNA; all life on earth contains 10% nitrogen by weight fraction. Therefore, cycling between hemisphere and biosphere is a necessity to allow growth.



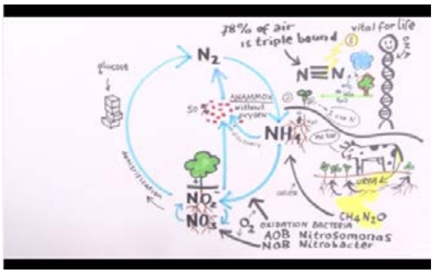
Di-nitrogen gas can be fixed from the air by two natural processes. First, lightning can break the triple bond and allow the nitrogen to combine with oxygen, forming nitrous oxides that will be washed from the air by rain. This is only a small part in nitrogen fixation. More work is performed by several bacteria and algae species. In anaerobic microenvironments, these organisms are capable to convert nitrogen and water into ammonium and hydrogen. Legumes are the most well known example of a symbiosis between nitrogen fixing bacteria and the roots of higher plants, natural fertilizing plant growth. Plants use this ammonium to incorporate in their cell material via assimilation,



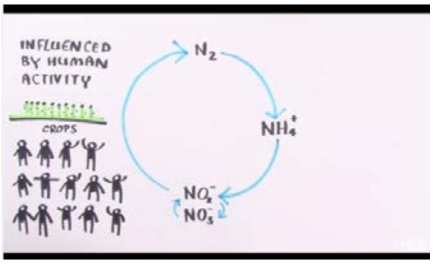
serving again as nitrogen source for animals and human. These excrete the unused nitrogen again as urea in feces and urine. Urea can be used directly by plants. But also many soil bacteria contain the enzyme urease that catalyzes the conversion of urea to ammonia CO2. Autotrophic ammonia-oxidizing bacteria or AOB gain energy from oxidizing ammonia to nitrite. Nitrite-oxidizing bacteria or NOB oxidize nitrite to nitrate. Most well known AOB and NOB are Nitrosomonas and Nitrobacter, respectively



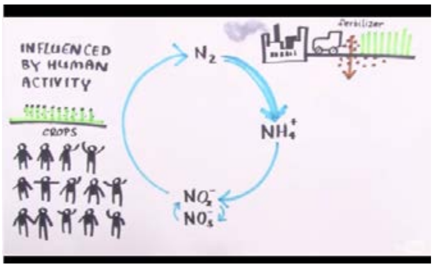
The ammonia and nitrate are readily absorbed by plants, and are the dominant sources of nitrogen for plant growth. Besides being used in plants, nitrite and nitrate, can also serve as electron acceptor by heterotrophic organisms instead of oxygen. This is called denitrification. A carbon source, as glucose, will serve as electron donor in this reaction. These heterotrophs produce di-nitrogen gas, which closes the cycle.



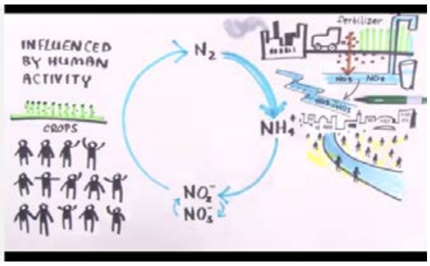
In the nineties, a microorganism was discovered that is capable of creating a short cut in the N-cycle; Anammox, an abbreviation of ANaerobic AMMonium OXidation. In a Dutch industrial plant an observation was made that ammonium and nitrite were removed together in absence of oxygen, leading to the discovery of this nice red bug. The Litho-autotrophic Anammox bacteria couple nitrite reduction to ammonium oxidation, producing di-nitrogen gas and water. It turned out that this process is responsible for 50% of the global reactive nitrogen loss from marine systems.



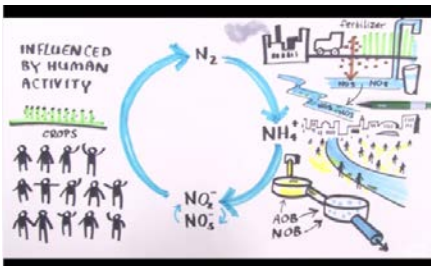
During the past 300 years, human activity influenced the nitrogen cycle in various ways. In the late 18th century the element Nitrogen was discovered and in the mid 19th century its important role in crop production was recognized. Less than 50 years later, a growing human population started to stress the known sources of nitrogen for food production.



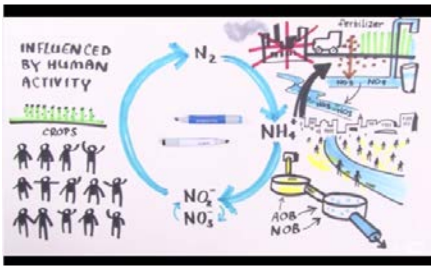
At that moment, the most important agricultural source of reactive nitrogen was biological fixation and natural deposits. The discovery of the anthropogenic nitrogen fixation by the Haber-Bosch process, relieved nitrogen shortage in food production, but also led to a large imbalance in the nitrogen cycle. Between 1860 and 2000, Nitrogen fixation increased 11 fold to 165 Terra gram Nitrogen per year.



This led to worldwide environmental problems, as eutrophication of lakes, rivers and marine ecosystems and losses in species diversity.. Additionally, massive nitrification led to acidification of soil and water and increased nitrite and nitrate concentrations in groundwater and drinking water. Problems not only occur in agricultural areas where fertilizers are used, but imbalance can also be found in dense populated areas, where many people excrete urea in large quantities.



Would this remain untreated, it would lead to the eutrophication problems mentioned before and threaten drinking water resources. Therefore, these unnatural high amounts of Urea are transported to local sewage treatment plants, where the natural process of nitrification and denitrification is enhanced in large aerated and anoxic tanks with many AOB, NOB and heterotrophs. So the imbalance in the local nitrogen cycle is solved by increasing the recycling rate to di-nitrogen gas, to prevent eutrophication of the direct surroundings and accumulation of mobile nitrogen ions in ground water reserves.



Or should we recover the fixed nitrogen from sewage, in a form that is suitable for transport, and use it as a fertilizer at the lands that need it for agriculture? In that way we could short circuit the N cycle, preventing to use the high energy consuming Haber-Bosch processes and restore the natural balance between growth of crops and excretion of fixed nitrogen.