Science Arena Publications
Specialty Journal of Agricultural Sciences
ISSN: 2412-737X
Available online at www.sciarena.com
2018, Vol, 4 (3): 9-15

Harmful Effects of Intensive Nitrogen Fertilizer Usage to Humans and Managing of Risks

Muhammad Sarwar[1*], Roohi Aslam[2]

[1]National Institute for Biotechnology & Genetic Engineering (NIBGE), Faisalabad- 44000, Pakistan.
[2]NUTECH School of Applied Sciences and Humanities (NUSASH), National University of Technology (NUTECH), Islamabad, Pakistan.

Abstract: *While nitrogen fertilizer is added substantially to harvest augmentation in plants produce, nonetheless unnecessary usage of this chemical has raised severe dangers to human health and environment. Rate of nitrogen fertilizer use has an adjacent affiliation by nitrate gathering in soil, ground water, surrounding environment, plus leafy and root vegetables. This article concentrates on research information on the harmful effects of too much addition of nitrogen fertilizer and its fate in the surroundings. Generally, public water utilities are required to maintain nitrate levels below a Maximum Contaminant Level (MCL) of 10 mg/ L nitrate-nitrogen (N) that is instituted to defend contrary to methemoglobinemia (blue baby syndrome), to which children are specifically vulnerable. Besides methemoglobinemia, various further health hazards have been connected with consumption of nitrate-polluted drinking water, together with diabetes, different cancers and thyroid conditions, and adversative reproductive outcomes (particularly neural tube faults). The paramount way out is to discover a substitute water resource for consumption and food preparation purposes of water otherwise decrease the basis of nitrate contamination. Infant nourishing ways to decrease ingestion of nitrate and nitrite are consume of breast milk, use of previously diluted fluid formulas otherwise usage of low-nitrate water to dilute concentrated fluid or else processed formulas, and the consumption of vegetables that are rich in nitrate must be restricted till infants are 4-6 months old. Consumers can reduce hazard of acquaintance to nitrogen through cautiously usage of domestic foodstuffs and by escaping of spaces wherever it is being dispensed excessively to fertilize crops. Poisonous activity and other adversative effects of N-nitroso compounds can be prohibited by consuming of antioxidants containing fruits and vegetables and vitamin C. This article might be helpful to reduce negative effects of nitrogenous chemicals to human health and safety in many outlined ways by usage of fertilizers safely to maximize their benefits and limit risks.*

Keywords: *Nitrogen, Inorganic Fertilizer, Nitrate, Toxicity, Nitrite, Cancer, Health.*

INTRODUCTION

Artificial fertilizers comprising one or more of the nutrients mainly nitrogen and other essential elements are required for plant development while applied to the soil or other medium (Sattar et al., 2005; Sarwar, 2011; 2012; Sarwar et al., 2011). The inorganic nitrogen fertilizers have been introduced to enhance the crops yield during 1950s. Based on standard conditions, elemental nitrogen (N) is a colorless, distasteful and commonly inert diatomic gas. It constitutes 78% by volume of earth's atmosphere, however this cannot be consumed by one or the other plants or animals directly. For consuming by animals or plants, it needs to be converted into a reduced state i.e., NO_2^-, NO_3^- and NH_4^+. Nitrogen is essentially required as macronutrient by plants.

Nitrogen is a basic element of chlorophyll, nucleic acids, amino acids and proteins, so, it exists in whole living organisms. It upsets a number of plant tasks like development, metabolism, growth and resource distribution (Ginting et al., 2003; Watts et al., 2010). Globally, over the past half century, the doubling of crop produce is linked with seven fold rise in N fertilizer usage (Han et al., 2016). It is estimated that half of the worldwide foodstuff creation is boosted through adding of N fertilizers to upsurge in crops produce (Tilman et al., 2002).

Unnecessary Practice of Nitrogen Fertilizer is Without Profit Benefit

The unnecessary expenditures of nitrogen fertilizer outcome with small nitrogen use efficiency have definitely not produced profits. Nitrogen use efficiency for many of the plant species varies from 30 to 50%, while remaining 50-70% nitrogen is being used by soil microorganisms and misplaced through leaching or volatilized to nitrous oxide (Wuebbles, 2009; Ng et al., 2016). This disturbs natural environment by N enhancement, nitrate pollution in external and groundwater, in this manner altering the biodiversity and make happening the greenhouse gas emission. As soon as fertilizer is added to soil, the mineralization begins based upon different aspects such as type of fertilizer (Lobell, 2007), temperature, soil type, soil microorganism, water content and field managing (Griffin et al., 2008). Excess of nitrogen in aquatic environment results in intensive algal growing in coastal areas and fresh water lakes, consequently limiting the oxygen supply to underlying organisms (Fan et al., 2010).

When superfluous nitrogen fertilizer is added, the phyto-availability of nitrate from vegetables upsurges that postures prospective menace to human health (Gastal and Lemaire, 2002). Scientists have identified the nearby connection among environmental problems and unnecessary usage of nitrogen fertilizer (Wang et al., 2002). In a trial, it has been detected that only 4% maize produce improvement is observed on addition of 30% undue nitrogen fertilizer, whereas the nitrate harm amplified by 53%. In contrast, only 10% yield is decreased by adding of 30% less N fertilizer, however the nitrate harm through leakage decreased to 37% fewer (Donner and Kucharik, 2003). Similarly, the decline in produce has been observed in *Phleum pretense* L. Champ; on doubling up the quantity of N fertilizer amount and extra N gathered in the soil (Sharifi et al., 2011).

Nitrate and Nitrite Toxicities and Risks to Human Health

Nitrate and Nitrite ions naturally occur in soils and waters by way of fragment of the earth's nitrogen cycle. Nitrate and nitrite may as well become free into the soil, water and air at spaces wherever stuffs, for instance, fertilizers are made or added. Nitrite has two oxygen atoms and one nitrogen atom, while nitrate has one more oxygen atom. Nitrates are ultimate product of N fertilizer and if these not engaged rightly through plant roots, percolate below to water ways. Highest nitrate concentration occurs in green leafy vegetables such as lettuce (Liu et al., 2014). Within many of the developed and under developing nations, their peoples drink ground water for consumption. Nitrate level is high in ground water under agricultural land and in rivers, streams and lakes due to nitrogen fertilizer runoff from arable lands. Taking in nitrate filthy ground water or consuming of high nitrate containing vegetables may lead to serious pathological conditions in human. Scientists have set 0-3.7 $mg \cdot kg^{-1}$ body weight as tolerable everyday nitrate consumption (Santamaria, 2006). However, the reference rate of nitrate is 7.0 mg kg^{-1} body weight per day while the public water utilities require keeping below 10 mg/ L nitrate nitrogen as Maximum Contaminant Level (MCL) (Mensinga et al., 2003).

Nitrate reductase activity (NRA) is generally affected by lighting situation and thus drops the conversion rate of nitrate to amino acid leading to greater nitrates concentration (Tamme et al., 2009). Ingestion of nitrate dirtied drinking water and consuming diets of excessive root and leafy vegetables are the main source of human exposure to nitrogen fertilizer (Jones et al., 2016) that results adversative health effects i.e., thyroid, cancer, neural tube defects, diabetes and blue baby syndrome (methemoglobinemia). The harmful effects of nitrates on health by ingesting of nitrate contaminated drinking water can be explained by three mechanisms (Ward, 2009). First mechanism describes the development of methemoglobin, thus blood's oxygen carrying ability is repressed, because micro flora of infant's stomach transform nitrate to nitrite that binds with hemoglobin in competition with oxygen. Second mechanism relates to the establishment of endogenous N-

nitroso compounds. The reduction of nitrate to nitrite centrals to the creation of different nitrosating mediators in acidic stomach situations. The nitrosating mediators intermingle with amines and amides of proteins otherwise with precursors of medicines causing in creation of N-nitroso compounds. These N-nitroso compounds are probable teratogens and carcinogen as demonstrated in diverse animal investigations. Thirdly, the high nitrate concentration in drinking water hinders the iodine uptake that leads to hypertrophic changes in thyroid gland. Associated mechanism of human cancer is perhaps owing to the creation of N-nitroso compounds endogenously. The exogenous causes like consumption of preserved foods, fishes, beers and more or less medicines can boost the development of N-nitroso compounds (Catsburg et al., 2014). Several information designate that 45-75% human's interactions to N-nitroso compounds rise from in vivo situations (Tricker, 1997). Certain occupations and some cosmetics impact exogenously to the creation of N-nitroso compounds. The acidic environment of normal human stomach due to nitrite and nitrostable amides or amines from fish and meat may lead to the creation of N-nitroso compounds endogenously. Infants and children exposure to endogenous nitrosation may have adverse health effects. Scientists have observed that dietary intake of antioxidants existing in vegetables and fruits check the development of N-nitroso compounds, thus intake of antioxidants is negatively associated with various cancers (Ferrucci et al., 2010).

Nitrate in ingestion water begins upsetting the health of the over-all population at intensities in the range of 100 to 200 mg/ l nitrate-N, however the effect on any given individual may be influenced by several other reasons, together with further sources of nitrate and nitrite in the food. Some of the nitrate disbursed may be transformed in the body to nitrite that under suitable situations can associate with amines (slices of protein molecules regularly establishing in foods, decaying plants, medications, soil and sometimes water, cigarette smoke etc.,) to produce nitrosamines, which are well-recognized cancer-causing matters. To this point, the single studies connecting nitrate in drinking water with cancer have elaborated nitrate levels that are quite great (at or above 100-200 mg/ l nitrate-N) (Mary, 2009).

The customary quantity for nitrate in consumption water is 10 milligrams per liter (10 mg/ l) nitrate-N, or 45 mg/ l nitrate-NO3. Short-term acquaintance to consumption water with a nitrate level at or just beyond the health standard of 10 mg /l nitrate-N is a possible health problematic predominantly for children. Children drink great amounts of water comparative to their body weightiness, particularly if water is used to blend powdered or concentrated formulas or juices. Likewise, their young gastrointestinal structures are further likely to permit the reduction of nitrate to nitrite in comparison to mature digestive tracts. In general, the occurrence of nitrite in the gastrointestinal region of babies may be able to lead disease methemoglobinemia. Methemoglobinemia is the greatest noteworthy health problematic linked with nitrate in consumption water. Blood comprises an iron-based compound termed as hemoglobin that transfers oxygen. When nitrite is existing, hemoglobin may be transformed to methemoglobin that cannot move oxygen. Within the blood of adults, enzymes repetitively transform methemoglobin back to hemoglobin and methemoglobin intensities generally do not surpass 1%. Neonatal babies have lesser intensities of these enzymes and their methemoglobin level is generally 1 to 2%. Once identified, methemoglobinemia can be freely inverted, even though with anoxia long-lasting harm may have arisen (Feig, 1981).

Infant Feeding Practices to Minimize Intake of Nitrate and Nitrite

Methemoglobinemia may be stopped by limiting the drinking of nitrite and nitrate, and through the restrictive chances of bacteria, have to decrease nitrate in diet to nitrite earlier to ingestion (Shearer et al., 1972).

1. Breast feeding. Little of somewhat nitrate becomes into breast milk, unless the mammy is ingesting very huge amounts of nitrate. Similarly, bacterial infection is not a problematic while breast milk is ingested directly by baby.
2. Bottle feeding. Use the previously diluted fluid formulas, otherwise practice low-nitrate water to dilute concentrated liquid or powdered formulas. Likewise, mixed formulas must be placed under refrigeration and used quickly to lessen bacterial decrease of nitrate to nitrite.

3. Vegetables. As various vegetables are rich in nitrate, their ingesting must be restricted till a child is 4-6 months old and their gastrointestinal region has satisfactorily developed. General practitioner can guide persons to resolve while to add fresh foodstuffs. Vegetables must continuously be prepared when are fresh and refrigerated at the appointed time afterward cooking to lessen bacterial action.

Few clear-cut signs are linked with methemoglobin intensities among 1 and 10%. On greater stages, signs of cyanosis generally give the impression. Children with this state have bluish mucous membranes and can as well have gastrointestinal and respirational complications. On methemoglobin planes beyond 20 to 30%, the key special effects result from the blood's harshly reduced oxygen-carrying ability and are mentioned to as anoxia. On methemoglobin stages about 50 to 70%, brain injury, otherwise expiry may happen. Consuming drinking water with nitrate intensities close to the drinking water standard does not usually surge the methemoglobin level of humans further than initial stages. Several persons, nevertheless, can have bigger vulnerability to methemoglobinemia owing to experience to antioxidant medicines and compounds, or else other situations that might prevent the body's capability to reconvert methemoglobin to hemoglobin (for instance, pregnancy or certain rare diseases) (Wilson et al., 1999).

Lowering of Nitrate Level in Water

The superlative way out is to catch a substituted water source for cooking and drinking purposes of water. Another option is to effort to eliminate or else decrease the source of nitrate pollution, though decrease of nitrate concentrations in our well is improbable to be instantaneous. There are no simple techniques to eliminate nitrate from water in the houses. Since, nitrate does not vaporize in the mode as chlorine does, freezing, boiling or allowing water to stand does not decrease the nitrate intensity. Infact, boiling of water meant for more than 10 minutes can mark the nitrate additional concentrated. Boiling of water in an aluminum pot can as well change nitrate to nitrite. For any treatment unit, frequent water testing is necessary to determine whether the system is still working effectively (Russell, 1978).

Acquiring of Low-Nitrate Water

When a public or private water source has raised nitrate intensities, at that point acquiring of bottled water is one of best alternatives, although in bottled water, nitrate levels may differ greatly. Municipal water deliveries are alternative possible source of small level nitrate water. Hauling of water from lakes, springs, wells or streams may be hazardous, both for the reason that of the unidentified levels of nitrate and owing to the probable occurrence of other impurities, particularly bacteria. Bacterial contamination is a dual problematic by way of it may be liable for the lessening of nitrate to nitrite, however further notably, the bacteria themselves may be able to cause disease. Hazards as well are linked with gathering of rainwater owing to asbestos or else other toxins from the roofing material. Alternative water deliveries are simply as good as their source, their storage and their collection method. So, prior to using any source of water, find out precisely what the intensities of nitrate and bacteria are in those resources (Shuval and Gruener, 1972).

Merits of the Current Work

An addition of nitrogen fertilizers to the crops may be necessary for providing of nutrients to help plants thrive better. An accurate answer to this is that we do not have any alternative option, which has capacity to replace the artificial fertilizers. However, its use becomes injurious to human health when it is over-applied and without an appropriate soil test. While farmers often use more quantity than what is recommended and over time this excess nitrogen pollutes water and air. Oxidized nitrogen, a byproduct of synthetic fertilizers, also increases smog, which may be related to higher incidence of respiratory illness and asthma. With nitrogen, it is critical to apply no more than is needed and usually better to apply in small regular doses. It is best to time the applications to coincide with the periods when the crop really needs of nutrition, so, this is safer to apply chemical fertilizer only when there is a nutrient deficiency in soil (Grosse et al., 2006). For that reason, the merits of the current research are that the studies should further account for the potentially different effects of dietary and water sources of nitrate and must include the population using private wells

for whom exposure levels are often higher than public supplies. So, we should end up with foods which are lacking in viable nutrition and also loaded with residues form other chemicals. This consequence is probably the worst of all, especially in light of the fact that natural methods of growing plants are easier, more economical and more viable. There is dire need to adjust the doses of applied fertilizers, need to educate the farmers about balanced fertilization, need based irrigation and fertilizer application, and integrated nutrients use so that nutrient losses to the ground water can be stopped, and apply these in integration with organic manures. Precision methods of applying fertilizers, as opposed to broadcasting methods reduce waste and damage caused by nutrient runoff. Therefore, the benefits of fertilizer use should have to be better communicated to the public at large.

Conclusion

Though fertilizers have their benefits, there are also downsides to their usage, particularly with regard to synthetic nitrogen fertilizers. Nitrogen uses at injudicious levels cause a loss of certain plant species, depletion of soil nutrients, contamination of water as well as environment and harmful effects to human's health. Soluble substance, nitrogen soaks deeply into the soil after a rainstorm or after irrigation, reaching ground water and nearby wells. When babies under a year old and elderly people ingest water with high nitrogen levels, they can develop symptoms such as gastrointestinal swelling and irritation, diarrhea and protein digestion problems, various cancers, adverse reproductive outcomes, diabetes, thyroid conditions, and also diminishing of the natural disease-fighting and pest-fighting mechanisms. In this article, the author has tried to make alert to overall public, farming health practitioners, community and agricultural scientists for the hazard involved to human health with too much usage of nitrogen fertilizers. Growers sometimes might require to add nitrogen fertilizer to their farms and gardens to make available just the precise nutrients for the plants growth. Since at this time, its amount used and demand have been typically increasing globally. Unnecessary usage of nitrogen fertilizers to enhance the crops productivity necessarily does not contribute to produce improvement rather it is lost through denitrification, leaching or volatilization. It pretenses menace to human health and as well results in severe ecological issues. Principally, on ingesting of nourishments having greater nitrate matters has added to endogenous nitrosation, which can lead to various kinds of human cancers, thyroid condition, diabetes and neural tube defects during fetus development. Nitrate addition in leafy or root vegetables, ground water, fish, processed food, beer, medications and some pathological situations might add to endogenous nitrosation that in the long run centrals to numerous types of human cancers and other medical conditions. However, consuming of antioxidants and vitamin C present in several fruits and vegetables may balance the nitrate acquaintance to people there by protecting the human being from the carcinogenic activity of N-nitroso compounds. Growers who use or apply nitrogen for farming, can reduce their exposures by using it according to the instructions. In order to control the nitrogen falls, there must be integration of scientific disciplines and further work on N-storage and denitrification rates. Such management may help to attenuate the undesirable cascading effects and eliminate environmental N-accumulation, which are urgently needed to further enhance our understanding of cancer risk associated with nitrate ingestion

References

1. Catsburg, C. E., Gago-Dominguez, M., Yuan, J. M., Castelao, J. E., Cortessis, V. K., Pike, M. C., Stern, M. C. (2014) Dietary source of N-nitroso compounds and blader cancer risk: finding from Los Angeles bladder cancer study. Int. J. Cancer 134(1): 125-135. doi: 10.1002/ijc.28331.
2. Donner, S. D., Kucharik, J. A. (2003) Evaluating the impacts of land management and climate variability on crop production and nitrate export across Upper Mississippi Basin. Global Biogeochemical Cycle, 17 (3): 1-10.

3. Fan, X. H., Li, Y. C. (2010) Nitrogen release from slow-release fertilizers as affected by soil type and temperature. Soil Sci. Soc. Amer. J. 74: 1635-1641.
4. Feig, S. (1981). Methemoglobinemia. In Hematology of infancy and childhood, ed. D.G. Nathan and F.A. Oski. W.B. Saunders Co., Philadelphia.
5. Ferrucci, L. M., Sinha, R., Ward, M. H., Graubard, B. I., Hollenbeck, A. R., Kilfoy, B. A., Schatzkin, A., Michaud, D. S., Cross, A. J. (2010) Meat and components of meat and the risk of bladder cancer in yhe NIH-AARP Diet and Health Study. Cancer 116(18): 4345-4353. doi: 10.1002/cncr.25463.
6. Gastal, F., Lemaire, G. (2002) N uptake and distribution in crops: An agronomical and ecophysiological perspective. J. Exp. Bot. 53: 789-799.
7. Ginting, D., Kessavalou, A., Eghball, B., Doran, J. W. (2003) Greenhouse gas emissions and soil indicators four years after manure compost applications. J Environ. Qual. 32: 23-32.
8. Griffin, T. S. (2008) Nitrogen availability. Nitrogen in Agricultural Systems; Schepers, J., Ruan, W. R. Eds.; SSSA Inc. and ASA Inc.: Madisin, WI, USA. pp. 613-646.
9. Grosse, Y., Baan, R., Straif, K., Secretan, B., El Ghissassi, F., Cogliano, V. (2006) Carcinogenicity of nitrate, nitrite, and cyanobacterial peptide toxins. Lancet Oncol., 7 (8): 628-629.
10. Han, M., Wong, J., Su, T., Beatty, P. H., Good, A. G. (2016) Identification of Nitrogen Use Efficiency Genes in Barley: Searching for QTLs Controlling Complex Physiological Traits. Front. Plant Sci. 7:1587-1604.
11. Jones, R. R., Weyer, P. J., Curt, T., Valle, D., Choi, M. I., Anderson, K. E., Cantor K. P., Krasner, S., Robein, K., Laura, E., Freeman, B., Silverman, D. T., Ward, M. H. (2016) Nitrate from Drinking Water and Diet and Bladder Cancer Among Postmenopausal Women in Iowa. Environ. Health Perspective. 124: 1751-1758.
12. Liu, C. W., Sung, Y., Chen, B. C., Lai, H. Y. (2014) Effects of Nitrogen Fertilizers on the Growth and Nitrate Content of Lettuce (Lactuca sativa L.). Int. J. Environ. Res. Public Health. 11: 4427-4440.
13. Lobell, D. B. (2007) The cost of uncertainty for nitrogen fertilizer management: A sensitivity analysis. Field Crop. Res. 100: 210-217.
14. Mary HW. (2009). Too Much of a Good Thing? Nitrate from Nitrogen Fertilizers and Cancer. Rev. Environ. Health, 24 (4): 357-363.
15. Mensinga, T. T., Speijers, G. J., Meullenbelt, J. (2003) Health implications of exposure to environmental nitrogenous compounds. Toxicol. Rev. 22: 41-51.
16. Ng, J. M.-S., Han, M., Beatty, P. H., Good, A. (2016). Genes, meet gases: the role of plant nutrition and genomics in addressing greenhouse gas emissions, in Plant Genomics and Climate Change, eds. D. Edwards and J. Batley (New York, NY: Springer). 149-172.
17. Russell, C.S. (1978). Safe drinking water: Current and future problems. Resources for the Future, Inc., Washington, D.C.
18. Santamaria, P. (2006) Nitrate in vegetables: Toxicity, content, intake and EC regulation. J. Sci. Food Agri. 86: 10-17.
19. Sarwar, M. (2011) Effects of Zinc fertilizer application on the incidence of rice stem borers (Scirpophaga species) (Lepidoptera: Pyralidae) in rice (Oryza sativa L.) crop. Journal of Cereals and Oilseeds. 2 (5): 61-65.
20. Sarwar, M. (2012) Effects of potassium fertilization on population buildup of rice stem borers (lepidopteron pests) and rice (Oryza sativa L.) yield. Journal of Cereals and Oil Seeds. 3 (1): 6-9.
21. Sarwar, M., Ahmad, N., Tofique, M. (2011) Impact of Soil Potassium on Population Buildup of Aphid (Homoptera: Aphididae) and Crop Yield in Canola (Brassica napus L.) Field. Pakistan Journal of Zoology. 43 (1): 15-19.

22. Sattar, M., Sarwar, M., Hussain, G. (2005). Impact of pH, Nitrogen and Protein Contents in Some Cucurbits on the Population Build-Up of Whitefly, Bemisia tabaci (Homoptera: Aleyrodidae). Pakistan Journal of Zoology, 37 (4): 275-279.
23. Sharifi, M., Zebarth, B. J., Burton, D. L., Rodd, V., Grant, C. A. (2011) Long-term effects of semisolid beef manure application to forage grass on soil mineralizable nitrogen. Soil Sci. Soc. Amer. J. 75: 649-658.
24. Shearer, L.A., J.R. Goldsmith, C. Young, Kearns, O.A., Tamplin, B.R. (1972). Methemoglobin levels in infants, in an area with high nitrate water supply. Amer. J. of Public Health, 62:1174-80.
25. Shuval, H.I., and N. Gruener. (1972). Epidemiological and toxicological aspects of nitrates and nitrites in the environment. Amer. J. of Public Health, 62:1045-51.
26. Tamme, T., Reinik, M., Roasto, M. (2009) Nitrates and Nitrites in Vegetables: Occurrence and Health Risk. In Bioactive Foods Promoting Health: Fruits and Vegetables; Watson, R. R., Preedy V. R. Eds.; Academic Press: Salt Lake City, UT, USA. pp. 307-321
27. Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., Polasky, S. (2002) Agricultural sustainability and intensive production practices. Nature, 418: 671-677.
28. Tricker, A. R. (1997) N-nitroso compounds and man: sources of exposure, endogenous formation and occurrence in body fluids. Eur. J. Cancer Prev. 6(3): 226-268.
29. Wang, Z. H., Zong, Z. Q., Li, S. X., Chen, B. M. (2002) Nitrate accumulation in vegetables and its residual in vegetable fields. Environ. Sci. 23: 789-799.
30. Ward, M. H. (2009) Too much of a good thing? Nitrate from nitrogen fertilizers and cancer. Rev. Environ. Health. 24: 357-363.
31. Watts, D. B., Torbert, H. A., Prior, S. A., Huluka, G. (2010) Long-term tillage and poultry litter impacts soil carbon and nitrogen mineralization and fertility. Soil Sci. Soc. Amer. J. 74: 1239-1247
32. Wilson W.S., Ball A.S., Hinton R.H. (1999). Managing Risks of Nitrates to Humans and the Environment Woodhead Publishing Limited. p. 348.
33. Wuebbles D. J. (2009) Nitrous Oxide: No Laughing Matter. Science, 326 (5949): 56-57.