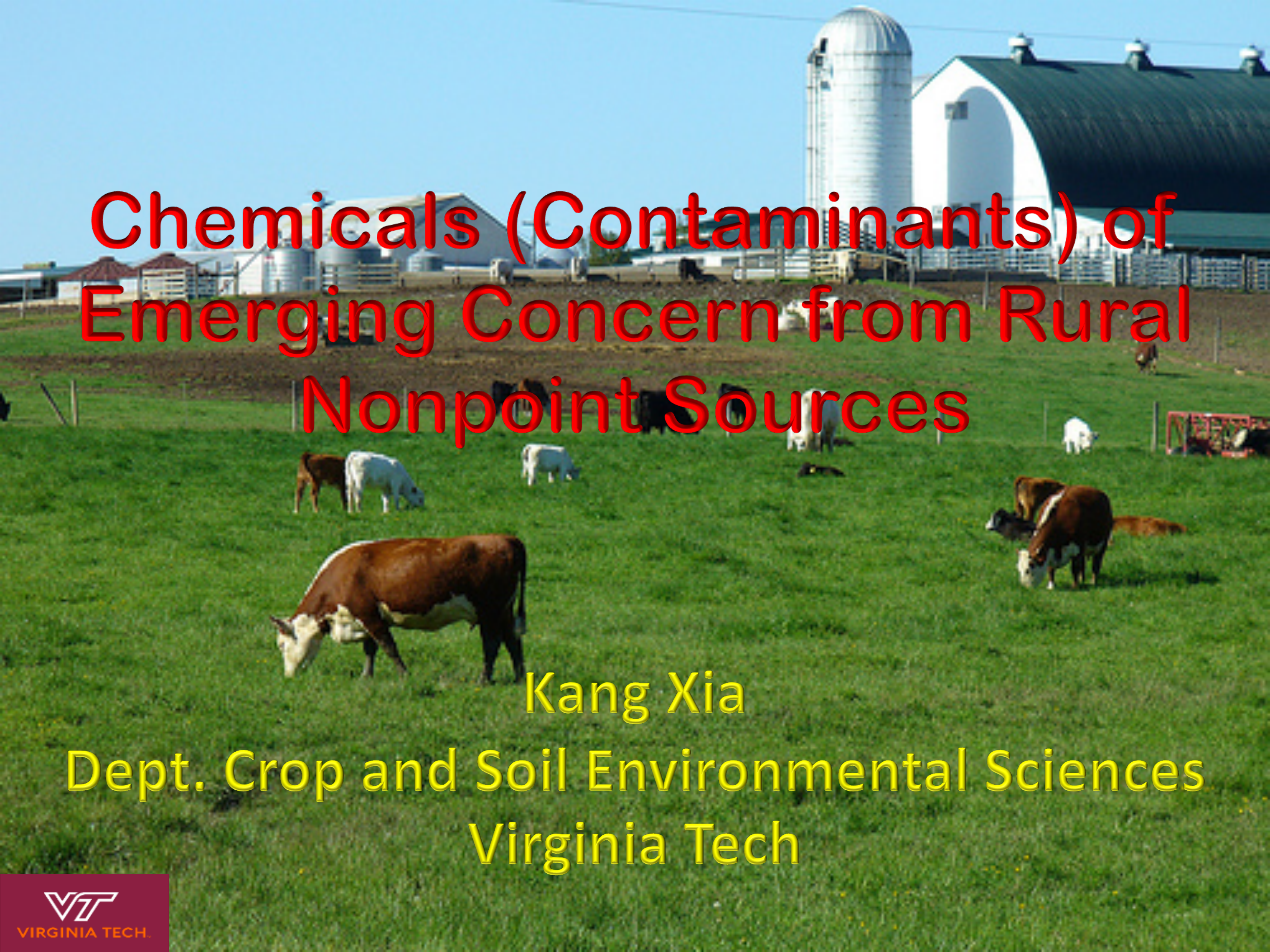

Chemicals (Contaminants) of Emerging Concern from Rural Nonpoint Sources

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VIRGINIA TECH

What are CECs?

Human uses

- Prescription drugs
- over-the counter drugs
- Therapeutic drugs
- Veterinary drugs
- Fragrances
- Cosmetics
- Sun-screen products
- Diagnostic agents
- Nutraceuticals (e.g., vitamins)
- Illegal drugs
- Flame retardants
- Additives in consumer products

Animal production uses

- Therapeutic (disease control)
- Sub-therapeutic (growth promotion)

Widespread occurrence of CECs in aquatic systems

- **United States**

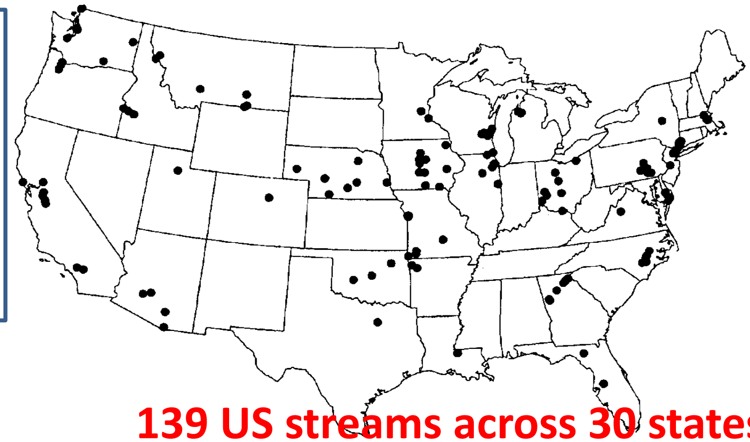
(Environ. Sci. Technol, 2002, 36:1202-1211)

82 of the 95 ECs were found

ECs in 80% of the streams

ppt to several hundreds ppb levels

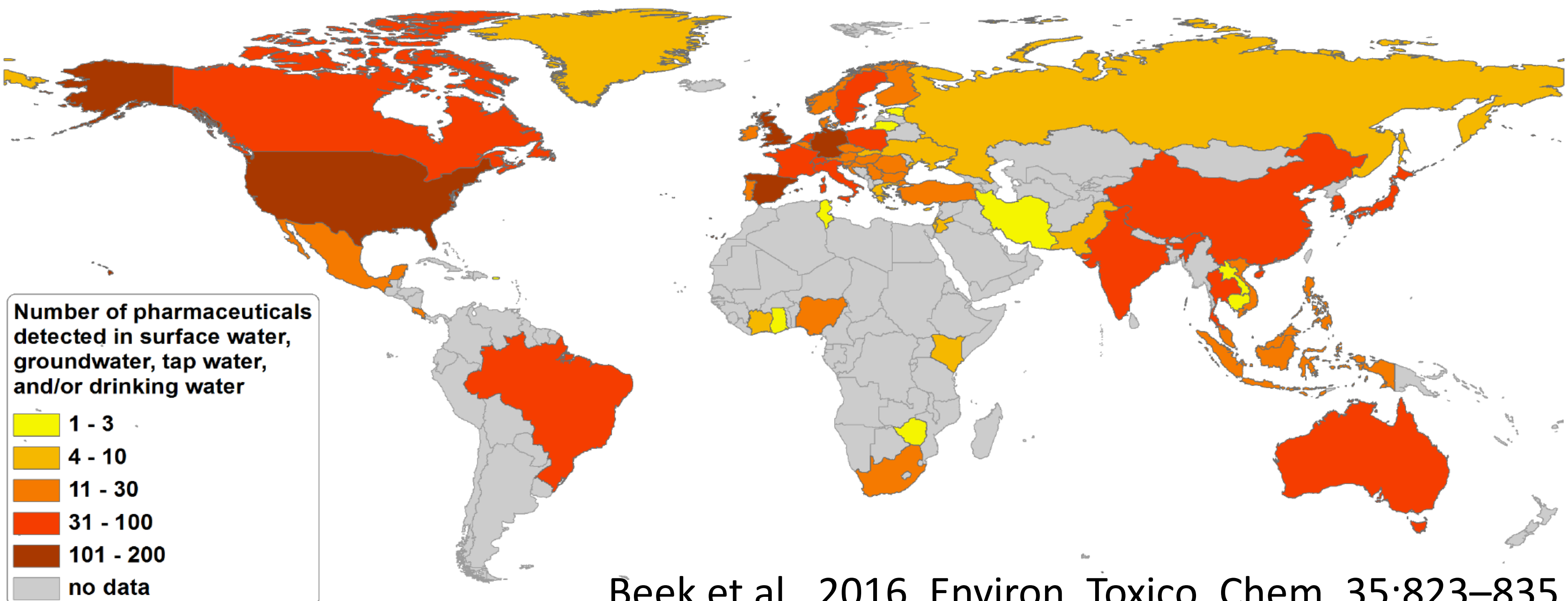
31 antibiotics
15 prescription drugs
7 nonprescription drugs
18 steroids and hormones
24 personal care-related compounds



139 US streams across 30 states

- **Worldwide**

631 CECs have been detected in 71 countries

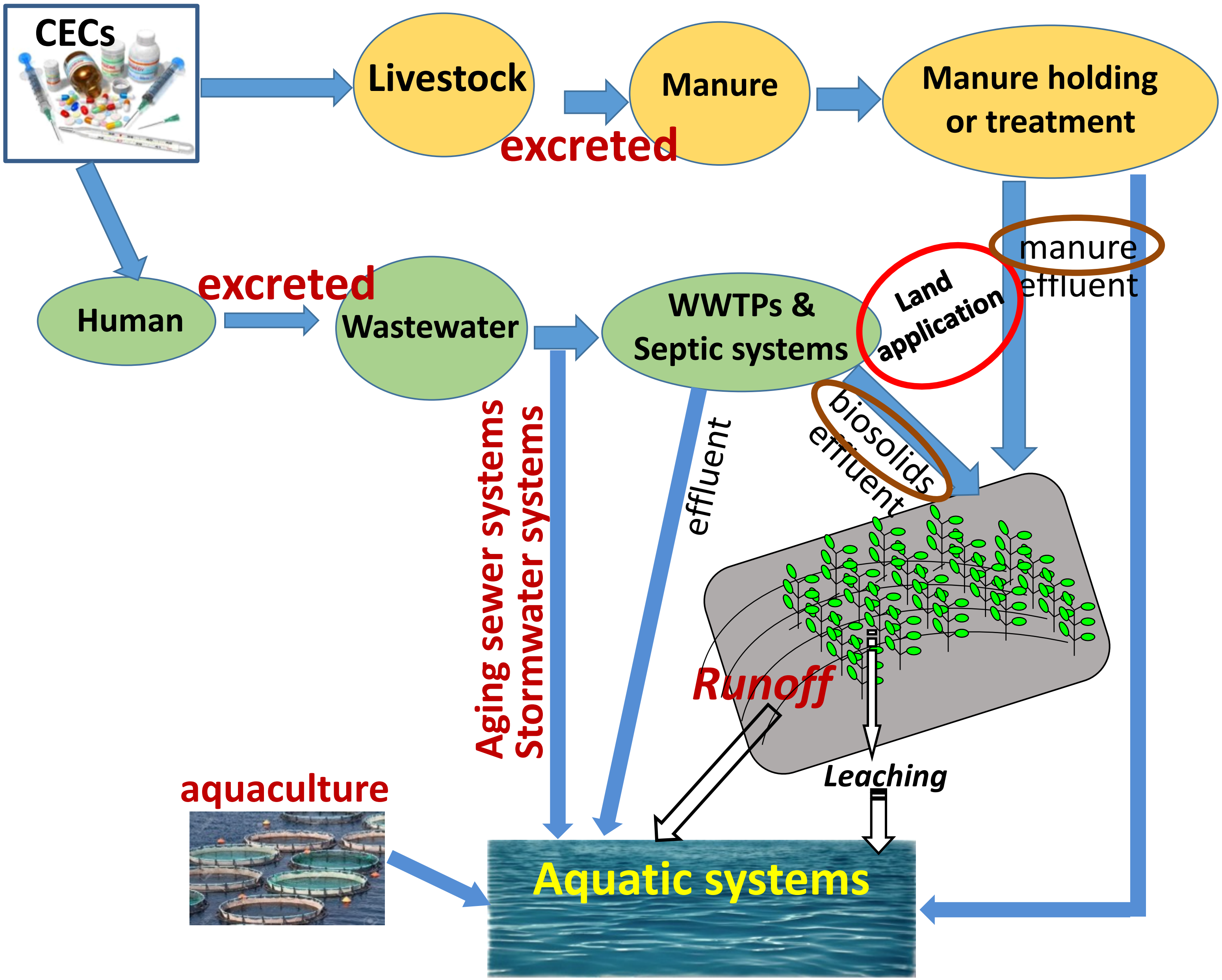


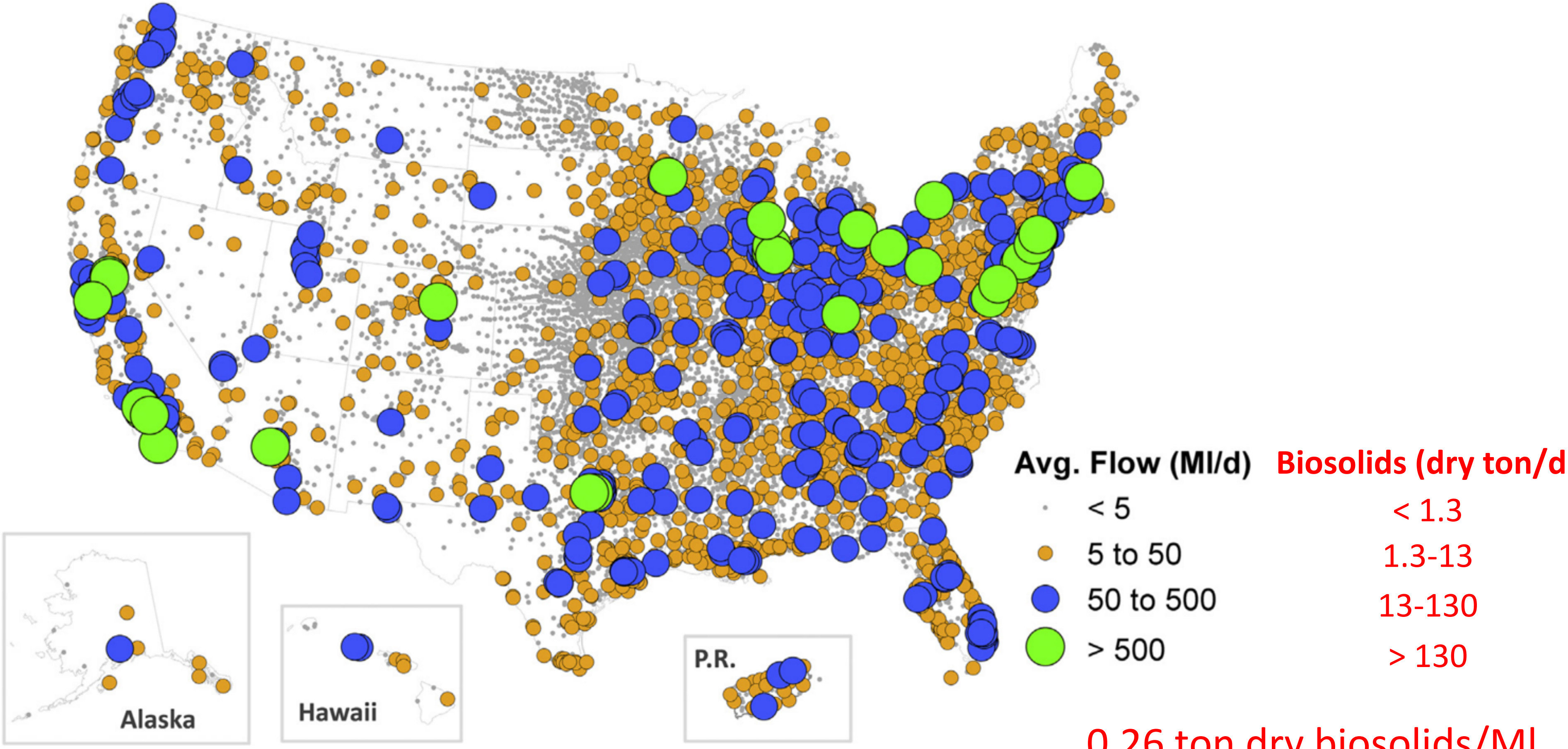
Beek et al., 2016. Environ. Toxico. Chem. 35:823–835

CECs in the Chesapeake Bay and its watershed:

- Limited occurrence datasets
- Tend to mirror national studies

Environmental pathways of CECs



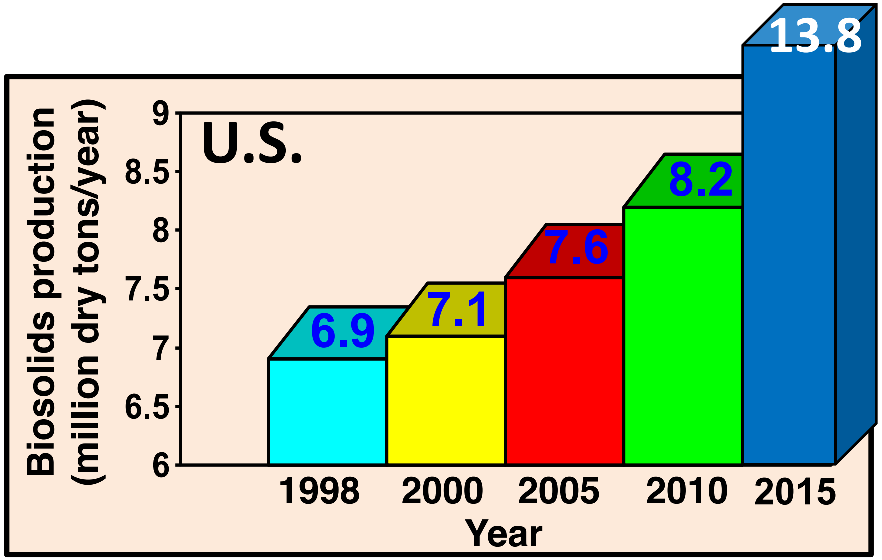


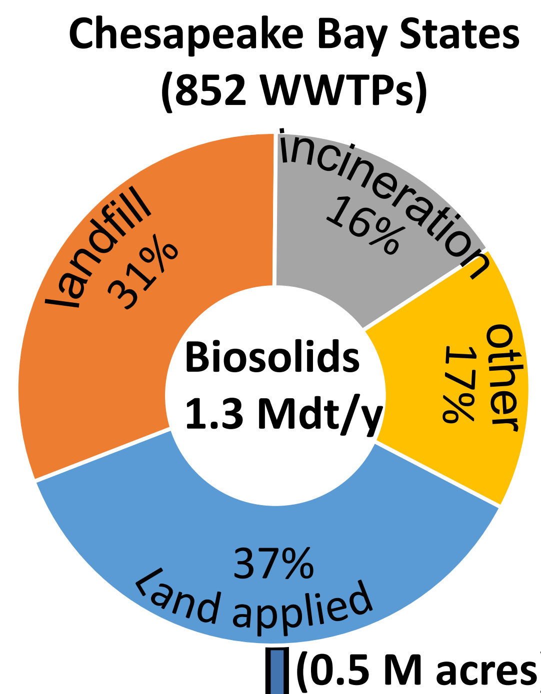
0.26 ton dry biosolids/Ml wastewater treated

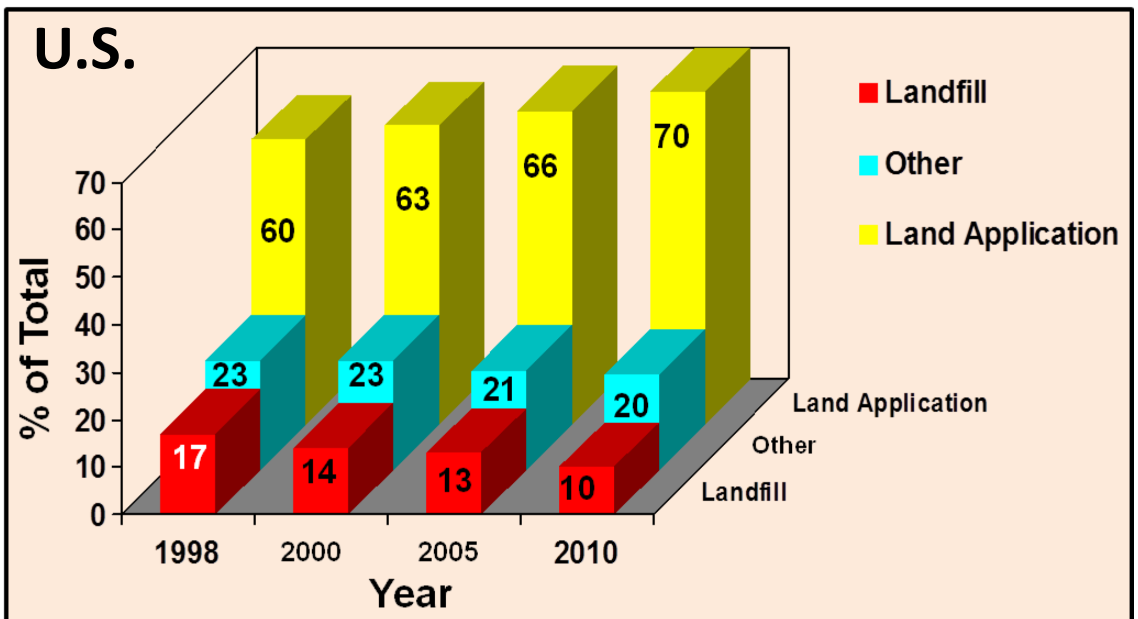
Spatial distribution of 15,014 US WWTPs classified by daily average influent flow.

Seiple et al., 2017. J. Environ. Management 197:673-680

Biosolids production, usage, and disposal







Benefits:
- primary nutrients
- secondary nutrients
- root growth promoters
- enhance soil structure
- C sequestration

(Brown et al., Environ. Sci. Technol., 2011, 45:7451)

Source: U.S. EPA, 1999

Seiple et al., 2017. J. Environ. Management 197:673-680

Occurrence of CECs in biosolids

Figure 2. Geographic Distribution of 80 POTWs Originally Selected for Sampling

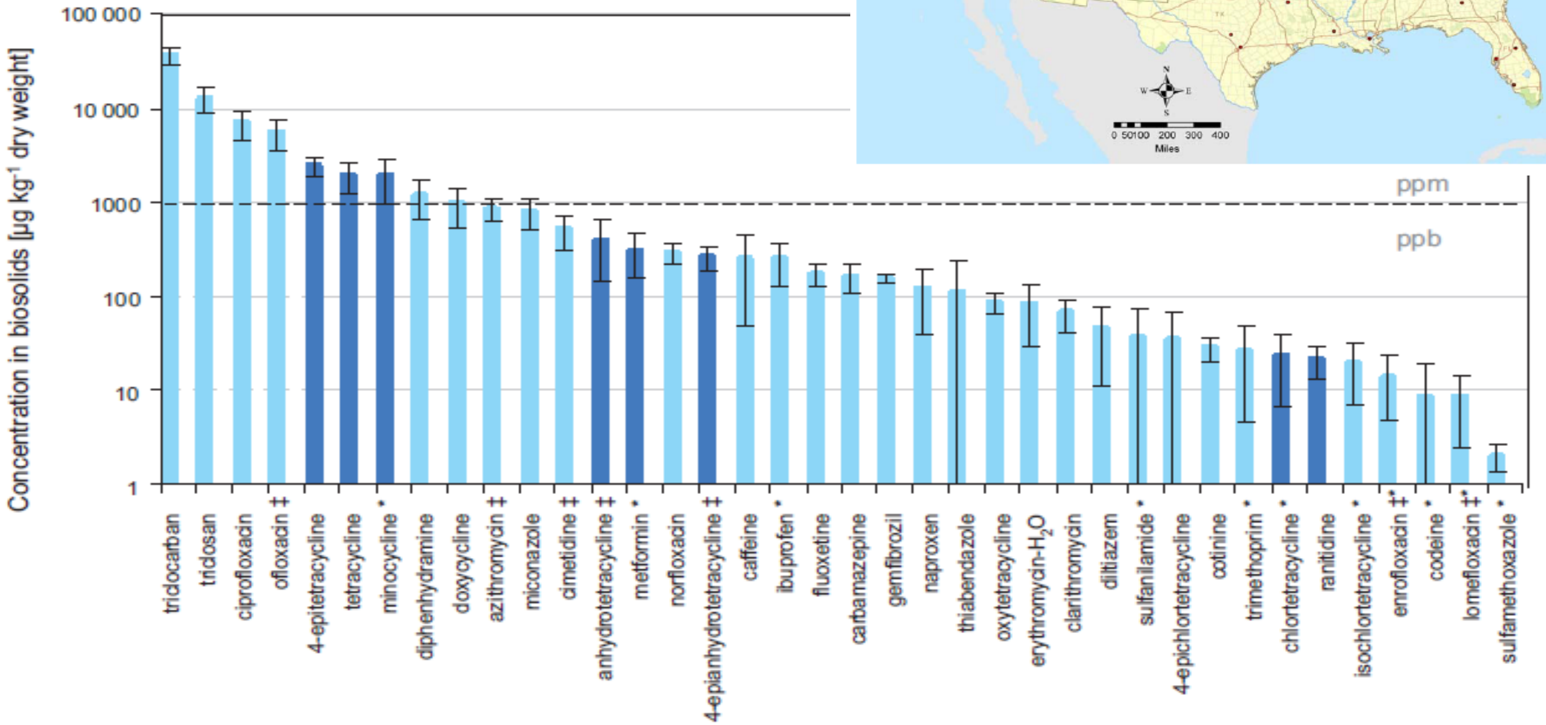


Fig. 1 – Rank order of mean concentrations for 38 PPCPs detected in composites of a total of 110 U S biosolids samples from 94 treatment plants in 32 states and the District of Columbia. Newly detected compounds are shown in darker hue. Error bars depict ± one standard deviation (n = 5). Some concentrations represent estimates only (‡) and some analytes were detected inconsistently (*).

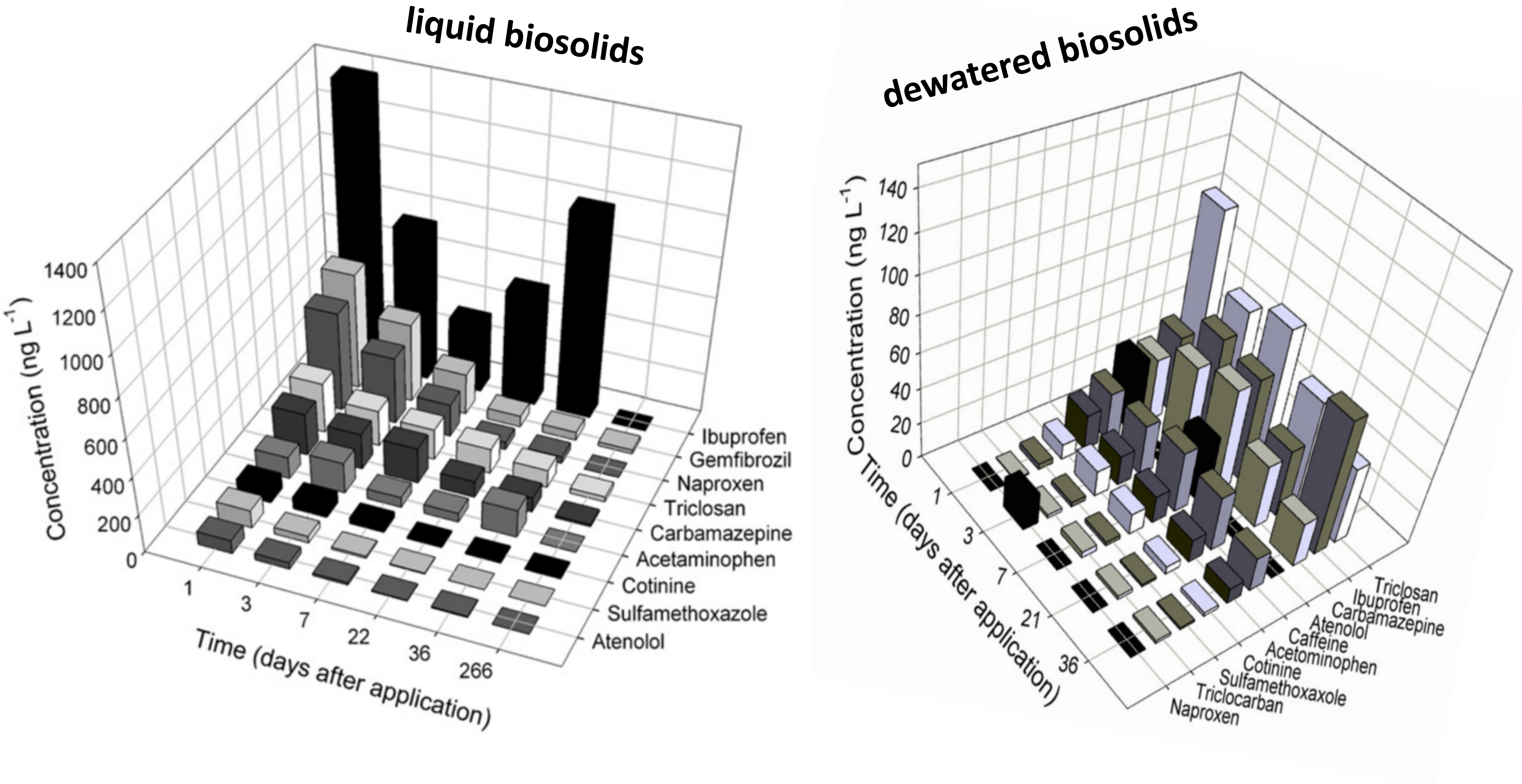
Water Research, 2010, 44:658

Occurrence and fate of CECs in biosolids-amended land?

TCC, TCS, PBDEs, and 4-NP in soil after 33 consecutive years of biosolids application (Environ. Toxic. Chem. 2010. 29:597)

Result summary:

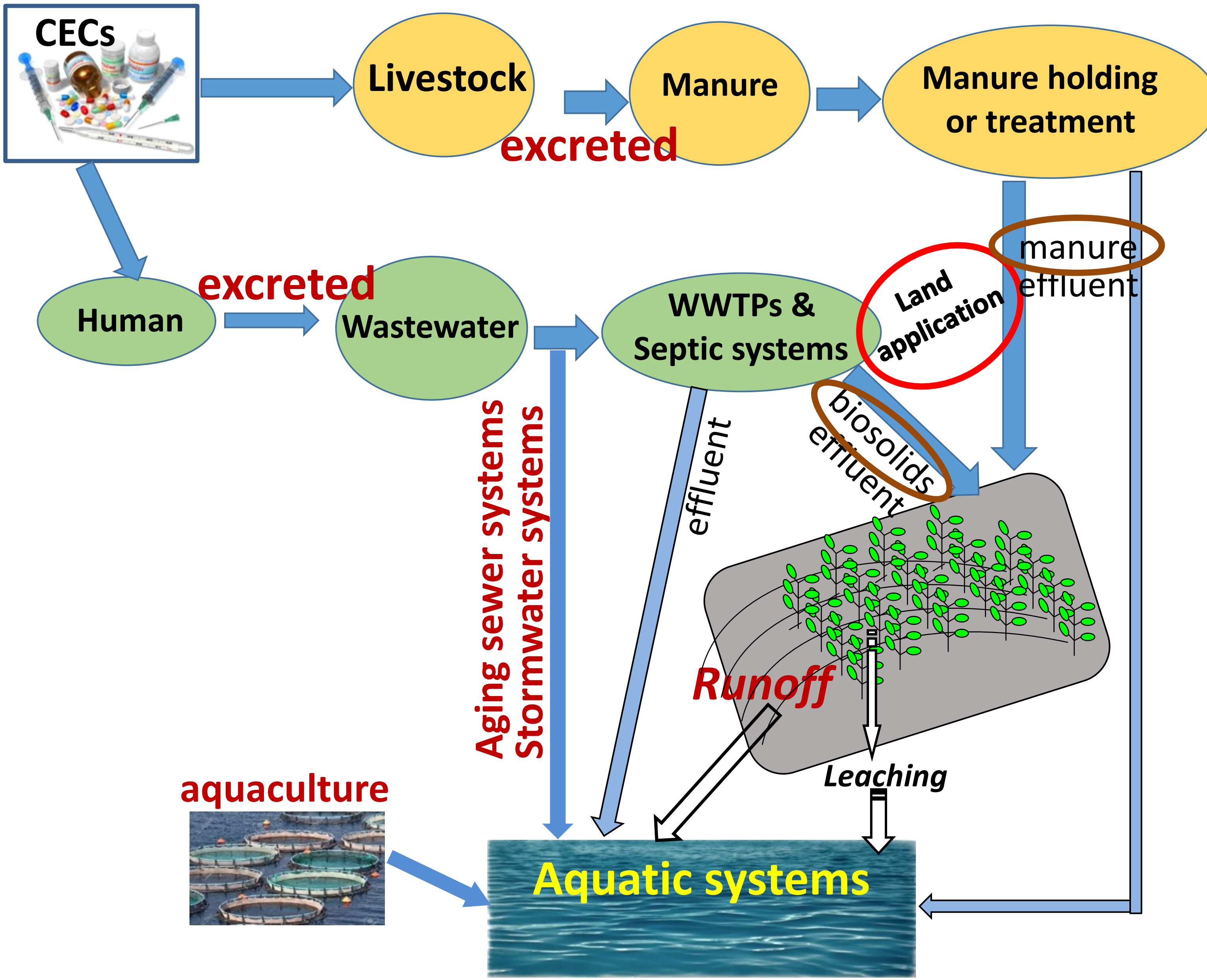
Target compounds	Results
Levels in soil	increase with biosolids loading
	sharp decrease with soil depth
PBDEs	persistent
TCC, TCS, 4-NP	less persistent
Concentrations in soil	4-NP > TCC > PBDEs >TCS (180:26:14:1)
PBDEs, 4-NP	immobile
TCC, TCS	limited mobility
Plant (corn) uptake	No



Concentrations of CECs in surface runoff from a field at various times post-application of broadcast incorporated municipal biosolids.

Topp et al., 2008. Sci. Total Environ. 396: 52-59
Sabourin et al., 2009, Sci. Total Environ. 407: 4596-4604

Environmental pathways of CECs



Animal manure production and usage

Exhibit 5-4: U.S. Livestock Production							
Animal Type	**Units**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Dairy Cattle	Billion lbs milk/yr	156	166	178	185	193	201
Beef Cattle	Billion lbs/yr	28	28	28	29	30	30
Swine	Billion lbs/yr	19	19	21	22	23	24
Poultry	Billion lbs/yr	5	5	5	5	5	5
Sheep	1,000 head	8,886	7,998	7,998	7,977	7,939	7,872
Goats	1,000 head	2,495	2,495	2,495	2,495	2,495	2,495
Horses	1,000 head	6,000	6,325	6,642	6,970	7,314	7,661

Source: 1995-2005 values are based on USDA, 1996; 2010-2020 are values from extrapolation analysis.

- **Animal manure generated/year:**

  U.S. > 1 billion tons of dry matter

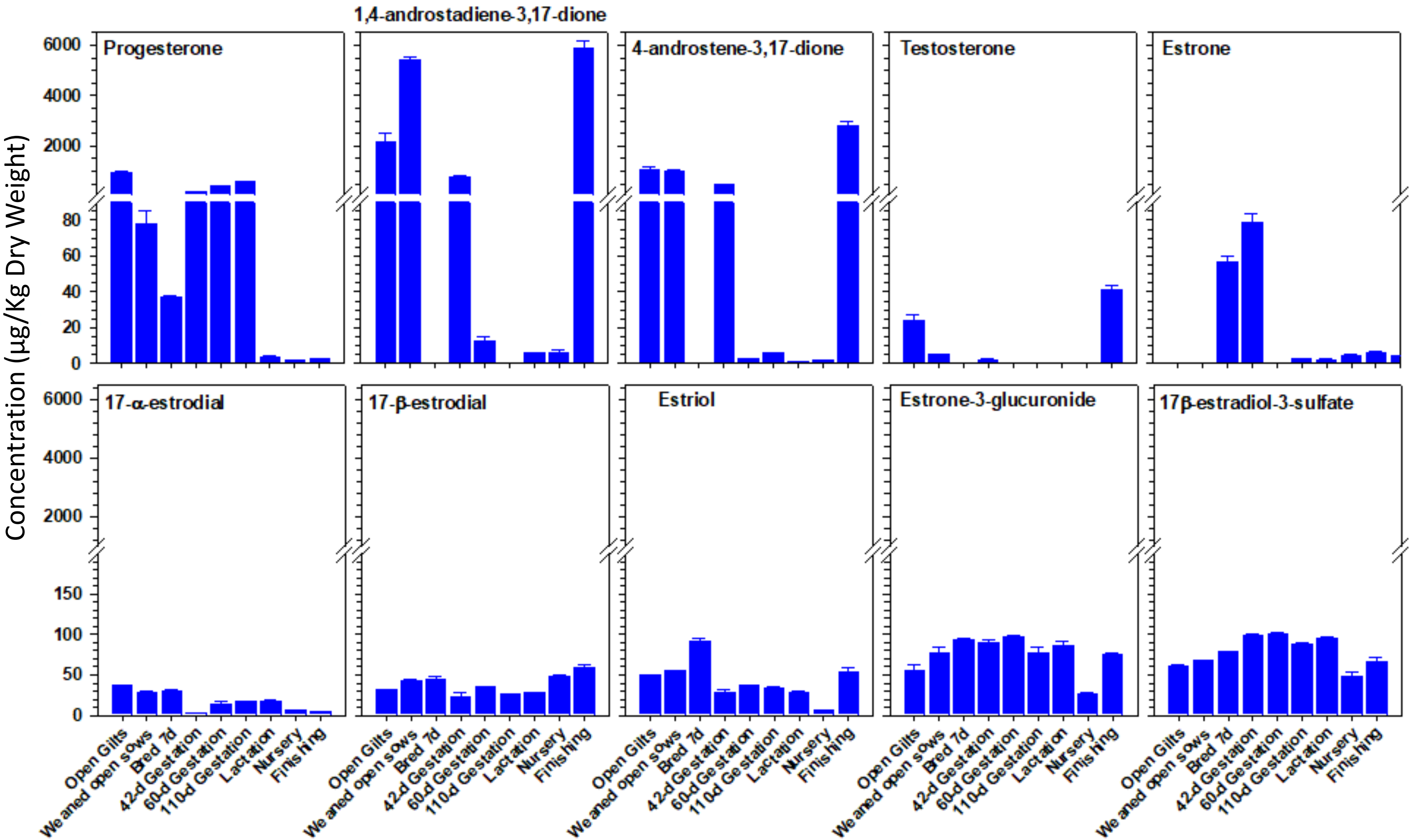
  Chesapeake Bay States > 44 million tons of dry matter

- **Land application of animal manure**

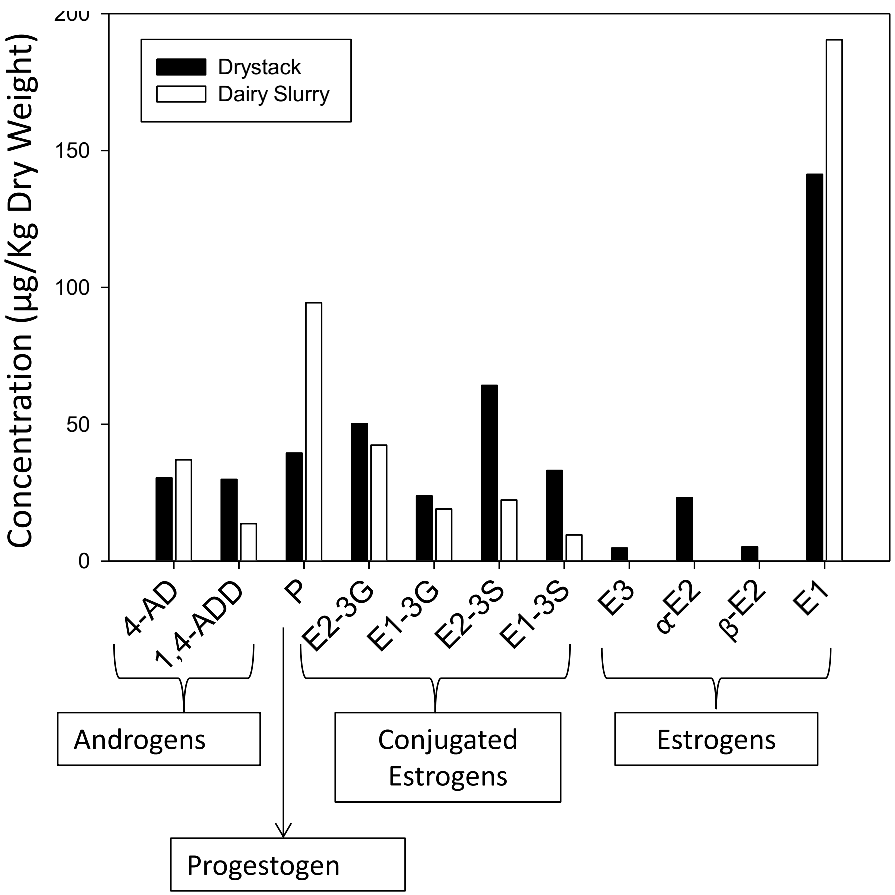
  Manure is applied to 48% of farmland in the Chesapeake Bay States

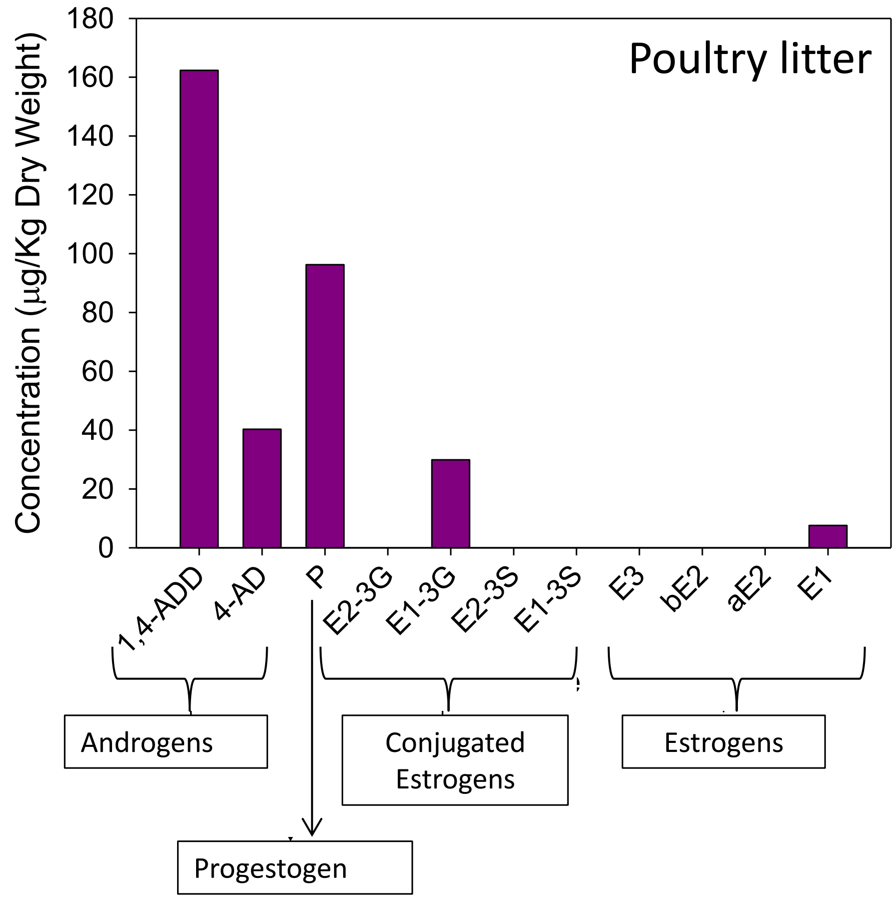
Benefits:
- primary nutrients
- secondary nutrients
- enhance soil structure
- Soil organic matter
- C sequestration

Occurrence of CECs in animal manure - hormones



Concentrations of progestagens, androgens, and estrogens in swine manure generated at different life stage.





Each year United States farm animals excrete:

Estrogens	49 t
Progestogen	4.4 t
Androgens	279 t

Lange et al., 2002, Analytic Chimica Acta. 473:27-37

Occurrence of CECs in animal manure - antibiotics

Antibiotics approved for domestic use in food-producing animals in the United States in 2015

Drug Class	Annual Totals (kg)[2]	% Subtotal	% Grand Total
Aminoglycosides[1]	344,120	2%	2%
Amphenicols	44,968	<1%	<1%
Cephalosporins[1]	32,341	<1%	<1%
Fluoroquinolones	20,063	<1%	<1%
Ionophores	4,740,615	30%	30%
Lincosamides[1]	182,543	1%	1%
Macrolides	627,770	4%	4%
Penicillins[1]	936,669	6%	6%
Sulfas	380,186	2%	2%
Tetracyclines[1]	6,880,465	44%	44%
NIR[1,4]	1,387,236	9%	9%
Subtotal	***15,576,975***	***100%***	***100%***

(FDA Annual Summary Report on Antimicrobials Sold or Distributed in 2015 for Use in Food-Producing Animals)

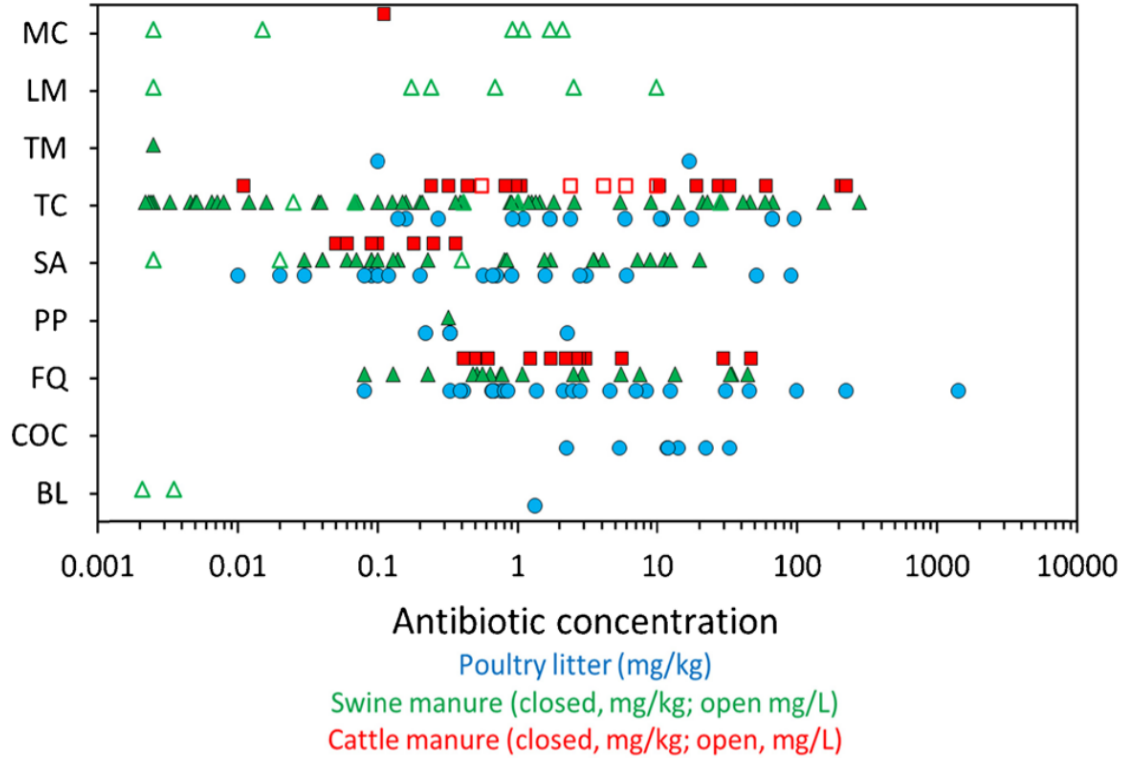


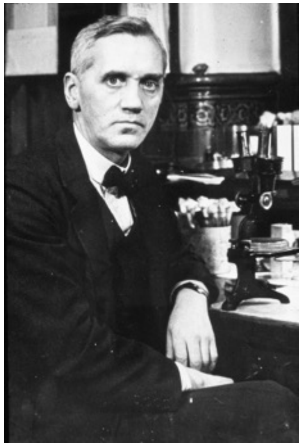
Fig. 1 Antibiotic concentrations detected in poultry, swine, and beef cattle manure. Data was aggregated from available reports [13, 16, 18, 21, 39–59]. Antibiotic class codes on the *y*-axis are as follows: *MC* macrolide, *LM* lincosamide, *TM* trimethoprim, *TC* tetracycline, *SA* sulfonamide, *PP* polypeptide, *FQ* fluoroquinolone, *COC* coccidiostat, *BL* beta-lactam. For clarity, only the minimum and maximum antibiotic concentrations from individual studies were included here. This list is not exhaustive but is meant to convey the relative antibiotic detection and concentration ranges in animal manures

(Van Epps & Blaney, 2016, Curr Pollution Rep. 2:135–155)

Why are antibiotics used in animal production?

Alexander Fleming' Nobel lecture in 1945:

"The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant."



Alexander Fleming

- 1955 – 1st scientific report on usage of antibiotics in food animal production for growth promotion *(Science. 1955. 121:733-734)*

From the practical point of view, this study indicates that antibiotics and arsonic acids would be of greatest value in promoting growth (i) when first used in a poultry-feeding enterprise and (ii) under the environmental conditions usually surrounding farm feeding. If once used and then discontinued, feeding performance may still be somewhat improved, because the contamination level has been lowered. Continued use of these substances at low levels, however, would help to insure maximum results, because an "infected" area can be reestablished through disuse (5). Indications are that such use of antibiotics and arsonic acids in feeds will not build up a resistant microflora that future poultry populations will have difficulty to live with.

- 1950-now,
  - US animal production ↑ 100%
  - # of production units ↓ 80%

- >50,000 chickens /year
- >1,000,000 chickens/year

1949

Antibiotics

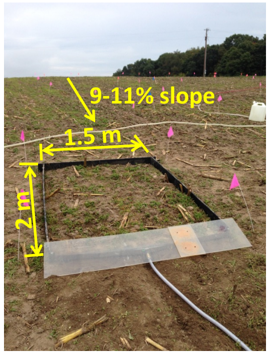
- *therapy*
- *control & prevention*
- *growth promotion*

Concentrated feeding operations (CFOs)

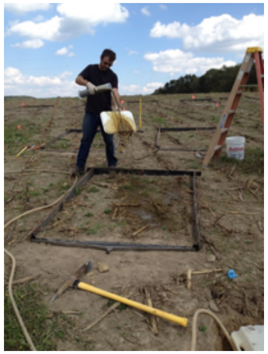
US antibiotic production: 55,000 tons/y
- **~70% → animal use**
- **~30% → human use**

Journal of Water and Health. 2010. 8:646-670.

Occurrence and fate of CECs in manure-amended land?



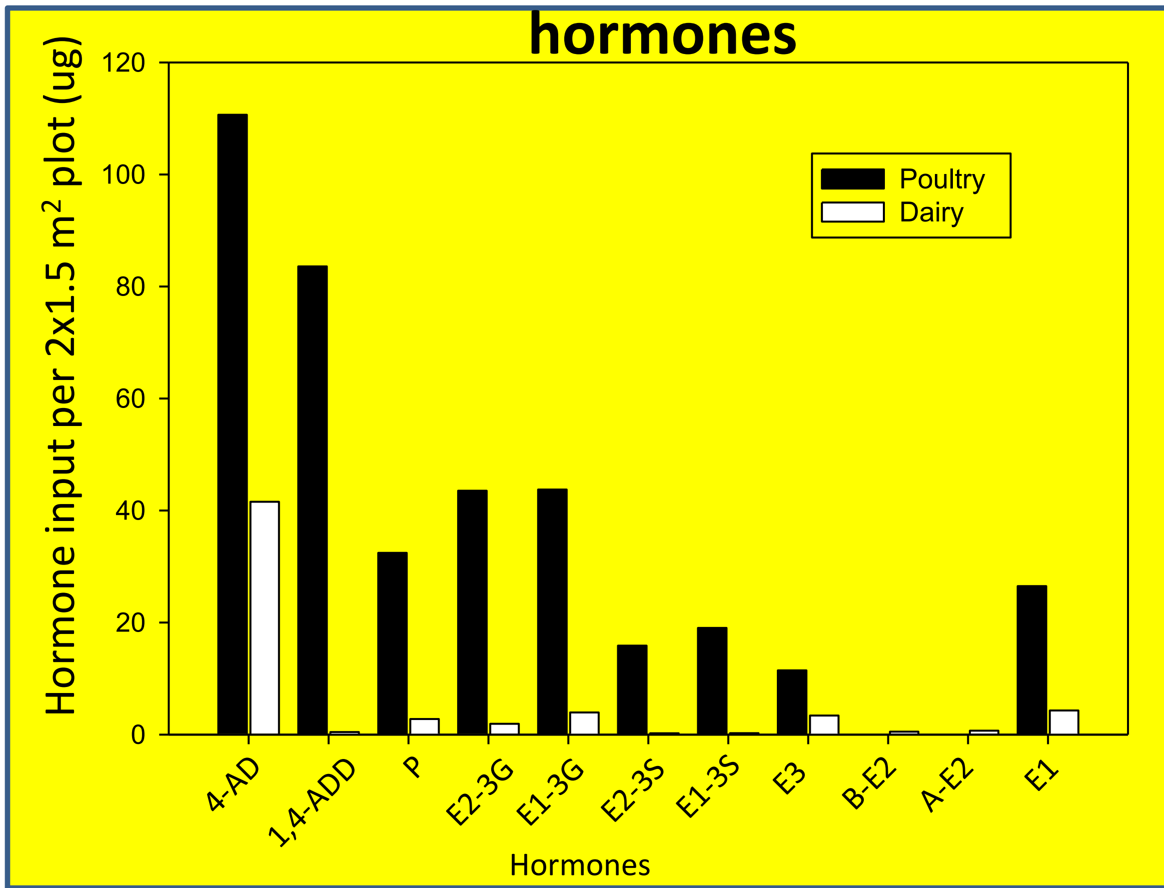
2x1.5 m^2 plot



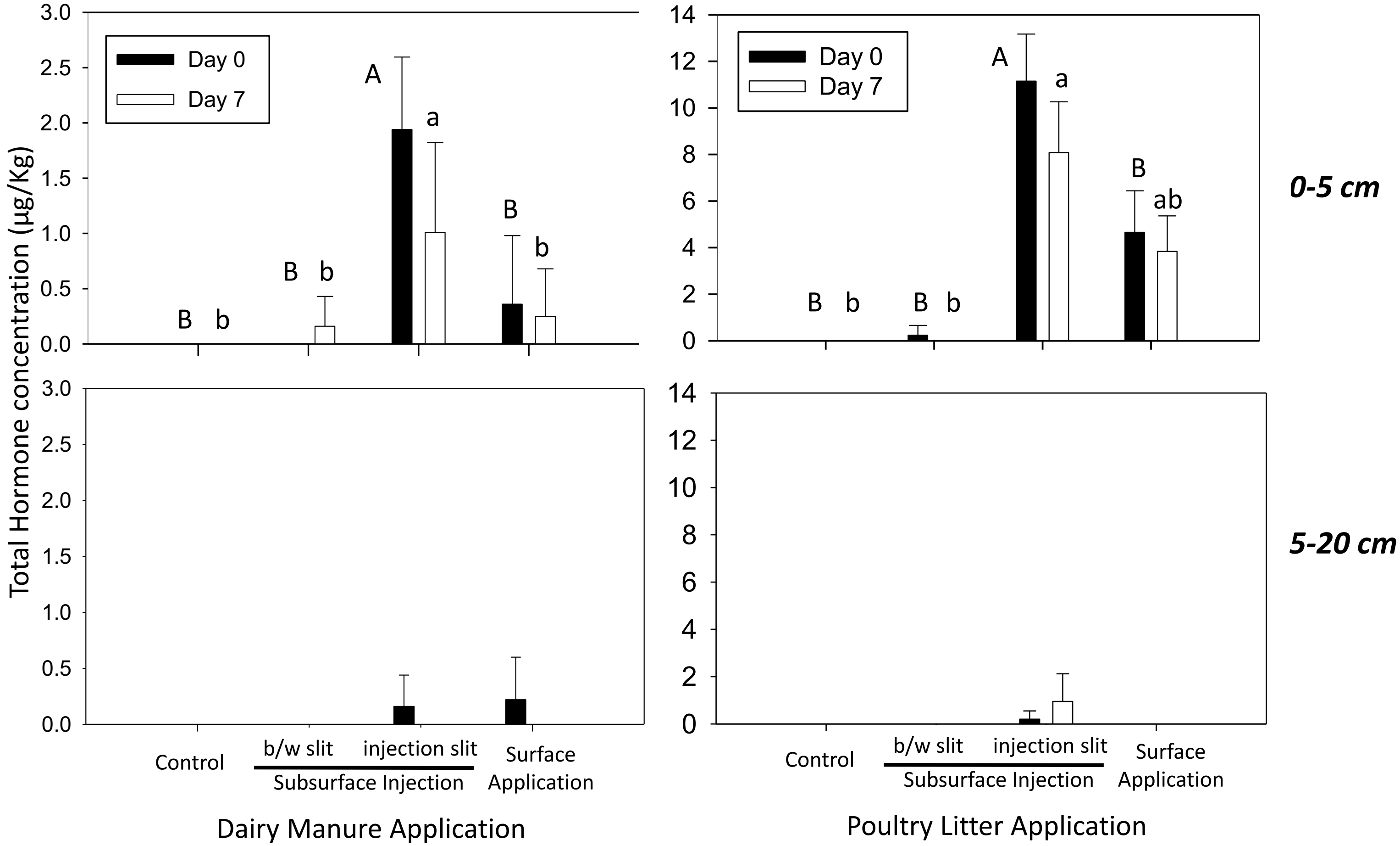
Surface application

Subsurface injection

Rainfall simulation

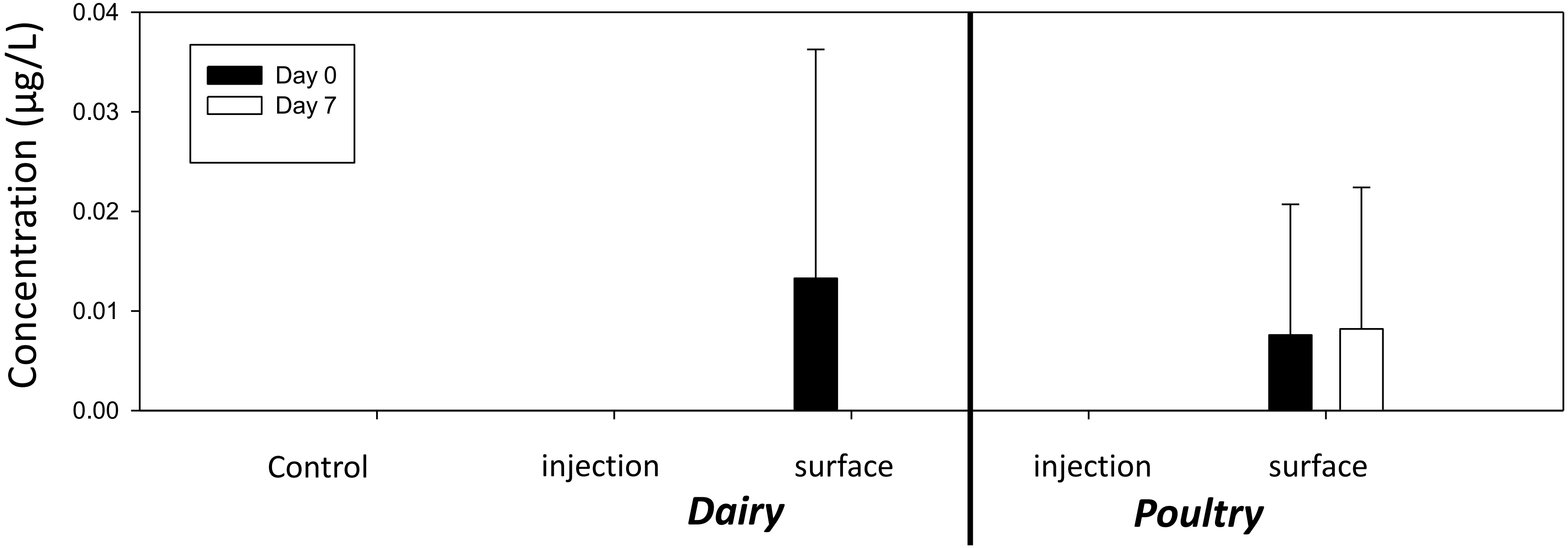


Total hormone concentration in soil



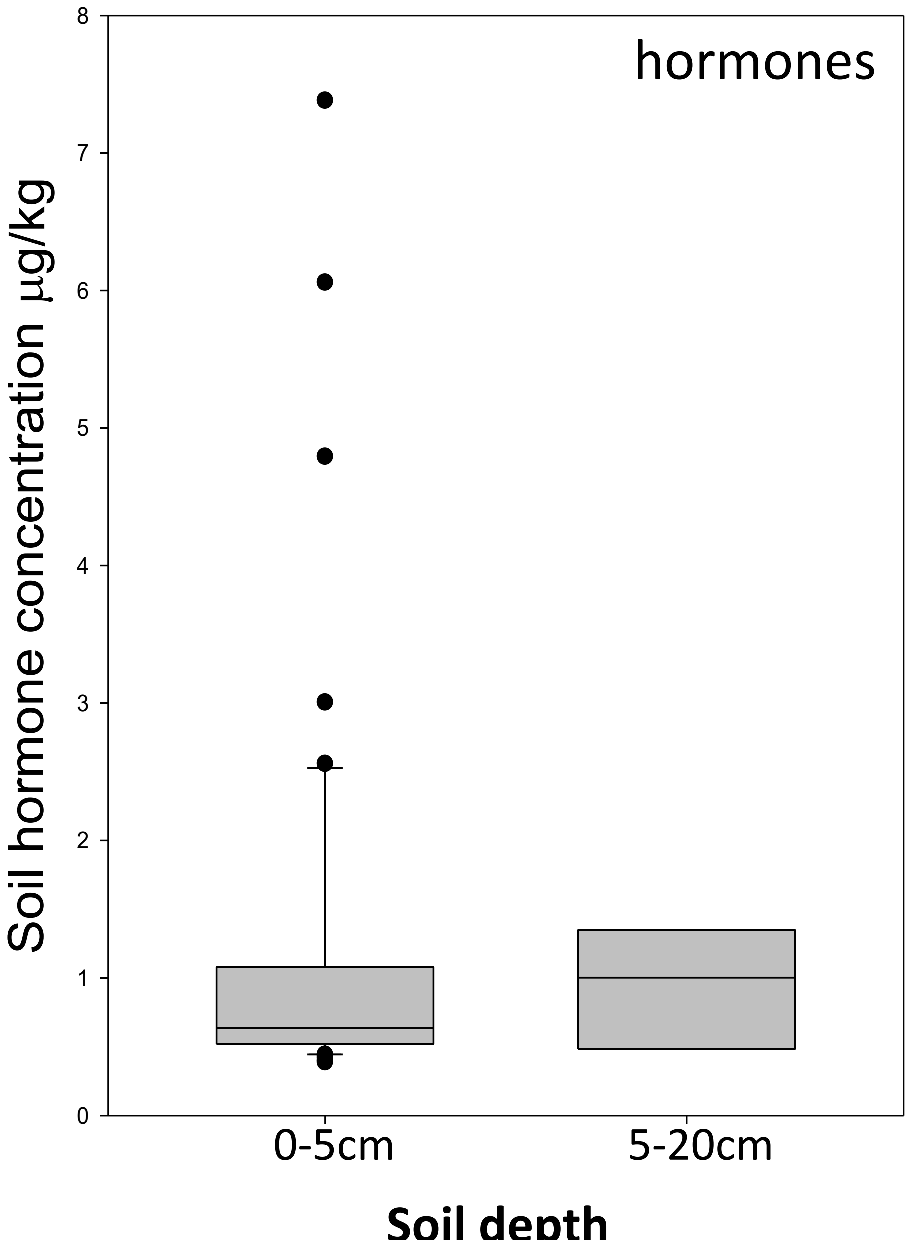
- ***Minimal leaching*** – concentrated in top 0-5 cm soil
- ***Concentrated in the injection slits***

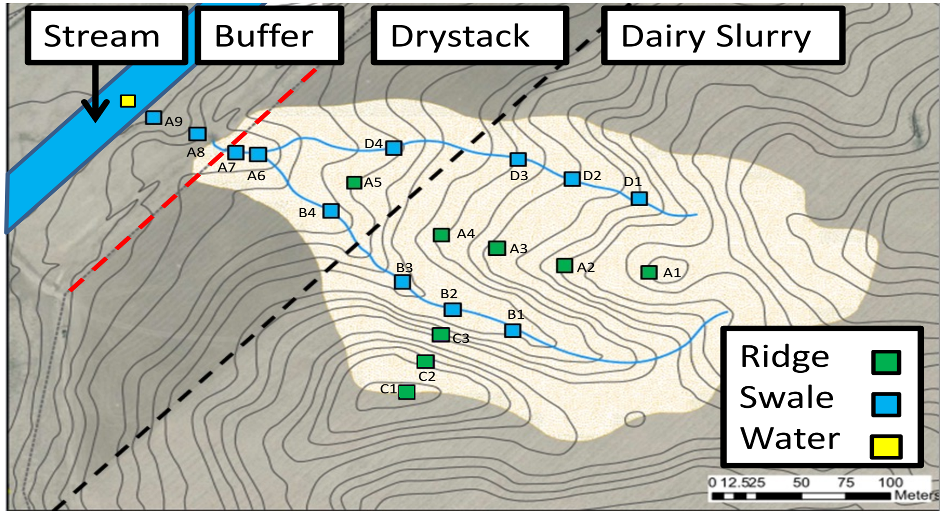
Total hormone concentration in surface runoff



- ***Subsurface injection reduces hormone surface runoff***

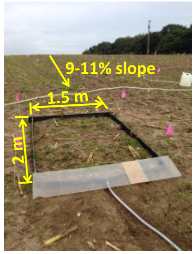
Surface applied manure



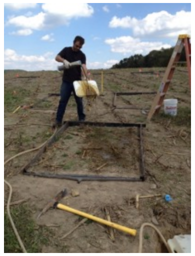


- ***Minimal leaching*** – concentrated in top 0-5 cm soil
- ***Downslope movement***
- ***Buffer is effective*** – none-detectable in the stream
- ***Progesterone more persistent*** – detectable 3 months after manure application
- ***Similar observation*** – DE coastal plain poultry litter amended soils (Water Air Soil Pollut, 2012, 223:2821–2836)

Occurrence and fate of CECs in manure-amended land?



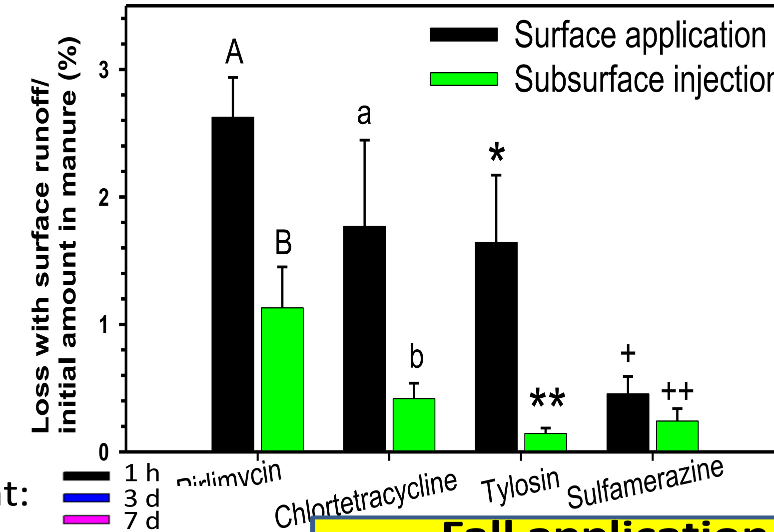
2x1.5 m^2 plot



Surface application

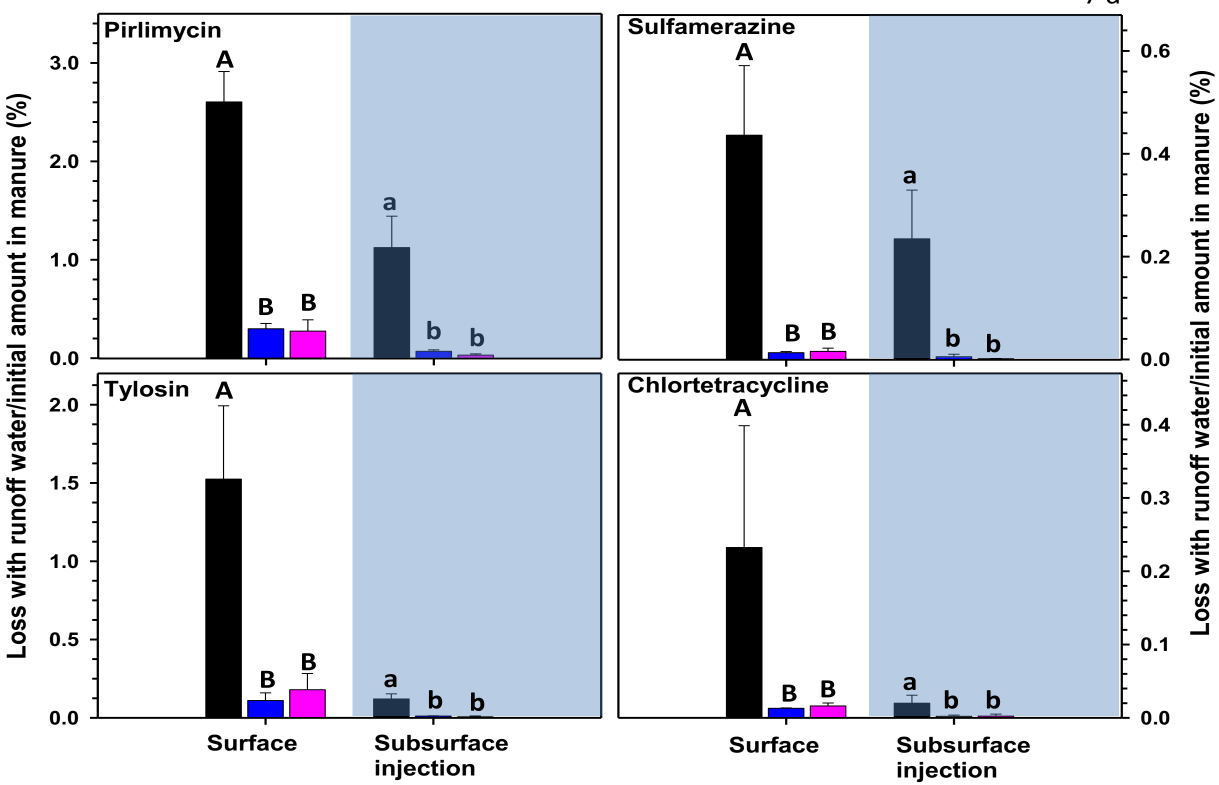
Subsurface injection

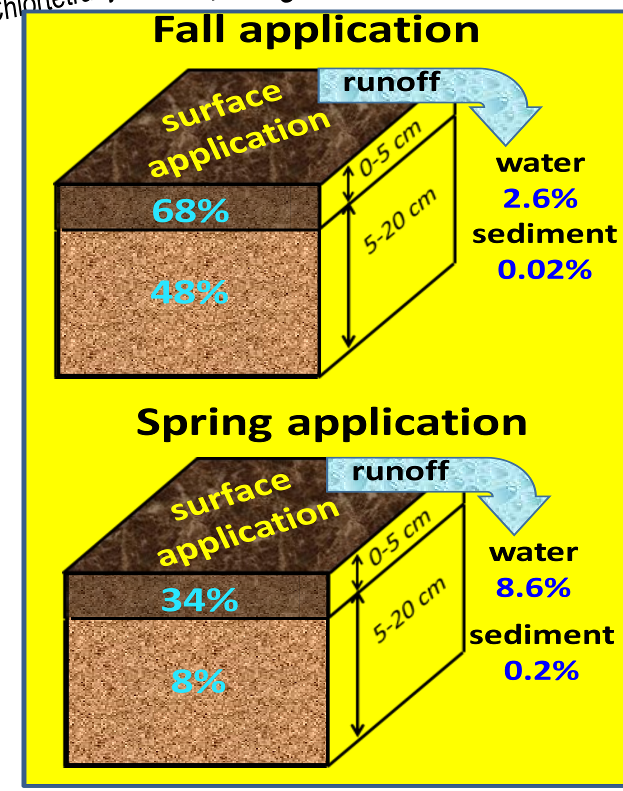
Rainfall simulation



Antibiotics in surface runoff

Time gap between manure application and rain event:

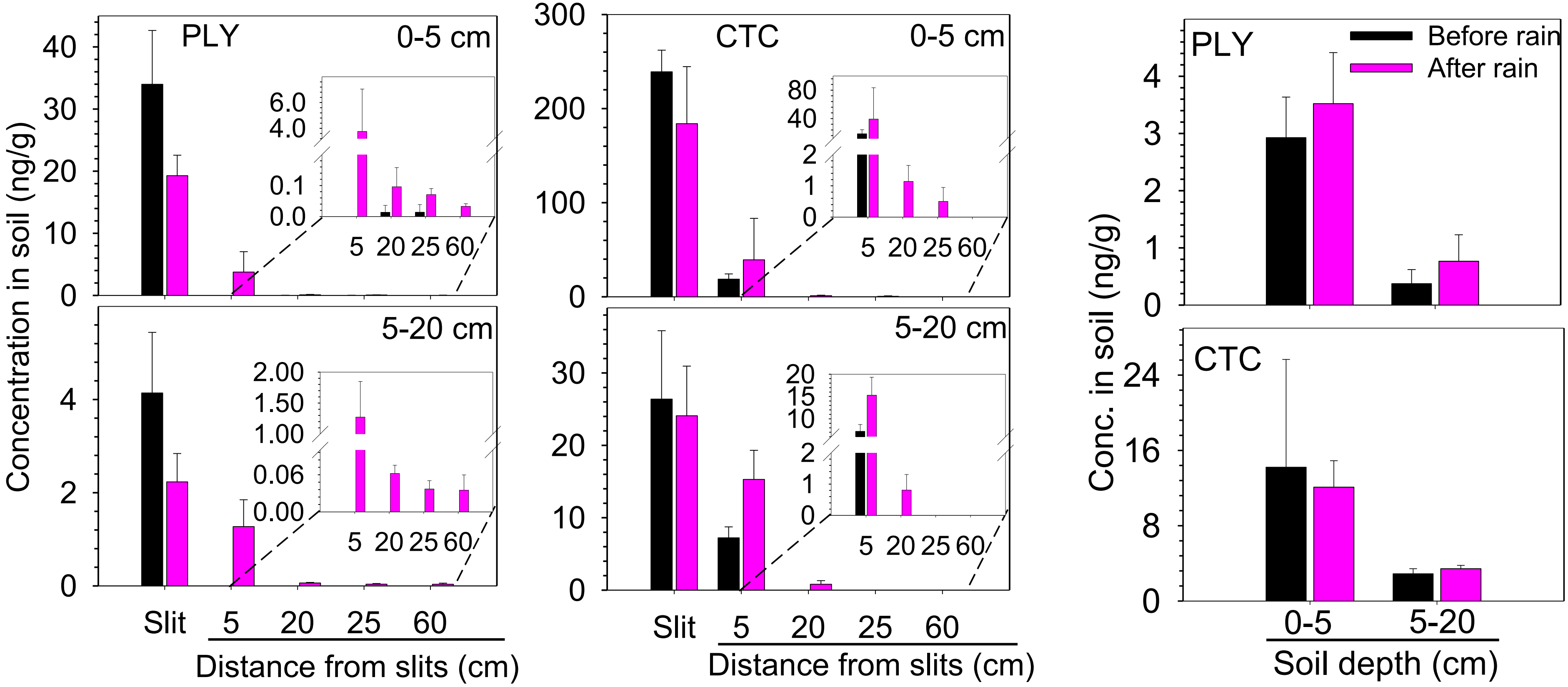




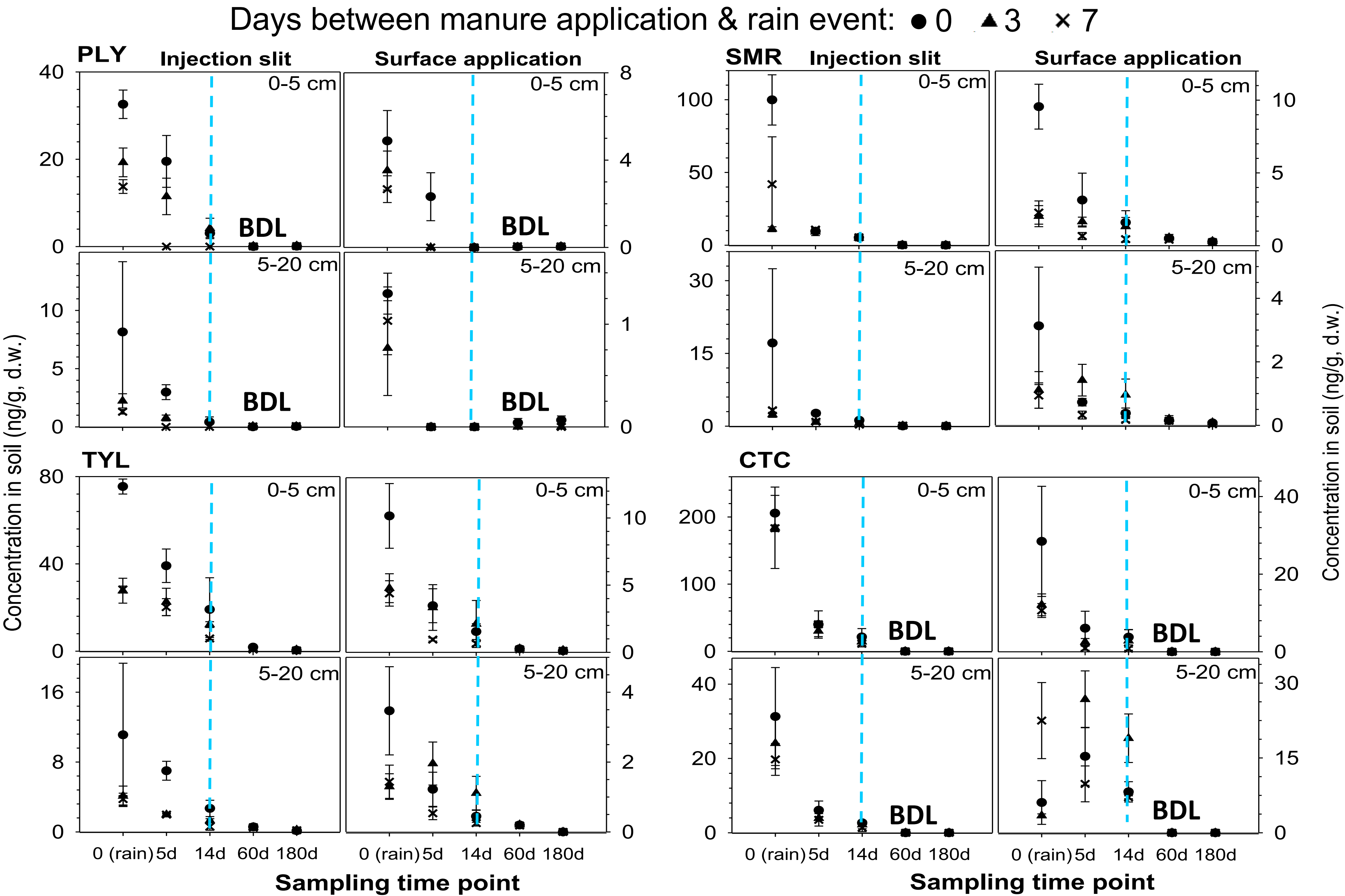
Spatial distribution of antibiotics in soil

Subsurface injection
(rain on day 3)

Surface application
(rain on day 3)



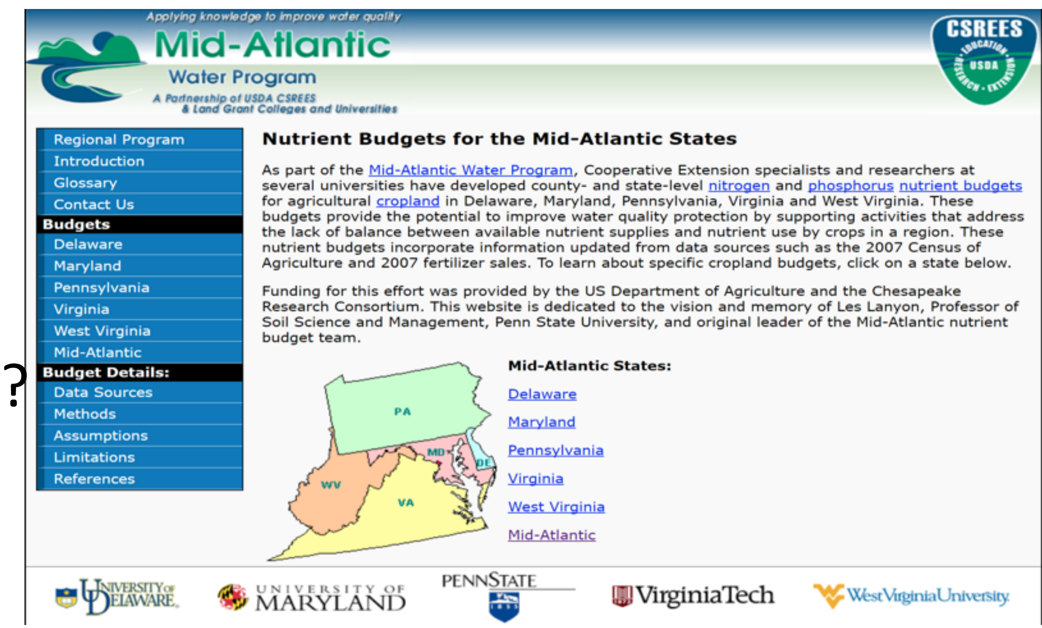
Temporal change of antibiotics in soil

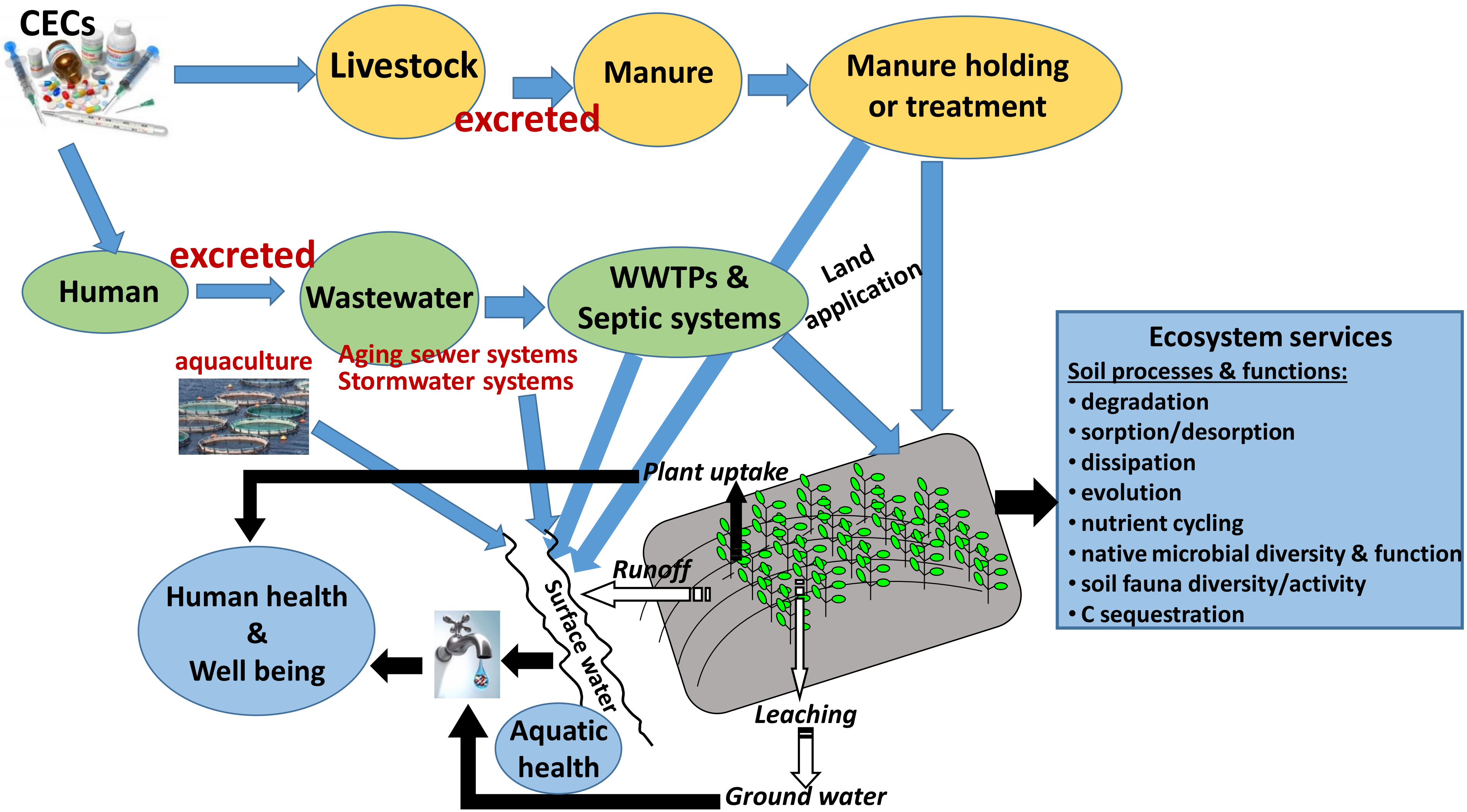


Chemicals (Contaminants) of Emerging Concern from Rural Nonpoint Sources

- **We do know:**
  - Wide spread occurrence of CECs in biosolids and manure
  - Land application of biosolids and manure → occurrence of CECs in soil and runoff → aquatic environment
  - Proper biosolids/manure management and land application methods can reduce input of CECs

- **What we don't know:**
  - CECs budget in CBW?
  - Antibiotic resistant?
  - Environmental impact?





Pathways of chemicals of emerging concern and their impact

Acknowledgements

- Graduate students & postdoc researchers
- Collaborators

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- USDA-NIFA award # 2017-67019-26401
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Thank you!

Questions?