



Poultry Production and Environmental Health

Hanan Al-Khalaifa*

Environment and Life sciences Research Center, Desert Agriculture and Ecosystems Program, Kuwait Institute for Scientific Research, P.O. Box 24885, 13109 Safat-Kuwait

Abstract. The localization and intensification of the poultry industry over the past 50 years has incidentally created a largely ignored environmental management crisis. As a result of these changes in poultry production, concentrated animal feeding operations produce far more waste than can be managed by land disposal within the regions where it is produced. However, much less attention has been given to the potential risks related to poultry waste constituents, including ammonia, pathogenic bacteria, antibiotic-resistant bacteria, and residues of the drugs added to poultry feeds. In addition, there are several chemicals emitted from poultry litters, which in turn affects the environment in both beneficial and detrimental ways. Several steroid hormones and trace elements are also found to impact the environment and human population. This paper will focus on the effects of poultry production on the environment, and vice versa, and the methods used to utilize poultry litter to mitigate the effects on the environment and climate change.

Keywords. *poultry, environment, animal feeding operations, climate change*

*Correspondence:
hkhalifa@kisir.edu.kw

Nitrogen

Considerable quantities of nitrogen (N) are consumed in feed and excreted by poultry. The excretion of N is largely due to the excess protein and amino acids fed to poultry. This excess occurs because the ratios of amino acids in the feedstuffs fed to poultry are not perfectly balanced in the corn, soy, wheat, and other grains and ingredients used to formulate poultry diets. To meet the minimum requirements for certain essential amino acids, some amino acids that are in abundance in the feedstuffs are consumed in excess. In addition, not all amino acids are fully digested by poultry.

In practical poultry diets, approximately one-third of the N is incorporated into the tissues and eggs of the bird, and two-thirds is excreted. In the case of poultry, N is excreted as uric acid and as undigested protein in fecal waste. Approximately 50% of the N content of freshly excreted poultry manure is in the form of uric acid. The N in uric acid can be very quickly converted to ammonia (NH₃) by hydrolysis, mineralization, and volatilization (Oenema et al., 2008).

Silva culture studies in North America and Europe document accelerated forest growth in recent years, and a portion of this faster growth has been attributed to increased atmospheric N inputs (Kurz et al., 1995; Brinkley and Hogberg, 1997). European forests that receive N from atmospheric deposition also show an increase in nitrate leaching, as much as 30% of inorganic N deposition (Likens et al., 1996). Several studies have shown that in temperate zones, fertilizer inputs and atmospheric N can lead to soil acidification (Reuss and Johnson, 1986; Huenneke et al., 1990).

Many plant species in unmanaged ecosystems are adapted to low N environments. Emissions of N compounds can result in N fertilization and species change in natural ecosystems. A number of fertilization studies have demonstrated that increased N availability promotes the dominance of fast-growing, nutrient-rich plant species to the detriment of slower growing, nutrient-poor species (Tilman, 1997; Aerts and Berendse, 1988; Houdijk et al., 1993).

Ammonia Emission

Ammonia is a colorless, water-soluble gas by-product of the microbiological decomposition of organic nitrogen compounds in manure. Modern intensive animal feeding operations and the relatively large quantity of NH_3 produced by the excreta associated with these facilities has heightened environmental concerns over NH_3 emissions. It has been suggested that nearly 50% of the NH_3 emissions from human-related (anthropogenic) sources come from livestock operations (Aardenne et al., 2001) (most of the rest come from inorganic fertilizer). Poultry production has been estimated to be responsible for 1.9 million metric tons of ammonia emissions annually.

Once emitted, NH_3 can rapidly react with acidic compounds found in the atmosphere, such as nitric acid and sulfuric acid, and be converted to aerosolized ammonium particles, typically as ammonium sulfate and ammonium nitrate. As aerosols, N compounds can impact ecological balance, biodiversity, and water systems. Deposition back onto soil, vegetation, or water usually occurs within a matter of days and thus in relatively close proximity to the emission source. Once deposited, N can impact soil acidity, forest productivity, terrestrial ecosystem biodiversity, stream acidity, and coastal productivity (Galloway and Cowling, 2002).

Acid Rain

Ammonia (NH_3) volatilization from poultry litter results in a buildup of atmospheric NH_3 in chicken houses, which is detrimental to both farm laborers and birds. Ammonia loss from litter is detrimental to the external environment because it results in acid rain as well as low N/P ratios in litter, which increases the likelihood of excessive phosphorous runoff into adjacent water bodies. High atmospheric N contributions in the formation of acid rain that may damage plant life cause excessive fertilization of soils and vegetation, increase algal blooms in surface waters, and damage aquatic life. In general, plant growth globally is limited by N. Deposition of N, therefore, can cause increased plant growth (Matson et al., 2002).

Ground Water Contamination

According to Bitzer and Sims (1988), excessive application of poultry litter in some cropping systems has resulted in NO_3 contamination of groundwater. Problems caused by high NO_3 concentrations in drinking water include methaemoglobinaemia (blue baby syndrome), cancer, and respiratory illness in humans, and fetal abortions in livestock (Stevenson, 1986). High concentrations of P in surface waters, largely resulting from surface runoff of sediment P, causes eutrophication (Schindler, 1977; Sharpley et al., 1996). Eutrophication has been suggested as the main cause of impaired surface water resources (US Environmental Protection Agency, 1996). Kingery et al. (1994) found significant accumulation of NO_3 and extractable P near the soil bedrock when poultry litter was used for fertilizing pastored land in north Alabama. In corn (*Zea mays* L.), poultry litter causes significant leaching of NO_3 to ground water (Liebhardt et al., 1979).

Trace Elements

Trace elements are added to poultry feed for disease prevention and enhanced feed efficiency. High concentrations are found in poultry litter (PL), which raises concerns regarding trace element loading of soils. Cu, Zn, and As occur in PL as a result of their use as growth promoters or biocides in poultry feed (Sims, 1995). Reported PL concentrations of Cu and Zn were 1196 and 631 mg/kg (Van der Watt et al., 1994), 55 and 647 mg/kg (Edwards et al., 1997), 718 mg/kg (Moore et al., 1998), 97 and 378 mg/kg (Nicholson et al., 1999), and 743 and 501 mg/kg (Jackson et al., 1999), respectively. Arsenic concentration in PL is variable. For example, Sims and Wolf (1994) reported a range in As concentration from 0 to 77 mg/kg. Other studies have also reported As concentrations within this range, such as 30 to 37 mg/kg (van der Watt et al., 1994), 43 mg/kg (Moore et al., 1998), and 35 mg/kg (Jackson et al., 1999).

Fate of Arsenic

Organic arsenicals used in poultry feed are converted to inorganic arsenicals in poultry

waste, limiting the feasibility of waste management alternatives. The presence of inorganic arsenic in incinerator ash and pelletized waste sold as fertilizer creates opportunities for population exposures that did not previously exist. The removal of arsenic from animal feed is a critical step toward safe poultry waste management. Arsenic in waste results from the use of arsenicals added to poultry feed for growth promotion and prevention of parasitic infections. Elevations in soil arsenic levels have been reported in fields where poultry wastes have been applied (Gupta and Charles, 1999). This form of arsenic is readily leachable and may therefore move into groundwater (Rutherford et al., 2003).

Arsenic is recognized as a human carcinogen by the U.S. Environmental Protection Agency (EPA), National Research Council (NRC), International Agency for Research on Cancer, National Toxicology Program, and American Conference of Industrial Hygienists, and exposures have also been associated with increased risks of heart disease, diabetes, neurologic effects, and birth defects in humans. A comprehensive re-assessment of health risks of arsenic performed by the NRC in 2001 (NRC) formed the basis for a recent regulatory decision by the U.S. EPA to lower the maximum contaminant level for drinking water by five-fold (US EPA, 2001). As noted by Arai et al. (2003), this action must raise concerns about land disposal of arsenic-laden poultry wastes because of the likelihood of ground-water contamination.

Steroid Hormones

Livestock such as sheep, cattle, pigs and poultry, as well as other animals, excrete hormone steroids. In poultry waste, a concentration ranging from 14 to 533 ng/g dry waste with an average of 44 ng/g for E2 (estradiol) was reported by Shemesh and Shore (1994) and Shore et al. (1988, 1995).

Recent studies have shown that disposal of animal manure on agricultural land could lead

to movement of estrogenic steroids into surface and ground water (Bushe'e et al., 1998; Nichols et al., 1997, 1998; Peterson et al., 2001; Shore et al., 1995). E2 has been found to be mobile and has been detected in runoff from manured land (Nichols et al., 1997, 1998). Nichols et al. (1998) determined an average E2 concentration of 3500 ng/l in the runoff from a pastoral land applied with 5 mg/ha of manure (poultry litter). Ground water has been reported to be contaminated with E2 (Peterson et al., 2001; Shore et al., 1995). Shore et al. (1995) believed that a constant E2 concentration of about 5 ng/l in spring waters was caused by infiltration of E2 through the soil profile to the ground water.

Peterson et al. (2000) measured E2 concentrations ranging from 6 to 66 ng/l in mantled karst aquifers in northwest Arkansas. The observed E2 concentration trends imitated the changes in stage over the recharge event. The contamination was associated with poultry litter and cattle manure waste applied on the area.

Conclusion

Poultry litter applications provide nutrients for crop production and build soil organic reserves. The organic matter benefits crop production *via* increases in soil water-holding capacity, water infiltration rates, cation exchange capacity, structural stability, and soil tilt. However, the same nutrients that make poultry manure a good fertilizer can, under some circumstances, be detrimental to the quality of groundwater and downstream surface water. Nutrient imbalances in forages due to excessive poultry litter applications have been observed. Poultry wastes are known to contain many pathogens, which could potentially contaminate both surface water and groundwater resources. Therefore, it is concluded that more applied work and effort is needed for developing innovative new practices of better utilization of poultry waste without creating more environmental problems.

References

- Aardenne, J. V., Dentener, F. J., Olivier, J. G. J., Goldewijk, C. G. M. and Lelieveld, J. (2001), "A 1×1 resolution data set of historical anthropogenic trace gas emissions for the period 1890-1990". *Global Biogeochemical Cycles*, Vol. 15 No. 4, pp. 909-928
- Aerts, R. and Berendse, F. (1988), "The effect of increased nutrient availability on vegetation dynamics in wet heathlands", *Vegetatio*, Vol. 76 No. (1-2), pp. 63-69
- Arai, Y., Lanzirrotti, A., Sutton, S., Davis, J. A., & Sparks, D. L. (2003), "Arsenic speciation and reactivity in poultry litter", *Environmental science & technology*, Vol. 37 No. 18, pp 4083-4090
- Binkley, D. and Högberg, P. (1997), "Does atmospheric deposition of nitrogen threaten Swedish forests?", *Forest Ecology and Management*, Vol. 92 No. 1, pp. 119-152
- Bitzer, C. C. and Sims, J. T. (1988), "Estimating the availability of nitrogen in poultry manure through laboratory and field studies", *Journal of Environmental Quality*, Vol. 17 No. 1, pp. 47-54
- Edwards, D. R., Moore, P. A., Daniel, T. C., Srivastava, P. and Nichols, D. J. (1997), "Vegetative filter strip removal of metals in runoff from poultry litter-amended fescue grass plots", *Transactions of the ASAE*, Vol. 40 No. 1, pp. 121-127
- Galloway, J. N. and Cowling, E. B. (2002), "Reactive nitrogen and the world: 200 years of change". *AMBIO: A Journal of the Human Environment*, Vol. 31 No. 2, pp. 64-71
- Gupta, G., & Charles, S. (1999), "Trace elements in soils fertilized with poultry litter", *Poultry science*, 78(12), 1695-1698
- Houdijk, A. L. F. M., Verbeek, P. J. M., Van Dijk, H. F. G. and Roelofs, J. G. M. (1993), "Distribution and decline of endangered herbaceous heathland species in relation to the chemical composition of the soil", *Plant and Soil*, Vol. 148 No. 1, pp. 137-143
- Huenneke, L. F., Hamburg, S. P., Koide, R., Mooney, H. A. and Vitousek, P. M. (1990), "Effects of soil resources on plant invasion and community structure in Californian serpentine grassland". *Ecology*, Vol. 71 No. 2, pp. 478-491
- Jackson, B. P., Miller, W. P., Schumann, A. W. and Sumner, M. E. (1999), "Trace element solubility from land application of fly ash/organic waste mixtures", *Journal of Environmental Quality*, Vol. 28 No. 2, pp. 639-647
- Kingery, W. L., Wood, C. W., Delaney, D. P., Williams, J. C. and Mullins, G. L. (1994), "Impact of long-term land application of broiler litter on environmentally related soil properties", *Journal of Environmental Quality*, Vol. 23 No. 1, pp. 139-147
- Kurz, W. A., Apps, M. J., Beukema, S. J. and Lekstrum, T. (1995), "20th century carbon budget of Canadian forests". *Tellus B*, Vol. 47 No. 1-2, pp. 170-177
- Liebhardt, W. C., Golt, C. and Tupin, J. (1979), "Nitrate and ammonium concentrations of ground water resulting from poultry manure applications", *Journal of Environmental Quality*, Vol. 8 No. 2, pp. 211-215.
- Likens, G. E., Driscoll, C. T. and Buso, D. C. (1996), "Long-term effects of acid rain: response and recovery of a forest ecosystem". *Science-AAAS-Weekly Paper Edition*, Vol. 272 No. 5259, pp. 244-245
- Matson, P., Lohse, K. A. and Hall, S. J. (2002), "The globalization of nitrogen deposition: consequences for terrestrial ecosystems". *AMBIO: A Journal of the Human Environment*, Vol. 31 No. 2, pp. 113-119
- Moore, P. A., Daniel, T. C., Gilmour, J. T., Shreve, B. R., Edwards, D. R. and Wood, B. H. (1998), "Decreasing metal runoff from poultry litter with aluminum sulfate", *Journal of Environmental Quality*, Vol. 27 No. 1, pp. 92-99
- NRC (National Research Council) (2001), *Arsenic in Drinking Water: 2001 Update*. Washington, DC: National Academy Press
- Nicholson, F. A., Chambers, B. J., Williams, J. R. and Unwin, R. J. (1999), "Heavy metal contents of livestock feeds and animal manures

- in England and Wales". *Bioresource Technology*, Vol. 70 No. 1, pp. 23-31
- Oenema, O., Bannink, A., Sommer, S. G., Van Groenigen, J. W. and Velthof, G. L. (2008), "Gaseous nitrogen emissions from livestock farming systems". *Nitrogen in the Environment: Sources, Problems, and Management*, Second edition, J.L. Hatfield & R.F. Follett (Eds.) Acad. Press, Amsterdam, pp. 395-441
- Peterson, E. W., Davis, R. K. and Orndorff, H. A. (2000), "17 β -Estradiol as an Indicator of Animal Waste Contamination in Mantled Karst Aquifers". *Journal of Environmental Quality*, Vol. 29 No. 3, pp. 826-834
- Reuss, J. O. and Johnson, D. W. (1986), *Acid deposition and acidification of soils and waters*. Springer-Verlag
- Garbarino, J. R., Bednar, A. J., Rutherford, D. W., Beyer, R. S. and Wershaw, R. L. (2003), "Environmental fate of roxarsone in poultry litter. I. Degradation of roxarsone during composting". *Environmental Science & Technology*, Vol. 37 No. 8, pp. 1509-1514
- Schindler, D. W. (1977), "Evolution of phosphorus limitation in lakes". *Science*, Vol. 195 No. 4275, pp. 260-262.
- Sharpley, A., Daniel, T. C., Sims, J. T. and Pote, D. H. (1996), "Determining environmentally sound soil phosphorus levels", *Journal of Soil and Water Conservation*, Vol. 51 No.2, pp. 160-166
- Shemesh, M. and Shore, L. S. (1994), "Effects of hormones in the environment on reproduction in cattle". *Factors Affecting Calf Crop* (eds. Fields, M.J. and Sand, R.S.) CRC Press, Florida, pp. 287-297
- Shore, L. S., Correll, D. L. and Chakraborty, P. K. (1995), "Relationship of fertilization with chicken manure and concentrations of estrogens in small streams"
- Shore, L. S., Shemesh, M. and Cohen, R. (1988), "The role of oestradiol and oestrone in chicken manure silage in hyperoestrogenism in cattle". *Australian veterinary journal*, Vol. 65 No. 2, pp. 68-68
- Sims, J. T. (1995), "Characteristics of animal wastes and waste-amended soils: an overview of the agricultural and environmental issues"
- Sims, J. T. and Wolf, D. C. (1994), "Poultry Waste Management: Agricultural and Environmental Issues". *Advances in agronomy*, Vol. 52 No.1, pp. 2-72
- Stevenson, F. J. (1986), "Cycles of carbon, nitrogen, phosphorus, sulphur and micronutrients". *Cycles of carbon, nitrogen, phosphorus, sulphur and micronutrients*
- Tilman, D. (1997), "Community invasibility, recruitment limitation, and grassland biodiversity". *Ecology*, Vol. 78 No.1, pp. 81-92
- US Environmental Protection Agency, (1996), Environmental indicators of water quality in the United States. EPA 841-R-96-002
- U.S. EPA (U.S. Environmental Protection Agency) (2001), Federal Register Notice January 22, 2001-National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. Available: http://www.epa.gov/safewater/ars/arsenic_finalrule.html [accessed 19 November 2004]
- Van der Watt, H. V. H., Sumner, M. E., & Cabrera, M. L. (1994), "Bioavailability of copper, manganese, and zinc in poultry litter". *Journal of Environmental Quality*, Vol. 23 No.1, pp. 43-49