WATER CONTAMINATION FROM RURAL PRODUCTION SYSTEMS

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Contents

Summary

This is a general overview of water pollution caused by rural production systems. All water resources are affected by the presence of different substances used in agriculture as well as seepage from septic tanks and waste lots. The excess of nutrients flowing to surface waters can cause eutrophication and consequent algae bloom and the death of fish due to the oxygen depletion. Pesticides used to obtain healthy plants and consequently high crop yields, will contaminate surface and ground waters, as well as estuarine marine areas. Irrigation used in several areas to improve crop production must be managed correctly so as not to endanger soil quality. Improper agricultural management can bring about salinization and erosion; great extents of the best arable land in the world are now exposed to wind and water erosion. Animal production in

grasslands or feedlots may not cause water pollution with the same intensity, but the resulting manure is always a subject of concern. Manure should be treated as a resource, not as a waste product; when used excessively as a fertilizer it becomes a pollutant. Different agricultural practices that affect water quality are mentioned. The importance of education is emphasized, people in general and farmers specially must understand the hazards deriving from water contamination. Water management to conserve quality does not only mean less contamination; it is also protection of the soil and the water resources of the whole watershed.

1. Introduction

"All things are water", was stated by Thales of Miletus, the Greek philosopher, 2600 years ago. This is very true, as water is essential for the development of all living forms, so it is very important to protect all water resources in view of their ever-increasing demand. Thomas Malthus was already aware of this, over 200 years ago, when he expressed his concern over the oncoming problems of expanding agricultural food production needed to satisfy the growing demands of human population all over the world.

Before 1870 crop production expanded by the incorporation of virgin land, crop rotation and the use of simple methods of pest control. In the last 50 years, the main transformation of the agricultural food production systems has occurred outside the farming sector: mechanization, commercial fertilizers, agricultural chemicals, hybrid seeds as well as intensive animal production, are constantly being improved in order to boost food production.

As demands for food increase, arid or marginal land is being added to extend the agricultural areas, so improving irrigation systems became essential as more crops were produced per unit area. The possibility of contamination of the water being used in the farm area increased, too. Pesticides can contaminate both ground and surface water and enter the food chain; the excessive use of nitrogen and phosphorus by means of inorganic fertilizers may also alter the quality of water.

Water used in irrigation allows higher crop yields but it also favors the dissolution of excess chemicals which runoff to surface and ground water. As problems arise, it becomes more and more evident that it is necessary to use water with responsibility to preserve the environment.

In order to use water resources efficiently it is necessary first to become aware of the factors that alter the quality and amount of water used. These factors may vary according to the type of soil, the amount of salts present in it, and the pollution coming from rural production systems, and industries and human settlements nearby. Some pollution may also be due to improper management, accidental spilling or even simple ignorance. It is therefore extremely important to make the population aware of the need to use water rationally to maintain this resource's sustainability.

Unfortunately, there is scarce international information concerning water quality in rural areas of small and dispersed populations. Recent studies carried out in Eastern European countries by the IIASA (International Institute for Applied System Analysis), within the Program of Hydric Resources Evaluation, determined that ground water available in rural areas is now of lesser quality than it was 30 years ago, all this due mainly to lack of controls.

In many ways, fresh water is the most critical world resource and the most threatened. About 3% of all the water in the world is fresh water, but only a tenth of this is available. As population grows, the demand for water increases, but the supply doesn't.

Data available from the beginning the 20th Century show that the average use of water at the time was of about 400 km^3 year^{-1}, 87% of which was used for food production. By 1950, the total amount of water used had triplicated, 74,5% of which (some 820 km^3) was used in agriculture. By the beginning of the 21st Century it is estimated that the water needed might be about 5000 km^3 year^{-1}, of which only 68% (about 3400 km^3 year^{-1}) is expected to be used for agriculture.

The proportion of fresh water used for agriculture purposes varies broadly throughout the world, from 88% in Africa, and 86% in Asia, to 59% in South America, and 49% in Central and North America, and only 33% in Europe and Oceania. Over 60% of all the water used comes from underground resources, which are generally less polluted than surface water**.** Both sources should be protected to avoid costly cleaning procedures in the near future. It is essential that governments understand the importance of water protection as a priority subject especially as waterways are frequently shared by neighboring countries and need to be managed as a common water system.

The principal aim of this article is to consider the contamination of all water resources as far as rural production systems are concerned.

2. Water Pollutants in rural areas

Water bodies may be classified into surface and underground water.

Surface waters are subdivided into two groups:

- Resting, non-flowing or standing water bodies, such as ponds, lakes and wetlands, in which degradation and binding to organic material are natural detoxification methods.
- Flowing waters, such as streams and rivers, whose detoxification depends in their depth and flowing speed, for the dilution and distribution of pollutants.

Underground waters are classified, according to the depth in which they are found, into two groups:

- waters coming from the unsaturated part of the ground
- water obtained from aquifers, which lie further down from the surface and pollution sources and are consequently less contaminated.

Although it has been clearly established that there is a direct relationship between agriculture and water contamination, the main causes for water pollution have not been established yet, in many cases, because it is often difficult to evaluate the long term, complex effects of pesticides and agricultural chemicals on both humans and environmental health. This problem is a research priority in many countries.

The effects of these chemicals on the environmental health are variable because they are the result of a combination of factors, such as the persistence and their soil binding properties, and the site and setting in which they are applied, the soil and weather conditions, the proximity to water bodies or wells, as well as different management practices like timing and rate of application.

Soil is the main source of water contaminants. Substances present in the soil reach the water resources through a series of mechanisms, such as hydraulic and eolic erosion, lixiviation and volatilization. These mechanisms may be involved in different ways, according to the rural production system being considered.

To understand the complexity of the main pollutants involved in rural areas, they will be discussed separately.

2.1 Nitrogen

Nitrogen (N) is an essential nutrient in the production of food and fiber. The amount of nitrogen required is much larger than that of other plant nutrients. Fertilizers containing N are extensively used in farming.

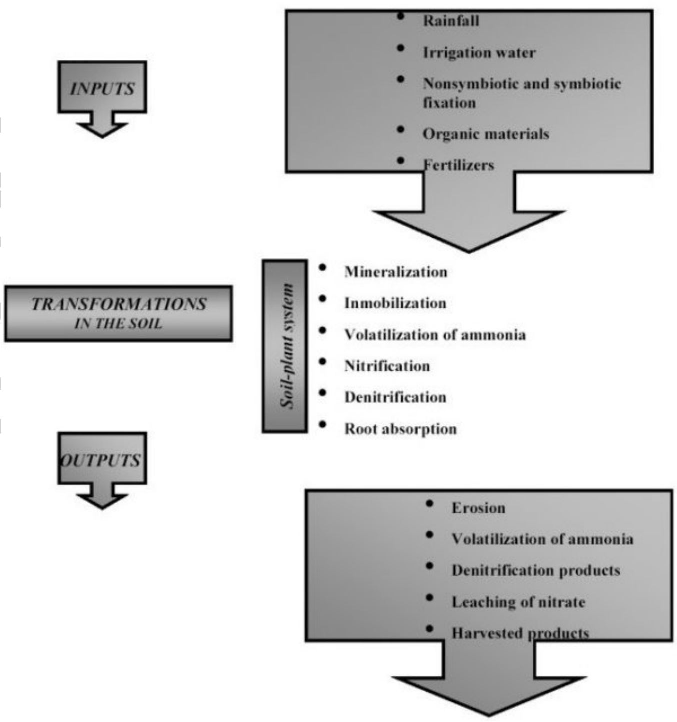

Figure 1: Inputs and outputs of nitrogen from the soil-plant system.

Organic N is present in soil as a natural compound; however, much of the inorganic nitrates found in groundwater is considered a final oxidation product of nitrogenous organic material and can, therefore, be linked to agricultural practices. The concentration of nitrates in most natural ground water is normally small (a few milligrams per liter); when it is elevated it may be an indicator of anthropogenic activities.

Diffuse or non-point sources of N might come from the use of manure or N containing fertilizers or legume rotations. It is essential to point out that there are many other sources of N in the environment causing point pollution such as septic systems, industrial waste water and feedlot discharges.

Inputs and outputs of nitrogen from soil – plant system and nitrogen transformation within the soil are shown in Figure 1.

High nitrate (NO_3^-) levels in water present a serious health problem, because the ingestion of such water may reduce the oxygen carrying capacity of blood (methahemoglobinemia, blue baby disease). Nitrate is reduced to nitrite (NO_2^-) and the iron (Fe) of the hemoglobin in blood is oxidized and a new compound, the methahemoglobin, which doesn't carry oxygen, is formed. Infants are more liable to suffer these ill effects than adults.

The maximum NO_3^--N levels for potable water for humans recommended by the United States Environmental Protection Agency in 1973 was set at 10 mg L^{-1}. The World Health Organization (1971) and the European Economic Community (1980) have established levels of 10.2 and 11.3 mg L^{-1} respectively. In Argentina this level is established at 10.2 mg L^{-1} (see in appendix 1 the conversion factors of nitrogenous compounds).

Conversion Factors for concentration of nitrogenous compounds

- Nitrate in ppm = Nitrate in mg/kg = Nitrate in mg L^{-1}
- ppm x 0.0001 = % Nitrate
- % Nitrate x 10.000 = ppm
- Potassium or sodium nitrate x 0.61 = Nitrate
- Potassium or sodium nitrate x 0.14 = Nitrate–nitrogen
- Nitrate–nitrogen (NO_3-N) x 4.45 = Nitrate
- Nitrate–nitrogen (NO_3-N) x 3.29 = Nitrite

Appendix 1: Conversion factors of nitrogenous compounds

In many parts of the world the distribution and prevalence of nitrate contamination in drinking water hasn't been thoroughly surveyed. In the United States some studies suggest that nitrates are present at detectable levels in 90% of the domestic wells, more than 10% of which exceeded the recommended levels (10 mg L^{-1} of NO_3^--N). Wells that are old or shallow, or those located in permeable soils or near cropland and feedlots prove to be more vulnerable to nitrate contamination.

In Argentina, 40 to 50% of the rural communities obtain water from private wells. An extensive research has been carried out to estimate the number of wells containing high nitrate levels, and to survey the incidence of the risk factors related to the detected contamination. Data are shown in Table 1.

Uses (1)	**(2)**	**Percent of wells (in the sampled area) unfit for consumption owing to nitrate level**				**Most common risk factors**
		North Central Area (n 139)	**North Eastern Area (n 149)**	**Central Area (n 574)**	**Central Western Area (n: 491)**	
Permanent	**H**	50.0	61.2	47.0	54.8	Shallow, old and dug wells
	A	6.0	4.9	0.4	1.9	Septic systems near the wells (less than 15 meter)
Eventual	**H**	38.9	69.2	47.5	55.6	Effluent lagoons in dairy farms
	A	0.0	7.7	3.4	3.7	Feedlot operations near the wells
Exceptional	**H**	27.6	50.0	31.6	69.4	Manure accumulation in watering areas
	A	0.0	1.6	0.4	5.8	Accidental spills

(1) Uses are referred to the shared use of the well by humans and animals in the same farm.
- Permanent expresses a continuous sharing.
- Eventual expresses some sharing in water use.
- Exceptional expresses occasional sharing of water use, for example windmills in pasturelands.

(2) H: maximum permissible level for humans (45 mg L^{-1})
A: maximum permissible level for animals (500 mg L^{-1})

Table 1: Nitrate levels in groundwater in rural areas in Argentina

Nitrates are the most conspicuous substances added to agricultural soils, because they are very soluble and are readily leached, representing a health hazard in water supplies. Nitrates are therefore considered an outstanding problem to be taken into account in any production system where nitrogen is involved.

2.2 Phosphorus

Phosphates can be the major pollutants of surface waters. Commercial fertilizers usually contain phosphorus (P) in the form of phosphates together with nitrogen as their main components. Other sources of phosphate producing water pollution can be animal manure, detergents, and some other natural sources.

Groundwater pollution by phosphates is not very important, as these tend to remain fixed to soil particles, but phosphates may reach surface waters through erosion. Phosphorus in these waters is frequently the limiting nutrient and its presence in levels as low as 50 $\mu g.L^{-1}$ (ppb) produces eutrophication. In these conditions, blue-green algae grow in excess, depleting oxygen supplies in water, as shown in Figure 2.

Figure 2: Different eutrophication stages of Bitel Creek, Chascomús Argentina

If oxygen reduction is severe enough, fish will die. The algae growth also complicates water treatment and can hamper the effectiveness of treatment equipment. The excess of N and P in water due to accidental or systematic discharges of organic effluents, is also responsible for the algae blooming in coastal waters, such as the toxic red tides all around the world or the Pfiesteria outbreaks on the Atlantic estuaries of the United States. The negative effect of these substances on fish and shellfish in coastal areas is serious.

Potassium (K) is also present in most fertilizers, but there are no significant side effects described on ground or surface water, because it is adsorbed to the sediment particles. Other essential elements, added to cropland in smaller quantities are filtered by soil particles, and so far have not been proven dangerous to water supplies.

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Biographical Sketches

M. A. Herrero has an Academic degree, Engineer in agriculture, animal husbandry oriented, 1982; Master of Science and Technology Management, 2002, University of Buenos Aires. Associate full time regular Professor of the Agriculture area of the Department of Animal Production. School of Veterinary Science, University of Buenos Aires. Postgraduate studies in Water management, Chemical aspects of Environmental contamination, in Groundwater vulnerability, sustainable and rational rotational grazing and Transference of Science and technology. Research interest since 1985 in water quality for animal production and health and water contamination from animal production systems. Five fellowships to work in Spain and United States of America on those topics. Seventy related scientific publication, and chapters of books related to water pollution. More than 120 presentation to congresses. Participation in postgraduate courses, extension activities for farm producers. Awards and distinctions received on: Scientific and technological production , Univ. of Buenos Aires, 1994 and 1995; Incentive on Science production, Ministry of Education, Argentina, 1995 to 1999, and two President award for a project of water management in rural areas involving community (2002 and 2004). Distinction from the Renee Thalman scholarship program, University of Buenos Aires, 1997 to work in Water Management in Texas Tech University (USA), and from the Government of Spain in 1995, 1998, 2005 and 2008 to work in Water contamination from Agricultural sources in the University of Zaragoza, Spain and Portugal. Participation in international meetings related to water quality for diverse uses and management of water resources (OAS and UNESCO).

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