Fate and Transport of Hormones & Antimicrobials

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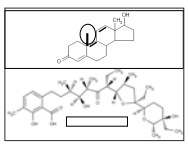
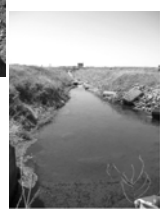


Basic Properties & Source Concentrations*

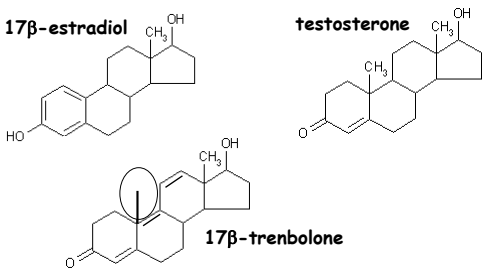
Fate Processes



Transport Processes

2

Hormones: Natural & Synthetic Estrogens & Androgens



Hormones are weakly polar compounds that do not exhibit a charge (0) in the environment

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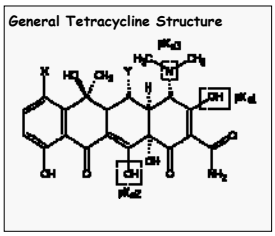
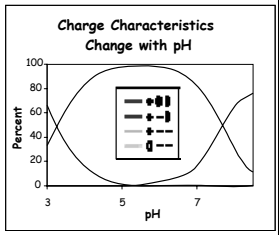
Antimicrobials (antibiotics and antiparasitics) range in size and polarity, and their behavior in soil and water is depend on acidity (pH).





Antibiotics can exhibit a positive charge (+), a negative charge (-), both charges (+ -) at the same time, or no charge (neutral) depending on pH (a measure of acidity).

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Large portions of antibiotics are not adsorbed or degraded by the animal, thus excreted in feces and urine

Antibiotic	excreted	mg/kg or mg/L (in near fresh manure)
Tetracyclines	75 – 80 %	<1 to 200 beef, swine, poultry
Monensin	50 – 90 %	1 to 5 cattle
Tylosin	50 – 90 %	3 to 8 swine

Natural hormones are also excreted in feces and urine

5

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Manure is land-applied based on N needs
Swine manure: 65,000 to 130,000 lbs/ha
~1 to 3 % mass relative to soil in a hectare

Municipal biosolids, which are also land applied, contain antimicrobials and hormones as well as other personal care products

6

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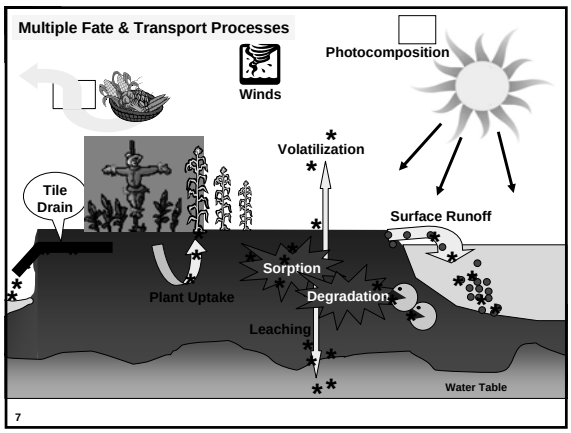
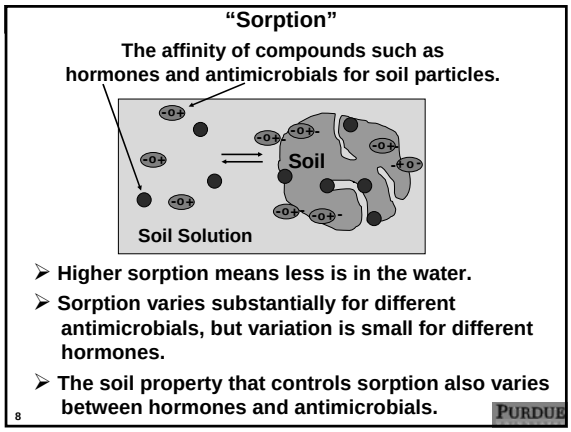

Multiple Fate & Transport Processes
Photocomposition
Winds
Volatilization
Tile Drain
Surface Runoff
Sorption
Plant Uptake
Degradation
Leaching
Water Table
7


"Sorption"
The affinity of compounds such as hormones and antimicrobials for soil particles.
Soil
Soil Solution
Higher sorption means less is in the water.
Sorption varies substantially for different antimicrobials, but variation is small for different hormones.
The soil property that controls sorption also varies between hormones and antimicrobials.
8
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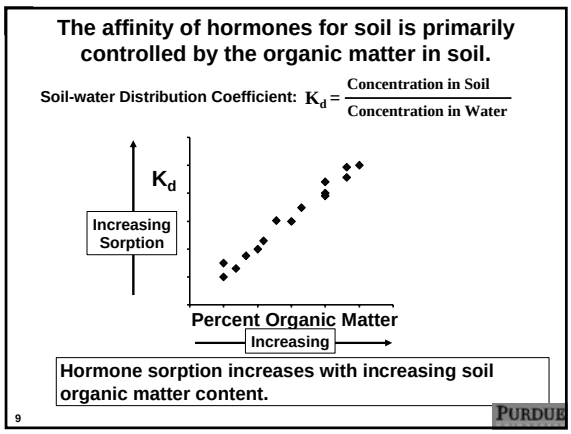
The affinity of hormones for soil is primarily controlled by the organic matter in soil.
Soil-water Distribution Coefficient: $K_d = \frac{\text{Concentration in Soil}}{\text{Concentration in Water}}$
K_d
Increasing Sorption
Percent Organic Matter
Increasing
Hormone sorption increases with increasing soil organic matter content.
9
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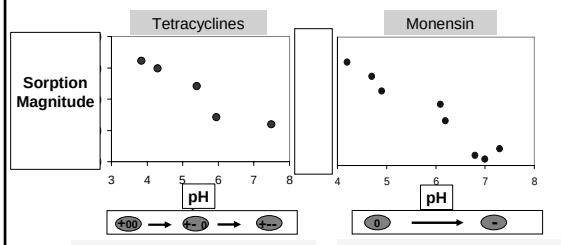
Sorption is pH-dependent for almost all antimicrobials



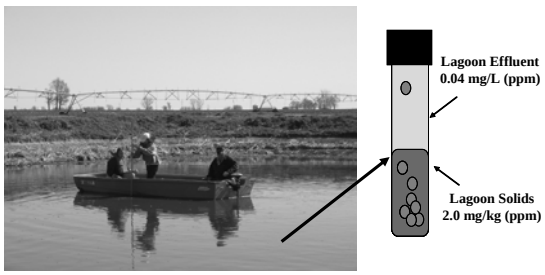
Sorption correlates well to **Soil Cation Exchange Capacity** from clay & organic matter

Sorption correlates well to **Soil Organic Carbon**

The soil property of greatest importance in estimating affinity to soil depends on the type of antibiotic

10

Antimicrobials and hormone (●) distribution in holding ponds of manure flushed out of animal housing units



Typically much more antimicrobial or hormone is associated with the solids compared to the liquid

11

Microbial Degradation

Half lives ($t_{1/2}$): time for 50% loss of target compound

$t_{1/2}$ ranges from a few days to over one year

Low Oxygen (anaerobic) Manure Pit → decreasing $t_{1/2}$ → **High Oxygen (aerobic) Agriculture Field**

Conditions that favor activity of aerobic bacteria tends to reduce antimicrobial & hormone persistence

Preferred Temperature: 20°C to 37°C

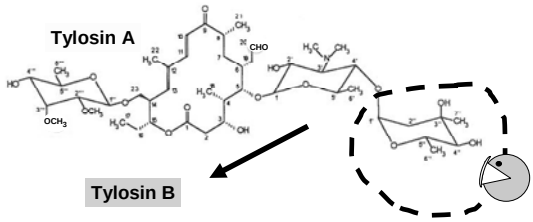
Preferred Moisture: not flooded; not dry

Preferred pH range: 6 to 8

Soil only ≈ Manure + Soil

12

Degradation ≠ complete mineralization
only that the parent antibiotic is changed



Degradation of antibiotic may not equate to loss of antibiotic activity

13

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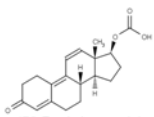
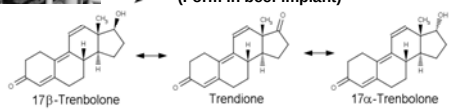
Degradation May Be Reversible



(Form in beef implant)



(Most active form) **(Primary form in manure)**

Reversible degradation within soil (likely small) and within unintended receptor such as fish

14

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Abiotic Degradation (*not dependent on bacteria*)

- **Nitrates can enhance antibiotic photolysis in water.**
- **Dissolved humic materials can enhance or hinder antibiotic photolysis**

Soil surfaces can enhance transformation of antibiotics and hormones, but microbial processes dominate

15

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Plant Uptake of Antimicrobials

Yes, for some antibiotics and some plant species.

HOWEVER

Estimated potential daily intake for a human consuming these plants is in the order of a few µg/day - **not an amount expected to pose a threat to human health**

Noteworthy

Humans take antibiotics at the 50,000 to 500,000 µg/day level.

Streptomycin and oxytetracycline are approved for use in many food crops including several fruits, potatoes, and celery.

16

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Antimicrobial & Hormone Transport through Soil with Infiltrating Water: Leaching

- Leaching is generally inversely proportional to sorption
- The higher affinity an antimicrobial or hormone has for the soil, the slower it will leach
- The more resistant an antibiotic or hormone is to degradation, the more time it has to leach
- Antimicrobials and hormones sorbed to mobile clay colloids or dissolved organic matter will move faster than expected

17

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Transport with Overland Flow: Run-Off

Rainfall rate > infiltration rate
Saturated soils can not hold additional water

What moves with water run-off?

- ✓ **Hormone-laden soil**
- ✓ **Hormone-laden manure**
- ✓ **Antibiotic-laden soil**
- ✓ **Antibiotic-laden manure**
- ✓ **Antibiotic-resistant bacteria***

Run-off is considered to contribute more to inputs from manure and antibiotics to streams than leaching

18

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Tile Drainage and Facilitated Transport

- Midwest soils are typically fertile, but poorly drained
- To enhance productivity, drainage is facilitated by an artificial subsurface drain network placed ≈ 1 m below the soil surface
- Excess soil water (and associated constituents) is rapidly moved to surface waterways
- Preferential flow paths to tiles develop over time reducing the effect of soil attenuation on transport

Relative contribution not well known yet

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Concentrations decrease over time while in storage and once land applied: (degradation & dilution)

Oxytetracycline from Calves* (fed 60,000 ppb in milk)	
Fresh manure	872 ppb
Bedding	367 ppb
Aged manure (1 mo)	19 ppb
Aged manure (4 mo)	2.1 ppb
Soil	0.006 ppb
Tile Drain Water	Not detected

Current issues of greater focus:

- Transfer & growth of antibiotic resistant bacteria
- Hormones

20 (* Example from study by De Liguoro et al. 2003) PURDUE

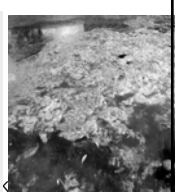
Potential Impact of Antimicrobials versus Hormones

Antimicrobials

Low concentrations not likely to affect humans.

Too low to induce antibiotic resistance in native bacteria

Bluegreen algae impacted in the ppb **range - food chain implications??**



Hormones at low part per trillion (10 to 100 ppt) in waterways can adversely affect the reproductive biology of aquatic species (sex and diversity in fish) and possibly other wildlife.

And then……what about mixtures????

21

Summary: *General Rules of Thumb*

- Major transport processes of manure-borne constituents includes leaching, run off, and tile drainage.
- Antimicrobial sorption to soils increases (↑) with ↓ soil pH, ↑ % clay and ↑ % organic matter (OM).
- Hormone sorption to soils increases (↑) with ↑ %OM.
- Antimicrobials & hormones generally degrade faster in moist aerobic soil environments reducing their persistence.
- Antimicrobial concentrations in plants are several orders of magnitude lower than what we take orally.
- Antibiotic-resistant bacteria are a currently a greater concern than antibiotic concentrations in the environment.
- Very low hormones concentrations are still of concern and can negatively impact aquatic species.

22