A CITIZEN’S GUIDE
To The Regional Economic and Environmental Effects of Large Concentrated Dairy Operations

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HOW TO USE THIS DOCUMENT

The rapid proliferation of large dairies across the United States has made it difficult for citizens' groups and permitting agencies alike to intelligently review the growing number of applications for concentrated dairy operations. Often, residents of an area are not notified of an application in a timely manner and, when they are notified, they are provided with only a limited amount of time to review an application that has had months of intensive preparation. Further, since most members of permitting agencies and local groups are not associated with the dairy industry, just locating sources of data to confirm or contradict a claim made in a permit is a major task. This paper has been assembled to assist in this process.

The first section of this paper is a general overview of the dairy industry and of the context in which large concentrated animal operations interact with a host area. This section also contains information on health issues, property valuation issues, and other general regional impacts that will affect the economic and social life of the region. Sources are carefully cited so the interested reader can use the facts and figures presented in an appropriate way.

The second section contains most of the current data pertaining to dairies from the most respected and unbiased sources of information about dairy operations. As a result, this document draws heavily on research done by the States of Minnesota and Ohio and by the US Department of Agriculture. Each table or chart is carefully cited to allow the user to refer to the original document. In the case of health-related issues, a large number of current sources on this area are provided at the end of the health section. Tables in the second half of the document allow the reader to determine the impact from manure, milk waste, nutrients, and other outputs of dairy operations on the local environment. In each section, examples and descriptive text are provided to allow each reader to make his/her own calculations of every aspect of dairy operations. These calculations will change based on the crop yields of the land used to spread manure. For this reason, local crop yield data along with its nutrient requirements should be used to "customize" calculations of the amount of land required for nutrient spreading.

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Introduction

The economic model that became capitalism is based on efficiencies from standardization, specialization and concentration of productive resources. As capitalism developed and this model was applied to production activities, social and environmental problems such as child labor, unhealthy working conditions, unfair labor practices, and polluting activities often occurred. Over time, these issues were dealt with in the industrial sector through a framework of laws and regulations.

Recently, the dairy industry has joined an agriculture trend toward industrial production--Concentrated Animal Feeding Operations (CAFOs)--that exceeds the capacity of the land on which it is located to naturally process animal waste. In a fundamental sense, the ability of the land to naturally process animal waste defines the limits of sustainable agriculture. Agriculture can only be environmentally sustainable if it produces no more waste than the land available for waste application can absorb. Waste produced in excess of this amount must, at some point, be transferred off land used by the CAFO in the form of air- or water-borne pollution and when this occurs, the costs of this waste are shifted away from the land where the waste is generated.

Unfortunately, the dairy industry's shift to industrial CAFOs outpaced laws and regulations governing agricultural activities--laws and regulations that were meant for a non-industrial sector. This occurred partly because agriculture is viewed by the state and by society in general through a lens colored by the assumption that the enterprise of agriculture is a "closed system" where the density of animals is compatible with the land's ability to recycle animal waste.

One central rationale of laws to regulate industrial waste was the recognition that the assumption of a closed system did not apply to industries. Industrial waste often polluted the environment of those who lived around (or many miles from) the industry and laws were necessary to prevent the harm to society that might come from contact with this pollution. The laws governing industrial waste forced industry and the consumers of its products to "internalize" (pay for) the costs of dealing with this pollution.

The assumption of a closed system is usually no more applicable to dairy CAFOs than it is to any other industrial operation, but dairy CAFOs, masquerading as agricultural enterprises, have used the absence of laws governing agricultural pollution to avoid paying the costs of the waste generated by their operations. The reason dairy CAFOs must shift the costs of their waste to someone else is that they are faced with significant diminishing returns in their operations. This has become the central issue in the debate about the two contracts under which dairy CAFOs operate--the explicit contract that governs their relationships within the financial organization in which they exist, and the implicit contract between the CAFO and the region or community in which it is located.

This section is organized in several parts to deal with these issues:

Section I:

1. A brief explanation of some of the industrial organization issues involved in operating large, corporate dairy farms, a brief explanation of the two contracts that govern the behavior of corporate dairy firms--the business contract and the contract with the community that hosts the firm, and the implications of these issues for the community.

2. An examination of the question of efficiency of production--whether large dairy farms are more efficient than smaller, conventional dairy farms.

3. An examination of the impacts of large diary CAFOs on regional economic development.

4. A description of the various costs associated with dairy production that may be shifted to the region in which the dairy is located.

Section I

I. THE INDUSTRIAL ORGANIZATION AND CONTRACT ISSUES INVOLVED IN OPERATING LARGE, CORPORATE DAIRY CAFOs AND THE IMPLICATIONS OF THESE ISSUES FOR THE COMMUNITY.

Price is the mechanism by which any market conveys basic information about supply and demand for a good. But the markets in which dairy Concentrated Animal Feeding Operations (CAFOs) compete are very different from the old perfect competition-based models of agricultural production. As a result, the effects of these markets on the life and economies of local communities have changed significantly.

Conlin has identified ten major trends underway in the dairy industry:

1. Dairy farms are restructuring to larger, more specialized farms that are multi-person owned and operated, on a relatively smaller land base with greater vertical integration with the market and input sectors, and more diversity in size and production processes.
2. Higher priority given to management goals: efficiency, profitability and life quality with higher productivity per unit of labor, feed, and asset, more emphasis on effective management of people, adoption of cost effective technologies, use of outside expertise and greater systemization, routinization and specialization of production tasks.
3. Implementation of quality management concepts such as management information systems, strategic and tactical business plans and action protocols, team work, and monitoring and control systems.
4. Increased business networking and collaboration through joint ownership, creative financing and risk sharing, leasing arrangements, closer linkages between production and consumption, more outsourcing operational phases, and greater use of external advisors.
5. Greater price volatility with less government involvement in regulating prices of feed and milk, and expanding potential for export pressures and greater use of price risk tools such as futures, options, and contracts.

6. Stronger consumer driven markets with more emphasis on quality defined in human health/safety risks, consumer tastes, packaging and product preferences, with growing competitive opportunities in international markets and niche markets and product differentiation.
7. Restructuring of the dairy industry business/service sector with mergers, and consolidations having fewer processing plants, greater privatization of information, globalization of technology and services, with a feed industry becoming more price driven with greater use of commodities, and separation of consulting services from product sales.
8. Changing public policy with markets being more driven by supply/demand and quality, less regulation of pricing policies, broader public input on agricultural policy, particularly issues related to the environment, food safety, and animal care. The dairy business will be more sensitive to broad government policies related to taxes, interest rate, environment, health, trade, crop programs, etc.
9. Stricter environmental protection policies related to protection of ground water and air quality that will bring greater integration of manure application with the cropping and land characteristics.
10. Cow numbers will shift to regions that have dairy friendly communities with plentiful supplies, cost competitive feed and services, with a desirable climate, infrastructure of dairy support services and markets, and where there is access to capital.[1]

Initially, the issue of dairy CAFOs seems simply to be one of price and efficiency. However, to a large extent it is really an issue of information. As Jones has noted, in agriculture

> [t]he critical emphasis is changing from resource allocation based on price to allocation based on strategic advantage...Until greater transparency of information in economic signals between industry levels occurs, there is a strong incentive for producers to develop formal partnerships through cooperatives, joint ventures, or vertical arrangements.[2]

These partnerships usually create two contracts of interest when a dairy CAFO enters a region:

1. the contract with the CAFO's organization where information is equally shared and where the motives of all players are a consistent and singular search for profit, and
2. the contract between the community and the CAFO where asymmetrical information exists.

When a dairy CAFO enters a rural region, it strikes a bargain with the rural community in that region. This implicit contract is usually formed around stated, not written, promises of jobs and economic growth for the region that the dairy CAFO will provide in return for land, water, access, power and the other factors that are required for the dairy CAFO to operate. This implicit contract also implies a certain physical relationship with the region that manifests itself in the presence (or lack) of pollution, traffic, resource consumption, etc., that arise from the operation of the dairy.

The dairy CAFO organization is typically well informed about the implied contract with the region because it extended the verbal offers on which the contract is based, but the citizens of the region are privy to very little information about the dairy's explicit contract with its organization. As a result, there is an incentive on the part of the dairy CAFO to shift costs between the contracts based on each party's access to information about those costs. The party with the least information about costs is most likely to have those costs shifted in its direction.

The size and complexity of dairy CAFO organizations is significant. In 1998, the top fifty milk cooperatives in the U.S. ranked on volume of milk accounted for 120 billion pounds of the national production of 157 billion pounds in 1998. They claimed 70,820 member dairy farmers. The ranking of the largest cooperatives continue to shift as more mergers occur. As Table I-1 shows, just ten milk cooperatives accounted for half of total 1998 U.S. milk production:[3]

Table I-1. Dairy consolidation—top ten cooperatives

Dairy Cooperative	Member Milk (bil. pounds)	Number Members
Dairy Farmers of America, Springfield, MO	31,500	18,453
Land O Lakes Inc., St. Paul, MN	7,988	6,400
California Milk Producers, Artesia, CA	6,750	336
Foremost Farms USA, Barb, WI	5,400	5,850
Family Dairies, Madison, WI	5,256	7,625
Darigold Farms, Seattle, WA	5,050	878
Dairylea Cooperative Inc., Syracuse, NY	4,886	2,369
North Central AMPI, New Ulm, MN	4,400	5,000
Dairymans Cooperative Creamery Assn., Tulare, CA	4,212	245
Manitowoc Milk Producers Cooperative, Manitowoc, WI	3,540	3,230

The second-ranked cooperative, Land O Lakes, has merged with ninth-ranked Dairymans Cooperative Creamery Association since these 1998 figures were compiled.
Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. D/E-32.

Local, county, state, and national laws and policies on the environment and on zoning are important determinants of the location of dairy CAFO facilities.[4] Further, these laws and policies affect the ability of dairy CAFOs to control information about their operations and they are major determinants of the role the dairy will play in the physical, social and economic environment of a region. Thus, the physical relationship between the dairy CAFO and the region is essentially predetermined by the rules and policies that are already in place in the region--and this set of rules and policies is based on the pivotal assumptions that

1. All agricultural operations are similar to the conventional, closed systems that previously dominated agriculture.
2. Animal waste is a natural product that, while annoying, is essentially harmless.
3. The waste of ruminate animals is essentially benign where environmental safety is concerned.

As a result of these assumptions, when a CAFO enters a region it encounters a set of rules that have generally been structured to control a kind of agricultural production whose inputs and waste byproducts are not representative--either in quantity or chemical composition--of the Concentrated Animal Feeding Industry.

The question here is not whether the dairy CAFO can make an implied contract with the region. Instead, the issue is that in addition to this contract being physically defined around incorrect assumptions, it will also be based on asymmetrical information that heavily favors the dairy. Such a contract is likely to work in only one direction--it is likely to increase the profits of the dairy CAFO by shifting the operating costs of the CAFO either to the region in which it is situated or, through some mechanism of pollution migration, to another region further removed from the CAFO. The certainty of this outcome follows directly from existence of asymmetrical information about the operation of the dairy CAFO and from the motivation of the operators of the dairy.

The term asymmetrical information refers to a situation where one of two individuals in an agreement or contract possesses more information than the other individual about the nature of the bargain. If one individual possesses critical additional information about the contract, this individual can use his proprietary information to gain an advantage in the bargain.[5] In theory, the permitting process used to evaluate dairy CAFO applications should insure that the citizens of a region are fully informed about all aspects of the dairy's proposed operation. If this was indeed the case, there would be no asymmetrical information. However, a permitting process based on the incorrect assumption that all agricultural projects are conventional in nature allows the dairy CAFO operator to withhold significant amounts of information from the residents of the region in the following ways:

1. The CAFO uses claims that its methods of handling waste are technologically advanced and thus, proprietary, to block release of information about the specifications and performance of its waste handling systems.
2. The usual position of the CAFO as a contract operator or coop member associated with larger, out-of-area corporate interests may limit even the dairy CAFO operator's knowledge of the source of inputs (feeds, hormones, antibiotics, etc.), the rationale behind the amounts and types of inputs selected, and the actual value of the product (the milk) to the owner.
3. Out-of-area ownership and the use of Limited Liability Partnerships (LLPs) severely limits the ability of regional residents to determine the motivation, trustworthiness, and credibility of those who own and operate the dairy CAFO.
4. The practice of building dairy CAFOs as turn-key operations limits the ability of regions to establish any reliable record of CAFO performance before committing to a fully-constructed operation.
5. The legal protection extended to the CAFO by permitting authorities may insulate the CAFO from disclosures that may provide the only source of information about out-of-state operations. For example, an Idaho law specifically exempts from disclosure "records gathered by a local agency or the Idaho Department of Commerce...for the specific purpose of assisting a person [e.g. a corporation] to locate, invest in or expand business operations in the state of Idaho."[6] And manure management plans in Iowa can be changed on site without notifying the Iowa Department of Natural Resources of the changes. The working copy of the plan is held by the CAFO operator is not available for public scrutiny.[7]
6. And finally, the dairy CAFO permit approval process is often so rushed that residents of the region have insufficient time to learn enough about the proposal to ask intelligent questions or to do relevant research on the proposal.

In combination, these factors create an agreement (contract) between a dairy CAFO and a region that is based on verbal promises of jobs and economic development, but for which the actual information needed to validly assess the impact of the CAFO on the physical, social and economic environment is withheld from the public and is available only to the owners/operators of the diary. The result is that the county or other permitting agency has inadvertently created what economists call a moral hazard, a process that occurs when one party is better informed than the other about the characteristics of the transaction. By definition, a moral hazard leads to lower efficiency and to higher costs to the party that is least informed (in this case, a higher cost to the region that hosts the dairy CAFO.)

Having created a moral hazard, the region is now faced with a second economic condition called adverse selection. This provides an incentive for additional producers who also want to shift costs to the residents of the region to migrate to the area. Thus, additional CAFOs of all kinds are likely to be attracted to the region. As Milgrom and Roberts note, adverse selection is "a kind of precontractual opportunism that arises when one party to a bargain has private information about something that affects the other's net benefit from the contract and when those whose private information implies that the contract will be especially disadvantageous for the other party to agree to a contract."[8]

Casson has laid out the general outlines of the relationship that develops between the region and the dairy CAFO as a result of these factors by noting that:

> the crucial question... is whether the other party to the transaction can be trusted. There are two fundamental approaches to engineering or creating trust. The one most commonly used in much of the Western world is to monitor performance through the institutional and legal system and penalize those parties that do not fulfill their negotiated commitments. The alternative approach to engineering trust is to manipulate the incentive structure so that individuals fulfill their commitments based on rewards they receive rather than penalties they incur.[9]

For dairy CAFOs, the issue of trust is directly tied to out-of-area ownership and the asymmetrical information in the agreement between the dairy and the community. Since the motivation of the dairy is to create profit, not to control pollution or engage in any of the other social benefits the region may desire, a dairy CAFO can only be trusted to act in its own self interest. The interests of the region could initially be protected by disclosure of full information concerning the operations of the dairy during permitting. However, due to the factors already discussed, the dairy CAFO usually controls the information in this part of the process. The only recourse for the region is monitoring by knowledgeable regulators.

Unfortunately, monitoring measures compliance with laws that are often crippled by the same underlying assumptions about the nature of agriculture listed earlier in this section. Dairy CAFOs are often able to use laws based on loose, conventional agricultural standards to avoid pollution controls that would more fully assign the costs of waste to the dairies. In addition, most of the factors that made it difficult to get information on proposed dairy CAFO operations during the permitting process also complicate attempts to monitor CAFO operation. This leads to a condition called low separability. Separability is "...the feasibility to see who has done the work. With low separability, the principal [in this case, the region] will face either high control costs or intense cheating."[10]

So far, the history of dairy CAFO operations shows that cheating is likely. And it is made even more likely by the decision on the part of many regulating agencies to rely on citizen complaints instead of more costly professional monitoring. If monitoring fails or is not effectively implemented, the only other option for controlling the behavior of the dairy is through economic incentives. But, as previously noted, a powerful economic incentive structure is already in place and this incentive structure has been formalized in the explicit contract between the CAFO, its own organization, and its investors. This contract directs the CAFO to operate in such a way as to maximize profit, and if it can do this by shifting the costs of its waste to its neighbors in the region, that is how it will operate.

II. THE ISSUE OF ECONOMIC EFFICIENCY.

General Attributes of Efficiency

The economic issue of efficiency in production is central to the rationale for all Concentrated Animal Feeding Operations. In this argument, the economic issue usually discussed is the concept of increasing returns to scale where the efficiencies are realized when more capital is brought to a production process. The resulting capital intensive process has a much higher reliance on machines and technology and is less reliant on labor. In the dairy CAFO process, raw materials (feed, water. etc) are submitted to cows in concentrated dairy facilities and the output is milk.

In so far as the cows and their confinement facilities can be treated as machines, the CAFO philosophy is that they can be “improved” through the addition of capital to the production process. This “improvement” comes through standardization of breeds and sizes, use of hormones and antibiotics, control of growth rates and animal disease, and increased specialization of workers, managers, and animal handling facilities.

If this was all there was to the CAFO process, one would expect efficiency of operations to continue to increase as more capital in the form of cows and buildings was added to the process. In other words, the maximum efficient size of dairy CAFOs would be extremely large. Further, this concentration would bring other benefits. For example, a former Agriculture Commissioner in Minnesota has stated that

> As farms and feedlot operations get larger, there will be opportunities for important land and resource restoration to occur. Greater production of crops on fewer acres will make land available for important resource restoration activities. The prairies of the state have been mostly eliminated, and some of our most important biodiversity issues must be approached by restoring grassland habitats.... The larger farming operations will also provide greater opportunities for better management of wastes and capital intensive management methods for improved air and water quality".

The Commissioner's point can only be valid if the efficiency of farm and feedlot operations continually increases as they get larger and larger. In this sense, efficiency means that average costs continue to drop. However, this is not the case. Efficiency peaks as concentration rises because the cost of waste disposal for a concentrated animal operation increases sharply after one surpasses the ability of the land to absorb the waste. The fact that dairy CAFOs may be able to avoid this cost by shifting the cost of their waste to the surrounding region makes no difference--the confined operation is still less efficient in an economic sense.

The Commissioner's statement also contains an unstated assumption--that the waste generated by concentrated operations stays on the site and that the land is capable of absorbing an unlimited amount of waste material. Carried to its (il)logical conclusion, the Commissioner's statement would lead one to concentrate all dairy cows on a single feedlot.

We already have a large body of law that regulates similar problems for industry that arose from a similar condition to the one the Commissioner proposes: a point source of pollution from some concentrated industrial activity was damaging the health of the surrounding environment. Theoretically, this concentration of industry in various locations should have, in the Commissioner's words, "[made] land available for important resource restoration activities" (because it was not covered by factories.) Instead, the waste flows from those concentrated activities ruined the surrounding environment and, in the case of acid rain, the environment thousands of miles away.

Further, the switch to dairy CAFO's only confines the animals in less space, it does nothing to reduce the amount of land needed to raise feed for the animals and it does nothing to reduce the amount of land that ultimately is needed to recycle the animal waste. For this reason, the switch back to conventional farming simply places the animals on the land that is also used to grow their feed and uses the animal manure responsibly to fertilize that land so that feed can continue to be grown in a more-or-less closed system. In addition, spreading the animals out in this manner reduces the need for antibiotics.

The Efficient Size of Dairy CAFOs—General Theories

If all the economic costs of dairy CAFO operation are considered, two economic concepts--diseconomies of scale and diminishing marginal returns--both mandate that the efficient size of most dairies should be relatively small. To understand why smaller and medium sized dairies have lost market share to the CAFO giants in spite of this expectation, it is necessary to investigate how the expected effect of these two economic concepts has been altered by the actions of the dairy CAFO industry.

The first economic concept--diseconomy of scale—usually comes into play when problems associated with some element of a production process increase much faster than the size of the process itself increases. With dairy cows, such a situation occurs with attempts to control the disease and stress that occur when animals are kept in a concentrated setting. This situation is further complicated by the use of the growth hormone rBGH to boost milk production—a hormone that has significant physiological effects on the cows.

The second, more powerful economic concept called diminishing returns also ought to act to limit the size of efficient dairy CAFO operations. Under this concept, when units of a variable resource (such as cows) are added to a fixed resource (such as land) one reaches a point where the marginal product (the amount of milk from the last cow added to the operation) of the variable resource begins to decline. Because of the costs of handling animal waste responsibly, the point at which this decline occurs is closely related to the ability of the land on which the dairy CAFO is located, and the land over which the CAFO will apply its waste effluent, to absorb and recycle the manure. If diminishing returns to a dairy CAFO did not exist, all the dairy cows in the world could be raised on a single, small plot of land. This is clearly the becoming the philosophy of some in the dairy industry who recognize no limits to dairy herd growth. Such a view completely disregards the costs associated with diminishing returns from dairy waste and concentrated living.

To overcome these costs, dairy CAFOs have been designed to take full, economic advantage of the assumptions about the nature of modern agriculture were listed in the previous section—assumptions that not only form the basis for dairy CAFO permitting and regulating but also establish the tax and subsidy policies that create the economic environment in which dairy CAFOs operate. These assumptions allow important costs of dairy CAFO operations to be either omitted or understated in the profit and loss calculations of the dairy. They also allow a dairy CAFO to take advantage of important tax and investment opportunities that, in effect, subsidize its operation. All these factors artificially inflate the amount of profit available from dairy CAFO operations and generate short term gains for developers and investors. While this would be significant in itself, artificially inflated profits also act to draw more investment into dairy CAFO operations, contribute to the proliferation of dairy CAFOs, and provide an economic incentive for an organizational model that gives rise to the four common attributes of every dairy CAFO:

(1) The use of capital intensive production methods. Dairy CAFOs use less labor and more machinery to achieve production output.

(2) Employment of a production methodology that maximizes the tax benefits of the corporation.

(3) The use of vertically integrated operations where separate divisions of the same company or co-op produce the different stages of a product and market their output to one another.

(4) The use of cost shifting to reduce the costs of production. Cost shifting occurs when the costs of health problems, traffic, social problems and pollution (odors, chemical and particulate air pollution; chemical, pathogen, and particulate water pollution) are transferred to the residents of a region and are neither paid by the company responsible for the costs nor included in the price of the products they market.

In summary, arguments about the efficient size of dairy operations assume that the purpose of the organization and hence, the output of its operations, are both known and clearly specified; i.e., the purpose of a dairy CAFO may be assumed to be milk production. Further, these arguments also assume that the dairy CAFO and the smaller, more conventional dairy to which the CAFO is compared both have the same fundamental production objectives. However, as the above-listed attributes demonstrate, it is not clear that milk production is the primary objective of a typical dairy CAFO. Indeed, because a typical CAFO is designed to

1. maximize tax benefits in both industrial and agricultural categories, and
2. maximize subsidies for both industrial and agricultural operations, and
3. shift as many costs as possible to the local region while
4. producing an agricultural commodity--milk,

it is not clear what weight if any, one should give to efficient sizes for milk production when discussing a dairy CAFO operation. Any discussion of efficiency is further complicated by the fact that the price of milk is likely to be set either by law or by large compacts and organizations instead of being set by the need to directly compete with other producers of milk.

Specific Research On Dairy Efficiency

The Economic Environment in which the Dairy Industry Operates

The recently implemented federal order reform has made milk pricing more transparent and competitive. Higher quality producers now receive higher milk prices than lower quality suppliers. Further, milk prices are now dependent on component values, which are linked to dairy commodity prices for cheese, butter, nonfat dry milk and whey and pricing information is available on the internet. This links component prices and the amounts producers see in their milk checks and mean that no one is isolated from market forces. The 50-100 cow family dairy farm must now compete directly with large-scale dairy operations. [11]

Milk processors have undergone significant consolidation, and some dairy cooperatives have changed from regional cooperatives into national cooperatives. Consolidation has also accelerated at the farm level as large-scale, western dairy operations have expanded first in Idaho, New Mexico and California and then Nebraska, Kansas and Indiana. These dairies are expanding further and using their marketing power to extract premiums for high-quality milk. [12]

Meanwhile, cow numbers on farms continue to increase in response to high milk prices and low feed costs. Monthly milk production per cow increased in 2000 while demand for milk and dairy products hwas stable. Growth in milk supply in the face of stable demand depressed milk prices and should result in a future decline in cow numbers. Beyond the number of cows, three other factors predict future milk prices: health of the U.S. economy, feed prices and summer weather. All these factors make it likely that the dairy expansion will slow and that cow numbers will continue to decline. [13]

Dairy Industry Consolidation

Since 1990, the US dairy industry has become increasingly consolidated—both in terms of the number of dairy farms and in terms of the states in which significant growth of dairies has occurred. [14] Table I-2 shows how dairy farm concentration has changed in new and old dairy production states.

Table I-2. Shifts in percent of US milk production--percent of US market share

	1998	**1993**	**1991**	**1987**	**1984**	**1973**	**1960**
California	17.5	15.2	14.5	12.5	11.3	8.7	6.6
Wisconsin	14.5	15.2	16.2	17.4	17.4	16.3	14.4
New York	7.5	7.6	7.5	8.0	8.4	8.5	8.4
Pennsylvania	6.9	6.8	6.8	7.1	7.0	5.8	5.6
Minnesota	5.9	6.4	6.6	7.3	7.6	8.0	8.3
Idaho	3.7	2.1	2.0	1.7	1.6	1.4	1.3
Texas	3.6	3.9	3.6	3.0	2.8	2.8	2.4
Michigan	3.4	3.6	3.5	3.7	3.9	4.1	4.2
Washington	3.4	3.3	3.0	2.6	2.6	2.0	1.7
New Mexico	2.8	1.8	1.3	.7	.7 .	3	--
Ohio	2.8	3.1	3.2	3.4	3.4	3.8	4.2
Iowa	2.4	2.7	2.8	2.5	2.8	3.5	4.8
Arizona	1.7	1.2	1.2	1.0	.9	.6	--
Vermont	1.7	1.7	1.6	1.7	1.6	1.7	1.6
Florida	1.5	1.7	1.7	1.6	1.4	1.6	1.1
Missouri	1.5	1.9	1.9	2.0	2.0	2.6	3.0
Indiana	1.4	1.5	1.5	1.6	1.7	2.0	--
Illinois	1.3	1.7	1.9	1.9	1.9	2.4	3.4
Virginia	1.2	1.3	1.4	2.6	1.5	1.5	1.6
Colorado	1.1	1.0	.9	.8	.7	.7	--
Kentucky	1.1	1.4	1.5	1.6	1.6	2.1	2.6
Kansas	1.0	0.7	0.8	0.9	0.9	1.3	1.5
Oregon	1.0	1.1	1.1	1.0	1.0	.9	--

Sources: USDA Economic Research Service, Dairy Situation, March 1985-92. USDA Agricultural Marketing Service, Dairy Market News, Vol. 55, Rep. 10, 1988. USDA Economic Research Service, Dairy Outlook, February 23, 1988. Adapted from: USDA, NASS, http://usda.mannlib.cornell.edu/re…ssr/dairy/pmp-bb/1999/mkpr0299.txt

The greatest gains in market share have come in the Western states of California, Washington, Arizona, New Mexico, and Idaho. California has increased its market share by a factor of more than 2.5 since 1960 and is still growing. Pennsylvania, Michigan, and Vermont are the exceptions in the Northeast and Midwestern regions in that they have tended to hold their market share. States losing market share have been in the more traditional dairy areas-Wisconsin, Minnesota, Iowa, Illinois, Ohio, New York, Missouri, and Kentucky. Traditional dairy production areas tend to have smaller herd sizes and more diversified operations that grow a major portion of the feed supply that is marketed as milk.[15] Table I-3 shows how dairy herd size is linked to states and regions.

Table I-3.
Herd size profile percent inventory by size groups for selected states – 1998

	1-29	**30-49**	**50-99**	**100-199**	**200-499**	**500+**
			Percent of total cows			
California	--	--	--	3	18	78
Wisconsin	5	21	43	18	10	3
New York	3	11	34	26	15	12
Pennsylvania	5	25	37	22	10	2
Minnesota	6	22	40	16	12	4
Michigan	5	11	25	32	18	10
Idaho	1	2	6	12	19	61
Washington	--	1	4	16	32	47
New Mexico	--	--	--	1	3	96

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. D/E-24.

Consolidation has occurred at the same time that productivity per cow has undergone dramatic increases. Productivity per cow increased three fold between 1945 and 1998, producing 17192 lbs. milk per cow annually nationally in 1998. Washington ranks number one in productivity at 21,476 lbs. milk per cow annually.[16]

Profits and Efficiency

The most important indicator of dairy farm profits is the cost of waste handling. A Minnesota study found that the cost of compliance with certain EPA regulations affects moderate size dairies more adversely than large size dairies. Large scale dairies can more easily amortize the extra capital investment costs involved with EPA compliance. This suggests that moderate size dairies faced with needing to make investments to meet the EPA standards may choose to expand the scope of their operations, if financially able. [17]

A 1994, University of Minnesota study explored three alternative dairy production systems:

Purchasing all feed.
Purchasing grain and raising the additional forage.
Raising all forages and grains to feed the herd.

This analysis was based on a new start-up dairy with the land and field machinery investment determined by the cropping plan. The systems were analyzed over a range of herd sizes from 138 to 828 cows. The dairy facilities, parlor, manure system, feed storage and housing were designed to meet herd sizes. Summary results of this study are shown in Table I-4.[18]

Table I-4. Economic performance comparison of three dairy farming systems.

	Herd size (stalls/cows)					
	100/138	**200/276**	**300/414**	**400/552**	**500/690**	**600/828**
Total assets, $/cow						
Purchase all	3,361	3,152	2,997	2,883	2,845	2,859
Raise forages only	5,393	4,831	4,590	4,447	4,402	4,410
Raise forages & grains	6,594	5,863	5,603	5,391	5,334	5,300
Return on assets, %						
Purchase all	2.5	9.9	12.8	15.6	16.8	17.5
Raise forages only	5.8	11.5	14.2	16.1	16.8	17.2
Raise forages & grains	4.7	10.0	12.4	14.3	15.2	15.5

Source: University of Minnesota, 1994.

This study of a new, start-up dairies suggests some key points:

The dairy industry is capital intensive and there are substantial capital efficiencies gained up to 300 to 400 cows for all three systems. Gains are still realized beyond 400 cows but at a much slower pace. Capital efficiencies are largely due to dilution of two large fixed cost items: the milking center and waste management systems because these costs are not increased greatly by increasing cow numbers. [19]

However, these two costs can have very different impacts on both efficiency and profit calculations. Because the design and cost of milking centers are strictly determined by health regulations, and because much of the nation's milk supply is handled as interstate commerce, a fairly uniform national input determines costs. As a result, there is little a dairy can do to avoid or reduce costs in this category. On the other hand, waste management is generally regulated by county or state rules, and national regulations only come into play when significant pollution of federal waterways or some similar activity occurs. Thus, waste management is an area where significant, profit-increasing shortcuts can be taken, and if such shortcuts are not allowed in a specific state, the absence of federal regulation allows a potential dairy farmer to shop for a state where regulations are loose and enforcement is lax.

If the dairy is a new, start-up operation, cropping machinery and the land base required to feed the herd may add to the capital requirements. Capital investment requirements are reduced by 15 to 20% for the option of raising forages and buying grains compared to raising all the forages and grains. The capital investment is further reduced by 40-45% for purchasing all feed. [20] However, if the dairy is an existing operation where the land and machinery is already owned by the farmer, costs can be reduced considerably by using forage grown on the farm. A comparison of eight grazing dairy herds with eight confined dairy herds in Wisconsin showed that grazing farmers saved an average of $24 per cow in out-of-pocket costs, and had a cash return of $.46 more per hundred weight of milk.[21] Further, Pennsylvania State University studies show that grazing can save a total of $150 per cow annually over conventional confinement dairies, with most of these savings coming in feed costs, labor costs, improved animal health, and reduced culling.[22]

Another recent study conducted at the University of Minnesota North Central Research and Outreach Center compared confinement and intensive rotational grazing for lactating dairy cows over two years. They found that cows in confinement produced 5 to 8% more milk than the grazing cows, but total production costs were reduced by 30% for grazing cows. While milk production was very sensitive to pasture quality changes, net return to grazing averaged $64.05/cow over confinement in 1991 and $88.66/cow over confinement in 1992. [23]

The concept of net return/cow or per acre rather than milk production should be the key emphasis of all dairy farms. Managed seasonal grazing allows design of calving patterns to take full advantage of available pasture, the number of cows milking during the winter months is either reduced to a minimum or completely stopped, winter feed storage needs are reduced, and more quality time is provided for the farm family. In addition, the refinement of pasture systems for replacement heifers allows for further reduction in overhead costs to the dairy herd and more optimal heifer growth to first calving. [24]

Literature on dairy herd size and efficiency:

There is no support in the agricultural economics literature for large increases in efficiency as the size of dairy herds grows beyond 200-300. And there is no support for any claims of efficiency for dairy sizes of the kind found in the new, large dairy CAFOs where thousands of animals swamp the land's ability to naturally process the waste. In fact, all of the research conducted thus far on efficiency has been done on herd sizes that are so small that the waste generated by the herd should be easily manageable on a dairy farm of normal size. For example:

In 1999 Richards and Jeffrey found that the average Alberta dairy is highly efficient compared to the best farmers in the industry. Neither investment in human capital or feed quality were important in determining dairy efficiency. The maximum efficient herd size was about 70 cows.[25]

In 1989, Kumbhakar, Biswas, and Bailey found that for dairies of up to 160 cows some economies of size may exist. Large farms (of about 160 cows) are technically more efficient. [26]

Tauer and Belbase working with data on farms of 20 to 275 cows, found that while more cows made a dairy more efficient, they could only explain less than 10 percent of what contributed to successful dairy operations.[27]

In 1996, Ahmad and Bravo-Ureta studied 96 Vermont dairy farms with between 20 and 220 cows. They showed a significant negative relationship between herd size and technical efficiency; i.e., as herd size increased, efficiency decreased.. This finding was consistent with prior work by Bravo-Ureta (1986) and Byrnes et al. (1987) but conflicted with the results of Kumbhakar et al. above.[28]

In 1989, Bailey et al., looked at Ecuadorian dairy farms of from 11 to 130 cows. They found that efficiency increased with farm size, but that capital was a more important factor in efficiency increases.[29]

In 1990, Weersink, Turvey, and Godah found that for dairy farms in Ontario with herd sizes of 15 to greater than 50, efficiency slightly increased with herd size but farms of any size could be efficient.[30]

In 1986, Bravo-Ureta found statistically significant evidence that there was no relationships between dairy farm size and technical efficiency. [31]

Bravo-Ureta and Rieger, in a 1990 study, found that for dairy farms in New York and New England there was a weak relationship between dairy farm size and efficiency.[32]

Tauer found in 1993 that farms with an average of 108 cows were subject to some increasing returns to scale although milking stanchions were not more efficient than stalls and multiple daily milking was also not more efficient.[33]

In sum, the literature shows that there may be some small increases in efficiency when dairy farms expand from twenty to 250. This is logical since herd sizes in this range are small enough that conventional dairies would already have enough land to recycle the dairy waste from the increased herd size. However, when dairy herds grow to the size of those at the large dairy CAFOs, diminishing returns occur as the costs of responsible waste management rises. For example, when 1996 Minnesota Farm Business Management records were summarized by high and low profit groups within 6 herd size classes, results suggest production cost per 100 pounds of milk to be similar for the high profit farms within all size categories except the very smallest herd size group. The margin of difference between the low and high profit herd within the size groups diminished as herd sizes increased and the cost structure appears to change with different size herds.[34]

Profitability in the Dairy Industry

As the previous section shows, dairy size is not inherently indicative of efficiency. Neither is it a good indicator or profitability. USDA researchers compared differences in the traditional milk producing states (MN, MI, WI, NY, VT, PA, NY, VT) with non-traditional milk producing states (FL, CA, WA, TX, AZ). They found significant differences in the resource base, and the structure of profitability and management practices between the traditional (68 cows) and non-traditional (370 cows) dairies. The factor found contributing most to net farm income regardless of location was size of the operation, but size was irrelevant in explaining per unit returns from dairy. In other words, size causes increases in milk production and income, but on a per-cow basis it has no effect on profit levels.

High productivity and low debt to asset ratios were strongly related to profitability. The importance of management ability to the profitability of the farm business is also noted in a five-state survey of the northeastern and north central region of the U.S. and Canada which found that well-managed farms are able to compete in per-unit profitability with farms many times larger. This is consistent with overall conclusion by Hallam of an "L"-shaped cost curve which becomes flat at fairly low farm sizes—indicating that only expansions in size from the smallest dairies contributes to per unit profit and to efficiency.

El-Osta found that the factors contributing to higher levels of profitability in traditional dairies were low investment costs in land and equipment (which is likely to be the case in older dairies that already own their land and equipment), control of purchased feed cost, age of the operator, use of automatic takeoffs and artificial insemination, and level of adoption of capital- and management-intensive technologies (record keeping combined with parlors).

Factors in non-traditional dairies that also contribute to profitability included lower per cow expenditure for forage production, purchased feed, hired labor, and per cow investment. Per unit returns for dairies with advanced, capital intensive milking parlors rather than traditional parlors were lower—showing that investment in this kind of technology did not pay off. The study shows that the incentives for non-traditional dairies to continue expansion come from production and marketing economies, management expertise, tax incentives, specialization, labor saving equipment, timeliness of getting things done, non-farm investment, and farm consolidation.[35] Note that increased efficiency and increased per-unit profit are not among these incentives.

III. The Economic Effect of Dairy CAFO Production On Regional Economies

What the literature says about the economic effect of dairies

In 1999 the University of Minnesota Extension Service published a descriptive report that traces the linkages between dairy farms, dairy processors, and other sectors in the state's economy. It found that the 22,037 persons employed on dairy farms and processing plants support another 22,222 persons in support industries and another 9,437 in consumer sectors. In total, the dairy industry supports 53,696 jobs in the Minnesota economy. The value-added income earned by dairy producers and processors was $1.02 billion and supported another $1.39 billion in support and consumer industries.[36] Thus, both the employment and income multipliers were about 2.4.

While this study demonstrates the importance of the existing dairy industry, it cannot be used to estimate the impact of expansion or contraction of the size of the dairy industry. Estimates of the impacts of expansions or contractions in the dairy industry would need to examine potential offsetting effects in other industries—in other words, if the workers who were laid off in the dairy industry were quickly hired elsewhere, there would be little economic effect. Thus to examine the net effects would require explicit definition of the offsetting effects in other sectors.[37]

Two other regional economic impact studies for North Dakota and Idaho have also been completed. A 1993 study examined the impacts on North Dakota of twenty new 500-cow herds to the state's economy. Using regional input-output analysis, this study estimated a total value-added income increase of $18 million or about $900,000 per 500-cow herd. The study also claimed that an estimated 580 full-time secondary jobs would be created, as well as 140 direct jobs. These estimates are valid only if the following two assumptions are true:

> First, new jobs must go to in-migrants or to new entrants to the labor force. If the new jobs go to existing workers who are commuting to jobs outside the region then the new income to the region would be lower than estimated.
>
> Second, if the jobs go to workers who already work within the region and in-migrants do not come in to take their jobs, this development could drive up wages in the region. Then the number of total jobs would not increase as rapidly as shown in the estimate.[38]

Another 1993 study that examined the impacts of dairy production in Idaho showed that Idaho had 24 percent more dairy cows in 1991 than in 1970. Using an Idaho regional input-output model, the authors estimate that milk production and processing accounted for 6 percent of the state's gross income in 1989, measured in value-added terms. However, due to differences in the local economic structure the multiplier effects varied considerably from region to region and this must be regarded as only a descriptive study that has no implications about the potential impacts of changes in the size of dairy herds.[39]

All of these studies addressed the general importance of the dairy industry. Yet, none of them satisfactorily addressed the net changes in a region's economy due to changes in the dairy industry. The North Dakota study probably comes the closest to doing this but both the estimates and the offsetting effects would need to be localized to guide zoning policies. Since the nature of the impacts depends on the structure of the local economy, both the size and the distribution of the impacts will vary with the region being studied. This was demonstrated in the Idaho study that reported differing multipliers for the same processing sectors in different regions. In areas of very high unemployment and little rural residential development there will be minor off-setting effects. However, if labor markets are tight and the land is likely to be used for high valued residential developments, the offsetting effects will be high [40] And finally, none of these studies specifically addressed the regional impact of the purchasing practices, hiring practices, and externalities (the costs of odor, water pollution, etc. that shifted to the residents around the dairy) associated with large dairy CAFOs.

How large Dairy CAFOs are Likely to Affect the Regional Economy

There is a significant difference between economic growth and economic development. Economic growth concentrates on short-term changes in jobs or prices while economic development has the objective of creating a diversified economy that is capable of providing jobs, economic stability and economic growth for the citizens of a region over the long term. As a result, most communities have begun to focus on economic development and in regions where agriculture has been the mainstay of the economy and most rural regions are now trying to diversify to avoid the economic problems that have characterized the agriculture industry over the last twenty years.

Large dairy CAFOs with concentrated masses of animals neither diversify a rural regional economy nor improve the long term economic health of a region. Instead, the few likely economic benefits come as short term gains to developers and investors and do not contribute to the long-term economic development of the region. In addition, the economic characteristics of large dairy CAFOs are fundamentally incompatible with regional economic development. Regional economic development proceeds on the premise that the wages paid and purchases made by a company are transferred to other individuals or companies in the region. The multiplier effect of these payments further assumes that they are again spent within the confines of the region, that they do not "leak" into other areas of the state or nation, and that they are not offset by other economic activity in the region. However dairy CAFOs are structured so that they cannot aid regional economic development for the following reasons:

(1) Constraints on Regional Economic Development Due To Employment

As a capital intensive company, a dairy CAFO is designed to minimize the number of workers and hence, minimize the economic impact on the region. For the employment multiplier to operate at the levels specified in the Department of Commerce RIMS II model, all employees must both live and work in the region. Ideally, these employees would buy a hamburger at a local restaurant that buys milk and meat from a local producer, who buys feed from a local farmer, etc., etc. However, given the short commute from most rural regions where dairies are located to larger, urban areas, it is likely that most workers will live well outside the region. If workers live outside the region, the worker's wages are transported out of the region each month and they are spent in the urban economies and the local employment multiplier will be further depressed.

Some dairy jobs may be filled with local people. To the extent that these dairy workers live in the local region a portion of their wages may be spent in the local economy. However, the proximity of shopping in urban areas is again likely to lessen the impact of these expenditures.

Finally, the size of the employment multiplier further depends on the amount of purchases that the proposed dairy itself makes in the region. Research shows that large scale agricultural operations are more likely to purchase their inputs from a great distance away, bypassing local providers in the process.[41] A 1994 study by the University of Minnesota Extension Service found that the percentage of local farm expenditures made by livestock farms fell sharply as size increased. Farms with a gross income of $100,000 made nearly 95% of their expenditures locally while farms with gross incomes in excess of $900,000 spent less than 20% locally.[42]

Confined animal production can occasionally benefit local grain and forage sellers, but only when it consumes all the grain or forage produced in the county. If the county has to export even one bushel of grain or one bale of hay, all the grain and hay in the county will have to be priced at a lower level that will enable the grain to compete in the export market.[43]

(2) Constraints on Regional Economic Development Due To Taxes

Federal, state and local taxes are levied on taxable amounts calculated on federal returns. The numerous tax write-offs that are possible because large dairy CAFOs are sometimes treated as industries and, at other times, treated as farms, significantly decrease the amounts of taxes paid locally. At the same time the operations of the dairy CAFO create significant social, health and traffic costs that the local government must finance. The local government, in turn, must rely on increased taxes to pay these CAFO-induced costs--and this can decrease other economic activity in the region.

For example, additional costs associated with hosting a CAFO include increased health costs, schooling costs, traffic, accidents, and repairs. One Iowa community estimated that its gravel costs alone increased by about 40% (about $20,000 per year) due to truck traffic to hog CAFOs with 45,000 finishing hogs. Annual estimated costs of a 20,000 head feedlot on local roadways were $6447 per mile due to truck traffic.[44] Colorado counties that have experienced increases in livestock operations have also reported increases in the costs of roads, but specific dollar values are not available.[45] In addition, an Iowa study found that while some agricultural land values increased due to an increased demand for "spreadable acreage," total assessed property value, including residential, fell in proximity to CAFO operations.[46]

(3) Constraints on Regional Economic Development Due To Vertical Integration

Vertical integration requires purchases from and sales to other members of the vertically integrated company, not from local producers and suppliers. The same method of doing business holds true for the large dairy cooperatives. Thus, vertically integrated companies and dairy cooperatives stimulate regional economies only to the extent that all elements of the production and processing cycles are located in the region. Historically, this factor has severely limited the economic impact of dairy CAFOs on the regions in which they are situated.

(4) Constraints on Regional Economic Development Due To Cost Shifting

The previous three sections have described the reasons inherent in the structure of diary CAFOs that most of the money from a CAFO will either be directly spent outside the region or it will quickly migrate there. However, through cost shifting the CAFO will leave the costs of its odor, health risks, surface water pollution, ground water pollution and in the long run, its abandoned lagoons and facilities for the region to deal with. This directly effects both long and short run economic development.

Put bluntly, every company has many choices of location and active recruitment is practiced by most regions. Quality of life is a major factor in decisions to locate in a region, and most companies would never consider locating in an area where a CAFO is operating. In addition, CAFOs can adversely impact the value of neighboring property in the region.

For example, in the Saline County, Missouri, study, researchers at the University of Missouri collected data on 99 rural land and non-family real estate transactions of more than one acre. There are

35 CAFOs in Saline County; 32 are primarily swine, two are beef, and one is poultry. 39 of these properties included a house. The researchers found that proximity to a CAFO does have an impact on property values of nearby property if the property has a house on it.. Based on the averages of collected data, loss of land values within 3 miles of a CAFO would be approximately $2.68 million or approximately $112 per acre.[47]

Palmquist et al., in a 1995 study in North Carolina, found that neighboring property values were affected by large hog operations based on two factors: the existing hog density in the area and the distance from the facility. The maximum predicted decrease in real estate value of 7.1 percent occurred for houses within one-half mile of a new facility in a low hog farm density area. A 1997 update of this study found that home values decreased by $.43 for every additional hog in a five mile radius of the house. For example, there was a decrease of 4.75% (about $3000) of the value of residential property within 1/2 mile of a 2,400 head finishing operation where the mean housing price was $60,800. [48] A 1996 study by Padgett and Johnson found much larger decreases in home value than those forecast by Palmquist. In Iowa, CAFOs decreased the value of homes in a half-mile radius by 40%, within 1 mile by 30%, 1.5 miles by 20% and 2 miles by 10%.[49]

Conclusions

A large dairy cannot diversify a rural regional economy already dependent on agriculture. Instead, it damages the ability of the region to attract diversified economic growth and it is likely to cause property values around the dairy site to decrease. In the long run, the legacy of air and ground water pollution that often accompanies large dairies hinders long-term economic development and makes the region a magnate for other dirty operations who are looking for contaminated, brown field sites that can be used for further contaminating operations.

When rural regions are faced with the prospect of such operations they should evaluate the proposed land use based on the following questions:

1. Does the proposed use make sense in light of budgetary, political, environmental and health considerations given the likely health and environmental effects of the proposed dairy?
2. Does the proposed use make sense in terms of the region's ability to host such a facility given likely groundwater supply and contamination issues?
3. Have all costs and all benefits been fairly considered? In particular, have the potential health costs of air and water pollution, the costs of site remediation, and the potential costs of waste treatment all been considered?
4. What are the short run and long run economic impacts? In the short run, construction employment usually goes to outside sources in most rural communities. In the long run, there will be an increase in some jobs, but where will the workers live, what will the level of pay be, where will the money be spent, and which jobs will not come to the region because of the proposed dairy?
5. Who benefits from this land use? Who does not benefit? Is there any vehicle in place to reimburse residents whose quality of life or health is degraded by the proposed facility?
6. Does the proposed land use create an environment that helps the region maintain a stable, diversified economic base?

IV. Factors that Shift the Costs of Large Dairy CAFOs To Local Residents

Ground Water Pollution

Large, concentrated animal operations such as diaries require massive amounts of water. This can result in substantial draw downs of aquifers in areas where aquifer content is limited and declining. And this shifts the real cost of the dairy's water to other water users in the area by increasing pumping and well drilling/deepening costs. About 5 to 10 gallons of fresh water per day for each cow milked are used in a milking center where flushing of wastes is not practiced. However, where manure flush cleaning and automatic cow washing are used, water use can be 150 gal/d/cow or more.[50]

Aside from high water usage, the main water-related environmental problem from dairy production is the same as that from other livestock operations: animal waste discharge into waterways or aquifers. Runoff from dairy operations flows from pastures and, in more concentrated form, from barns and manure piles. These discharges overload natural waterways with nitrogen and phosphorous compounds, collectively termed nutrients. Excess nutrient loads encourage algae growth, reduce dissolved oxygen, and impair the habitat for fish and other species. In some areas, the percolation of dissolved minerals into groundwater contributes to the salinity of water supplies.[51]

In addition, nitrogen and other contaminants can flow into underlying aquifers, making the water unusable for drinking--even for animals. For example, in California's Central Valley, dairy farmers discovered their cows were aborting calves after drinking water from wells contaminated with nitrates--nitrates that leeched into the groundwater from the manure of other dairy cattle. When wells are contaminated with nitrates, human health problems can also result. For example, the LaGrange County Health Department in Indiana identified six miscarriages among women whose wells had been contaminated by nitrates. High concentrations of nitrates cause 'blue baby syndrome'--a disease that damages the red blood cell's ability to carry oxygen.[52]

In addition to these problems, the runoff from cattle manure also carries pathogens that can cause disease and death. For example, the recent case at a New York fair where E. coli 0157:H7 killed an elderly man and a three-year-old girl, and sickened more than 600 others, was blamed on well water that may have been contaminated by nearby dairy cow barns. [53]

A more common pathogen in dairy manure is cryptosporidium. In 1993 an outbreak of cryptosporidium in the Milwaukee, Wisconsin drinking water system made 400,000 people sick and led to the deaths of more than 100 people. The suspected cause of this outbreak was runoff from dairy cattle manure.[54] It is interesting to note that at the time of this outbreak, a 500-cow dairy herd was considered to be a large farm and a 1400-cow dairy operation was only proposed in Wisconsin 1998.[55]

Air Pollution from Odor and Emissions

(1) Gaseous Emissions

Open manure storage facilities can be a very significant source of on-farm odors and volatile gases. They are the most apparent odor source, especially if there are no visual barriers from neighbors or passersby. One method to reduce odors and gaseous emissions from open manure storage units is to place some type of cover on the surface. Further, reasonably low emissions may come from dairy manure storage basins that have a natural crust.[56] However, lagoon covers of any type do nothing to stop gasses and odors generated in barns and confinement buildings, and these are the source of about 60% of all odors from Concentrated Animal Feeding Operations.

(a) Hydrogen Sulfide

The Minnesota study reported that an investigation of air quality in six Alberta commercial free-stall dairy barns concluded that the concentrations of hydrogen sulfide (H_2S) were low (the maximum recorded value was 145 ppb), and the possibility of detecting more than trace concentration of H_2S was remote where manure was removed from free-stall dairy units with solid passageways. However, significant quantities of hydrogen sulfide can be released during agitation of stored liquid manure. Research has documented peak hydrogen sulfide concentrations near the floor of dairy barns during agitation at 70 ppm.[57]

(b) Ammonia

Studies of the air quality in six Alberta commercial free-stall dairy barns also found concentrations of ammonia (NH_3) present in all six barns and the overall mean values ranged from 7 to 20 ppm. The overall mean NH_3 production rates ranged from 1.7 to 4.4 L/[hour-cow (500 kg cow)].[58] Table I-5 relates ammonia generation to the method of housing dairy cows.

Table I-5. Influence of housing type on dairy ammonia emissions

Type	Management	Ammonia	Units
Dairy	Freestall	7-13	g/LU/day
	litter	260-890	mg/500 kg/hr
	cubicles	843-1769	mg/500 kg/hr

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. H-39.

(c) Methane

Methane emissions are both a global and a local problem. They are a significant cause of global warming and they result any time manure is stored and begins to decompose. As a result, methane generation is dependant on the storage method selected and the ambient temperature at the storage location. Tables I-6 and I-7 demonstrate that three times more methane is generated by dairy cows than by any other farm animal type. Further, the use of liquid slurry or solid manure management both result in much higher methane emissions than pasture/feedlot operations.

Table I-6. Estimated methane emissions from livestock and poultry waste

Animal Type	Methane Emissions (kg/year per animal)
Cattle in feedlots	23
Dairy	70
Swine	20
Caged Layer	0.3
Broiler	0.09
Turkey and ducks	0.16

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. H-41.

Table I-7. Measured methane emission factors (MCF) for dairy cows

System Type	MCF estimates	MCF measured at 20°C
Pasture/Feedlot	10	0.3
Liquid slurry	20-90	55.3
Solid	10	45.7

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. H-41.

(2) Odors

There is evidence that odors from concentrated animal facilities can produce real illnesses in affected populations adjacent to these facilities. A report by the State Health Director of North Carolina notes that exposure to environmental odors results in physiological stresses that may result in a variety of symptoms including headache, nausea, loss of appetite, and emotional disturbance. Odors may exacerbate stress-related illnesses. The symptoms may result from odor annoyance, stress associated with odor exposure, and conditioned responses to odors. The literature also reports that exposure to odors may exacerbate asthma symptoms.[59] The following excerpts of articles address human response to environmental odors:

N. P. Shukia (1991) "In the case of humans, the immediate physiological stresses produced by odors can cause loss of appetite and food rejection, low water consumption, poor respiration, nausea, and even vomiting, and mental perturbations. In extreme cases, offensive odors can lead to deterioration of personal and community well-being, interfere with human relations, deter population growth and lower its socio-economic status."[60]

Dennis Shusterman (1992) "Environmental odor pollution problems generate a significant fraction of the publicly-initiated complaints received by air pollution control districts. Such complaints can trigger a variety of enforcement activities under existing state and local statutes. However, because of the transient timing of exposures, odor sources often elude successful abatement. Furthermore, because of the predominantly subjective nature of associated health complaints, air pollution control authorities may predicate their enforcement activities upon a judgment of the public health impact of the odor source. Noxious environmental odors may trigger symptoms by a variety of physiologic mechanisms, including exacerbation of underlying medical conditions, innate odor aversions, aversive conditioning phenomena, stress-induced illness, and possible phenomenal reactions."[61]

Shim and Williams (1986) "Many patients complain that some odors worsen their asthma. Perfume and cologne are two of the most frequently mentioned offenders. A survey of 60 asthmatic patients revealed a history of respiratory symptoms in 57 on exposure to one or more common odors. Odors are an important cause of worsening of asthma. From a practical standpoint, sensitive asthmatic patients should be advised to eliminate odors from their environment as much as possible."[62]

Susan Knasko (1993) "The effects of intermittent bursts of pleasant, unpleasant, and no experimental odor on human task performance, mood, and perceived health were tested in this study. Odors did not influence any of these measures; however, subjects who had been exposed to the malodors reported retrospectively that they thought the odors had a negative effect on all of these factors."[63]

Pierre Caralini (1994) "With regard to general health complaints, it was found that when exposed to odorant concentrations, some people are annoyed and of these people, only some report general health complaints. Exposure in itself does not directly cause general health complaints. Annoyance is the intervening variable between exposure and general health complaints. A possible explanation for the relation between annoyance by malodor and general health complaints might be found in the personality and attitudes of the exposed individual. Finally, we found confirmation for the appraisal hypothesis, i.e., the extent to which individuals regard malodor as threatening is positively related to odor annoyance."[64]

Shusterman, et. al. (1991) "Retrospective symptom prevalence data, collected from over 2000 adult respondents living near three different hazardous waste sites, were analyzed with respect to both self-reported 'environmental worry' and frequency of perceiving environmental ("particularly petrochemical) odors. Significant positive relationships were observed between the prevalence of several symptoms (headache, nausea, eye, and throat irritation) and both frequency of odor perception and degree of worry. Headaches for example, showed a prevalence odds ratio of 5.0 comparing respondents who reported noticing no such odors and 10.8 comparing those who described themselves as 'very worried' versus 'not worried' about environmental conditions in their neighborhood."[65]

Health-Related Problems

(1) Respiratory disorders

Clinical and epidemiological studies of confinement farmers in the dairy, swine, and poultry industries have shown an excess of acute and chronic respiratory disorders among workers exposed to high dust levels and various toxic gases. Acute health effects are particularly common. These are manifested mainly by symptoms of respiratory irritation (cough, phlegm production, and frequent wheezing), upper respiratory and eye irritation, acute decreases in lung function during the work period, and increased rates of upper and lower respiratory infections (Donham et al., 1984b, 1988, 1989; Dosman et al., 1988; Holness et al., 1987; Iversen et al., 1989; Iversen and Pederson, 1990; Iversen and Takai, 1990; Reynolds et al., 1994; Terho, 1990; Vohlonen et al., 1987; Wilhelmson et al., 1989). The rates of allergic disorders (asthma, rhinitis) are increased also among farmers in animal and poultry confinement facilities (Amishima et al., 1995; Donham et al., 1984b; Iversen et al., 1989; Noorhassim et al., 1995; Prior et al., 1996; van Hage-Hamsten et al., 1985; Vogelzang et al., 1997; Wilhelmson et al.,1989). [66]

(2) Other diseases

Incidents of human disease attributable to contact with livestock waste have been reported. Stanley et al. (1998) isolated Campylobacter jejuni from groundwater in the Arnside area of Cambria. Some of the strains isolated were of the same biotype as the ones from a dairy farm situated within the hydrological catchment of the polluted spring indicating that the groundwater was a vehicle for bacterial transmission. In a longitudinal study of four dairy farms, it was suggested that E. coli O157:H7 was disseminated from a common source on these farms and that this strain could persist in the herd for up to 2 years (Shere et al., 1998).[67]

Large numbers of viruses are excreted in infected animal feces. In fact, enteroviruses have been found in all animal species that have been extensively studied. These animal viruses can gain entrance to streams, lakes and other bodies of water via land application of animal wastes or by direct contamination from pastures and feedlots. Constant fecal contamination of open water in pastures and washings of pens, closed lots and dairy operations are important in this respect. (Malherbe et al., 1967).[68]

(a) Campylobacter

Berndtson et al. (1996) isolated Campylobacter from flies netted in anterooms of barns containing positive broiler flocks in Sweden. Urban and Broce (1998) isolated Salmonella and three other kinds of bacteria from 43% of house flies and blow flies netted around dog kennels in Kansas, where meat from a neighboring rendering plant was the main food for the dogs. And recently, Iwasa et al. (1999) isolated the enterotoxic E. coli O157:H7 from 1.6% of house flies netted directly from cattle manure piles at 1 of 4 dairy farms in Hokkaido, Japan. Collectively, these studies demonstrate that varying percentages of flies netted around animals and their manures can harbor isolatable loads of potentially pathogenic bacteria.[69]

A wide variety of wild and domestic animals also serve as reservoirs of Campylobacter that normally colonize their gastrointestinal tract (Angulo, 1997). The foods that have been implicated in outbreaks are milk, poultry and red meat (Varnam and Evans, 1991). A relatively large number of outbreaks are water-borne, because this pathogen has the ability to survive in water in an infectious state (Nachamkin, 1997). From a subset of the NAHMS 1996 national dairy study herds tested using a PCR test, 100% of herds tested had positive cows with an individual milk cow prevalence of 43%. [70]

(b) Salmonella

A variety of animal species are reservoirs of infection, including cattle, swine, and poultry. Information from the NAHMS 1996 national dairy study indicates at least 28% of dairy operations have milk cows shedding Salmonella at any point in time (Wells et al., 1998). There is also evidence of clustering of Salmonella on certain dairy operations. [71]

In Germany, Salmonella was detected in 50% and 36% of samples of biowaste and fresh compost, respectively. The seepage water from these sources was found out to be a reservoir of Salmonella; Salmonella enteritidis survived in seepage water for 42 days at 5 $_{0}$C (Knop et al., 1996). In lake water, Campylobacter jejuni survived longer than C. coli both at 4 $_{0}$C and 20 $_{0}$C (Korhonen et al., 1991). Salmonella were found in the environment of a dairy two years after the occurrence of a clinical outbreak of salmonellosis. Samples of recycled flush water were positive for Salmonella indicating that hardy organisms can become established in the environment of modern free-stall dairies that use recycled water in their manure flush systems (Gay and Hunsaker, 1993). [72]

(c) E. coli

Cattle are considered the primary reservoir of human infection from E. coli O157, though other species including dogs, horses, flies, and birds have cultured positive (Hancock et al., 1998). From the NAHMS 1996 national dairy study, 24% of dairy herds had at least one culture-positive milk cow, with a milk cow prevalence of about 1% (Wells et al., 1998). These estimates are consistent with those from the NAHMS 1995 national feedlot study (63% of feedlots, with higher sampling per feedlot, and 1% of fecal samples). Typical duration of shedding is short. [73]

The source of transmission for a large number of E. coli outbreaks has been confirmed to be cattle asymptomatically infected with E. coli O157:H7 (Rajkowski, et al. 1998). The contamination has been clearly identified to occur at the milking parlor in outbreaks associated with dairy products (Morgan, 1993). Direct transmission from cattle to humans has also been documented (Armstrong et al., 1996). [74] Because cattle are a natural reservoir of E. coli O157:H7, more than 30 surveys have been conducted in the U. S., U.K and Europe to determine the prevalence of this pathogen in feces of bovine populations. Herd prevalence between 22% and 100% indicated that E. coli O157:H7 is widespread in both beef and dairy cattle where the prevalence appears to be highly variable within herds (Armstrong et al., 1996; USDA/APHIS, 1997). The median percentage of E. coli positive animals within herds calculated from those studies was 1.7 %, and the range varied from 0 in four cases to 63% in a recent report (Jackson et al., 1998). [75]

(d) Listeria monocytogenes

Very little is known about the ecology of Listeria monocytogenes on dairy operations, though it is considered to be ubiquitous in many environments. Weber found 33% of 138 German cattle shedding in feces (1995). Risk factors among French farms included poor quality of silage (pH > 4.0), inadequate frequency of cleaning the exercise area, poor cow cleanliness, insufficient lighting of milking barns and parlors, and incorrect disinfection of towels between milkings (Sanaa, 1993). [76] Listeria can survive and grow at refrigeration temperatures; milk, cheese and ready-to-eat meats have been implicated in many outbreaks. This is a characteristic that distinguish this bacterium from other foodborne pathogens, even a few contaminant cells can be enough inoculum to reach infectious dose levels (Bell and Kiriakides, 1998). [77]

(e) Mycobacterium paratuberculosis

The NAHMS 1996 national dairy study has estimated at least 22% of dairy herds have at least one Mycobacterium paratuberculosis test-positive cow with a milk cow prevalence of 3.4% (NAHMS, 1997). The prevalence in dairy herds is greater than that found in U.S. beef cow-calf operations. Control of infection is possible, though requires long-term commitment using currently available tests.[78]

(f) Cryptosporidium parvum

Cryptosporidium parvum is important as a water-borne pathogen. Many different species of animals shed C. parvum oocysts, including cattle. Oocyst shedding appears to be clustered in young calves (primarily less than 30 days of age) and efforts to detect shedding of oocysts from cows around the time of calving have failed to date (Atwill et al., 1998). The NAHMS 1991-92 national dairy heifer study estimated at least 90% of dairy operations were positive for C. parvum, with 22% of preweaned dairy heifers shedding oocysts at any one point of time and nearly 50% of calves shedding the pathogen 1-3 weeks of age (NAHMS, 1993). Because of the clustering of fecal shedding in very young calves, environmental control may be feasible, with focus on preventing calf feces from contaminating surface water. [79] There have been 14 documented incidents of cryptosporidium disease outbreaks in U.S. and Canada since 1984 (Frey et al., 1998). Four of these events were linked to nonpoint source agricultural pollution, the others were primarily caused by septic tank and human sewage contamination.[80]

(g) Giardia lamblia

Very little is known about Giardia lamblia on dairy operations in terms of prevalence or control measures but the organism has been isolated in 50% of beef calves (NAHMS, 1993). [81]

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Dairy Waste Lagoon Seepage and Runoff Problems

(1) Lagoon Seepage

Waste lagoons, even with clay liners, allow waste to leach into the ground below the lagoon. In fact, lagoon specifications allow leakage through the clay liners at a rate up to 0.036 inches per day. At the maximum allowable rate, a three acre lagoon could legally leak more than a million gallons a year. A study of self-sealing of earthen liquid manure storage ponds found that a seal usually formed within 12 weeks of construction. Earthen-lined dairy manure storage basins have seepage losses primarily because of freezing, earthworm activity, roots, and pedogenesis. Most of the pollutants are lost to ground water through macropores in the sidewalls and these losses can be significant. For example, a study of seepage from a 600,000 gallon clay-lined earthen manure storage system for a 100 cow dairy operation in central Minnesota found that seepage averaged 5 gal/d from the bottom and 102 gal/d from the sidewall of the lagoon during the first 3 years of operation. The main contaminants leached were sodium and chloride, with very small fractions of nitrogen and phosphorus leached. [82]

Lagoon seepage has been calculated with fairly high precision. Ruhl studied earthen basins with above-grade, earth-walled embankments and compacted clay liners. Monitoring systems were installed below the compacted clay liners both in the sides and the bottom of the basin. Seepage from the basin ranged from 400-2200 gallons per day except during 1 month and three month periods when 3800 to 6200 gallons per day. Seepage flow in area units ranged from .025 to .43 inches/day. Except during the first three months when the basin was filling, seepage flow was greater through the sidewalls than through the bottom of the basin.[83] Ham found that after accounting for evaporation, lagoon seepage could be accurately determined to within +/- .5 mm per day. The lagoons studied ranged in size from .5 to 2.5 ha (1.24 to 6.2 acres), had waste depths that varied between 1.5 and 5.6 m (4.92 to 18.4 feet) and were built with compacted soil/bentonite liners. Average seepage rates were 1.2 mm/day (.05 inch).[84]

Seepage from manure holding basins and lagoons can have a very serious impact on ground water quality, especially from nitrate and ammonium. These impacts are greatest with unlined earthen manure storage systems, and lined pits constructed in coarse textured soils. Seepage losses generally occur when the sidewalls become cracked or develop macropores. Lined basins and lagoons which are properly constructed, engineered, and managed can still be a serious threat to ground water quality when they are constructed in coarse textured soils or karst terrain. Unlined earthen manure storage systems may develop a slowly permeable seal after several weeks of operation, but generally pose a much greater risk for pollution of ground water by seepage than lined storage facilities.[85]

(2) Runoff from Dairy Waste

A 1982 study of fecal bacteria was conducted in surface water from 0.2 acre sandy clay loam plots receiving liquid dairy manure, fertilizer or no fertilizer for six years. Liquid manure was applied at three rates, and was either plowed under after harvest, plowed under in spring prior to seeding, or plowed under with split applications in spring and fall. In one treatment, manure was applied to snow or frozen ground. Fecal bacteria levels in runoff from manure applied in fall or spring at any rate were not significantly different from fecal bacteria counts in fertilized or unfertilized plots, and were from one to two orders of magnitude greater than the primary contact level of 200 CFU/100 mL. Application of manure to snow or frozen ground resulted in significantly greater counts of fecal bacteria in runoff than any other treatment. [86]

A 1996 study developed an accurate method for identifying fecal streptococci from waste matter of dairy cattle and other sources in the presence of five antibiotics. Discriminant analysis of the antibiotic resistance patterns from each source was used to classify the source of fecal streptococci in water samples from two streams draining agricultural areas in Virginia. The source of fecal streptococci in Cooks Creek was 59% beef cattle, 18% dairy cattle, 11% human, 11% wildlife, 1% chickens, and 0% turkeys. In Muddy Creek the sources were 68% beef cattle, 15% wildlife, 8% chicken, 6% dairy cattle, 2% turkeys, and 1% human. Thus, in these two watersheds, over 80% of the fecal streptococci were from domestic livestock.[87]

Fecal coliform from surface applications of dairy manure is rapidly transported to subsurface tile drains in fine sandy loam through macropores if the soil was wet before application or a heavy rainstorm occurred within hours of manure application. Rapid transport has also been observed through soil macropores to tile drains (within roughly an hour after the onset of precipitation) under conditions typical of Iowa and Minnesota.[88] Studies of survival and leaching of fecal coliform and fecal streptococci in a soil receiving dairy manure with spring or fall application and no-tillage or conservation tillage show that manure significantly increases fecal bacteria in leachate (3,000 to 60,000 CFU/100 mL) compared to unmanured soils. Neither tillage nor timing of manure application affected fecal coliform concentrations in leachate. For example, a 1999 study of pathogen losses in subsurface drainage water from dairy manure and urea applied to corn found E. coli in 24% of the tile drain water samples from manured plots, but no E. coli were found in tile drain water from fertilized plots.[89] Table I-8 shows the nutrient concentrations in the runoff from feedlots and pastures.

Table I-8. Nutrient concentration in runoff from a dairy feedlot and manured pasture

Parameter	Dairy Feedlot	Manured Pasture
	——— mg/L———	
Chemical Oxygen Demand	1185	181
Total Kjeldahl Nitrogen	76	13.2
Nitrate-Nitrogen	4.5	8.0
Total Phosphorus	34	7.2

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. G-35.

Dairy Waste Management and Land Application

This category has such large and complicated potential impacts on the surrounding economic and physical environment that it is the subject of the entire following section.

SECTION II

Dairy Cow Manure Handling

Note**:** It is claimed that when a cow is on rBGH (recombinant bovine growth hormone—used to stimulate milk production) their appetite increases dramatically as does their production of milk. Studies show that rBST is effective in raising milk yields by 14% if the cows are injected every two weeks and about 30% of American dairy cows are being injected.[90] However, published figures for waste excretion from dairy cows are usually based on data and information from animals raised without hormones. If the nutrition and production conditions arising from the use of rBGH are not taken into account, any calculation of waste generation may underestimate the amount of waste from cattle using rBGH. And if rBGH use is accounted for, the waste generated by any operation not using rBGH is overestimated. If the cattle do indeed lose weight and bone mass, and if they die earlier, then the chemical composition of the waste of rBGH-fed cattle is also likely to be different as will be the diets fed to these cattle and the water use per rBGH-fed cow.

(1) Dairy waste generation and storage

Dairy operations vary, and each operation presents its own unique problems. Many older dairy operations were not designed with sufficient consideration of waste management. As a result, a properly designed waste management system may require major modifications or alterations of existing facilities.

Dairy animals are typically managed on pastures in partial confinement. While animals are on pasture, their waste should not be a pollution concern if stocking rates are not excessive, grazing is evenly distributed, manure from other sources is not applied, and grazing is not allowed during rainy periods when the soils are saturated. To reduce pollution of streambeds, access to the stream can be restricted to stable stream crossings and access points.[91]

The primary goal of all waste treatment is to eliminate human pathogens. A secondary goal is to reduce the biochemical oxygen demand (BOD--the carbon and nutrient substrate for microbial decomposition) so that the waters that receive waste runoff do not become anaerobic. Finally, some heavy metals must be removed before the waste is discharged. In a sewage treatment plant for human waste, aerobic decomposition kills human pathogens and reduces the BOD while the settling process removes heavy metals to sludge which then must be safely disposed of.

One reason the concept of diminishing returns should be a powerful deterrent to large CAFOs is that the cost of responsibly handling and treating animal waste is so high. Anaerobic decomposition in animal waste lagoons is less effective at eliminating human pathogens and BOD, and it leaves heavy metals in the lagoon. As opposed to assumptions about its natural and thus, harmless, nature, livestock manure creates pollution with a strength that far exceeds raw municipal sewage. As Table II-1 shows, the BOD concentration in undiluted livestock waste is 160 times more powerful than raw municipal sewage and ammonia is 200 times more concentrated. Even after it has been flushed to lagoons, manure effluent is still 57 times more powerful than raw sewage.

Table II-1. Pollution strength of livestock and municipal waste

Type of Waste	BOD5 mg/l	Ammonia, NH_4N mg/l
Undiluted Livestock Waste	40,000	10,000
Manure Lagoon Effluent	14,400	-
Runoff From a Concrete Lot	1,000	-
Runoff From a Dirt Lot	500	-
Raw Municipal Sewage	250	50
Treated Municipal Sewage	30	1.5

Source: Understanding the Pollution Potential of Livestock Waste, Illinois Environmental Protection Agency, 1991.

Exposure of land-applied wastes to sunlight and microbial activity in the soil will generally finish the job of pathogen control, and the nutrients that affect BOD may be used by crop plants. In effect, application to farm land is a final step in the "treatment" of animal waste if the amount of land to which it is applied is sufficient to perform this function.[92] The need to apply animal waste from CAFOs to the land to destroy human pathogens in the waste exists whether or not methane is generated from the waste to create power. This, in turn, requires the construction of lagoons to hold the effluent until it can be applied to the land.

All of this implies that the dairy CAFO has enough land for responsible nutrient application, and it further implies that the number of animals at the dairy has been decided based on the amount of spreadable acreage available--and not vise-versa. It also implies a climate that is mild enough to allow year-round application, or sufficient, leak-free lagoon capacity to see the CAFO through the winter months. In sum, the requirement to spread the waste to kill pathogens creates a significant decision point in the ability of the CAFO to responsibly handle waste.

Securing the amount of spreadable acreage required by a CAFO is usually a daunting task. If the CAFO is located in areas where the climate is unfavorable for waste application for major parts of the year or where the soil is so poor that few crops are grown and little spreading can occur, spreading the waste on the land may simply be impractical. Many CAFOs have realized this and their response has been to simply put the waste in large lagoons until the liquid evaporates. This creates two major problems: first, lagoons leak and lagoon storage does nothing to destroy the pathogens in the waste. And second, the materials in the waste--nitrogen, phosphorus, heavy metals, and salts--are concentrated in pits for which there are usually no remediation plans even though they would qualify as hazardous waste dumps based on the chemical makeup of the materials.

No matter what collection system is in place, 100 percent of excreted manure is seldom recovered due to physical losses on the farm. A recent survey of Midwest confinement livestock farms, NRCS indicated that percentages of manure (feces and urine) recovered was eighty percent for lactating dairy cows, but only sixty percent for other animals on the dairy farm. Grazing animals will distribute the majority of their manure within the pasture system, so recovery for field application is not necessary, but manure is recoverable inside loafing barns, milking barns, and feeding areas.

(a) Manure output and milk production

One of the major factors contributing to animal manure output and composition is the feeding regimen and digestibility of the feed nutrients. A good example would be the changes in a typical lactation of a dairy cow. Daily and annual excretion estimates of various fractions and nutrients by Holstein dairy cows are shown in Table II-2. This example represents a cow producing 18,150 lbs. of milk per lactation which is about the average level found in herds on the Dairy Herd Improvement Association (DHIA) program, and also about the average production reported by dairy farmers. As milk production increases, the total amount of manure and the ratio of urine to feces increases. The digestibility of the feed averages 62 percent in this example with 38 percent of the dry matter intake (DMI) excreted. The example shows the effect of feeding varying dietary protein, phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) levels. It also shows typical outputs of sodium (Na) and chlorine (Cl).[93]

Phosphorus in the diet will require an additional acre of land per cow to dispose of manure and prevent potential P accumulation effects on the environment. Reduction of dietary P in dairy cow diets is becoming well accepted, and a dietary level of only 0.38% P appears to be adequate. At this level of phosphorus in the dairy cow diet, farmers have a better chance at avoiding P buildup in their soil. Proper balancing of total dietary protein and digestibility of protein for dairy cows at different production levels will help control nitrogen (N) excretion rates as indicated in Table II-2. The amount of K excreted is more critical from an animal health viewpoint since high levels of K in manure are taken up by plants and are returned in the forage.[94]

Table II-2. Daily and yearly excretion estimates of various fractions and nutrients by Holstein cows.[a]

	Daily milk and dry feed intake for:				Total for Year
	0-30 days	31-70 days	71-205 days	206-365 days	
Milk, lb/cow	100	70	50	Dry	18,150
Dry feed intake, lb/cow	55.8	46.3	39.2	25.2	14,462
	Excretion for cow described in column above				
Fraction or Nutrient	lb/day	lb/day	lb/day	lb/day	lb/yr/cow
Raw manure (feces + urine)	195.0	160.0	125.0	80.0	47,475
Feces (wet)	125.0	100.0	75.0	45.0	28,825
Urine	70.0	60.0	50.0	35.0	18,650
Total solids (38% of DMI)	21.2	17.6	14.9	9.6	5,496
Volatile solids	17.7	14.7	12.4	8.0	4,580
Total N (NRC, low)	0.899	0.727	0.601	0.364	223
Total N (NRC, high)	1.030	0.846	0.698	0.439	260
Urea + ammonium N (NRC, low)	0.408	0.308	0.249	0.125	92
Urea + ammonium N (NRC,high)	0.500	0.391	0.319	0.178	118
P (diet 0.40% P)	0.123	0.115	0.107	0.101	40
P (diet 0.45% P)	0.151	0.138	0.126	0.103	46
P (diet 0.60% P)	0.235	0.208	0.185	0.151	69
K (diet 0.8% K)	0.296	0.265	0.239	0.201	88
K (diet 1.2% K)	0.519	0.450	0.396	0.302	146
Ca (diet 0.65% Ca)	0.242	0.217	0.195	0.164	72
Ca (diet 0.90% Ca)	0.382	0.333	0.293	0.227	108
Mg (diet 0.20% Mg)	0.102	0.086	0.073	0.050	27
Mg (diet 0.35% Mg)	0.185	0.155	0.132	0.088	49
Na (diet 0.35% Na)	0.145	0.127	0.112	0.088	42
Cl (diet 0.55% Cl)	0.197	0.178	0.161	0.138	60

[a] Adapted from (Van Horn, et al., 1996). Crude protein percent of total diet dry matter used in calculations for cows producing 100, 70, 50, and dry cows for "NRC (National Research Council -nutrient requirements for dairy cattle, 1989), low diets" were 16.0, 14.8, 13.8, and 11.0%, respectively. Respective crude protein percents for "NRC, high diets" were 17.5, 16.4, 15.3, and 12.0% of total diet dry matter.

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. J-28.

Feed waste of 10 percent can result in an additional 40 percent of total solids in a dairy waste. Dairy cow stalls are often covered with bedding materials that improve animal comfort and cleanliness. Virtually all of the organic and inorganic bedding materials used for this purpose will eventually be pushed, kicked, and carried from the stalls and added to the manure. The characteristics of these bedding materials will be imparted to the manure. Quantities of bedding materials added to cow stalls and resting areas are shown in Table II-7.[95]

(b) Milk center waste

Milking centers—the milk house, milking parlor, and holding area—can produce about 50 percent of the waste volume, but only about 15 percent of the total solids in a dairy enterprise (Table II-3). Because this very dilute wastewater has different characteristics than the waste from the cow yard, it is sometimes managed by a different procedure. The values used to compute characteristics from milk houses are from research by Cornell University completed in 1979 in New York.[96]

About 5 to 10 gallons of fresh water per day for each cow milked are used in a milking center where flushing of wastes is not practiced. However, where manure flush cleaning and automatic cow washing are used, water use can be 150 gal/d/cow or more. Dairies employing flush cleaning systems use water in approximately the following percentages for various cleaning operations:

Parlor—cleanup and sanitation	10%
Cow washing	30%
Manure flushing	50%
Miscellaneous	10%[97]

Lagoons that receive a significant loading of manure, such as from the holding area or the cow feed yard, generally operate in an anaerobic mode (table II-4). Supernatant (upper liquid layer of the lagoon) concentration in an anaerobic lagoon is much greater than that in an aerobic lagoon. [98]

Sludge accumulates at a rate of about 0.073 cubic foot per pound of total solids added to the lagoon. This is equivalent to about 266 cubic feet per year for each 1,000 pound lactating cow equivalent if 100% of the waste is placed in the lagoon.[99] If a dairy waste lagoon receives wastewater only from the milk house or the milking parlor, the lagoon generally exhibits a very dilute supernatant and operates in an aerobic mode (Table II-4). The rate of sludge accumulation in such lagoons is slow.[100]

Table II-3. Dairy waste characterization—milking center

Component	Units	- - - - - - Milking center* - - - - - -				
		MH	**MH+MP**	**MH**	**+MP**	**+HA**
				**		***
Volume	ft^3/d/1000#	0.22	0.60	1.40		1.60
Moisture	%	99.72	99.40	99.70		98.50
TS	% w.b.	0.28	0.60	0.30		1.50
VS	lb/1000 gal	12.90	35.00	18.30		99.96
FS	"	10.60	15.00	6.70		24.99
COD	"	25.30	41.70			
BOD	"		8.37			
N	"	0.72	1.67	1.00		7.50
P	"	0.58	0.83	0.23		0.83
K	"	1.50	2.50	0.57		e3.33
C:N ratio		10	12	10		7

* MH – Milk house; MP – Milking parlor; HA – Holding area.
** Holding area scraped and flushed—manure excluded.
*** Holding area scraped and flushed—manure included.
Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-9.

Table II-4. Dairy waste characterization — lagoon

Component	Units	- - - - - - Lagoon - - - - - - - - -		
		- - - Anaerobic - - - -		Aerobic*
		Super-natant	**Sludge**	**Super-natant**
Moisture	%	99.75	90.00	99.95
TS	% w.b.	0.25	10.00	0.05
VS	lb/1000 gal	9.16	383.18	1.67
FS	"	11.66	449.82	2.50
COD	"	12.50	433.16	1.25
BOD_5	"	2.92`		0.29
N	"	1.67	20.83	0.17
NH_4-N	"	1.00	4.17	0.10
P	"	0.48	9.16	0.08
K	"	4.17	12.50	
C:N ratio		3	10	

* Milk house and milking parlor wastes only.
Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-10.

(2) Dairy waste collection, transfer and storage

The first step in evaluating a manure-handling system is to estimate how much manure and wastewater are generated. The housing system used by the dairy influences the amount of bedding or dilution water used, which influences manure characteristics. Table II-5 lists manure production and nutrient content for typical dairy cow weights. The manure nutrient values are for fresh manure and urine without storage and handling losses-- variation can be expected due to animal age, feed ration, type of confinement, method of manure handling, and other factors. [101]

Manure containing less than 15 percent total solids (or more than 85 percent water) will be a slurry when mixed and can be handled as a "liquid." Generally, if the total solids are greater than 15 percent, as when bedding is added or drying occurs, the manure is handled as a solid. [102]

Table II-5. Manure production and nutrient content

Animal	Animal	Manure	Manure	Manure	N	P	K
Species	size, lb	lb/day	cu ft/day	Gal/day	------lb/day-----		
Dairy cattle	150	13	0.19	1.5	0.06	0.011	0.04
	250	22	0.32	2.4	0.11	0.023	0.07
	500	43	0.66	5.0	0.22	0.047	0.15
	1000	89	1.32	9.9	0.45	0.094	0.29
	1400	120	1.85	13.9	0.59	0.131	0.41

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. J-27.

Solid manure is a combination of urine, bedding, and feces with no extra water added, such as that found in a loafing barn, bedded pack, calving pen, or open lot with good drainage. Semi-solid manure has little bedding and no extra liquid added. Little drying of semi-solid manure occurs before handling. Solid and semi-solid manure is generally handled with tractor scrapers, front-end loaders, or mechanical scrapers.

Liquid manure has water added to form a flowable mixture that can be handled by solids-handling pumps. Liquid manure is usually less than 8 to 10 percent solids. Very liquid manure is usually only 1 to 2 percent solids and is common with flushing and lagoon systems. Liquid and slurry manure are handled with scrapers, a flushing gutter, gravity-flow gutters, or storage under slotted floors. Liquids are spread on fields with tank wagons or irrigation.

Open-lot systems require scraping and open-front shelters for manure packs. Solid manure from a shelter or lot is moved to storage with a tractor scraper and front-end loader. A sheltered system can store manure in a tank under the building or in outdoor storage. For an under-the-building storage tank, manure is transferred through a slotted floor or drain plug and collected in the tank. With outdoor storage, manure is removed from the building with a mechanical or tractor scraper, front-end loader, flushing gutter, or gravity-flow channel. [103]

The manure in paved holding areas generally is easier to manage, and the areas are easier to keep clean. If the holding areas are unpaved, the traffic of the livestock tends to form a seal on the soil that prevents the downward movement of contaminated water. Care must be taken when removing manure from these lots so that damage to this seal is minimized.[104] Paved lots generally produce more runoff than unpaved lots. On unpaved lots, the runoff may be controlled by diversions, sediment basins, and underground outlets. The volume of runoff can be reduced by limiting the size of the confinement area, and uncontaminated runoff can be diverted if a roof runoff management system and diversions are used.[105]

The method used to transfer the waste depends largely on the consistency of the waste. Liquid and slurry wastes can be transferred through open channels, pipes, or in a portable liquid tank. Pumps can be used to transfer liquid waste as needed. Solid and semi-solid waste can be transferred by mechanical conveyance equipment, in solid manure spreaders, and by pushing them down curbed concrete alleys. Semi-solid waste has been transferred in large pipes through the use of gravity, piston pumps, or air pressure. [106]

(3) Liquid Dairy Waste Systems

Liquid handling is used in many dairy facilities with free-stall housing where manure is collected and removed from the barn with a tractor-mounted scraper, mechanical alley scraper, flushing system, or slotted floor. Depending on site conditions, manure can be stored in earth basins, below-ground tanks, or above-ground tanks. Common methods for transferring liquid dairy manure to storage include gravity, large piston pump, pneumatic pump, and centrifugal chopper pump. [107]

Free-stall manure with little added bedding can be transferred to storage by gravity. In general, 4 to 6 feet of elevation drop between the floor of the barn and full storage level is adequate for manure to flow over 100 feet. Terrain that slopes about 10 percent away from the barn for 250 to 300 feet can provide enough head pressure for both filling and emptying a liquid storage by gravity. [108]

A key factor in the design of any liquid-storage structure is provision for agitating the waste prior to irrigating or loading the tank spreader. Without complete agitation, solids will accumulate in the structure and reduce storage capacity. When placed in a storage structure, undiluted manure from cattle usually will develop a crust of floating solids. This crust helps control odors and should not be disturbed until the waste is agitated, just prior to field spreading. [109]

The principal advantage of the flush system for collecting manure is that it can be automated. To minimize the amount of water to be field spread, some means of recycling clarified wastewater for flushing may be desirable. In a flush system, a large volume of water flows from one end of a building to the other, down a sloped, shallow gutter. The water scours manure from the gutter or alley and removes it to a lagoon or storage. Two types are common on dairy farms:

* Wide open gutter, used in dairy free-stall alleys, holding areas, and milking parlors.
* Under-slat gutter, used in beef buildings where residue or disease transmission is a concern. [110]

Water may be recycled from a lagoon, holding pond, or earthen storage. If irrigating, producers may use fresh water for flushing rather than recycled water. In a flushing system, a pump transports either fresh or recycled water to a flush tank at the high end of the gutter. The flush tank periodically releases a large volume of water into the gutter. Some systems use a large-capacity pump operated by a time clock to supply flush water instead of a flush tank. Pump flushing uses much more water than tank flushing. [111] Table II-6 provides the volumes of water used per animal serviced by a flushing system.

	Gated tank	Pump flush
Gal/d/ft^2 alley surface	2.5	15.0

Gal/d/cow	80.0	550.0

Dairies that have gated tank flush cleaning and automatic cow washing commonly use 100 to 150 gal/d/cow, but multiple flushing and alternative equipment may double this amount.[112]

Table II-6. Recommended total daily flush volumes (MWPS 1985)

Animal type	**gal/head**
Swine	
Sow and litter	35
Prenursery pig	2
Nursery pig	4
Growing pig	10
Finishing pig	15
Gestating sow	25
Dairy cow	100
Beef feeder	100

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 10-5.

(4) Semi Solid or Solid Dairy Waste Systems

Where adequate amounts of bedding are used to make manure stackable, manure can be stored on an open or covered stacking slab with or without retaining walls. Any rainwater that falls on the storage must be collected and contained in a storage tank, earth basin, or holding pond.[113] Solid handling is used by many dairy operations with comfort-stall or free-stall barns with added bedding. Typical manure storage time varies from 3 months or more to a few days with a daily haul system. An second, liquid-handling system is required for milking-center waste. (See 4 below) The storage area can be a stacking slab or covered storage. Roofed storage keeps out precipitation so manure can be handled as a solid or semi-solid.

(a) Estimating Solid and Semi-Solid Storage Capacity Requirements

A minimum storage capacity of 3 months is necessary, but for better management and hauling flexibility 6 months or more of storage capacity should be available. Storage capacity requirements are based on animal manure production, amount of bedding used, and any stored liquids (rain, snow, runoff).[114]

Table II-7. Daily bedding requirements for dairy cattle

	- - - - - - - - - - Barn type - - - - - - - - - -		
Material	Stanchion stall	Free-stall	Loose housing
	- - - - - - - lb/d/1000# - - - - - - -		
Loose hay or straw	5.4		9.3
Chopped hay or straw	5.7	2.7	11.0
Shavings or sawdust		3.1	
Sand, soil, or limestone		1.5	

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-7.

To estimate the required storage volume of manure and bedding, add the manure production volume to half of the bedding volume because bedding volume is usually halved during use. If animals have access to an outdoor lot and manure from the lot is not added to the solid or semisolid storage, assume half the daily manure production volume when estimating storage capacity. Additional capacity would be required for drainage water, lot runoff, and, possibly, lot scrapings. Therefore:

> Storage capacity = Number of animals x Daily manure production {Tables II 2, 5} x Desired storage length in days + Half total bedding volume[115]

(5) Milking-Facility Dairy Waste Systems

(a) Human Waste

Toilet water from milking facilities must be handled separately from milking center wastewater. A septic tank/leach bed system is normally used. Milking-center toilet wastes may also be piped to the waste system of a nearby house. Under no circumstances should they be mixed into animal waste systems. [116]

(b) Milking Facility Waste

Milking house waste and contaminated runoff must be stored as a liquid in a waste storage pond or structure. Manure may be stored as a slurry or liquid in a waste storage pond designed for that purpose or in a structural tank. It can be stored as a semi-solid in an unroofed structure that allows for the drainage of excess water and runoff or as a solid in a dry stacking facility. In humid areas the stacking facility should have a roof. [117]

Both the daily volume and the strength of milking-center wastewater must be considered when designing milking facilities. Table II-8 provides estimated daily quantities of wastewater. As herd sizes increase, less water is used per cow because the milking equipment wash water does not increase proportionately. The values given are for facilities with parlors and they assume that holding areas are scraped and not washed down. Milking in stanchions produces less wastewater per day, and the quantity of wastewater from milk rooms will be only one-third to one-half of the values given in Table II-8. [118]

Table II-8. Estimated quantities of wastewater discharged from milking centers

Cows Milked	Quantity
Up to 50	7 to 10 gal/cow-day
50 to 150	4 to 6 gal/cow-day
More than 150	2 to 4 gal/cow-day

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

(c) Food wastes and wastewater

Food processing of dairy products can result in considerable quantities of solid waste and wastewater. Many of these wastes can be used in by-product recovery procedures, and not all of the waste must be sent to disposal facilities. Food processing wastewater may be a dilute material that has a low concentration of some of the components of the raw product. On the other hand, solid waste from food processing may contain a high percentage of the raw product and exhibit characteristics of that raw product. Tables II-9 and II-10 present characteristics of wastewater and sludge from the processing of milk and milk products.[119]

Table II-9. Dairy food processing waste characterization

Product/Operation	**- - - - Wastewater - - - -**	
	Weight lb/lb milk processed	**BOD_5 lb/1000 lb milk received**
Bulk milk handling	6.1	1.0
Milk processing	4.9	5.2
Butter	4.85	1.46
Cheese	2.06	1.8
Condensed milk	1.85	4.5
Milk powder	2.8	3.9
Milk, ice cream, & cottage cheese	2.52	6.37
Cottage cheese	6.0	34.0
Ice cream	2.8	5.76
Milk & cottage cheese	1.84	3.47
Mixed products	1.8	2.5

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-20.

Table II-10. Dairy food waste characterization—processing wastewater

Component	**Units**	**Industry Wide**	**- -Whey - -**		**Cheese**
			Sweet Cheesecheese	**Acid water sludge**	**waste-**
Moisture	%	97.60	93.10	93.40	97.50
TS	% w.b.	2.40	6.90	6.60	2.50
VS	"	1.49	6.35	6.00	
FS	"	0.91	0.55	0.60	
COD	"		1.30		
BOD_5	"	2.00			
N	"	0.077	7.48		0.18
P	"	0.050			0.12
K	"	0.067			0.05

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-20.

(d) Alternative milking center waste handling methods

The use of conventional septic tanks and leach beds for milking-center waste is not acceptable for three reasons:

1. Large herds generate too much milking wastewater.
2. Sanitizing chemicals used to clean milking equipment may kill septic system bacteria.
3. Manure solids washed from parlor floors will clog the leach bed.[120]

A modified septic tank system using a presettling tank, a treatment tank, a dual leach bed, and proper management may work if solids are pumped out of the presettling tank on a regular basis (monthly or bimonthly) and the effluent discharge is alternated between the two leach beds on a monthly or bimonthly basis. [121]

Rather than using a leach bed, effluent is sometimes discharged every 2 to 5 days onto cropland, pasture, or a designated grassed infiltration area via (1) sprinkler irrigation, (2) controlled flood irrigation, or (3) discharge into gradient infiltration terraces. The size and shape of the disposal area is affected by soil types, vegetation, topography, proximity to streams, and quantity of wastewater and the vegetation on the disposal area must utilize the nutrients in the wastewater and be harvested. [122]

Another alternative method of handling milking center wastewater is to put it into a liquid-manure system where milking-center wastewater provides the necessary dilution of liquid waste. However, some form of effluent lagoon is required and such a lagoon is usually designed with enough volume to provide one year's storage of this waste. [123]

(6) Land Application of Dairy Manure

There are two principal objectives in applying dairy cow manure to land:
1) ensuring maximum utilization of the manure nutrients by crops and
2) minimizing water-pollution hazards.
Surface spreading and subsurface injection are the two most common land-application methods. Several guidelines must be followed to minimize environmental hazards:

* Test soil to establish existing soil-fertility levels.
* Test manure and wastewater to determine nutrient content.
* Select an application rate that does not exceed crop nutrient requirements and avoids soil contamination, crop damage, and runoff and contaminated tile flow.
* Check soil moisture before applying liquid wastes, and adjust application rates to avoid runoff.
* To avoid runoff, do not apply manure to frozen or saturated soils.
* Calibrate application equipment to obtain the desired application rate.
* Incorporate raw or untreated manure to reduce odors and nitrogen losses.[124]

Adequate land area must be secured to allow for manure application. One approach to determining the amount of land required is to only apply the amount of nutrients removed in the harvested crop. This will prevent nutrient buildup in the soil beyond suggested agronomic and environmental levels. Excess application may induce nutrient deficiencies in the soil and increase the potential for excess nutrients to enter waterways. Phosphorus is the nutrient of major concern on soils with high phosphorus fertility levels. Phosphorus applied to fields as manure or commercial fertilizer can move into bodies of water during erosion and runoff events, and is largely responsible for the accelerated eutrophication of many bodies of water. It also accumulates in soils if applied in quantities greater than those removed by crops.[125]

(a) Factors Controlling Application Rate--rule-of-thumb estimates

Table II-11 can be used for rule-of-thumb estimates of available nutrients in different manure for the common methods of manure management. Table II-11 is limited to:[126]

i. Solid and slurry manure applied in tons
ii. Available nutrients, first year only.
iii. Situations where there is little carryover of nutrients from previous manure applications.
iv. Common methods of manure management.

Manure liquids are not included because manure of this type will be diluted 4 to 10 times so that it can be flushed into storage or treatment facilities. With this method of waste management, a large loss of nitrogen can occur during storage, and tests should be made to determine the nitrogen concentration.[127]

The amounts shown in the tables are in pounds of available nutrients per ton. The estimated nutrients vary considerably according to the climate and waste management system. The tables also show the estimated moisture content, which can be used as a guide. The tons are the actual weight of the manure as it is applied, which includes moisture and bedding. Use reliable local data if they are available. In most cases, manure changes weight during storage and treatment because it almost always gains or loses moisture.[128]

An example of moisture gain is seen in waste management for dairy cows in the northern part of the country. Typically, the manure is placed in storage daily in either a covered tank or an open storage pond. The milking center wastewater is added, which amounts to about 5 or 6 gal/cow/day. If 5 gallons of wash water are added daily to the manure from a 1,400-pound cow, the volume is increased by about 35 percent. Similarly, if the original moisture content is 89 percent, it is increased to almost 92 percent. Consequently, it is then necessary to haul more than 13 tons of manure to the field for every 10 tons excreted if there is no drying or further dilution.[129]

Table II-11. Rule-of-thumb estimates--available nutrients in manure from dairy cows

Management system	**Final moisture**	**Nutrients available first year**		
		N	**P_20_5**	**K_20**
	%	---------lb/ton ---------		
1.Fresh manure, collected and applied daily, incorporated before drying.	89	7	3	5
2.Manure collected daily, 50% processing water added, stored in covered tank, applied seasonally, incorporated before drying.	92	3	3	5
3.Manure placed daily in open storage pond; 30% processing water added; liquids retained; spread annually in fall; incorporated before drying; cool, humid climate; evaporation = precipitation.	92	3	3	4
4.Bedded manure, unroofed stacking facility (bedding is 10% by weight); spread in spring before drying; cool, humid climate; evaporation = precipitation.	82	3	2	4
5.Manure, no bedding, stored outside; leachate lost; spread in spring before drying; cool, humid climate.	87	3	2.5	4

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 11-33, 34.

The factors that most often limit the amount of manure that should be applied to cropland are existing soil-fertility levels, manure nutrient content, crop nutrient needs, site limitations, slope, runoff potential, and leaching potential. Tables II-11 and II-12 provide average nutrient values. The nutrient composition of waste is affected by housing and the waste-handling system. Bedding and additional water can dilute manure, resulting in less nutrient value per pound. [130]

As a rough rule of thumb, the Illinois soil conservation service has calculated that on land producing 150 bushels of corn per acre and 40 bushels of soybeans per acre in rotation, 1.2 acres are needed to use the yearly production of phosphorus excreted by each 1000 pounds of dairy cows. 2.4 acres are needed to dispose of potash for each 1000 pounds, and 1.1 acres would be required per 1000 pounds to dispose of nitrogen, assuming a 50 percent loss of N. These acreage amounts would increase in areas where crop yields are smaller.[131]

A detailed accounting of nutrient flow conducted in Florida found that 23 percent of the feed N and P was accounted for in milk outputs leaving 77 percent of feed nutrients excreted. Approximately 24 percent of manure N and P were excreted in the milking area where 5 percent of manure N was lost. In the feeding area 28 percent of the manure N was excreted. The remaining manure N and P were excreted in the pasture and lanes to and from the pasture. A further 45 percent of the manure N was volatilized but all of the P was available. [132]

Table II-12. Annual Raw-Manure Production per 1,000-Pound Animal Weight

Animal Type	**Manure Production**		**Percent Solids**	**Nutrient Content**					
	Tons/yr	**Gal/yr**		**N**	**P_2O_5**	**K_20**	**N**	**P_2O_5**	**K_20**
				lb/ton			**lb/1,000 gal**		
Dairy	15	3614	12.7	10.0	4.1	7.9	41.5	17.0	32.8
Beef	11	2738	11.6	11.3	8.4	9.5	45.4	33.7	38.2
Veal	11.5	2738	8.4	8.7	2.1	9.0	36.5	8.8	37.8
Swine									
Growing pig	11.9	3008	9.2	13.8	10.8	10.8	54.6	42.7	42.7
Mature hog	5.9	1425	9.2	13.9	10.8	10.8	57.5	44.7	44.7
Sow & litter	15.9	3894	9.2	14.2	10.7	11.1	58.0	43.7	45.3
Sheep	7.3	1679	25.0	22.5	7.6	19.5	97.8	33.0	83.5
Goat	7.0	1789	31.7	22.0	5.4	15.1	86.1	21.1	59.1
Poultry									
Layers	9.7	2464	25.0	27.3	23.5	13.2	107.5	92.5	52.0
Broilers	13.1	3285	25.0	33.4	16.7	12.5	133.2	66.6	49.8
Turkey	8.4	2044	25.0	23.7	20.8	16.9	97.4	85.5	69.5
Horse	8.2	2048	21.0	12.1	4.6	9.0	48.4	18.4	36.0

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

Improvements in N use efficiency by dairy cattle can be achieved with nutritional management or ionophores which selectively suppress bacteria in the rumen that produce ammonia. Dutch researchers suggest that the maximum N use efficiency may be about 0.43, although such high efficiency depends on temperature stress, incomplete feed digestion and variable feed quality. Recent research in Wisconsin has suggested that dairy rations could contain 0.38 percent P, rather than the currently recommended 0.48 percent P, which would decrease P excretion in manure by 25 to 30 percent without reducing milk production or reproductive efficiency. [133]

Nutrient losses during storage and handling reduce the amount of nutrient available for land application. Phosphorus and potassium losses are usually negligible but nitrogen losses can be significant. Table II-13 provides nitrogen losses during storage and handling. Land application methods also affect the amount of nutrients available for crop uptake. Most losses occur within 24 hours of application. Manure should be incorporated into the soil as soon as possible after application. Injecting, chiseling, or knifing liquid manure into the soil minimizes odors and nutrient losses to the air or as surface runoff. [134]

Table II-13. Percentage of original dairy manure nutrient content retained in various storage systems[a]

Method	**N**	**P**	**K**
Daily spread	80	90	90
Dry + roof	70	90	90
Earthen Storage	55	60	70
Lagoon/flush	30	40	60
Open lot	60	70	65
Pits + slats	75	95	95
Scrape/storage Tank	70	90	90

a Adapted from Moore and Gamroth (1993 - National Data base)

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. J-43.

Tables II-14, II-15 and II-16 present approximate nutrient values for land-applied solid and liquid manure, taking into account handling and storage losses. The amount of nitrogen available in the soil depends on the method of application and days to incorporation. [135]

Table II-14. Typical losses between excretion and land application adjusted for dilution in the various systems—dairy manure

These values are in addition to land application losses.

System	% Nitrogen lost
Solid	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Deep pit (poultry)	15-35
Liquid	
Anaerobic pit	15-30
Above-ground storage	10-30
Earth storage	20-40
Lagoon	70-80

Adapted from MWPS (1985)

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. J-43.

Table II-15. Approximate fertilizer nutrient value at time applied to land - solid handling systems[a]

Type of Livestock	Bedding vs. No Bedding	Dry Matter	Nutrient Content			
		%	Total N[b]	NH4[c] lb/ton	P2O5[d]	K20[e]
Swine	Without bedding	18	10	6	9	8
	With bedding	18	8	5	7	7
Beef cattle	Without bedding[f]	52	21	7	14	23
	With bedding	50	21	8	18	26
Dairy cattle	Without bedding	18	9	4	4	10
	With bedding	21	9	5	4	10
Sheep	Without bedding	28	18	5	11	26
	With bedding	28	14	5	9	25
Poultry	Without litter	45	33	26	48	34
	With litter	75	56	36	45	34
	Deep pit (compost)	76	68	44	64	45
Turkey	Without litter	22	27	17	20	17
	With litter	29	20	13	16	13
Horses	With bedding	46	14	4	4	14

[a] Manure spreader capacity: 1 bu = 40 to 60 lb.
[b] Ammonium N plus organic N, which is slow-releasing.
[c] Ammonium N, which is available to the plant during the growing season.
[d] To convert to elemental P, multiply by 0.44.
[e] To convert to elemental K, multiply by 0.83.
[f] Open dirt lot.

Source**:** Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

Table II-16. Approximate fertilizer nutrient value at time applied to land - liquid handling systems[a]

Type of Livestock	Manure Storage	Dry Matter %	Nutrient Content Total N[b]	 NH4[c]	 P2OS[d]	 K20[e]
			lb/1,000 gal			
Swine	Liquid pit	4	36	26	27	22
	Lagoon[f]	1	4	3	2	4
Beef cattle	Liquid pit	11	40	24	27	34
	Lagoon[f]	1	4	2	9	5
Dairy cattle	Liquid pit	8	24	12	18	29
	Lagoon[f]	1	4	2.5	4	5
Veal calf	Liquid pit	3	24	19	25	51
Poultry	Liquid pit	3	80	64	36	96

[a] Application conversion factors: 1,000 gal = about 4 tons; 27,154 gal = 1 acre-inch.
[b] Ammonium N plus organic N, which is slow-releasing.
[c] Ammonium N, which is available to the plant during the growing season.
[d] To convert to elemental P, multiply by 0.44.
[e] To convert to elemental K, multiply by 0.83.
[f] Includes feedlot runoff water and is sized as follows: single-cell lagoon - 2 cu ft per 1 lb animal wt. Two-cell lagoon - cell 1, 1 to 2 cu ft per 1 lb animal wt; cell 2, 1 cu ft per 1 lb animal wt.
Source**:** Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

Tables II-17, II-18, and II-19 can be used to estimate the availability of ammonia and organic nitrogen in the soil. The phosphorus and potassium applied to the soil will be available unless removed by surface runoff and soil erosion. Nearly 100 percent of total phosphorus and potassium from manure application are considered available the first growing season. It is important to note that manure contains much more potassium than magnesium or calcium, and after many years of continued manure application, the ratio of potassium to magnesium and calcium may be too high for optimum crop growth. To adjust the ratio, additional magnesium and/or calcium may have to be added. [136]

Table II-17. Average nitrogen losses by method of application and manure type.

Percent of nitrogen applied that is lost with 4 days of application.

Application method	Type of waste	% Nitrogen lost
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with	Solid	1-5
immediate cultivation	Liquid	1-5
Knifing	Liquid	0-2
Sprinkler irrigation	Liquid	15-35

a Adapted from MWPS (1985)
Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, http://www.mnplan.state.mn.us/eqb/scoping.html, September, 1999, p. J-43.

Table II-18. Method of calculating N availability of manure[a]

Available Nitrogen %		Time of Application	Days Until Incorporated[b]			
NH4	**Organic**	**Date**		**Days**		
50	33	Nov-Feb	25	33	Nov-Feb	>3
50	33	Mar-Apr	25	33	Mar-Apr	>3
75	33	Apr-Jun	25	33	Apr-Jun	>1
75	15	Jul-Aug	25	15	Jul-Aug	>1
25	33	Sep-Oct	15	33	Sep-Oct	>1

[a] The calculations are for all animal manure. It is assumed that 50% of the organic N in poultry manure is converted to NH4 rapidly and is therefore included in the NH4 column for calculating available N.

[b] Incorporation is the mixing of manure and soil in the tillage layer. Disking is usually enough tillage for conserving N availability.

Only about one-third of the organic nitrogen in animal manure is available to crops during the year it is applied, and the remaining two-thirds, residual organic nitrogen, becomes part of the soil organic matter. It is mineralized or becomes available at the rate of about 5 percent a year. To determine how much nitrogen will be available to crops from manure applications, growers must take into account the mineralized nitrogen that will become available from previous manure applications (Table 9). Manure is also a good source of phosphorus and potassium. Tables 1, 4, 6, or 7 can be used to calculate the amount of phosphorus and potassium that will be available from the manure. The phosphorus and potassium in manure will be as available to the crop during the year it is applied as would the equivalent amount of fertilizer-grade phosphorus and potassium.

Source**:** Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

Table II-19. Percentage of residual organic nitrogen made available from manure applied in previous years

Years After Application	Percentage of Residual N Available
1	5.0
2	4.7
3	4.5
4	4.3
5	4.1
6	3.9
7	3.7
8	3.6
9	3.4
10	3.2

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, http://oh.nrcs.usda.gov/fotg/OhioNRCSstandards1.htm, 1979-1999 various.

(7) Sources of Odors From Dairy Operations

There are three primary sources of odors from dairy operations: (1) buildings, (2) manure storage or treatment units, and (3) spreading of manure and waste waters on agricultural land. [137] As a rule of thumb, about 60 percent of odors come from confinement buildings and 40 percent come from the lagoons used to store the waste.

Because confinement buildings can be a significant source of odor, management of livestock and manure in the buildings is important. Little odor is generated in the first 3 to 5 days after manure is deposited, but if manure accumulates longer than 3 to 5 days, large amounts of offensive odors are released. Ammonia production peaks at 3 days and again at 21 days. Manure accumulated on open lots can pose greater odor nuisance during warm, wet weather than if the animals are totally under a roof. If animals become dirty with manure, their body heat will promote the rapid release of odors. [138]

A building's ventilation system exhausts large amounts of odors and gases generated within the building along with the ventilation air. If the building is dirty or has high dust levels, the result will be a higher odor level. Dust levels can be reduced with proper sanitation and regular cleaning. Animal fats and oils added to the feed can also reduce feed-dust generation. [139]

(a) Controlling Odors

The source of odors is the volatile compounds generated during the decomposition of manure. The two principal classes of odorous compounds are those containing sulfur, e.g., hydrogen sulfide, and those containing nitrogen in the amine form, e.g., ammonia. The generation of these compounds is affected by the type of livestock and is primarily associated with the level of protein and amount of roughage in feed rations. [140]

The manure-handling system also affects the rate of odor generation and the characteristic smell of the odor. Manure that is collected and field-spread daily has less offensive odors than stored manure. Also, manure handled as a liquid (slurry) will have a greater potential for odor than manure handled in a solid form with bedding. Research indicates that the transport of odors is also associated with dust particles or aerosols. Therefore, controlling dust or aerosol emissions will help control odors. [141]

(b) Site Selection

Four site selection factors help to minimize odor potential:

i. Isolation of the facility site.
ii. Direction and distance to neighbors.
iii. Prevailing wind direction.
iv. Air drainage. [142]

Operation size and prevailing summer wind direction affect required separation distances from neighbors. Odor potential increases when a neighboring residence is in a down-slope direction, and, in particular, when it is in a swale or small valley. During calm summer evenings, air next to the ground surface will be cooled and drift down-slope. This meteorological condition may continue for several hours each evening. When land is relatively flat, prevailing wind direction and distance to neighboring residences will affect the decision on where to locate the facility. If the site is sloping, the air-drainage factor must be considered and may outweigh prevailing wind directions.[143]

(c) Building Design and Manure Collection

Accumulated manure on lot surfaces will have more odor during warm, wet weather than manure in a storage area.

Daily scraping of manure from lot surfaces will reduce odor generation.

Manure left in a building longer than 3 to 5 days will have more odor than if removed to cropland or to outside covered storage more frequently.

Flush systems reduce odors inside a building and, consequently, the amount exhausted with ventilation air, but increase the volume of wastewater to be handled and land-applied and the amount of odor outside the buildings.

Reducing dust levels within a building will lower odor problems.

Scrubbing the exhaust ventilation air with filters will reduce odors from a building. [144]

i. Storage Units: Manure-storage structures should be covered. For dairy and beef manure, a floating crust usually forms and acts as a "lid." However, a floating crust may not form under two conditions: excess water or low pH. Therefore, it is important to divert all clean surface runoff away from the manure-storage structure. Storage units initially loaded in the fall or winter take longer to develop a crust than those started in the spring or summer. [145]

ii. Lagoons: There are two principal types of livestock-waste treatment lagoons: aerobic (aerated) and anaerobic (without air). A properly designed and operated aerated lagoon will not produce odors. However, aerated lagoons are more costly to operate and most producers choose anaerobic lagoons. Anaerobic lagoons become an important source of odor because of improper design (principally overloading) and poor management. [146]

(d) Manure Spreading

If manure must be spread when odors may be a problem, immediate soil incorporation by injection or plow-down will decrease the release of odors. Incorporation may also be necessary if limited storage capacity is available. With soil incorporation, less nitrogen will be lost by the volatilization of ammonia.[147]

Soil incorporation is sometimes not possible due to cropping or soil conditions. Research has shown that aerating stored liquid manure for as little as four hours before spreading removes most of the odorous sulfur compounds. However, these odors are simply released in a different area when aerating the manure storage.

Many operators use irrigation equipment to spread liquid manure on cropland. This application method can increase odor problems unless special precautions are taken to reduce aerosol drift because odors are transported with the aerosol. High-pressure spray (80 to 100 psi at nozzle) will atomize the wastewater into finer aerosols that can travel farther than larger droplets from lower-pressure nozzles. [148]

(e) Commercial Odor-Control Chemicals

There are four general types of odor-control chemicals:

i. A masking agent is a "perfume" odor to override an offensive odor.
ii. Counteractants are chemically designed to block the sensing of particular odors.
iii. Odor-absorption chemicals are reactive compounds to change the odor-causing chemical.
iv. Biological compounds such as enzymatic or bacterial products alter the decomposition pathway so that the odorous compounds are not generated. These compounds are added directly to the manure storage, and some are available to add to the feed. [149]

The effectiveness of various odor-control chemicals is questionable and the cost of odor-control chemicals varies greatly. Odor-control chemicals are usually an expensive alternative to proper design and good management. [150]

(8) Generating Methane From Dairy Manure Systems

Livestock manure that is handled in a slurry or liquid form and treated anaerobically in large cconcentrated animal production facilities (500+ dairy cows) produces biogas. Methane emissions can be reduced by recovering this gas and using it for on-farm energy needs. The biogas is captured by placing a floating, impermeable cover over the lagoon, sealed at the edges to prevent influx of air. Captured gas can be used as a cooking or lighting fuel or cleaned and used in generators, boilers, space heaters, or refrigeration equipment.[151]

The biggest problem with methane generation is that it is usually not economically feasible. For example, a case study evaluated the feasibility of a centralized digester in Tillamook County, Oregon. The study included 26,000 dairy cows with 68 percent located within a 16-km radius and 92 percent within a 40-km radius. The digester-power plant was not economically efficient and it was projected to operate at a $514,000/yr deficit. In addition, a $2.20/tonne surcharge was assessed to livestock producers for handling the manure. [152] The following sections give the specific economic costs and benefits of methane generation and use.

(a) Performance

Gas recovery rates depend on ambient temperatures and the farm's geographic location. Average gas recovery at US dairy farms range from 187-375 m3 biogas/ 1,000 kg of volatile solids handled. Assuming 10 kg of volatile solids produced daily by an average US dairy cow and a 60 percent methane content in biogas, daily recovery rates at dairy farms handling 100 percent of the manure produced can range from 112-225 m3 methane/100 head. At dairy farms handling 55 percent of the manure produced, the methane recovery rates are proportionate.[153]

(b) Capital and Installation ($2000):

For systems with a design lifetime of 10 years, total project costs are driven by the capital and installation costs of the gas recovery system and the gas utilization equipment. Installation costs for gas recovery systems on dairy farms using 15 percent of the manure are $87-214/cow; installation costs for dairy farms using 55 percent of the manure are $147-281/cow. On a 1000-head dairy farm, gas-fired chillers cost $32/head; wash water heaters cost $8/head (using 15 percent of the manure) to $15/head (using 55 percent of the manure); power generators cost $32/head (using 15 percent of the manure) to $71/head (using 55 percent of the manure). [154]

Installation costs for the following methane production facilities for dairy waste that produced gas for an end use such as electricity production or heating were reported by the EPA in the spring of 2000 (Table II-20).

Table II-20. Methane system capital costs

Location	**Year Built**	**Installed Cost (2000$)**	**Number of Cows**	**Cost Per Cow**	**Cost Per Cow Per Year**
CT	1997	$485,000	600	$809	$81
MI	1981	$294.000	720	$407	$41
VT	1982	$343,000	340	$1007	$101
CA	1982	$370,000	400	$925	$93
OR	1997	$310,000	1000	$310	$31
NY	1998	$214,000	1000	$314	$31
MN	1999	$330,000	1000	$330	$33
PA	1979	$612,000	2000	$306	$31
PA	1983	$212,000	250	$847	$85
CT	1997	$161,000	200	$803	$80

Source: AgSTAR Digest, United States Environmental Protection Agency, EPA-430/F-00-012, Spring, 2000, pp. 5-6, 9.

(c) Non-fuel Operation and Maintenance--Minimal maintenance costs (2000$)

Annual O&M costs for heating and cooling on dairy farms with 500-1000 head are $2.95/head; annual O&M for power generation costs $3.1/head (using 15 percent of manure) to $11.40 (using 55 percent of manure).

To make methane generation at a dairy CAFO economically viable, the costs enumerated above must be offset by the benefits from methane generation. If methane generation is used to create economic benefits from CAFO waste the cost/benefit breakdown still does not look promising. For example, the costs and benefits of a methane powered manure system with a 10 year design lifetime for dairy cows would be (in $2000):

Installation costs for gas recovery systems on dairy farms using

15 percent of the manure are	$87-214/cow;
55 percent of the manure are	$147-280/cow.

At an electric price of $0.10/kWh, annual benefit from gas recovered for on-site dairy farm power generation at dairy farms is $23/head (using 15 percent of manure) to $58/head (using 55 percent). Annual benefits from recovered gas for heating dairy wash water is at least $10.70/head.[155]

(9) Bion-based Systems For Handling Dairy Waste

In a Bion-type system, natural processes are used to handle environmental, water, air and waste problems and a large percentage of liquids are recycled. Flushing the barns releases a slurry of waste containing up to 5 percent solids. Waste effluent is routed to a small, designed wetland where much of the waste is biologically removed. The liquids are then returned to barns for re-use as flush water. Some treated liquid may be filtered--removing particulate matter to 0.5 microns--and then used for feed water. When this step is taken, it is estimated that less than five percent (5 percent) of total water needs will be drawn from wells. There is no lagoon and no irrigation system. Ozone injection may be used at various points in the system.[156]

Proponents of Bion-type systems claim that

Separated solids stack and are essentially odor-free.

Solids may be used immediately on crops. All crop nutrients are available.
Ozonation breaks ammonia into its components of nitrate and water, nitrogen levels are somewhat enhanced. Phosphorus levels are slightly decreased.
Odor levels are reduced:
Separated liquids and solids are, essentially, odor-free.
Barn odors have decreased.
Pathogens are removed
Costs are reduced:
Easily transported dried or composted solids are trucked to the spread site.
Substantial savings in labor and time.
Mortalities are composted, under low odor conditions, using a mixture of sawdust and solids.
Barn floors are cleaner.
Barn odors decrease noticeably.

Calculated costs for a bion-type system are quite low. An anaerobic digestion system, coupled with an engineered wetland system is typically claimed to require just over one-half acre of bare land. Such a system can process 15,000 gallons of effluent daily or about 5 million gallons per year. Each plant has a construction cost of approximately $250,000, yielding a cost of about three cents per gallon or about 40 cents per cow per day.[157]

Unfortunately, bion-type systems have some major drawbacks. They are highly susceptible to imbalance in the biological components of the systems (the wetlands) and when bion-type systems are not working well, they are not working at all. Further, bion-type systems only function when temperatures are above freezing--and warmer temperatures work better than cooler temperatures. These drawbacks may make bion-type systems subject to high odor emissions, and bion-type systems are poor choices for areas that experience any prolonged periods of cool, winter weather.

(a) Conclusion--costs vs. benefits

The costs of treating dairy CAFO waste in a responsible manner are substantial. And since the costs of the systems involved are additions to the current large dairy CAFO flush and dump in lagoons systems, these costs represent one measure of the costs the diary is shifting to the local region and thus, avoiding. The $.40 per cow per day cost of the bion-type system adds $146 per year to the cost of each cow. This alone is enough to nullify the slight cost advantage of larger dairy CAFOs over smaller, more conventional dairy farms. Since these methods of waste handling are not required in smaller, more conventional dairies where sufficient land is available to spread the manure, it is clear that most, if not all of the cost advantage of larger dairy CAFOs is presently coming from shifting the costs of dairy waste to the surrounding region.

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