Pesticides in the Aquatic Environment

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Water: our most precious natural resource

- Clean water is essential to human health and healthy aquatic ecosystems

Fisheries and Aquatic resources

- Highly valuable natural assets enjoyed by millions of Americans

Protecting our aquatic resources

- Concern over effects of human activities on water quality and aquatic life
- Pesticides are one group of toxic compounds that can have a profound effect on water quality and aquatic life
- Understanding how to prevent pesticides from entering our aquatic systems is necessary to protect our watersheds

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What is a watershed?

- **Watersheds** are the land area that contributes water to a specific water body, such as a pond, lake, wetland or catchment area
- Simply an area of land that drains the rainwater (or snow) into one location, such as a stream, lake, wetland, ocean

Photo taken by D.E. Cowley

- **Watersheds** vary in size and shape from a few square miles to thousands of miles
- Every stream, tributary, or river has an associated watershed, and small watersheds join to become larger watersheds
- Also called **Drainage Basins**

D.E. Cowley

Rio Grande


NORTH
WEST
Eugene
Boise
IDAHO
MONTANA
Sheridan
Grand Teton 13,771 ft
WYOMING
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
Minneapolis
Rochester
Sioux Falls
Cedar Rapids
Des Moines
Green Bay
Milwaukee
Rockford
Chicago
Michigan
MICHIGAN
Lansing
Detroit
ONT.
Fort Wayne
IND.
Columbus
Peoria
Terre Haute
OHIO
Indianapolis
NEBRASKA
Lincoln
Omaha
MISSOURI
Springfield
Columbia
Louisville
KANSAS
Topeka
St. Louis
ILL.
KY.
Evansville
Clarksville
Nashville
Reno
Sacramento
Salt Lake City
UTAH
Cheyenne
Denver
Colorado Springs
San Jose
Fresno
Mount Whitney 14,494 ft
St. George
Las Vegas
UNITED STATES
COLORADO
Wichita
Springfield
Joplin
OKLAHOMA
ARKANSAS
Memphis
Tulsa
Huntsville
Atlanta
Macon
Amarillo
Lawton
Oklahoma City
Little Rock
Birmingham
San Jacinto Peak 10,804 ft
Los Angeles
CALIF.
ARIZONA
Phoenix
NEW MEXICO
Rio Grande
Mexicali
San Diego
Ensenada
Tucson
Lubbock
Paris
Montgomery
Dallas
Monroe
Jackson
ALABAMA
Dothan
GA.
Abilene
Waco
Tyler
LA.
MISS.
TEXAS
Nogales
Ciudad Juárez
Baton Rouge
Mobile
SONORA
Austin
Lafayette
New Orleans
Nuevo Casas Grandes
Hermosillo
CHIHUAHUA
Houston
San Antonio
Guaymas
Ciudad Obregón
Chihuahua
Piedras Negras
Laredo
Hidalgo del Parral
Monclova
Ciudad Anáhuac
Gulf of Mexico
Los Mochis
Guasave
Torreón
Monterrey
DURANGO
Saltillo
Culiacán
MEXICO
Ciudad Victoria
San Fernando
La Paz
Durango
Tropic of Cancer
Mazatlán
Zacatecas
San Luis Potosí
Tampico
PACIFIC OCEAN
Aguascalientes
Mérida
Tepic
León
Bay of Campeche
Querétaro
Guadalajara
Campeche
Morelia
Puebla
Colima
Mexico City
Villahermosa
CAMPECHE
Chetumal
GUERRERO
OAXACA
BELIZE
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120°
115°
110°
105°
100°
95°
90°
85°
40°
35°
30°
25°
20°

Watersheds

- We ALL live, work and play in a watershed.
- Because water moves downhill, any activity that affects the water at one location can affect locations downstream.
- What we do affects EVERYTHING and EVERYONE else in the watershed

Photo taken by D.E. Cowley

Pesticides use in U.S.

- Approx. 1,000,000,000 (1 billion) lbs of pesticides used each year in U.S. alone
- Currently there are 11324 pesticide products registered in New Mexico (NMDA website)
- 1572 products for controlling broadleaf weeds in NM alone

Most commonly used pesticides in NM

Pesticide	Amount Used (LBS) (1997, NCFAP)
1,3-D	1,066,983
ATRAZINE	243,778
2,4-D	188,773
METOLOCHLOR	138,825
SODIUM CHLORATE	119,673
CHLORPYRIPHOS	82,912
PENDIMETHALIN	57,469
PROMETRYN	50,997
ALACHLOR	50,345
TRIFLURALIN	47,392
BENEFIN	47,010
MALATHION	42,883
TRIBUFOS	31,210
GLYPHOSATE	19,905

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Pesticides in our waters

- A percentage of these compounds leave the site of application and move off-site , ending up in surface and groundwater.
- As a result of this, pesticides are widely found in rivers, streams, lakes and even in drinking water

Movement and fate of pesticides

- Estimated that often less than 0.1 percent of a pesticide that is applied reaches target pest*
- 99.9 percent is an unintended environmental pollutant
- Ends up in soil, air, nearby vegetation and **water**
- Can pollute immediate area or move off site via drift, volatilization, leaching and runoff

*Pimental, D. 1995. Amounts of pesticides reaching targets pests: Environmental impacts and ethics. J. of Agr. & Env. Ethics 8:17-29

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Routes by which pesticides contaminate the environment

DRIFT:

Definition:

Pesticides are carried away from the target area by wind or air

Impact:

Can account for 2 to 25% of the chemical being applied. Can spread over distances from a few yards to several hundred miles.

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Routes of Contamination

VOLATILIZATION

Definition:

Pesticide evaporating from target area, and vapors/fumes in air can move away from site and be re-deposited on non-target site

Impact:

Volatilization is a major route of dissipation for some pesticides. Up to 90% of some pesticides volatilize from soil and water within a few days of application.

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Routes of Contamination

LEACHING

Definition:

The movement of pesticides through soil due to water movement

Impact:

Can lead to contamination of groundwater. Under certain conditions many pesticides can leach through soils.

Routes of Contamination

RUNOFF

Definition:

Rainfall and watering wash pesticides off plants or soil into storm drains and nearby waterways.

Impact:

Runoff from treated soils or lawns/landscape can contaminate surface water.
Example: One study found that up to 90% of the 2,4-D applied to turf was lost in runoff from a storm a few hours after its application.

Surface water contamination

- Widespread contamination of water by pesticides
- Results of USGS studies on major river basins across country showed >90% of water and fish samples from all streams had one, or more often, several pesticides
- Found in all samples from major rivers with mixed agricultural and urban land uses, and 99% of samples from urban streams

(Gilliom et al. 2006. The Quality of our Nation's Waters-Pesticides. U.S.G.S. Circular 1291)

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Frequently detected pesticides

- Among the 21 pesticides most often detected across the nation:
  - Herbicides: atrazine, 2,4-D, diuron, and prometon
  - Insecticides: chlorpyrifos, diazinon, carbaryl, malathion
- Many still commonly used by urban homeowners and school districts
- Trifluralin and 2,4-D found in water samples collected in 19 out of 20 river basins studied

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Concentrations greater than human health benchmarks (thresholds)

- Specifically, pesticide concentrations exceeded one or more human-health benchmarks in about 10 percent of agricultural streams, 7 percent of urban streams, and in 1 of the 65 mixed-land-use streams sampled by NAWQA.

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Concentrations greater than aquatic life benchmarks

- Of 186 stream sites sampled nationwide, 57 % of 83 agricultural streams, 83 % of 30 urban streams, and 42 % of 65 streams with mixed-land-use watersheds had concentrations of at least one pesticide (usually more) that exceeded one or more aquatic-life benchmarks

Water quality in the Rio Grande Valley: *Surface water*

- One or more pesticides were detected at 94% of the sites sampled in the Rio Grande and its tributaries, or drains.
- Include carbofuran, metolochlor, diazinon, Dacthal
- No pesticide concentrations detected exceeded EPA drinking water standards or state or federal guidelines (mixtures are not tested).
- Concentrations of DDT and its metabolites in sediment and whole fish confirms the persistence of this pesticide in the environment

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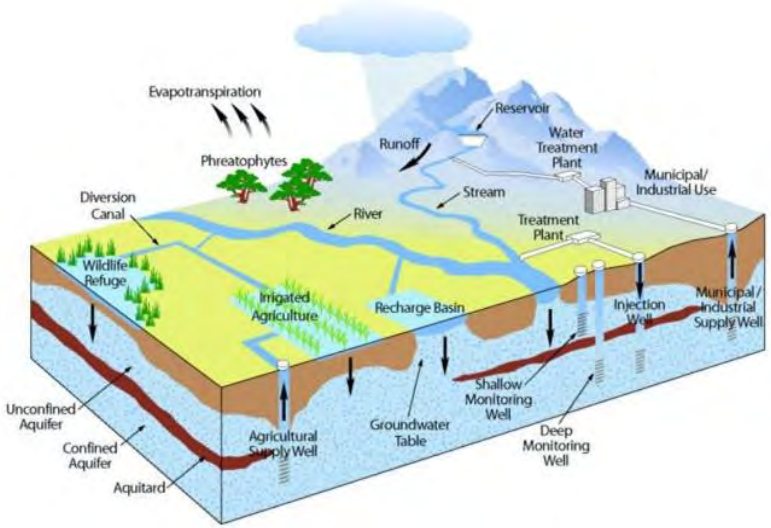
Importance of groundwater

- Groundwater is an important water source for all of us (50% of drinking water in US)
- The US uses about 77,500 million gallons of groundwater each day for all kinds of uses
- Approximately 90% of NM population depends on groundwater for drinking water



Ground water contamination

- Once groundwater is polluted it may take years-decades for contamination to dissipate
- At least 143 pesticides and 21 transformation products have been found in groundwater (USGS, 2006)
- Detections have been found in groundwater of more then 43 states.

Water quality in the Rio Grande Valley: *Groundwater*

- Pesticides were detected in ground water samples from shallow wells
- Samples from deeper groundwater (more typically used as drinking water source) contained one pesticide (prometon)
- Prometon and metolochlor were most frequently detected, although neither exceeded EPA drinking water standards.
- However, standards do not exist for all pesticides detected, nor for common <u>pesticide mixtures</u>

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Recap: Percentage of samples taken from urban areas across the US that contained 1 or more pesticides (USGS 2006)

- Fish: 100%

- Streams: 99%

- Shallow groundwater: 40%

Why are pesticides of interest?

- Concerns about the potential adverse effects of pesticides on human health and the environment via contamination of aquatic systems.

- Water is one of the primary means by which pesticides are transported from application site to environment.

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Some Environmental Problems associated with Pesticides in water

- Aquatic microorganisms affected
- Pyrethroids and stream sediments
- Fish and endocrine disruption
- Decline of amphibians
- Fish kills

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Aquatic Toxicology

- The study of the effect of environmental contaminants on aquatic organisms
- A pesticide's capacity to harm fish & other aquatic organisms is a function of:
  1. Toxicity
  2. Exposure time
  3. Dose /concentration
  4. Persistence

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Toxic effects

Lethal: cause death

LC50 = Concentration which causes death in 50% of the test organisms (mg/L or ppm)

- **Minimal : > 100**
- **Slight: 10 - 100**
- **Moderate: 1 - 10**
- **High: 0.1 - 1.0**
- **Extreme: 0.01 - 0.1**

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Toxic effects

Sublethal effects: Does not cause immediate death, but repeated exposure can reduce survival by:

- Reduced egg production and hatching
- Nest and brood abandonment
- Lower resistance to disease
- Decreased body weight
- Hormonal changes
- Reduced avoidance of predators

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Effects of pesticides on non-target aquatic organisms - fish

- Of the 30 commonly used lawn pesticides, 24 are toxic to fish and aquatic organisms
- Ex. Trifluralin (Snapshot) is highly to very highly toxic to both cold and warm-water fish and causes vertebral deformities in fish
- Ex. Chlorpyrifos, a common contaminant in urban streams, is very highly toxic to fish

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Effects of pesticides on <u>other</u> non-target aquatic organisms

- 2,4-D or 2,4-D containing products shown to be harmful to newts, frogs, crabs, shellfish
- Trifluralin is moderately to highly toxic to aquatic invertebrates, and highly toxic to shrimps and mussels
- Atrazine and alachlor damaged cells, blocked Ps and stunted growth of stream algae and diatoms

Example: Prometon -triazine

Ecotoxicity	***Effects noted***
Aquatic plants →	Population
Crustaceans →	Behavior, morphology
Fish →	Accumulation, development morphology, hormones, reproduction, mortality
Molluscs →	Intoxication, morphology
Zooplankton →	Intoxication, mortality
Phytoplankton →	Physiology, population, reproduction

Additional considerations

- **Mixtures** and **breakdown products** of pesticides occur in environment
- Additive or synergistic effects unknown
- “inert ingredients” in formulations protected by trade secrets and as such not tested
- Can sometimes be more toxic than active ingredients, and include carcinogens, teratogens, neurotoxins

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Example of importance of formulation

Glyphosate and Roundup

- Roundup surfactant (POEA) approx. 3X as toxic as glyphosate (on a weight basis)
- LC50 (Roundup) fathead minnow: 97 mg/L
- LC50 (Glyphosate) fathead minnow: 2.3 mg/L
- LC50 (POEA) fathead minnow 1.4 mg/L

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Additional considerations

- Some pesticides are known, probable or suspected **Endocrine disruptors** (hormone disruptors).

<u>Example: Atrazine</u>

Ecologically relevant doses of atrazine (≥0.1 ppb) produced gonadal abnormalities, chemical castration, feminization in frogs.

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What characteristics of pesticides influence how they act once in soil?

- Water solubility – refers to the ability of the chemical to dissolve in water. Affects mobility.
- Half life – refers to the length of time it takes for half of the pesticide to degrade. Affects persistence. Influenced by soil moisture, soil T^o, microbial population, etc.
- Soil adsorption coefficient (Koc) – refers to the tendency of pesticides to bind to soil particles. The more they bind, the less likely to leach into groundwater. Also affects mobility

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Half –life and Persistence in soil of some herbicides used in urban landscapes

Pesticide	**Product names**	**Koc (µg/g)**	**Half-life (days)**	**Water solubility (mg/L)**	**Leaching potential**
Glyphosate	Roundup	24,000	3-141	900,000	Ext. low
Dichlobenil	Casoron Norosac Barrier	400	60	21.2	Moderate
Clopyralid	Confront Transline Stinger	6	40	300,000	Very high
Orzyalin	Surflan	600	20	2.5	Low
2,4-D	Weedone	20	10	796,000	Moderate

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What management practices influence leaching and runoff of pesticides?

- Application rates

- Irrigation Regimes

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Reducing the Risk

1. Use a pesticide only when necessary
2. Use less toxic pesticides
3. Use Safe/Sensible Application Methods

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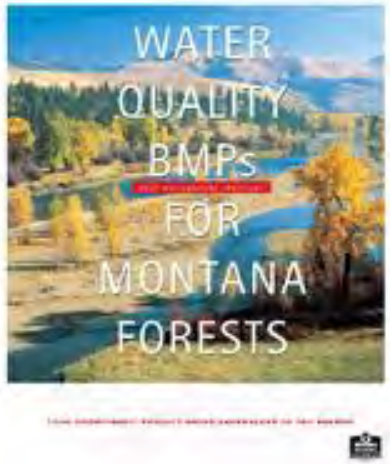
Best Management Practices (BMPs)

- Science-based holistic environmental management approaches aimed at reducing the possibility of pesticides and other chemicals and sediments of moving off treated areas into receiving water bodies



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BMPs: cultural practices

- Establish and maintain untreated buffer strips (10 to 50 ft) between treated areas and receiving surface waters to help prevent runoff of pesticides

- Weed control and tolerance: use of alternative control methods such as cultivation, and allowing some weed growth

BMPs: Pesticide use

- Control the rate, method, timing and type of chemicals being applied

Rate of pesticide application

- Use the appropriate (not excessive) pesticide rates. Use <u>as needed only</u> and eliminate routine maintenance programs.
- Adopt an integrated pest management (IPM) approach to use the least amount and least toxic of pesticides possible to achieve acceptable pest control.

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Type of pesticide

When possible, select pesticide based on:

- Lowest toxicity to humans, mammals, fish, birds and other invertebrates (bees)
- Aquatic toxicity should be low (high LC50)
- Rapid degradation and low leaching potential (e.g. higher soil adsorption, lower water solubility, shorter half-life)
- Lowest persistence (the more persistent, the greater chance of off-site movement via leaching or runoff)

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Type of pesticide

- Develop management programs that use pesticide (and fertilizer) formulations that have LOW runoff potential (e.g. liquid applications rather than granular formulations of pesticides)

Useful websites to learn about pesticide properties

- National Pesticide Information Center (NPIC) (http://npic.orst.edu/)
- Crop Data Management System (CDMS) database (http://www.cdms.net/)
- Extension Toxicology Network (http://extoxnet.orst.edu/)

Reduce risk of pesticide drift by:

- Using low volatility pesticides
- Using low pressure
- Using higher volume
- Using the largest spray nozzles and tips practical
- Spray as close to crop or soil as possible
- Not spraying at high temperatures or high winds

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Method and Timing

- Avoid pesticide applications just before anticipated rainfall events or when soil moisture conditions are high, or when very windy
- Prevent run-off by managing irrigation so application rates do not exceed infiltration capacity of the soil (i.e. water according to evapotranspiration and soil moisture)
- Do not apply pesticides in an area that is greater than can be quickly and efficiently watered in

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Summary

- Pesticides often considered a quick, easy solution for controlling weeds and insect pests

However, their use comes at a cost:

- Pesticides have contaminated soils, air, and surface and groundwater across the nation
- Pose significant risk to the environment and non-target organisms

We all need to do our part to reduce pesticide contamination through BMP practices and an overall reduction in reliance on chemical pest control

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