Reducing Pesticides in Agricultural Runoff

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This presentation will discuss reducing pesticides in agricultural runoff. Specifically, four areas will be addressed: First, why are we concerned with pesticides in runoff? Second, how big of a problem are pesticides in the environment, with some data. Third, a quick discussion of the mechanisms through which pesticides move offsite. And finally, a quick overview of best management practices (BMPs) that can help reduce pesticide losses.
Why are we concerned with pesticide runoff? One issue is the toxicity of some pesticides to aquatic organisms if those pesticides leave the farm field and make their way to rivers or lakes. Some insecticides, for example are directly toxic to aquatic invertebrates and fish at relatively low concentrations. Other chemicals, like herbicides may affect aquatic plants. If those organisms at the bottom of the food chain, like aquatic plants, insects, tiny crustaceans or small fish are affected, that can disrupt the entire food chain since these creatures may serve as food sources for larger organisms. Some effects on these organisms are \textit{acute} in nature, meaning that a single quick dose of a pesticide can kill or harm aquatic life. Other effects can be \textit{chronic} in nature, meaning that even at very low concentrations a pesticide may cause death or harm to aquatic life if they are exposed for a long period of time. Finally, there is the effect of \textit{bio-magnification}. Since a small fish may eat many tiny insects, and a larger fish may eat many small fish, certain chemical substances can increase in concentration in the tissues of animals as they work their way up the food chain.
Why are we concerned with pesticide runoff?

- Hormone-mimicking effects

**In the news: March, 2010**
Atrazine induces complete feminization and chemical castration in male African clawed frogs (*Xenopus laevis*) [model organism]


A second concern is the hormone mimicking effects of certain pesticides in the environment. Not long ago in the news, for example, was a study about how atrazine—an herbicide commonly used in some agriculture—can cause males of certain frog species to become infertile or change into females. (In the study mentioned here, the African frog is a model species, but these effects occur in other frog species as well.) We can imagine how these types of effects could be catastrophic to the affected species as well as to the food webs and ecosystems in which they reside.
Why are we concerned with pesticide runoff?

- Drinking water and human effects
  - benchmarks exist for many organic compounds
    (US EPA, Drinking Water Standards and Health Advisories — MCL; health advisory for child: one day, child: ten day, cancer risk, etc.)
  - Public concern - speculation about low chronic doses

A third concern is the risk of pesticides getting into drinking water and the potential effects on people. Benchmark concentrations or standards for drinking water have been developed for many organic compounds including certain pesticides. These are the concentrations above which there may be risk to people drinking the water. Both the federal Environmental Protection Agency (US EPA) and the State of New Jersey have lists of these benchmark concentrations for some substances. They are determined for a variety of effects—such as cancer risk for one substance and kidney damage for another—and for different scenarios—such as a child drinking this concentration for one day or for ten days or an adult drinking this concentration for their lifetime. The US EPA uses the term *Maximum Contaminant Level, or MCL*, to indicate an enforceable concentration in drinking water.

A somewhat separate issue is public concern about pesticides in drinking water or the environment, some of which may not be based on good science but instead on speculation about what effects people imagine chronic exposure to low concentrations could have people.
Why are we concerned with pesticide runoff?

- Regulatory benchmarks and concentrations for aquatic toxicity or human health can be quite low: parts-per-million, parts-per-billion, parts-per-trillion.

It should be noted that the regulatory benchmarks for pesticide concentration either in the environment or in drinking water can be quite low: in the range of parts per million, parts per billion, or even parts per trillion.
This is part of a table of regulatory limits for drinking water, from the USEPA, 2009 Edition of the Drinking Water Standards and Health Advisories. I've circled glyphosate (Roundup) here just as an example. The table indicates that the maximum contaminant level (MCL)—the enforceable limit—is 0.7 milligrams per liter (mg/L, or parts per million). The maximum concentration recommended for a child for one day of drinking water is 20 milligrams per liter. And for cancer risk, it’s “Not classifiable as to human carcinogenicity”, which means there isn’t sufficient evidence that is carcinogenic, but also not sufficient evidence that it isn’t.

Where do pesticides in the environment come from?

- The question is always asked: How does the risk of water pollution from agriculture compare to other land uses?

- The simple answer: considering all the variables and limited research, it’s difficult to answer...

Fairly commonly people ask about how the risk of water pollution from agriculture compares to other land uses. The simple answer is that the answer is not very simple, whether you are thinking about pesticides or about fertilizers or some other potential pollutant. There are many variables, site-specific considerations, and different management practices that can affect the potential for having pollutants in runoff, whether you’re talking about a corn field or a home lawn.
There are several non-agricultural sources of pesticides in the environment. In residential and urban settings, pesticides may be used for structural pest control, which may be sprayed outside the home. Applications to lawns or gardens may be common and may be applied to relatively large areas. Other areas such as golf courses, parks, and business properties may also receive relatively frequent and widespread applications. Applications to residential and urban areas may be increasingly important in considering sources of environmental water quality, since there is increased concern about the pyrethroid insecticides in the environment that are often used in these areas. Other non-agricultural uses include applications to roadsides, ditches, railways, and similar areas.

It is important when considering these sources to keep in the mind the concept of *non-point source pollution*. Often there is not a single culprit in a watershed, but small amounts of a pollutant can come from many and varied sources. Each property may contribute only a small amount, but in aggregate these small amounts may be enough to be a water quality issue in the local river or lake.
Where do pesticides in the environment come from?

Extent of the problem

- National NAQWA study of streams, 1997–2001
- Study area included all of NJ
- "Developed watersheds": agricultural, urban, or mixed land use
- Included legacy organochlorines (DDT et al.)
- Pesticides commonly found in water, bed sediment, and fish tissue (90% of the time)
- Pesticides found in > 50% of shallow wells below developed areas

Note: current focus for agricultural runoff in NJ is phosphorus and fecal bacteria (not pesticides)
Drinking water systems are tested for pesticides, though.


In order to give you some sense of the extent of pesticide contamination of natural waters, and to explore the role agriculture may play in this, I’m going to present some data from a national study conducted by the U.S. Geological Survey from 1992 to 2001. The data’s a little old now, but there aren’t many comprehensive studies on pesticide contamination. The study area included New Jersey and other watersheds throughout the nation. It looked at agricultural, urban, and mixed use areas, and included analyses for legacy pesticides, such as DDT. Results indicated that pesticides were commonly found in river water, river bed sediment, and fish tissue, and that pesticides were found more than half the time in shallow wells.

It should be noted at this point that the current focus concerning agricultural runoff in New Jersey includes phosphorus, nitrogen, and fecal bacteria. Other states, notably California, have invested more effort investigating pesticide runoff from agriculture. In New Jersey, though, drinking water systems are tested for pesticides, so the potential exists for the state to become more concerned if problems are found.

A map showing the studied areas. Note that New Jersey and nearby regions are significantly represented in this study.
This plot shows bar charts of how frequently pesticides were detected in water. Looking at the two blue bars in the top yellow box, the top bar indicates that pesticides were found in 97% percent of samples in stream water in agricultural areas. The second bar indicates that pesticides were found in 61% percent of samples in shallow groundwater in agricultural areas. For comparison, the next two bars down with the pink background show the same data for urban areas. These indicate that for urban areas, pesticides were found 97% of the time in stream water and 55% of the time in shallow groundwater. These data suggest that pesticide contamination of water resources is equally a concern in urban as in agricultural areas.
This plot shows data just for organochlorine pesticides, most of which are legacy pesticides like DDT, aldrin, and chlordane that are no longer used. Looking at the top two bars with the yellow background, they show that for agricultural areas, organochlorine pesticides were found 92% of the time in fish tissue and 57% of the time in river bed sediments. This suggests that those legacy pesticides, since they have long residuals in the environment, are still commonly found in the environment. The next two bars down with the pink background show the same data for urban areas, and indicate that for urban areas, organochlorine pesticides were found 94% of the time in fish tissue and 80% of the time in river bed sediments. Again, contamination of water resources by legacy pesticides is equally a concern in urban as in agricultural areas.
This plot shows the frequency that water samples exceeded human health benchmark concentrations. By “exceeded” we mean that the sample had more of a contaminant than is allowed by the benchmark. For both agricultural areas and urban areas, and for both stream water and shallow groundwater, pesticide concentrations exceeded benchmarks for human health less than 10% of the time. Note here that the previous slides were simply if pesticides were detected at all, but this slide is also considering the concentrations of those detected pesticides. It should also be noted that these results should be interpreted cautiously, since there may not have been benchmark concentrations established for some given pesticide even if it is in fact harmful to ingest. Also, we may not know if a set of pesticides has synergistic harmful effects. That is, if ingesting a bunch of different pesticides at low concentrations is just as harmful as ingesting one at a higher concentration. Finally, it should be noted that finding exceedances in 1% or 5% of shallow groundwater samples may not be trivial in considering public health.
This is a similar plot to the previous one, except that it considers aquatic life benchmarks instead of those for human health. Also, it considers river bed sediment instead of groundwater.
This is the last plot I’ll show from this study, showing detections for specific pesticides in streams. Note that all the bars on the left are for agricultural areas, and all the bars on the right are for urban areas. The darker bars indicate the portion of samples where that pesticide was detected at a concentration greater than 0.1 micrograms per liter (or parts per billion). This plot suggests that herbicides were commonly detected. One reason this may be is that we use more herbicides by weight, and they tend to be water soluble. Some insecticides stick to sediments or organic matter, and so may not move offsite as readily.
This next section will discuss the ways pesticides move off an agricultural field and into the surrounding environment.
Pesticides will tend to move offsite with water or wind. Many pesticides will stick to soil particles or plant debris. These pesticides can then be transported offsite if rain or irrigation creates runoff that carries these soil or plant particles offsite, and potentially through ditches or storm drains to nearby rivers or lakes. Other pesticides tend to be more water soluble. These can also be carried with any runoff water. Pesticides that tend to move with runoff are said to have a high runoff potential. Some pesticides are able to move through the soil with infiltrating water. These pesticides could then be leached down into shallow groundwater, which may then move to nearby streams or lakes, or could be leached deeper into groundwater that may be pumped for use as drinking or irrigation water. Pesticides that tend to move by leaching through soils are said to have a high leaching potential.

Pesticides also commonly move off target carried by wind or gentle air currents. This is called drift, and can be a significant source of pesticide losses, especially in windy conditions.

It should be remembered also that spills, leaks, and misapplications have the potential to produce significant pesticide losses.
In general, pesticide losses from agricultural lands are low: commonly less than one percent, or up to a few percent depending on the product and the conditions during application. The exception to this is when there is some kind of misapplication, such as applying before a large rain, or at incorrect rates or locations.
How do pesticides move offsite?

- Leaching potential
  - higher for water-soluble products
  - higher for products with a low tendency to adsorb to soil and organic material
  - herbicides often have these properties

- Runoff potential
  - product could move offsite dissolved in water
  - or product could move attached to soil particles or organic matter
  - many products tend to stick to soil particles, so move with sediments (incl. insecticides)
  - persistence – products with a longer residual have a greater chance to eventually move offsite

Leaching potential—the likelihood that a pesticide will move by leaching down through the soil—in general will be higher for water soluble products and those that have a low tendency to adsorb to soil particles and organic matter. Some herbicides have a higher leaching potential than some other pesticides.

Runoff potential—the likelihood that a pesticide will move offsite with runoff or stormwater—can be high for persistent products—those with a long residual, which may eventually move offsite. Products that are either water soluble or have a high tendency to stick to soil and organic particles can move offsite with runoff or stormwater. Some insecticides tend to stick to soil or organic particles, so move offsite with these particles if they move offsite.
Losses from product drift are more likely if there are windy conditions during application, but a pesticide can also move offsite if there is wind erosion of soils that have applied product.

The environmental risk of a pesticide doesn’t depend simply on the likelihood that a product will move offsite, but also on the environmental toxicity of the product and its persistence. Legacy chemicals like DDT and other organochlorines are relatively toxic and relatively very persistent in the environment, so even decades later, small amounts getting into streams or lakes today is problematic. In contrast, short-lived, low-toxicity products represent little risk to the environment.

You can look up the leaching potential, runoff potential, and toxicity of specific products on the PesticideWise website hosted by the University of California, Riverside. (http://www.pw.ucr.edu)
The next section of this presentation will discuss preventing pesticide losses. It will be only a very broad overview of Best Management Practices, or BMPs. The best practices for any particular application will depend upon the specific conditions of the site, the crop, the pest involved, and the product to be used.

One group of methods to prevent pesticide losses can be considered *source control* methods—that is, methods that prevent the product from leaching or getting into runoff in the first place. These methods are often used consistently by farmers, since following these good practices usually means better crops and lower pesticide costs.

First, it is important to know the product. The product label gives information about using the chemical effectively, and also minimizing environmental losses.

Second, following an integrated pest management approach (IPM) can reduce pesticide use while effectively controlling pests. While a full discussion of IPM is beyond the scope of this presentation, key elements include correctly identifying pests, determining if the level of pest pressure is sufficient to warrant undertaking any control measures, choosing products and control measures carefully, and keeping good records.
During applications, drift losses can be prevented by not applying in windy conditions, using wind breaks to prevent widespread drifting, and maintaining soils and soil cover to prevent the wind erosion of soils.

Leaching and runoff can be avoided by not applying product before heavy rains, controlling irrigation to avoid excessive leaching or runoff, and following label instructions if they call for delaying irrigation after product application.
Losses can be minimized by avoiding misapplication of pesticides, such as applying them to roads or waterbodies, or at incorrect rates. Calibrating sprayers and spreaders, and checking for uniform application is helpful in ensuring proper product rates. Consider using improved application techniques such as application through drip irrigation systems or banded spraying, where appropriate.

All good cultural practices should be followed to maximize crop health and lower the need for pesticide applications. These practices include have appropriate drainage, nutrient management, irrigation, soil conditions, crop rotations, and plant spacing.
Since spills can be a significant way pesticides could enter the environment, proper storage and spill management for pesticides are essential. Pesticides should be stored indoors, protected from weather, and in an area with impermeable floors. Storage facilities should be kept locked. Pesticides should be kept in original containers with intact labels, and liquid pesticides should have a secondary storage container in case the main container leaks or spills. Spill kits should be available, and employees should be trained for what to do in case of a spill. Containers should be disposed of properly.
Preventing Pesticide Losses

Erosion and runoff control

- Prevent erosion
  - Use cover crops, minimum till, mulch, etc.
  - Amend soils or use other techniques to keep soil organic matter at appropriate levels
  - Protect roadways and other non-cropped areas
  - Use best practices on slopes, such as contour farming

Since pesticides can move offsite with soil particles eroded by wind or water, preventing soil erosion is integral in minimizing pesticide losses. Soil erosion can be minimized by using cover crops, minimum till practices, or practices that minimize exposed soils; amending soils with organic matter or composts where needed; protecting roads and other non-cropped areas with gravel, mulch or other soil-erosion-prevention measures; and using good practices on slopes like contour farming, to minimize soil erosion in those areas.
Because the major potential pathway of many pesticides moving offsite is with runoff and stormwater, managing the flow of this water is helpful in preventing pesticide losses. The first steps in agricultural stormwater management are determining where stormwater would run on to the site and where it would run off. The site should be investigated for problems, such as stormwater causing soil erosion. If there are problems, specific issues could be addressed—for example, using mulch or vegetation to minimize soil erosion where the water flows. If possible, also, water running onto the property could be diverted around the agricultural site.
Preventing Pesticide Losses

Erosion and runoff control

• Treat runoff and stormwater
  - Filter runoff and retain sediments with vegetative buffers, filter strips, straw wattles, synthetic hay bales
  - Also, ponds, impoundments, wetlands
  - Use rock protection, erosion control blankets, vegetation, gravel, or mulch to stabilize waterways

Runoff could also be treated before it leaves the site. Using vegetative buffers, filter strips, or straw wattles to remove sediment from problem water flows will help prevent any carried pesticides moving offsite. Likewise, ponds, impoundments, and wetlands help capture sediment and remove any pesticides. Protecting roads and waterways with vegetation, rocks, erosion control blankets, or gravel can prevent soil erosion from these areas.
Preventing Pesticide Losses

- Consider additional conservation practices and structural improvements

There are several resources which discuss conservation practices and structures in more detail. One to consider is a manual called *On-Farm Strategies to Protect Water Quality*, developed by the New Jersey Association of Conservation Districts, [http://www.nj.gov/agriculture/divisions/anr/pdf/BMPManual.pdf](http://www.nj.gov/agriculture/divisions/anr/pdf/BMPManual.pdf). Also consider contacting the Natural Resources Conservation Service (NRCS) or Farm Service Agency (FSA) to see what conservation programs may be appropriate for your operation.
Social considerations

• There has been increased public interest in the ecological role played by agricultural production

• The positive aspect of this is that more people are interested in where and how their food is produced... support for domestic, local, sustainable produce and goods

• The negative aspect is that these may lead people to the conclusion that agriculture — or “traditional agriculture” — may cause pollution through excessive use of chemicals

The final few slides in this presentation will briefly cover some social and regulatory considerations concerning pesticides in agriculture. On the social side, in recent years there has been an increase in public interest in the ecological role that agriculture plays. This interest can be seen in the rise of local food movements, community-supported agriculture, popular books and movies about agricultural production, and markets for organic and ecologically-minded products. The positive aspect of this interest is that more people are interested in where and how their food is produced, which in turn supports domestic agriculture and local production. The potential negative aspect of this interest may be that it could lead people to view “traditional agriculture” as causing pollution through agricultural chemical use.
Consider the regulatory environment surrounding agricultural pesticide use: For the most part, any pesticide losses from agriculture are considered non-point source pollution. Any pesticides in the environment could come from a diverse number of sources—that is in this case, many different farms—with any one potentially contributing only a small portion of the total. There is no single spot to monitor, like a discharge pipe from an industrial facility. Therefore it is difficult to construct fair and reasonable ways to regulate.

Note that some agricultural operations, like concentrated animal feeding operations (CAFOs) could be considered point-sources and fall under different kinds of regulations from general agriculture.
At the federal level, the primary legislation behind water quality regulations is the Federal Clean Water Act. In this law, agriculture is largely excluded from most of its provisions, with the states accepting this responsibility. Under the section covering non-point source pollution, states are charged with determining if specific rivers and lakes are not meeting water quality objectives. The states then go through a process of determining total maximum daily loads (TMDLs) for that waterbody, which indicate the sources of pollutants and the amount of reduction in loading of pollutants. For agriculture, states have tended to rely on education and voluntary programs to address any issues with agriculture and water pollution, though they may use regulatory approaches consistent with state law. New Jersey has several TMDLs developed for waterbodies across the state, some of which include agriculture as a potential source. Most of the developed TMDLs are for phosphorus or fecal contamination, with some for mercury, arsenic, or other pollutants (the list can be obtained from [http://www.nj.gov/dep/wms/bear/tmdls.html](http://www.nj.gov/dep/wms/bear/tmdls.html)). Pesticides, however, are considered in determining fish consumption advisories—these are historic pesticides and by-products DDT, dieldrin, chlordane, dioxin. And pesticides may also play a role in cases where biological life criteria are not met, but the specific cause is unknown.
At the state level, regulation or enforcement is often spurred by lawsuits. A successful lawsuit, for example, in California claiming that the state was not following its own water quality laws, motivated state regulators to initiate an agricultural water quality program. This program varies around the state, but includes water quality monitoring—including pesticides—and requires farmers to attend educational classes on water pollution prevention in some regions. It is not known ultimately what regulations the state will impose on agriculture to satisfy this lawsuit.

One estimate puts the number of states with some type of regulation preventing water pollution from agriculture at 33, and there has been a trend in recent years of states attempting to address non-point source pollution of water more seriously in recent decades.
Other laws concerning pesticides and agriculture include FIFRA (the Federal Insecticide, Fungicide, and Rodenticide Act), which is the primary federal law concerning pesticides in agriculture, and is concerned with pesticide registration, labeling, and compliance.

A current New Jersey state law regulating potential water impairments from agriculture is the Animal Waste Management Rule, which regulates the storage and land application of livestock manures.