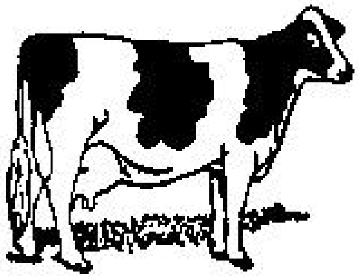

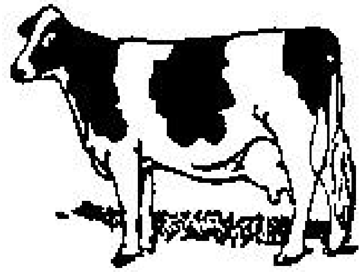

University of California Cooperative Extension
Dairy Manure Management Series

Water Quality

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INTRODUCTION

The availability and quality of water, an essential element, should concern all users. Water quality is characterized by its potential beneficial use. Standards are based upon these beneficial uses. Beneficial uses include agriculture, human and animal consumption, industry, navigation, recreation, fisheries, shellfisheries and wildlife activities. Materials may degrade water quality and impact beneficial uses.

The Environmental Protection Agency (EPA) is required to establish primary drinking water standards (11). Standards have been established to protect beneficial uses and exist for substances known to cause a human health risk (toxins, pesticides). These standards have been established to prevent harm to the animal, plant, and water populations and are evaluated by monitoring physical and biological qualities of water. They are legislated as parts of Federal laws. Federal, state and regional water quality regulations are established to prevent the contamination of ground and surface waters and to restore the quality of contaminated waters for the desired beneficial uses.

The two types of waters that can be contaminated are groundwaters and surface waters. Groundwaters are located underground, while surface waters (lakes, streams and estuaries) are above the ground.

Contamination of water originates from either point or non-point sources. Point source pollution is identified as pollution from a given source. Pollutants are collected into and potentially discharged from a single area (i.e. pipe). Discharges from livestock operations can be a point source of pollution.

California's Porter Cologne Act initially was passed to protect waters from point source

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contaminations. Subsequently, the Federal Clean Water Act (initiated in 1972) (6) was authored to "restore and maintain the chemical, physical and biological integrity of the Nation's waters." The primary focus was industrial point sources of contamination. Through this act and its amendments (7), the chemical (nutrients and toxins) and physical (oxygen demand, temperature, turbidity and sediments) properties of waters are regulated. Increased emphasis on biological monitoring is anticipated. Biological monitoring includes evaluation of insects, fish and plant life within a surface water source.

Non-point source contamination is from a broad and diffuse area. A field that has runoff is a non-point source for pollution because a large area is responsible for the pollution load. Potentially, the entire field is contributing to the contamination, not a single point in the field. Most agricultural operations are considered non-point sources of pollution. This makes identification and assessment of the contaminant source difficult. The contamination cannot be easily associated with a specific process and can be intermittent.

Non-point source contamination of groundwater has avoided major regulation until recently due to physical size and the general tendency to involve multiple political jurisdictions (17). The 1987 amendments to the Clean Water Act addressed non-point source pollution (7).

Dairy waste materials can be classified as both point and non-point sources of contamination, depending on herd size, proportion of confinement (time and space), and manure handling practices. Dairy waste materials include manure (urine and feces), foodstuffs, bedding and wash waters. Milk team wash waters may contain dilute acids, alkalis, detergents, sanitizers and manure nutrients. Each source of waste has specific compounds which may be of concern environmentally and which could potentially contaminate water.

The primary manure nutrients related to groundwater contamination are nitrogen (N) and phosphorus (P). Nutrients applied to soils in excess of the plants' requirements build-up in the soil over time, especially in arid areas. These nutrients migrate downward through the soil with water and eventually collect in the groundwater. Surface water pollution can result from these same nutrients. Additionally, dissolved oxygen (DO), bacteria load and sediment can contribute to pollution, all of which can result from contamination by manure.

GROUNDWATER

The primary agricultural components of groundwater contamination are nitrates, salts, pesticides, petroleum products and fertilizers (16). These chemicals may flow through the soil with water to the water table. In the absence of adequate soil moisture, most contaminants are not able to migrate downward to groundwater. Therefore, attention to nutrient application, water management and chemical storage is critical for preventing groundwater contamination.

Nitrates

Nitrates in drinking water at levels exceeding 10 ppm of Nitrate-N are potentially dangerous, especially to newborn and young animals (13, 14). Nitrate has been responsible for inadequate gains in young calves and abortions in milking cows (3). Consumption of water with elevated nitrate can cause Blue baby syndrome" in infants (5) and respiratory dysfunction in young stock. Specifically, nitrate is converted to nitrite in the digestive tract. Nitrite reduces the oxygen-carrying capacity of the blood which may result in brain damage and even death in infants. The maximum tolerable level of Nitrite-N is 1. At this time, nitrate and nitrite remain unclassified with respect to their carcinogenicity. These agents are members of

Group D: inadequate or no animal evidence of carcinogenicity (12).

Nitrogen is applied to land in fertilizers, manure solids and manure water, irrigation waters and crop residues. With time, microorganisms in the soil can convert various forms of nitrogen into nitrate. If plants do not use all the nitrate and there is excess soil moisture, water will serve as the vehicle for downward flow of nitrate. It is by this mechanism that nitrates eventually enter the groundwater. Continued excess application of nitrogen to soil will almost inevitably result in nitrate leaching into groundwater where aquifers are recharged. Soil type, water and nutrient holding capacity determine how long it takes before excess nitrate enters the groundwater.

Salts

The concentration of soluble salt (salinity) in soil will increase when application rate exceeds crop use and nutrient removal. The amount and distribution of rainfall and irrigation, the type of soil and underlying strata, the evapotranspiration (ET) rates, and other environmental factors affect the movement and deposition of salts. In humid areas, dissolved mineral salts have been naturally leached from the soil and substrata by rainfall. In arid and semiarid regions, salts have not been removed by natural leaching and concentrate in the soil.

Excessive concentrations of sad in the soil come from various sources. Irrigation waters, soil amendments and nutrient applications can deposit more sags than most agricultural crops can use. As the water is consumed by plants or lost to the atmosphere by evaporation, the sags remain and become concentrated in the soil. The accumulation of sags in soil eventually is detrimental to plant growth if unmanaged. To offset this condition, some people apply excessive irrigation water to leach sags below the root zone. This practice can ultimately deliver sags to underlying aquifers or surface waters. Attention to irrigation and nutrient application practices is necessary to maintain cropland productivity over decades of use.

Pesticides

Herbicides, insecticides, and fungicides are used to control crop pests. Improper storage of pesticides and improper application rate and timing are responsible for the contamination of groundwater. It is illegal to dispose of outdated or illegal pesticides manure holding or treatment ponds or piles. The end fate of pesticides in these environments is not known and is potentially dangerous. Proper pesticide storage and application guidelines are best obtained through pesticide certification courses. Such courses are recommended before pesticides are used and as an update on current technology.

SURFACE WATER

Surface waters include lakes, streams, creeks, wetlands, and seasonal waterways (including annual creeks and streams) and estuaries. The direct discharge of wastes into a waterway requires a valid waste discharge permit and is prohibited unless the discharge can be shown not to degrade the receiving water. Additionally, direct discharge is not permitted if it will harm the biological integrity of the water. Elements of surface water contamination can include sediment, nitrogen, phosphorus, bacteria, toxins and chemical and biochemical oxygen demand effects on dissolved oxygen (16). Each component can affect the chemical and physical integrity of waterways and alter habitats for living organisms, thereby altering the biological integrity of water.

Dairy waste can infiltrate surface water in a number of ways. Damaging and illegal point source release of wastes occurs when waste storage ponds or similar structures leak or overflow into nearby waterways. Relatively small volumes of waste can cause detrimental chemical changes in the water.

The chemical alteration may be restored in a relatively short time. However, restoration of destroyed habitats for aquatic life in affected waterways may take months or years.

More subtle, yet significant, sources of accidental discharge in waterways can occur during rains. Heavy or constant rainfall can discharge waste into surface waters from manured areas or from fields that are fertilized with dry or fresh manures. Special care must be taken if manure must be spread during the rainy season.

An often overlooked source of waste is the high use areas of large pastures. High use areas around feeders, water troughs and gates and lack of vegetation and can build up significant amounts of manure. When exposed to moving water from rain or down slope flows, these soiled areas are a source of pollution to nearby waterways.

Sediment

Sediment is the single most prominent cause of surface water contamination in California (10). Sediment is the result of erosion, and it is the solid mineral and organic material in suspension that is transported by air, water, gravity or ice. Sheer, fill and gully erosion can create sediment. On dairies, overstocked pastures, inadequate corral management and poorly timed tillage practices can lead to sediment problems. Eroded soil is redeposited as sediment on the field it came from or transported away from the field in the runoff.

Sediment affects water usage in many ways. Sediment deposited in creeks and streams eventually ends up in reservoirs. Sediment accumulation reduces the holding capacity of reservoirs and may also cause streams to become more shallow. This alters the environment for aquatic organisms (15). Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies and clog the filtering capacity of filter feeders and the gills of fish. Consequently, there is a reduction of fish, shellfish and plant populations and a decrease in the overall productivity of lakes, streams, estuaries and coastal waters.

The surface of a field is rich in nutrients and other chemicals because of fertilizer, manure and pesticide applications. Therefore, sediment which originates from surface soil has a higher potential for pollution than sediment from subsurface soils. Low density organic matter from field manure application is easily transported in flowing water. Consequently, sediment from cropland contains a higher percentage of finer and less dense particles than the soil from which it originated. Large particles are also readily removed from the soil surface because they are less cohesive.

Nutrients are also carried away with sediment soil particles. Pesticides, phosphorus and ammonium attach to and are transported with sediment. Eventually soil particles will release the bound chemicals on nutrients and contaminate the water. The speed at which this occurs will depend on existing physical chemical properties of the water.

Dissolved oxygen

Aquatic species utilize dissolved oxygen (DO) in respiration. Under normal environmental conditions the maximum DO concentration is 11 mg/l (milligrams per liter) or 11 ppm (parts per million) (18). When DO drops below 5 ppm, mortality occurs.

Biochemical oxygen demand (BOO) refers to the ability of organic material (dairy waste, decomposing bacteria, plants) to reduce the DO in water. Bacteria remove oxygen from water as they metabolize organic materials high in BOD. This oxygen depletion eventually results in the death of not only the bacteria, but of oxygen-dependent aquatic species. The subsequent decomposition of the bacteria will further reduce DO concentration in water.

Nutrient-enriched waters stimulate algae production, which increases water turbidity, which decreases sunlight penetration through the water. Submerged aquatic vegetation provides habitat for small or juvenile fish and will die without sunlight. The loss of the vegetation can have severe consequences for the food chain.

Bacteria

Dairy waste, either fresh, dry or in liquid storage, may contain high concentrations of coliform bacteria which are potentially hazardous to cattle and human health. The standard value of coliform bacteria in fresh cow manure is 500 colony-forming units/pound of fresh manure (1). This value can increase rapidly in appropriate environments. Fecal coliforms are a problem to human drinking water if the bacteria are in high concentration. Manure is a potential contaminant of domestic wells. Fecal bacteria can infiltrate wells when the manure management system and domestic well are not properly maintained.

Rain runoff in coastal areas can move soil, manure, and associated bacteria to ocean waters. Elevated coliform counts can result in temporary closing of oyster farms by local Departments of Health Services (2). Coliform bacteria counts are used as an indicator of human sewage contamination. It is not known if the elevated coliform counts originated from human, lifestock or wildlife (deer, ducks, etc.) sources. Inexpensive, readily available methods do not exist to differentiate human from animal contributions to coliform count.

Nitrogen

Eutrophication (first steps to death) occurs in lakes, estuaries and coastal waters when undesirable bacteria and algae displace desirable bacteria and algae. Nitrogen is a potential contributor to this process, and thus a key link in the cycle which can result in a dying lake. Nitrogen availability usually is the limiting factor for plant growth in aquatic ecosystems. If nitrogen is limiting the growth of bacteria or plants, its addition to the water in the form of leaching or runoff will potentially increase the vegetative growth of the body of water. As the bacteria and plants grow, die and decompose, the water is stripped of oxygen. The resulting change in the oxygen content of the water will affect the survival of aquatic species found within that particular body of water.

Nitrogen is awed to soil primarily by applying commercial fertilizers and manure, by growing legumes, by incorporating crops, through irrigation water and, to a much lesser degree, through rain. The addition of nitrogen to the soil may be beneficial for crop yield. The most biologically important inorganic forms of nitrogen are ammonium (WHO), nitrate (NO3-), and nitrite (NO2). The chemical form of nitrogen determines its impact on water quality. Ammonium is the form of nitrogen which is of greatest concern to surface water quality.

Ammonium contributes to BOD and reduces DO concentration in water. It forms ammonium hydroxide in water and is extremely toxic to fish and aquatic life (8). Ammonium hydroxide occurs in more alkaline water (pH ~ 7.0) and in warmer stream bank waters. Ammonium hydroxide concentrations between 0.5 to 0.65 ppm have caused 50% mortality of trout within 5.5 hours (9). Waters with low DO and high ammonium hydroxide or other toxic agents are more toxic than waters with low DO alone.

Ammonium becomes absorbed by the soil and is lost primarily with eroding sediment. Dissolved ammonium in surface water at concentrations above 0.2 mg/1 may be toxic to fish, especially trout. Dry waste, however, contains little ammonium. The addition of moisture establishes an environment which favors ammonium formation. Dry waste located in a dry stream bed can produce ammonia and ammonium as rains occur and water accumulates, resulting in fish kills.

Soil microorganisms can convert ammonia to nitrate-nitrogen. Nitrate-nitrogen is highly mobile and can move readily below the crop root zone, particularly in sandy soils. Nitrate can also be transported with surface runoff, but not generally in large quantities. Eventually, nitrate-nitrogen can be released from sediment and used by bacteria and algae for growth.

Phosphorus

The phosphorus content in most soils is low (between 0.01 and 0.2 percent by weight), and most of this phosphorous is not available for plant use. Phosphorous-containing manure and fertilizers are used to promote plant growth in phosphorous deficient soils. Excessive application of phosphorous can result in accumulation in soil, and when runoff and erosion occur, over-applied phosphorus can reach nearby surface waters. This is a particular problem when high-intensity storms increase the loss of inorganic phosphorus from croplands in the form of eroding sediments.

Phosphorus can be found in the soil in dissolved or particulate forms. Dissolved inorganic phosphorus (orthophosphate phosphorus) is probably the only form directly available to algae. Algae consume dissolved inorganic phosphorus and convert it to the organic form. Algae eventually die, reducing oxygen levels of water and resulting in death of aquatic organisms.

Unavailable phosphorus in the soil system can create water quality problems when it erodes with soil particles and is later released in streams. Phosphorus generally is the limiting nutrient for algae and bacterial growth in freshwater systems located in high rainfall, poor quality soil regions. In some estuary systems, both nitrogen and phosphorus can limit algae and bacterial growth. The addition of phosphorus as a non-point source pollutant can have an adverse effect in both freshwater and estuary systems because increased algal and bacterial growth decrease dissolved oxygen content in water.

Salts

Irrigation return flows provide the means for transporting the salts to the receiving streams or groundwater reservoirs. The total salt load carried by irrigation return flow is the sum of the original salt in the applied water plus the salt picked up from the soil. If the amount of salt in the return flow is low compared to the total stream flow, water quality may not be degraded. The process of water diversion for irrigation and the return of saline drainage water along a stream or river is not acceptable. This practice will progressively degrade the water quality downstream.

Pesticides

Pesticides or their degradation products may persist and accumulate in the aquatic ecosystems. Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species.

The amount of a field-applied pesticide that leaves a field in the runoff and enters a stream primarily depends on the time between application and the rainfall or irrigation as well as the intensity and duration of rainfall. Pesticide losses are greatest when rainfall is intense and occurs shortly after application and where such conditions favor water runoff and soil erosion. Pesticides can be transported to receiving waters either dissolved in water or attached to sediment.

Dairy Chemicals and Agents

Little is known about the toxicity of dairy sanitizers and cleaning agents. This toxicity is a factor of the concentration of the active forms of these compounds and how they interact with other chemicals in the environment.

The use of copper sulfate foot baths is common on dairies. Elevated levels of copper have been found in dairy lagoon waters and in surface waters adjacent to fields irrigated with these waters. High copper levels have been found in estuaries near dairies on the North Coast (4).

SUMMARY

Maintaining and improving the quality of water degradation is critical for the long term viability of a farm site and is mandated by Federal, state and local regulations. Society's increased environmental awareness is a driving force behind much of the legislation. Manure and dairy waste nutrients must be managed appropriately to avoid surface and ground water contamination. Implementation of appropriate management practices can eliminate or reduce non-point source pollution to surface and groundwaters.

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About this series...

This publication is part of a series on dairy manure management. The sections focus on specific issues relevant to the California dairy industry.

The purpose of individual sections is to provide current scientific information related to dairy manure management. Producers are required to integrate air, land, water, plant and animal resources. Each management decision may impact these separate but intertwined resources.

Factual, scientific information is needed by producers, regulators, planning commissions members, and citizens concerned about their environment. This series is designed to provide foundation knowledge about dairying and the environment. Further information is available through University of California Cooperative Extension.