There is currently much debate about sources of pollution, particularly nutrient pollution of surface and groundwaters. It frequently appears that everyone is quite confident everyone else is contributing far more than they are. The reality, particularly for nutrient pollution, is that we all are part of the problem and must be part of the solution. This paper offers a science-based perspective on nutrient pollution and how changes in technology, resource consumption and personal life style choices have accelerated nutrient pollution. I try to be objective but state my policy preferences for sustaining agriculture and addressing nutrient pollution.

Humans have clearly had some impact on the environment throughout their existence. This impact increased as we moved from hunter-gatherers to a less nomadic agrarian society, centered around villages.

The industrial revolution of the late nineteenth and early twentieth centuries started a period of rapid population growth and concentration in urban centers that continues today. This accelerated environmental degradation, particularly near urban centers. Mechanization of agriculture allowed cultivation of much greater expanses of land than ever before which resulted in severe erosion that impacted soil productivity. Sedimentation caused major physical changes in rivers and lakes and destroyed or altered habitat for many living resources. Most of these impacts were acute and somewhat localized.

There were also localized “hot spots” resulting from disposal or misuse of toxic compounds by industry. From before World War II through the 1960s, there was widespread application of toxic compounds in pesticides with little evaluation of ecosystem or human impacts. The effect of DDT and its metabolites on raptors (and other near shore birds) provides one well documented example of an unintended consequence of using compounds without evaluating impacts.

It was not until well after World War II that nutrient pollution was considered a major water quality issue. Nutrient pollution, and its consequences (low dissolved oxygen and poor water clarity) are now deemed the leading cause of degradation of lakes, rivers, streams, and coastal waters (US EPA, 1999). Nutrient pollution of surface waters causes excessive growth of algae
and is commonly termed eutrophication, or “overenrichment.” The most common problem is low or no dissolved oxygen as a result of the oxygen demand generated by decaying algae. The algae can also reduce water clarity thus making it difficult for underwater grasses to grow in the shallows. Nutrient pollution manifests itself in slow-flowing coastal areas, lakes and reservoirs and portions of some rivers.

The rapid growth in nutrient pollution that began after World War II was largely the result of major changes in science and technology, and lifestyles, particularly in the United States. New technologies meant we were able to create large quantities of readily available fertilizers from previously inert materials. It also meant we could generate new materials such as nylon that use nitrogen rich amino acids as a primary building block. New cleansers and detergents made shirts and dishes cleaner than ever, but contained large amounts of phosphorus. The ability to convert “inert” nutrient compounds into bioavailable forms for many uses began to grow exponentially.

Agriculture also began a change that has accelerated in the last two decades. Specialization, intensification, and concentration increased dramatically. In animal agriculture, particularly poultry, production concentrated into major production centers or regions.

The lifestyle change was no less significant. The combination of new fertilizers, improved genetics and rapid mechanization meant that more food could be grown with fewer people. Rural areas, that had lost population due to industrialization and the Depression, saw an ever greater migration to factory and office jobs in the city. Many people did not stay in the city but moved to “the new place” between the city and the country, the suburb. Nonproductive consumption of both land (for housing and commercial uses) and natural resources accelerated to per capita rates unprecedented in human history.

**Personal Nutrient Pollution**

People frequently ask “what is the source of nutrient pollution?” The answer is simple: people and their consumption choices and habits. One of the major issues facing the Chesapeake Bay is the rapidly expanding population due to people moving to the watershed, not childbirth. Each person brings with them a nutrient load that I term their personal nutrient pollution. There are obvious personal nutrient pollution sources like sewage and how we fertilize our home landscapes. A little less obvious are the products we use in our home. Ammonia as a cleaner and phosphate containing detergents are good examples.

Air pollution from our cars (and lawn mowers) is a major source of nitrogen pollution of water bodies. We own more cars and drive more miles every year with all projections for that trend to increase. Sports utility vehicles (SUVs) perhaps best illustrate our attitude about pollution in general (or nutrient pollution specifically). These large, gas-guzzling vehicles meet the qualification of a “truck” and are thus excluded from “fleet average” gas consumption requirements designed to improve energy efficiency in the US. These vehicles also have different pollution control requirements than automobiles. As a result, our most popular type of vehicle is really a “loophole” for car manufacturers to avoid environmental requirements. Belatedly, it appears the loophole will be closed.

We generate substantial nutrient pollution at the marketplace. Whether it is food waste, packaging wastes or the bright lights and signs, many types of nutrient pollution occur at the market place.
Nutrient pollution also occurs at the workplace. It can be through electrical consumption, production inefficiencies or wasting office products (eg. paper). Finally, we all demand certain levels of community service that generate nutrient pollution. Highway and street construction, ditches, stream channeling, school buses, schools and county seats are all sources of nutrient pollution that are there for us.

Land Consumption

There is another type of consumption, that nearly all groups agree is detrimental to the environment: land consumption. The per capita rate at which we convert land from a resource use of forestry or agriculture to a nonproductive commercial or residential use has been steadily increased since World War II. A few places are trying to slow the rate of land conversion but few are succeeding and none have stopped the loss of resource lands.

As of today, once we develop land, we only know how to make it more developed. It is lost from the resource base “forever.” I argue with my forester and environmental friends that they should work diligently to preserve both farm and forest land. There is a “purist” view that we should preserve forest land and let them develop the farm land. “Farm land is a major source of nutrient pollution while forests are our least polluting land use. Farm land is better than developed land but it can be sacrificed to protect forest.”

This argument is not necessarily based on false information but it would seem to be terribly short sighted. I argue that we must preserve as much farm land as possible for two good reasons. First, as long as land is in agriculture, it can be converted to forest, if society deems that appropriate. If we are producing too much food, we can selectively remove small to large amounts of land from production (a different version of the Conservation Reserve Program) and plant it to trees or other less polluting resource uses. We can selectively remove land that provides the greatest environmental benefit and/or are marginal for crop production. We may even wish to remove large tracts of agricultural lands in certain important watersheds.

The second reason to preserve both forest and farm land is that, globally, as many environmental nay-sayers like to point out, we must produce enough crops to feed a growing world. The more farm land, particularly prime land, that we preserve from development, the less marginal land must “be brought under the plow” and alternatively, the more forest/native lands that can be preserved.

I do not subscribe to the notions being put forward that we must feed all the world on an American diet, or that our rates of food (or resource) consumption can continue to increase at present rates. Residents of the United States currently represent less than 5% of the global population but are responsible for about one quarter of the consumption of natural resources (including food). I also do not believe that all alternative or “sustainable” agricultural production systems will necessarily result in drastic yield reductions.

I clearly disagree with the assumptions of those who argue that we cannot have both environmental protection and an agricultural production system to feed an expanding population. The global glut of agricultural products also suggests these assumptions are not valid in the short term. However, it must be recognized that global population will expand and agricultural production must meet whatever the food (diet) and fiber needs are for that population to exist reasonably.
The best way to be ready to feed that population while addressing environmental concerns, including nutrient pollution, is to minimize the loss of all resource lands, including farm land.

**Environmental Ethics and Responsibility**

The popularity of SUVs, discussed earlier, raises the question of personal/corporate ethics and responsibility as opposed to government regulation. During the last 30 years, it has been far too common for those who decry government regulation to also exploit every loophole available to avoid addressing environmental issues.

It can be argued that many individuals and corporations have used government requirements as a substitute for ethics and responsibility. If the government does not say it cannot be done, then it is acceptable. This is usually rationalized by the need to remain competitive and to produce at the lowest possible unit price. What is not explained is that we are not paying the real cost of many products, including food, but are avoiding, externalizing and subsidizing costs through environmental (and social) government programs and corporate decisions.

It is clear to me that individuals and corporations must act ethically and accept responsibility for environmental actions beyond government dictates. If not, the dire prognostications about unsustainable rates of resource consumption and impacts of (nutrient) pollution on our ecosystem may prove true.

We must recognize our role as a member of the ecosystem and our ethical responsibility to respect the air, water, soil, and biotic members of that ecosystem. Aldo Leopold (1949) described this as a “land ethic.” Leopold said that “a land ethic changes the role of Homo sapiens from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such.”

Somewhat ironically, Leopold’s essay was written at the beginning of the resource consumption binge we are still on today. It is equally interesting that Leopold, who died in 1948 prior to publication of The Land Ethic in A Sand County Almanac, has become so widely popular in the conservation community in the last two decades. Perhaps it has taken thirty to fifty years to recognize the lack of respect given to water, air, soil, and biotic as other rightful members of the “land-community.”

**Agriculture and Nutrient Pollution**

Research conducted during the last three decades have consistently suggested substantial losses of nutrients from agriculture to surface and ground waters (Logan, 1990). The increase in nutrient impacts appears to relate to both increases in fertilizer use and intensification and concentration of animal agriculture. In Iowa, Libra et al. (1987) found a good relationship between increases in fertilizer and manure use and groundwater nitrogen discharged from Big Spring.

The US Geologic Survey synthesized all monitoring data in the Chesapeake Bay watershed (Langland et al., 1995). This included analysis of 126 sites for which nutrient load data was available for more than three consecutive years. They found a strong positive relationship between high nitrogen and phosphorus loads and the amount of agricultural lands. Estimates of nitrogen
loads to the Gulf of Mexico by the Mississippi River indicate that agriculture is the dominant source (Giattina, personal communication). The abundance of data indicating that agriculture is a major source of nutrient pollution of surface and ground waters should not be a scientific surprise or an indictment of the American farmer. We have seen an enormous increase in the use of nitrogen and phosphorus in agricultural production in the last 50 years. During the same period, there has been intensification and concentration of confined animal operations, particularly in poultry.

Basic principles of plant growth, and economics, have taught us that as we approach maximum biomass production (crop yield), we get small yield increases for each additional unit of nutrient input. In fact, most still advocate that we increase fertilizer application as long as the revenue generated from yield increases is greater than the cost of the additional fertilizer.

I am not prepared to argue with the law of diminishing returns but I will argue that there may be more costs, particularly environmental, than just the cost of the additional fertilizer. We have clearly been aiming for yields on the “flat” upper end of the yield response curve. Plant nutrient use efficiency is not very high so substantial quantities of nutrients are left in the environment. This is further complicated by the “no risk” philosophy regarding nutrient use espoused by both the fertilizer industry and land grant university. This approach argues that since nutrients are inexpensive and crop yields are unpredictable, we should always apply enough nutrients to produce maximum possible yields. There are both economic and environmental consequences to this approach. Obviously, there will always be excesses in the environment following this philosophy. Economically if nutrients are purchased, or valued, we always lose money on overapplication of nutrients to avoid any risks of losing money to nutrient-limited yields.

It can be correctly stated that excess nutrients in the environment (in soils), do not necessarily result in nutrient pollution. However, at least in a humid climate, we farm in a naturally leaky system. Nitrogen, dominantly in the nitrate form for plant uptake, is highly mobile and leaches below the root zone and eventually through groundwater to surface waters. Many transformations could occur between root zone and river but the elevated levels of nitrogen in streams flowing from agricultural watersheds suggest much of it is surviving the trip.

Phosphorus was considered the easy nutrient to control until the last two decades. If we controlled erosion, we could control phosphorus loss, since most phosphorus was attached to sediment. Research in the 1970's (Sharpley et al., 1978) began to suggest that, at levels above agronomic optimum, substantial amounts dissolved phosphorus could be lost in runoff.

As the research base expanded, it became apparent that we would need to limit nutrient applications based on phosphorus. This was particularly critical for animal manures, where we were just succeeding at getting farmers to base manure application on nitrogen which resulted in over application of phosphorus. Poultry scientists were advised of the probability of the change to phosphorus based nutrient management a decade ago (Simpson, 1991).

There is now extensive data indicating that phosphorus losses to surface waters increase with increasing soil phosphorus levels (Sharpley, 2000). Areas receiving animal manures over a long period are most likely to have extremely high soil phosphorus levels. Thus, in our naturally “leaky” system, applications of both nitrogen and phosphorus at “maximum yield” levels result in substantial nutrient losses to surface waters.
Why is this not an indictment of the American farmer? To the extent that he did what science and society told him to do, it is. Society told the farmer we wanted a cheap, high quality and abundant food supply produced by a few people. Society did not emphasize (or perhaps recognize) environmental impacts until recently but now wants the farmer to address the environment without affecting the other three. A colleague, who works for a poultry processor, likes to say “pick three, any three, but not all four” with the implication that the environmental component cannot be one of the three. I argue it must be one of the four or we will eventually pay the true ecologic and economic costs of our “cheap” food policy. The real question is how cheap is too cheap?

Agricultural scientists provided the best knowledge available for the farmer to meet society’s challenge. We recommended nutrient rates that would not limit yield. Concentration and intensification were seen as progress by the scientific community with most public agricultural research geared to promote both. Much research had a principal focus on maximizing yields with no evaluation of environmental impacts. It did not always consider the economic well being of individual farmers and failed to evaluate the impacts of low profit margin agriculture on the net worth of rural communities. The farmer has responded well to science and society’s direction but has found himself with declining income, influence and respect, and increasing blame for environmental concerns, particularly nutrient pollution.

It is important to recognize that farmers had adopted many practices to reduce both erosion and nutrient pollution. Farmers were given financial and technical incentives to overcome the costs of such practices. For the most part, only practices that had no or positive impact on income were recommended. It was difficult to ask a “downsizing” group with limited income potential to take on costly new practices. I am afraid that we may have reinforced an observation Aldo Leopold (1949) made more than 50 years ago: “In our attempt to make conservation easy, we have made it trivial.” It is now difficult to ask farmers to meet some very challenging demands, particularly in this time of low prices and surplus commodities. Balancing nutrient use based on phosphorus and finding alternative uses for excess manure must be considered a part of the true costs of our food production system.

Ultimately, the costs must either be subsidized or paid directly by consumers. Environmental impacts are one of many concerns being raised about our “cheap food” policy that are likely to be debated during development of the next farm bill. Perhaps we need a formal national food policy that includes environmental impacts. I feel we must address agricultural nutrient pollution but, as we in Maryland know, it is difficult to do on a state by state basis.

Concentration and Intensification in Animal Agriculture

There has been tremendous concentration of confined animal production, particularly poultry, in regional centers during the last fifty years. The number of animals per operation has also grown dramatically. Data adapted by Coffey (1996) shows a relatively constant number of hogs produced from 1900 to 1993 but the number of farms raising hogs declined by nearly 20 fold. Poultry has seen major growth in total production and was the first animal industry to concentrate production in relatively small geographic regions. The concentration is driven by integration and efficiencies of locating production near processing and feed mill facilities.

Regional concentration has provided production efficiencies but it has also created regional nutrient imbalances. For example, a large part of the grain fed to poultry on Delmarva is grown outside the
production area. The result is that we have a surplus of waste nutrients in litter that were imported in feed grains. It may be possible to use all the litter for crop production on all of Delmarva, not just the poultry region, if application is based on nitrogen. It is clear that there will be substantial excess litter when we go to phosphorus based applications. This appears to be common in concentrated production.

Regional nutrient imbalances have principally developed since World War II. As farms have become less diverse, we have substantially changed the nutrient cycle from a more local, farm based cycle to a distant one directional path. Lanyon (2000) suggested that “the supply of balanced nutrients from off-farm following World War II shifted farm organization from an emphasis on biological feedback to other considerations, primarily economic incentives based on market transactions, and encouraged specialization in agricultural production.”

If waste nutrients were of sufficient value to return to the crop production region, there might not be a problem. If there were local high value alternative uses, there would be no problem. However, most animal waste nutrients are used on cropland near the production areas. High nutrient levels are common in both surface and ground waters in these areas (Logan, 1990, Langland et al., 1995).

Thus it is apparent to many in and out of agriculture that regional nutrient imbalances are an issue in concentrated animal production areas. Keith Rinehart (1996), recently retired poultry executive and nutritionist, known for his objectivity, said “Water pollution is the most damaging and widespread concern in regard to production agriculture, including the poultry industry... While the individual bird has become more efficient in the conversion of nutrients to meat or eggs, the large increase in animal units has led to an overall increase in environmental burden.” Regional nutrient imbalances are an environmental concern because we have not fully included the cost of waste management as part of the cost of animal production.

Summary

Technology and life styles have combined to immensely increase nutrient pollution in the U.S., and the developed world, during the last fifty years. Population growth and development and increased per capita resource consumption are the long term factors that influence nutrient pollution.

Modern agricultural production systems are major sources of nutrient pollution due to both their domination of the landscape in many watersheds and inefficiency of nutrient use in a “leaky” natural system. Concentration and intensification of animal production has created on-farm and regional nutrient imbalances. Monitoring and soil test data suggest the regional production centers are substantial sources of nutrient pollution.

Farmers have implemented many practices to address sediment and nutrient pollution. However, these practices must be acceptable to farmers within current production systems and economic conditions. The costs of waste management and environmental control have not been fully included in the cost of our food system. It is difficult to extract these costs from farmer/producers without passing these costs up the food system.

Every person who lives in or visits a watershed contributes to nutrient pollution of its waters. We also each contribute to nutrient pollution through lifestyle choices and resource consumption.
Agriculture is just one part of the problem, and solution, for nutrient pollution but an important one. It is critical that we work to address water quality issues so we can expect the same responsibility from all others.

REFERENCES


