5 Chemicals from agricultural activities

5.1 Introduction

World population and economic growth are driving an increasing demand for agricultural products. Coupled with the finite extent to which further land can be converted to agricultural use, this increasing demand has intensified the use of available agricultural land — a trend that is expected to continue. Intensification of agricultural production carries several potential risks to water supplies.

While agricultural practices vary enormously throughout the world (due to variations in population density, economics, climate, soil types and methods of cultivation), there are a number of common activities that are significant sources of pollution. The most common chemical contaminants in drinking-water sources arising from agricultural activity are nitrate and pesticides, although organic contamination from slurry may create threats to drinking-water and drinking-water treatment. Human excrement (night soil), animal manures, fertilizers and biosolids (sewage sludge) used for agricultural purposes may be a source of excess nutrients, particularly phosphorus, which can contribute to algal blooms in slow-flowing or still bodies of water (see Chapter 4).

Many agricultural activities are highly seasonal although some, such as intensive animal husbandry, are not. Thus, it may be appropriate to consider seasonal changes in risk.

5.2 Data sources

Information on agricultural practices that may impact on drinking-water may be obtained from direct surveys of catchments and from a variety of other sources, such as farmers' associations, agricultural authorities or university extension services. Information on pesticide use may be available from these sources but, in many countries, registration authorities are the most important source of information. Where pesticides are imported, customs authorities may also be able to provide valuable advice. The department of agriculture or farming organizations may know which pesticides are used in a particular catchment. Information on production of pesticides for local markets may be available from departments of industry, chambers of commerce, industry associations and similar bodies.

Simple field observations may prove useful in situations where official sources of information are deficient. For example, it may be difficult to obtain a full picture of pesticide use from official sources because there may be widespread illegal use of pesticides, or use of unregistered pesticides in some instances; also, official records may be incomplete due to smuggling of pesticides for purposes of evading taxation or other controls. In such situations, judgements need to be made about which pesticides are likely to be applied under observed field conditions.

5.3 Use of human excrement, animal manure, inorganic fertilizer and biosolids

5.3.1 Human excrement and animal manure

Animal manures have a long history of use as a fertilizer and are still widely used. Wastewater from intensive animal production farms and other sources is commonly used for irrigation. Human excrement is also used in some countries for fertilization of agricultural land. Animal manures and human excrement contain nitrogen in a variety of chemical forms (as nitrate, ammonium salts and organic nitrogen compounds). The nitrogen content of manure varies considerably, depending on the species from which it is derived and their feeding methods; generally, the nitrogen content is much higher in manure from poultry than from other livestock. The age of the manure and the conditions under which it has been stored also affect the nitrogen content. Longer storage, and the application of manure to the surface of soils, can result in the loss of up to 20% of the nitrogen content through the evaporation of ammonia. This loss is reduced to about 5% if the manure is ploughed into the soil.

Depending on local chemical conditions in soil, organic nitrogen may be broken down to inorganic nitrogen. Ammonium compounds can be oxidized to nitrite, and eventually nitrate, which may leach into groundwater and surface water should there be insufficient plant growth to take up the available nitrates. In anaerobic waters contaminated with nitrogen, ammonia and nitrite may also be present. Nitrite and nitrate should always be considered together, since they have the same toxicological effect and the same mechanism of action.

Slurries of animal manure may also be disposed of by application to land. Leaching of nitrates will occur where there is insufficient plant growth to take up the nitrogen and there is a net movement of water away from the root zone.

5.3.2 Chemical fertilizers

Chemical fertilizers are used in most parts of the world, although less so in developing countries because of the high cost. The nitrogen content in chemical fertilizers is known, and application rates can be determined accurately. These may vary depending on the cropping system used. Nutrients are more immediately available for plant uptake in chemical fertilizers than in manure; however, they may be more easily leached into groundwater if used in excess. Slow-release fertilizers reduce this loss.

5.3.3 Biosolids

Biosolids are the residue of the chemical, biological and physical treatment of municipal and industrial wastes, and septic tank treatment processes. A proportion of this material is used as a source of nutrients and as a soil amendment in many agricultural areas. Used at appropriate application rates, these sludges are a valuable resource. However, excessive application can lead to a number of problems, including leaching of nitrates into water sources. Depending on the source of the sewage, sludge may also contain a number of metals, but there is very little evidence for these being a significant source of contamination of water sources.

5.3.4 Nitrate levels

Factors such as soil type, climate, depth of the water table and the use of irrigation determine the rate and extent of nitrate transport into groundwater and surface water (Sumner & McLaughlin, 1996).

In relation to soil types, sandy soils are particularly vulnerable to nitrate leaching (Pionke et al., 1990; Weil et al., 1990), because the high permeability provides limited opportunity for plant uptake, a situation compounded by the addition of excess manure or fertilizer to obtain reasonable yields in this type of soil. Nitrate is retained more effectively in loamy soils containing large amounts of organic carbon, although leaching can still occur from this type of soil.

Rainfall is one of the most important climate factors affecting nitrate levels. Heavy rain causes an initial peak when infiltrating water flushes nitrate from the soil. In cold climates, nitrate leaching takes place during the spring thaw, and during the cooler months, when nitrogen uptake by plants is slow. Like rainfall, irrigation, particularly excessive irrigation, may increase the risk of nitrate leaching.

If the water table is shallow, there is a greater risk of high concentrations of nitrate occurring after a relatively short time, whereas in areas where the water table is deep it may take many decades before nitrate reaches the groundwater in sufficient quantities to raise the nitrate concentration above the guideline value.

Box 5.1 summarizes the main risk factors associated with manures, fertilizers and biosolids.

Box 5.1 Risk factors — manures, fertilizers and biosolids

Use of manures, fertilizers and biosolids for agriculture

The catchment area or water source is subjected to agricultural use.

Manures, fertilizers or biosolids are:

- applied to fields when no crops are present
- applied without measurement and without regard for crop uptake rates
- stored directly on soil with potential to leach liquid to ground or surface water
- stored in the open close to a well used for water supply
- used near a sinkhole, abandoned mine shaft, abandoned well or other feature that will allow water direct access to the water table.

Water table

The water table is close to the surface (e.g. at the end of the wet season, it is easily exposed by a hole dug with a shovel).

The aquifer is vulnerable to contamination.

Soil thickness

Manures and fertilizers are applied to fields where there is little soil cover.

Irrigation

Irrigation is practiced.

Health surveillance

There are cases of bottle-fed infants in the catchment suffering from ”blue baby” syndrome.

5.4 Intensive animal practices

Intensification of agriculture has increased fertilizer use and stock densities, increasing overall nutrient loadings from these diffuse nonpoint sources. At the same time, the growing demand for animal products has led to an increase in facilities for intensive animal production (sometimes known as “feedlots”), which are often point sources of contamination.

Feedlots, typically used for beef, pork and poultry, confine animals in open-air or completely enclosed pens under controlled environments to optimize growth and the quality of meat and other products. They may generate large amounts of wastes that have the potential to cause pollution of water resources if improperly managed. The main sources of pollution from these facilities are the improper disposal of manure, animal carcasses, wastewater, feeding and bedding materials. Wastewater may be generated by the washing down of the facilities and runoff from manure stockpiles, and may be a significant source of pollution from feedlots. As well as nutrients, it may contain salts that have been added to the feed. With a well-managed facility, much of the wastewater is retained and treated; however, poor management practices can allow large amounts of waste to contaminate water resources. In developed countries, these intensive stock-rearing practices have been implicated in water-pollution incidents.

Box 5.2 summarizes the main risk factors associated with feedlots.

Box 5.2 Risk factors — intensive animal production (feedlots)

Siting

Feedlots are sited close to existing water supply wells and rivers used for water supply (these pose a greater threat than facilities located at a distance from water supplies).

Feedlots are located next to sinkholes, abandoned mine shafts, abandoned wells or other features that allow drainage direct access to the water table.

Water management

Wastewater and water used for washing livestock stalls is allowed to percolate into the ground locally or through soakaways, or to contaminate surface water through runoff.

Wastewater from feedlots is collected for treatment in treatment ponds, which can leach into the ground or overflow.

Wastewater from treatment ponds is applied to fields in excessive amounts, contributing to nitrate leaching.

Additional information

Feedlots are uncontrolled and not regulated by government authorities.

Blooms of algae are frequently observed in nearby ponds and other water bodies used for drinking-water.

5.5 Use of pesticides

Coinciding with the increasing use of fertilizers is a growing use of pesticides, herbicides and other chemicals for the control of insects, weeds and fungal pathogens. A large number of these chemicals, with a wide range of different physical and chemical properties, are currently used in agriculture, where they have helped to increase crop yields. As analytical methods become more sophisticated, agricultural chemicals have been detected in water supplies more frequently. Most (> 95%) of these chemicals are at trace levels, with detection rates being higher in agricultural areas using these chemicals intensively. WHO has recommended guideline values for a number of specific pesticides.

The degree to which agricultural chemicals can be leached into groundwater through normal agricultural use depends on a number of factors. These include the extent to which the chemicals are adsorbed onto organic matter in soils, the extent to which they are volatilised from the soil, the rate of degradation within the soil, their solubility in water and the amount of percolating water that is available to mobilize them. The degree to which such chemicals can contaminate runoff to surface waters depends mainly on local rainfall and the extent to which the chemicals are adsorbed onto soil.

5.5.1 Pathways of contamination

The highest concentrations of agricultural chemicals in water supplies generally result from the percolation of contaminated runoff into natural and human-made pathways through the soils, although overspraying of water courses and poor disposal practices may also be important. The most common human-made cause of pollution of wells used to supply water relates to smaller facilities and to direct infiltration by contaminated runoff. Groundwater may be contaminated by leaching through highly cracked soils and fissured rocks. Some very soluble and mobile herbicides may leach to groundwater if they are applied at a time when the net movement of water is downwards and there is little transpiration by plants.

Agricultural chemicals are generally applied directly to plants (foliar spraying etc) or to the soil, and concentrations in surface waters are dependent on factors such as application rates (including overapplication and misapplication), interception loss on plants, soil characteristics and climate (particularly rainfall) and whether or not irrigation is used. Surface water is particularly prone to contamination by poor agricultural practices, such as inappropriate disposal of excess chemicals, water from the washing of application equipment and spills. Other important potential point sources of contamination include chemical storage facilities (particularly those near water sources), mixing sites for chemicals and animal treatment sites (eg dips and sprays) where concentrations, and the chance of spills, are likely to be high.

Box 5.3 summarizes the main risk factors associated with the use of pesticides.

Box 5.3 Risk factors — pesticides

Storage and mixing

Pesticides are stored and mixed with no appropriate precautions to contain spills.

Use

Pesticides are used:

- that are not approved for use by a national licensing authority
- at higher than the recommended application rates.

Pesticides are applied:

- immediately before heavy rainfall.
- directly to the soil immediately before irrigation, or to crops before spray irrigation.
- where the soil is thin and bedrock is exposed or on very sandy soil.
- near open wells, sinkholes or other features that allow direct access to the water table.

Disposal

Unused pesticide or washings from containers are disposed of in surface water, to soakaways or in other circumstances that will lead to rapid transfer to groundwater.

5.6 Irrigation and drainage

Irrigation and drainage can play a role in the transport of pollutants from their source to the water supply. They can also affect groundwater quality by altering the water and salt balance in the soil, which in turn changes its physical and chemical characteristics, and affects the leaching of chemicals in the soil. Table 4.1 indicates where irrigation and drainage may increase the concentrations of naturally occurring chemicals (see Chapter 4).

Irrigation water may be applied through surface channels, by subsurface trickle or drip systems, or by spray, all of which may cause salts to leach from soils in certain circumstances. Leaching of salts affects the quality of groundwater and surface water, and can have a severe impact in areas where natural water flows are relatively low. Under extreme circumstances, excess irrigation may not only lead to the leaching of salts to groundwater but may also cause a rise in the water table. In turn, this may result in high levels of salts being reintroduced into the soil at a point where they can impact on crops and contaminate surface water.

A number of contaminants may be introduced into the water system by irrigation. The large amount of water used in agriculture makes the risk of leaching nitrates and other chemicals potentially greater in areas that are irrigated. For example, where soils contain significant concentrations of selenium, the infiltration of irrigation water can leach this element and thereby contaminate water locally. The quality of the water used for irrigation is also important. When water with a very high mineral content or relatively acid water is used for irrigation, this can impact on both surface and groundwater by leaching minerals from soil and rock.

Drainage from irrigation systems may increase the rate of oxidation of organically bound nitrogen, giving rise to elevated nitrate concentrations.

Box 5.4 summarizes the main risk factors associated with irrigation and drainage.

Box 5.4 Risk factors — irrigation and drainage

Water application

Untreated or partially treated wastewater is used for irrigation.

A greater amount of water is applied than is required to maintain growth.

Irrigation is practised

- close to wells used for water supply
- on sandy or very permeable soils above aquifers used for drinking-water
- when the water table is close to the surface.

Soil acidity measurements indicate the potential for pH levels to be less than 4.5.

The pH of drainage water is:

- less than 5.5
- greater than 8.5.

5.7 References

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