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ENVIRONMENTAL IMPACTS OF NITRATE AND NITRITE

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Abstract:
The natural nitrogen cycle is significantly influenced by the human activity – principally by agriculture and transport. The excessive fertilizing, the organic matter content of sewage waters, and the emission of nitrogen oxides to the atmosphere – caused by vehicles and industrial activities – are unsettling the biosphere's nitrogen balance. The anthropogenic nitrogen surplus in soils, water bases and atmosphere means great problem, and its indirect effect is observable in our environment and daily life. Nitrite and nitrate pollutions are important and serious risks in spite of being relegated to the background in global environmental protection.

Keywords:
nitrate, nitrite, fertilizer, eutrophication, methemoglobin

1. SIGNIFICANCE OF NITROGEN

The nitrogen is present in the environment in many various forms and considerable amount. Nitrogen compounds are especially important from environmental, ecological and physiological aspect because they are indispensable constituents of e.g. proteins, nucleic acids or humus; they can be found in the atmosphere, in soils or in any living organism. The wide interval of nitrogen's oxidation state (-3 - +5) indicates the high number of the – essential, toxic, neutral or anthropogenic - components nitrogen can form. Among these numerous compounds nitrate and nitrite mean significant environmental risk and can cause long-term natural damages.

2. THE NITROGEN CYCLE

The elemental nitrogen of the atmosphere – because of its inert structure – highly resists chemical reactions; hence the most of organisms are disable to use it for biological processes. Only some microorganisms (e. g. Rhizobium, Azotobacter, Clostridium) can fix and convert nitrogen to accessible form for plants (ammonia, ammonium). Ammonia is oxidized by Nitrosomonas and Nitrococcus bacteria to nitrite which is converted to nitrate by Nitrococcus and Nitrobacter species during the nitrification process. These nitrogen forms are also available for the flora. Nitrogen compounds of organic residues are converted to ammonia in the course of ammonification then nitrified as well. A part of nitrite/nitrate content of the soil is returned to the atmosphere as elemental nitrogen and dinitrogen oxide by the activities of e.g. Pseudomonas, Paracoccus species (denitrification) (Figure 1).

Accordingly the presence of nitrate and nitrite in the soil is evident; these forms are the main nitrogen sources of plants and indirectly animals and mankind too. However natural nitrogen cycle is significantly influenced by human activities – principally by traffic and agriculture. The biosphere's nitrogen balance is affected by the overfertilizing, the high organic matter content of sewage or nitrogen oxide emissions of traffic and industry. Anthropogenic nitrogen surplus in the soils, water bases and atmosphere are both sources of environmental problems; the impact to the nature is clearly noticeable.

3. FERTILIZERS

Usually the nutrient content of soils does not correspond with the demands of cultivated plants; hence fertilizers are basic materials in nowadays' agriculture to increase the crop yields. However added nutrients influence the ion mobility and chemical attributes in soils and the components of soil water, the considered and responsible application of fertilizers not necessarily endangers the environment. Besides proportional nutrient supply can be ensured for the plants with fertilizers, some soil parameters can be optimized, such as alkalinity or structure.

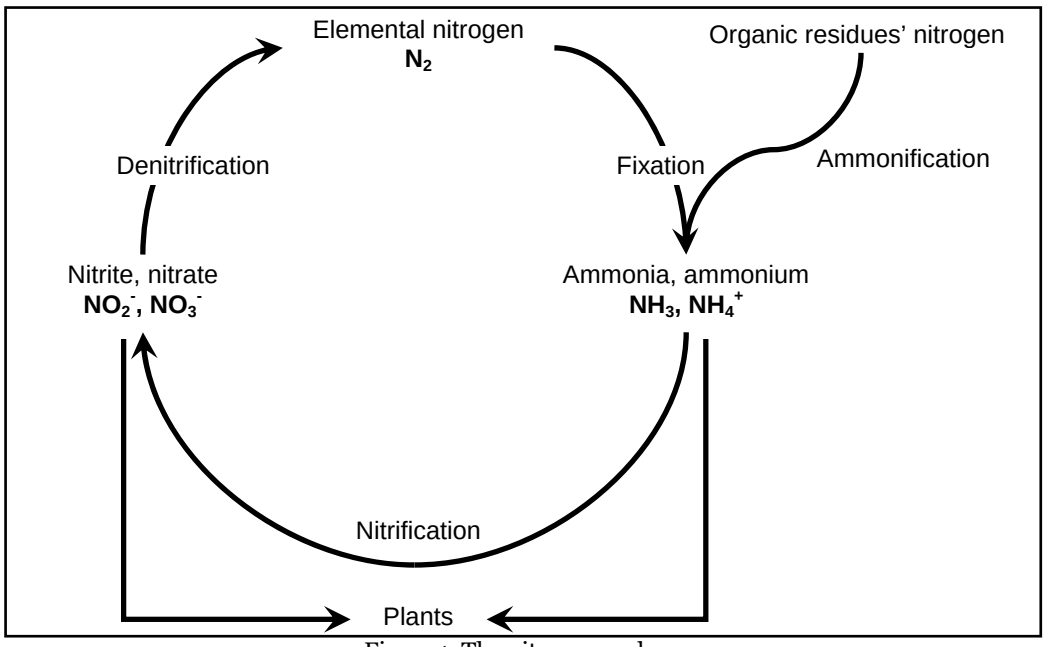

Figure 1. The nitrogen cycle

However the irresponsible usage of fertilizers can entail serious environmental and financial risks; incorrect dosaging can disturb the existing balance of nutrients, can cause the elements' immobilization and might reduce the product's quality and yield. Soil accepts and stores nutrients only in limited rate; if it is encumbered with fertilizers beyond this limit, nutrients will concentrate in the soil solution, soil water will be polluted and even salt accumulations will evolve. The surplus of organic matter might reach the drinking water bases by erosion, leaking of groundwater or surface runoff and threatens their quality and causes eutrophication.

Nitrogen fertilizers can be especially harmful because of their possibly high solubility; leaching rate of fertilizers' nitrogen content can reach 80% depending on weather, characteristics of soil, amount of fertilizer and vegetation.

Further risk of soil's high nitrogen level is the nitrate accumulation in vegetables. Under optimal circumstances organic acids – derived from oxidation of carbohydrates – form amino acids with ammonia enzymatically reduced from nitrate. These amino acids are essential components of vegetal proteins. If the nitrogen metabolism suffers disturbance, biosynthesis of proteins will slow down and nitrates and amino acids will accumulate in the plant organism. The accumulated nitrate can worsen the vegetable's tissue attributes, lasting and even its taste. High nitrate levels can be measured in e.g. lettuce, kohlrabi, radish, colewort and spinach.

4. NITRATE IN WATERS

Eutrophication of surface waters is caused by increased organic matter content – basically nitrogen and phosphorus compounds – originated from sewage or leaking from fertilized agricultural areas. Great amount of nutrients offsets the balance between photosynthesis and plant breathing: the water's oxygen concentration rises and the flora starts to proliferate. The multiplied species of fitoplanctons and algae further increase the nutrient amount of water however during their degradation processes the water's dissolved oxygen resource is consumed. Finally the lack of oxygen leads to almost complete disappearance of flora and fauna, decreasing biodiversity and the water loses its self-cleaning capability (Figure 2). Under natural conditions eutrophication occurs much more slowly (e.g. lake succession); the intensive organic matter input significantly speeds up the process.

High nitrite and nitrate content means direct risk where drinking water is supplied from polluted water bases. Leaked to groundwater, nitrogen compounds of fertilizers endanger the water quality of drilled wells and other water sources. The amount of nitrate ions stays unchanged during the conventional water cleaning processes; hence the nitrate content of consumed water is equivalent with the water base's.

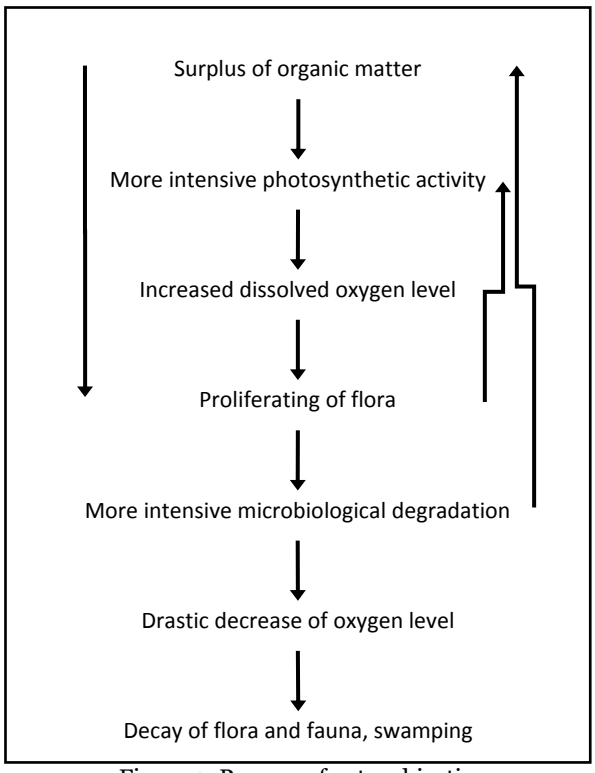

Figure 2. Process of eutrophication

5. NITROGEN COMPOUNDS AS AIR POLLUTANTS

Besides elemental nitrogen other nitrogen compounds are formed in the course of denitrification that harms the atmosphere. The gas phase losses of fertilizers can get to the atmosphere as nitrogen oxides (e.g. N_2O, NO_x) and take part in generating acid rains and tropospheric smog and thinning ozone layer. The great amount of organic matter can make the denitrification more intensive and considerable part of the fertilizer's nitrogen amount can get in the air. Flue gases are main sources of these types of air pollutions; the magnitude of fertilizer's impact is minor, but confirmed and not negligible.

6. NITRATES AND NITRITES IN FOODS

Nitrite and nitrate get in foods partly as a result of not suitable producing or handling processes and partly as additives. Food industry applies nitrite and nitrate components (e.g. E249 – KNO_2, E250 – $NaNO_2$, E251 – $NaNO_3$, E252 – KNO_3) primarily with conservation purpose. Most of meat products contain added nitrate and/or nitrite preventing appearance of pathogen microorganisms and ensuring the bright color of the meat. As mentioned, some vegetables' nitrate content can be high as well such as dairy products, cheeses, wines or flour.

7. PHYSIOLOGICAL EFFECTS

Nitrate and nitrite content of foods and drinking water can induce various medical problems – however most of these components usually leave human organism fast and without evolving any deleterious effect. Nitrite – reduced from nitrate mainly in stomach and small intense – can transform to nitrous acid that oxidizes the ferro-ion of hemoglobin and causing methemoglobinaemia. In the case of methemoglobinaemia blood's oxygen carrying capability decreases and even death can occur. Under normal circumstances 1-2% of human organism's hemoglobin is present in methemoglobin form; if this scale is about 10% symptoms of languor and concentration disturbance will be observable; 50% of methemoglobin is lethal. Nitrite poisoning is really rare in adult population because a special enzyme transforms back the methemoglobin to hemoglobin (Figure 3); however babies are highly endangered because in early age the methemoglobin reductase is not working adequately yet. Therefore the babies' nutriments and drinking water must not include nitrate or nitrite in even trace amount because in lack of medical help anoxic state ("blue baby" disease) is probably deadly.

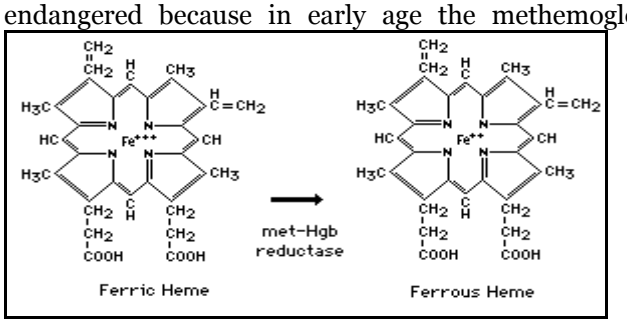

Figure 3. Structure of hemoglobin and methemoglobin

Another problem related with nitrite presence is the formation of nitrosamines and nitrosamides. These carcinogen N-nitroso compounds are particularly evolved in the acidic media of stomach through reactions of amides and amines with nitrite [2].

8. REGULATIONS

Because of the above environmental and physiological dangers controlling the nitrate and nitrite emissions and monitoring their concentration in foods and waters is important and required. Regulations, decrees and limit values exist to avoid the unnecessary, dangerous or harmful application of these compounds. The directives and regulations of the EU assign fertilizing parameters, limit values for drinking waters, vegetables, meat products etc., and lay emphasis on the protection of

nitrate sensitive regions (areas where nitrates can easily reach drinking water bases). Unfortunately national rules not always correspond to the international requirements.

9. CONCLUSIONS

Fast and effective solving of environmental problems caused by anthropogenic nitrite and nitrate is difficult task because of its complexity. The only long-term solutions seem to be the reasonable fertilizing and the adequate wastewater treatment. The environmental and medical risk can only be reduced with controlled emissions and international co-operation. Nitrate and nitrite pollutions are critical however often hidden problems of nowadays that should be taken much more serious.

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