Water Quality and the Swine Industry

Dr. E. Pip
University of Winnipeg

Primary land use frequency (%) among sites sampled in the five geographical regions (425 sites)

	Precambrian Shield (147)	Central Manitoba (104)	Southern Floodplain (98)	Southwestern Manitoba (64)	Northern Manitoba (12)
Minimal use	23.8	11.4	3.0	3.1	50.0
Cottages/ recreation	53.1	63.5	28.6	32.8	-
Cropland	--	2.9	37.8	48.4	-
Livestock/ poultry	1.4	5.8	17.3	7.9	-
Logging/ clearing	6.1	8.7	3.1	-	-
Mining	4.8	-	-	-	8.3
Hydroelectric	6.1	-	-	-	33.4
Urban	4.7	7.7	10.2	7.8	8.3

Primary Impact (total province)	Total dissolved solids mg/L (± S.E.) (range)	N
Minimal	134 (±34) (10 – 1990)	69
Cottages	194 (±12) (10 – 910)	195
Ag crops	395 (± 48) (70 – 3520)	71
Ag livestock	265 (±26) (50 - 680)	31
Logging/clear	120 (±17) (20 - 350)	13
Mining	1109 (± 911) (50 - 6560)	8
Hydro	58 (± 9) (30 – 100)	9
Urban effluent	273 (± 33) (20 – 770)	29

Primary impact	Nitrate-N mg/L	N
Minimal	0.22 (± 0.02)(0.01 – 0.80)	69
Cottages	0.30 (± 0.01)(0.01 – 1.43)	195
Ag crops	0.42 (± 0.03)(0.07 – 2.09)	71
Ag livestock	1.00 (± 0.54)(0.01 – 16.4)	31
Logging	0.32 (± 0.04)(0.01 – 0.61)	13
Mining	0.82 (± 0.57)(0.11 – 4.20)	8
Hydro	0.19 (± 0.03)(0.01 – 0.30)	9
Urban effluent	1.50 (± 0.93)(0.01 – 29.0)	29

Primary impact	Dissolved organic matter 275 nm (exponential scale)	N
Minimal (including bogs and marshes)	0.48 (± 0.06)(0.01 – 2.31)	69
Cottages	0.20 (± 0.01)(0.01 – 2.48)	195
Ag crops	0.30 (± 0.02)(0.02 – 1.18)	71
Ag livestock	0.31 (± 0.02)(0.07 – 0.60)	31
Logging	0.60 (± 0.13)(0.07 – 2.38)	13
Mining	0.17 (± 0.05)(0.01 – 0.36)	8
Hydro	0.19 (± 0.04)(0.10 – 0.54)	9
Urban effluent	0.69 (± 0.52)(0.10 – 16.3)	29

Primary impact	Cadmium µg/L	N
Minimal	2.0 (± 0.2)(<0.1 – 7.2)	69
Cottages	2.3 (± 0.1)(<0.1 – 13.0)	195
Ag crops	2.3 (± 0.2)(<0.1 – 8.3)	71
Ag livestock	2.1 (± 0.3)(<0.1 – 9.0)	31
Logging	2.1 (± 0.3)(<0.1 – 7.7)	13
Mining	14.2 (± 10.8)(0.3 – 79.7)	8
Hydro	2.4 (± 0.4)(<0.1 – 4.5)	9
Urban effluent	2.8 (± 0.3)(0.4 – 7.1)	29

Primary impact	Lead µg/L	N
Minimal	4.9 (± 2.1)(<0.1 – 11.0)	69
Cottages	10.3 (± 1.0)(<0.1 – 137.9)	195
Ag crops	10.8 (± 1.9)(<0.1 – 109.3)	71
Ag livestock	12.4 (± 3.8)(<0.1 – 116.9)	31
Logging	17.1 (± 6.3)(<0.1 – 132.5)	13
Mining	5.3 (± 1.4)(1.2 – 10.8)	8
Hydro	4.5 (± 2.3)(<0.1 – 21.6)	9
Urban effluent	13.4 (± 3.8)(0.3 – 109.5)	29

Primary impact	Copper µg/L	N
Minimal	8.1 (± 1.2)(<0.1 – 15.0)	69
Cottages	13.4 (± 2.3)(<0.1 – 237)	195
Ag crops	12.4 (± 2.1)(<0.1 – 80.7)	71
Ag livestock	10.7 (± 2.4)(<0.1 – 54.5)	31
Logging	20.6 (± 6.0)(<0.1 – 81.6)	13
Mining	42.1 (± 23.5)(<0.1 – 158.7)	8
Hydro	1.1 (± 0.4)(<0.1 – 7.0)	9
Urban effluent	25.3 (± 5.1)(0.1 – 100.2)	29

Significant human impacts (MB overall)

Parameter	Most significant impacts on MB water quality
TDS	1. Mining 2. Crops 3. Urban sewage 4. Livestock
DOM	1. Urban sewage 2. Logging 3. Livestock
Nitrate	1. Urban sewage 2. Livestock 3. Mining
Cadmium	1. Mining 2. Urban sewage 3. Hydro
Lead	1. Logging 2. Urban sewage 3. Livestock
Copper	1. Mining 2. Urban sewage 3. Logging

	Precambrian Shield	Central Manitoba	Southern Floodplain	SW Manitoba	Northern Manitoba
TDS mg/L	<10-6560 (mean =128)	70-910 (239)	70-890 (301)	90-3520 (400)	<10-1990 (208)
Nitrate-N mg/L	<0.01-4.24 (0.24)	<0.01-29.0 (0.77)	0.04-5.54 (0.48)	0.12-1.43 (0.42)	<0.01-0.58 (0.16)
DOM 275 nm	0.012-2.38 (0.363)	0.017-16.3 (0.400)	0.009-0.875 (0.254)	0.025-1.18 (0.240)	0.040-0.216 (0.114)
Cd µg/L	<0.1-79.7 (3.02)	<0.01-7.1 (2.08)	<0.1-9.0 (2.49)	<0.1-5.1 (2.05)	<0.1-3.5 (1.75)
Pb µg/L	<0.1-55.1 (6.7)	<0.1-133 (14.3)	<0.1-138 (9.3)	1.4-117 (15.6)	<0.1-56.8 (11.5)
Cu µg/L	<0.1-188 (10.4)	<0.1-100 (15.6)	<0.1-236 (16.0)	<0.1-237 (14.2)	<0.1-55.0 (13.4)

LOCAL impacts on water quality

- In central Manitoba, livestock and domestic sewage contributed the most to nitrate-N ($F = 2.70, p = 0.025$)
- In the Red River Basin, livestock , land clearing and crop production contributed the most to DOM ($F = 8.32$, $p = <0.0001$)
- The most vulnerable waters to contamination were streams in all geographical regions except Northern Manitoba
- 63% of livestock sites were located on streams
- The region most vulnerable was the Precambrian Shield

Water quality and soils

- **Only 53% of livestock sites sampled were located on clay soils**
- **26% were located on sand and gravel**
- **Clay soils were most likely to show high TDS and metal levels in overlying water**
- **Organic soils were highly correlated with DOM in overlying water**
- **Nitrate showed the greatest elevation on clay soils on the Precambrian Shield**

Multivariate Analysis

- Streams (< 2 m deep) most vulnerable to contamination, followed by ponds (>10 ha)
- On Precambrian Shield, streams significantly vulnerable for ALL parameters
- In Red River Basin, streams most vulnerable to nitrate-N and DOM
- In southwestern MB, streams most vulnerable to DOM
- Regions with the greatest frequency of livestock production were also the regions where nitrate-N and DOM contamination of surface water were most evident

In another study we compared surface water chemistry in southern Manitoba (49°20' - 50° 39'N, 96° 09' - 99° 17'W) during normal and high precipitation summers

"Normal" years = 1998 + 2001 combined

Precipitation 435 + 497 mm respectively January to September (Wpg. airport)

"Flood" year = 2005

Precipitation 547 mm January to September (Wpg. airport), concentrated in June and July

Impacts of high precipitation events

- High snowfall and rapid spring melt
- OR High summer precipitation and acute rainfall events
- Likely to increase with ongoing accelerated climate change
- Most affected areas: high water table, slopes, field drains, minimal vegetated buffer zones, shallow soils, floodplains

Total dissolved solids mg/L

	1998 and 2001 (nonflood)	2005 (flood)
Urban	269 ± 43 (50 – 630)(14)	350 ± 39 (60 – 760)(20)
Cottages	244 ± 31 (10 – 750)(30)	287 ± 82 (20 – 710)(11)
Cropland	417 ± 98 (70-3520)(34)	653 ± 84 (100-2150)(35)
Livestock	243 ± 53 (50 – 680)(12)	500 ± 84 (40-2625)(34)

Nitrate-N mg/L

	1998 and 2001 (nonflood)	2005 (flood)
Urban	**0.85 ± 0.37, 0.10-5.54 (14)**	**0.79 ± 0.11, <0.01-1.61 (20)**
Recreation	**0.30 ± 0.03, <0.01-0.66 (30)**	**0.51 ± 0.14, <0.01-1.76 (11)**
Cropland*	**0.38 ± 0.03, 0.07-0.93 (34)**	**1.06 ± 0.23, <0.01-7.6 (35)**
Livestock	**0.53 ± 0.14, 0.13-1.97 (12)**	**1.06 ± 0.26, <0.01-8.1 (34)**

*Includes chemical and manure fertilizer

Soluble reactive phosphorus mg/L

	1998 and 2001 (nonflood)	2005 (flood)
Urban	0.15 ± 0.06 (<0.01-0.86) (14)	0.18 ± 0.04 (<0.01-0.75) (20)
Cottages	0.04 ± 0.01 (<0.01-0.11) (30)	0.06 ± 0.02 (<0.01-0.17) (11)
Cropland	0.14 ± 0.03 (<0.01-0.62) (34)	0.26 ± 0.05 (<0.01-1.08) (35)
Livestock	0.14 ± 0.09 (<0.01-10.4) (12)	0.23 ± 0.06 (<0.01-1.34) (34)

DOM (275 nm)

	1998 and 2001 (nonflood)	2005 (flood)
Urban	0.193 ± 0.020 (0.126-0.391)(14)	0.313 ± 0.027 (0.196-0.683)(20)
Cottages	0.205 ± 0.025 (0.009-0.625)(30)	0.312 ± 0.006 (0.063-0.734)(11)
Crops	0.257 ± 0.024 (0.024-0.546)(34)	0.436 ± 0.062 (0.071-0.212)(35)
Livestock	0.306 ± 0.038 (0.086-0.482)(12)	0.363 ± 0.035 (0.007-1.03)(34)

Results of flooding on adjacent surface water

- High rainfall associated with increased nitrate, soluble phosphorus, TDS and DOM in adjacent waters
- Smaller water bodies showed higher increases than larger waters (e.g. ponds + streams >> lakes + rivers)
- MANOVA identified both land use and water body type as significant determinants for water chemistry impacts
- 10% of the 106 sites showed P:N ratios of >1.0 during both flood and non-flood seasons
- Findings supported Salvia-Castellvi et al. (2005)*

* Salvia-Castellvi, M.; J.F. Iffly, P.V. Borght and L. Hoffman. 2005. Dissolved and particulate nutrient export from rural catchments. Sci. Tot. Environ. 344: 51`-65.

Reduction of nutrient escape

- Containment of runoff from barn property
- Dykes IN PLACE in event of future lagoon overflow, liner failure, storage tank rupture
- Mandatory monitoring wells
- Increased mandatory permanently vegetated buffer zones around barns and spread fields (with interim controls if shelterbelts are to be planted)
- No drains directly into ditches or municipal drains
- Spreading setbacks from ditches and drains (currently not respected, some manure disposed directly in ditches)
- Sediment traps in weirs and culverts to retain particulates and particulate bound nutrients and organic matter
- No dribbling of manure on roadways (currently not respected)

Nutrient escape reduction

- More than 1 soil sample must be required per quarter section
- GPS location of soil samples
- Periodic sampling should also be done at stated depths below the surface.
- It should be a prosecutable offense to submit fraudulent soil samples.
- Soil sampling should be subject to random independent verification
- In a flood season, the nutrients are not utilized by crops, but escape to water. Manitoba Crop Insurance records should be used to identify operators who repeatedly claim for flood damage and these operators should be counselled with respect to other production options.
- Manure spreading on the same plot of land year after year should not be allowed.
- Surface water should be periodically monitored downstream of barns to identify point sources which can then be remediated.

Inadequacy of nutrient calculations

- Actual nutrient content of manure should be known, not average book values from U.S. Nutrient content varies.
- Volatilization of ammonia during and after spreading must be taken into account
- Federal Feeds Act should reduce both minimum and maximum phosphorus levels in feed for swine
- What kind of crop is planned is not enough information to calculate nutrient balance. More information is needed such as: average previous yield from that field, remaining nutrients in non-harvested portion of crop biomass, will the stubble be burned
- Nutrient uptake depends on seeding density, germination rates, weather conditions, length of growing season, weed competition, herbivory, genetic variety of each crop type, etc.
- Manure applied in the fall escapes in the spring
- Manure applied before rainfall event escapes to a greater extent
- Non-incorporation increases nutrient escape
- Manure applied repeatedly to same land area escapes to a greater extent
- Manure applied in a few large doses escapes to a greater extent than a greater number of smaller doses
- Nutrient uptake is affected by herbicide application. E.g. nitrate absorption is increased by exposure to 2,4-D or MCPA

Manure application

- Manure application in pastures and near dugouts must take into account the potential for pathogen spread to both livestock and wildlife
- Nitrogen content of manure may lead to nitrate toxicosis in cattle when applied in excess to hayland
- Nitrate toxicosis is exacerbated if hayland or pasture has been sprayed with herbicide
- Excess nitrogen application to cropland may lead to toxic levels of cyanogenic glycosides and alkaloids in some crops (e.g. clover, beet, celery, turnip, broccoli, sweet potato, lettuce, radish, cucumber, squash, sunflower, corn, etc.)
- Human consumption of high-nitrogen crops, or excess nitrate in wells, can lead to methemoglobinemia, liver damage, cancer

Winter manure application

- **Winter manure application is carried out by smaller operators**
- **In a given area, the cumulative effect of several smaller operators may exceed the animal units of a single larger barn**
- **Some operators have no manure storage facility and spread manure every day of the year**
- **Pathogens can enter wells in the spring**
- **NO WINTER APPLICATION SHOULD BE ALLOWED**

Pathogens in swine waste

- Many pathogens are easily cross-transferable between swine and humans
- Viruses mutate rapidly and many human epidemics start at the human-swine interface. E.g. swine flu, coxsackieviruses (swine vesicular disease), etc.
- Many bacterial illnesses. E.g. *Escherichia coli, Yersinia, Salmonella, Treponema, Streptococcus, Campylobacter, Pseudomonas, Listeria*, etc.
- Many bacterial pathogens are now multi-antibiotic resistant (R-factors). Subtherapeutic levels of antibiotics in swine feed contribute to R-factor development.
- Pharmaceuticals end up in water with thus far unknown effects on wildlife and on human health
- Protozoa (e.g. *Cryptosporidium, Entamoeba, Balantidium,* etc.
- Helminthic parasites (e.g. *Ascaris, Taenia solium,* etc.) Sparganosis when plerocercoid locates in human brain results in brain tumor.
- BSE has been experimentally shown to be transferable to pigs. Feed regulations should be amended so that swine feed contains no cross-species animal products.

Manure application in the winter months


http://www.extension.umn.edu/dairy/dairystar/01-14-06-Spiehs.htm

- Research focusing on the Sumas River watershed in B.C. found that late application of animal waste in the fall is likely to be the main cause of water pollution in the watershed
- Fecal coliform counts rose by four-times during the wet winter months

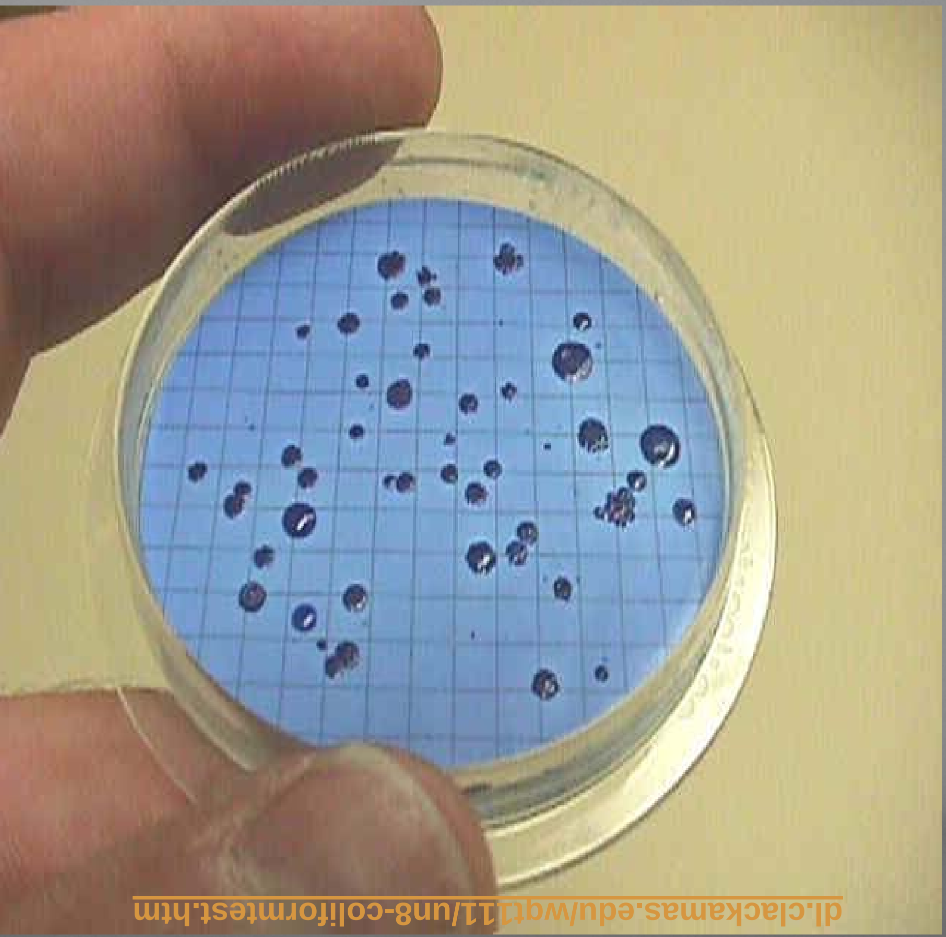
Antibiotic resistant bacteria

- Research conducted in a rural groundwater supply found that all non-coliform and 87% of coliform bacteria were resistant to at least one antibiotic and that 60% of the coliforms were multiple-antibiotic resistant (MAR)
- Genes coding for antibiotic resistance identical to those found in lagoons housing swine waste have also been found in groundwater and soil hundreds of meters downstream from the original source.
- Since the human and pig intestine has been found to facilitate horizontal gene transfer in pathogenic bacteria, consuming groundwater contaminated with these resistance genes may be able to bring a non-resistant pathogen into contact with the resistance gene and allow it to acquire these functions when inside the host .

Planning for Swine Disease Outbreak

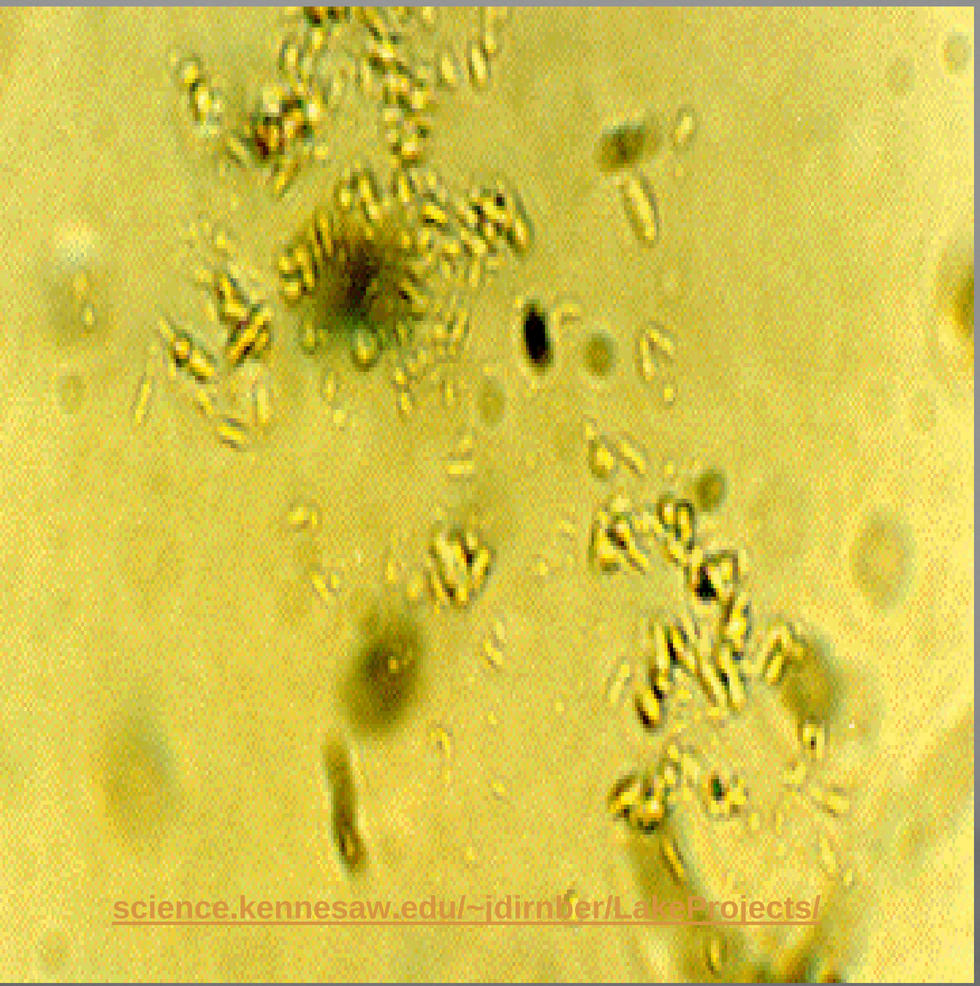
- EVERY OPERATOR MUST HAVE AN EMERGENCY DISPOSAL AND DISINFECTION PLAN IN PLACE IN THE EVENT OF A DISEASE OUTBREAK
- Composting of diseased animals must not be allowed to compromise ground or surface water
- Composting must be secure from wildlife contact

Well water contamination in Ontario



- A field study found that overall, bacteria was the most widespread form of water contamination
- 34% of wells had coliform counts higher than the acceptable limit
- As well, the percentage of wells contaminated with coliform decreased significantly as distance from feedlot operations increased
- Historical data indicated that these counts have increased significantly since 1950, and this is thought to be because of recent use of liquid manure applications

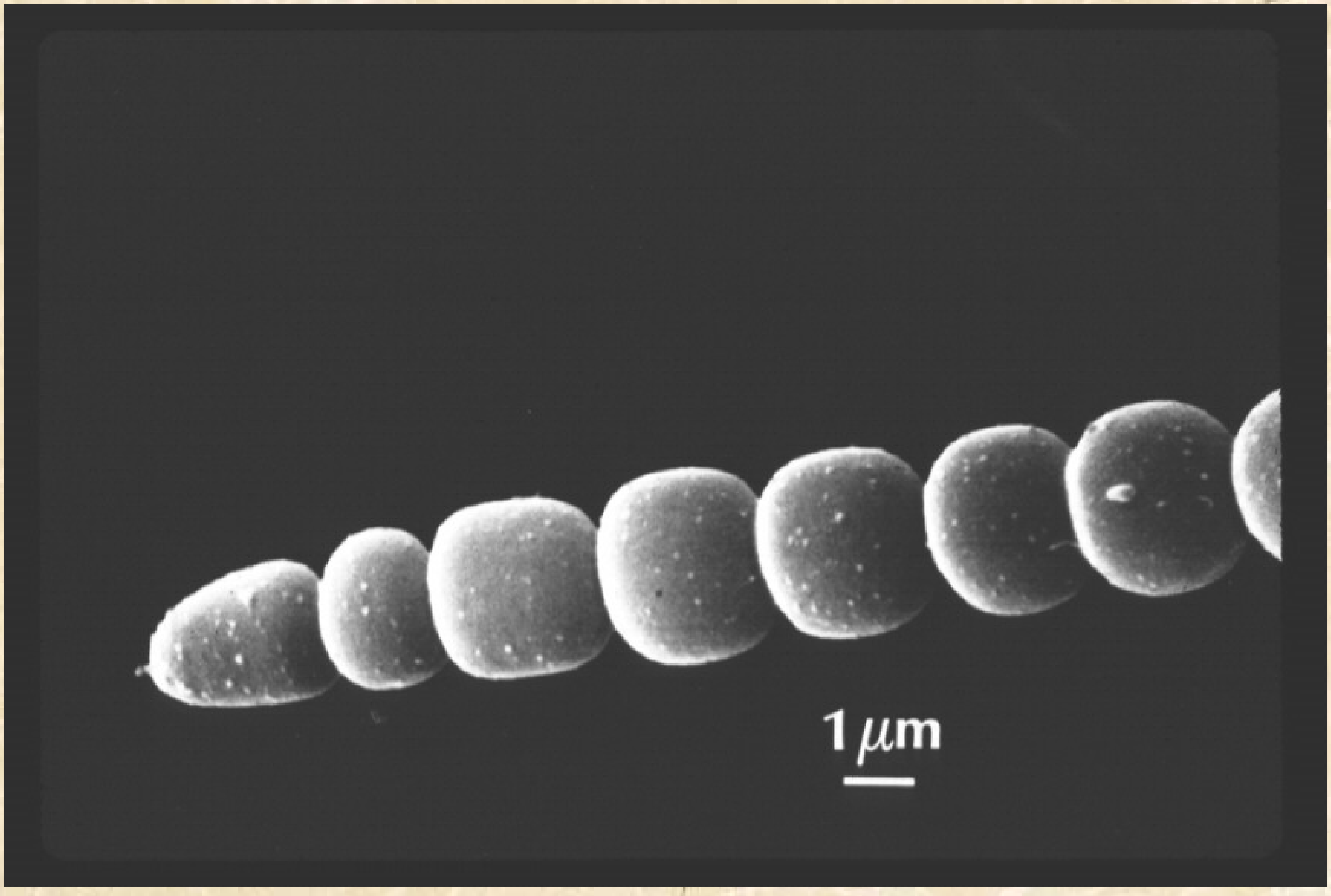
Soil as a source of coliforms



science.kennesaw.edu/~jdirnber/LakeProjects/

- This study also found that ***E. coli*** **and coliform levels were positively correlated with ammonia and nitrate.**
- **Saturated soil was also beneficial to coliforms as they are facultative anaerobes and may be able to out compete the natural microflora during low oxygen conditions**
- **This study led to the conclusions that manure in the soil enhances the presence of the virulent strain of** ***E. coli,*** **especially in no-till soils due to the enhanced microhabitat environment, and that application of manure along with rainfall or irrigation disperse the organisms into the soil. It was also found that if the pores in the soil column do not become clogged, the virulent** ***E. coli*** **can travel into deeper layers for more than two months.**

Nutrients and algae



Nitrogen and phosphorus feed algal blooms

- Phosphorus is the primary limiting nutrient in >90% of Manitoba surface waters
- At warm temperatures, cyanophytes proliferate
- Exacerbate nitrogen input by fixing atmospheric nitrogen (heterocysts)
- A number of genera (e.g. *Anabaena, Microcystis, Aphanizomenon, Nostoc, Oscillatoria, Lyngbya,* etc.) produce toxins
- Three main classes of toxins: hepatotoxins, neurotoxins, lipopolysaccharide toxins
- No antidote
- Chronic low level consumption is carcinogenic
- Increasing problem in Manitoba surface waters
- Increasing nutrients + climate change means that problem will inevitably increase
- Algal blooms in Lake Winnipeg can be seen from space

Ecological effects of algal blooms

- Algal mats with gas vacuoles float on surface and shade out all primary producers (macrophytes) underneath
- Oxygen depletion occurs when algal mats die and decompose
- Lead to both illegal and legal use of copper sulphate, which poisons aquatic organisms
- Copper sulphate enters drinking water
- Increased eutrophication accompanied by reduced species diversity and increased dominance of less desirable species
- Community destabilization facilitates invasion by exotic species of reduced value
- Algal biomass continues to decompose under winter ice, leading to winter fish kills

Deficiencies in current practices

- Current regulations (e.g. setback requirements, forbidden areas, containments, etc.) must be realigned with reality
- Monitoring and enforcement are poor. Response to complaints may be uselessly tardy.
- Consequences for operator are poor to non-existent
- The TRC approves applications which do not meet minimum standards: setbacks, manure application in drains, manure storage, sustainability of spread fields, exemptions to minimum land areas, lack of soil samples, lack of odor control, no hydrological data, etc. In a number of instances, it has been demonstrated the TRC did not read the application in sufficient detail and overlooked vital inadequacies. TRC should be qualified for their job.
- Local municipal councils feel powerless to reject unwelcome applications because of the new Planning Act. In some cases, councillors have conflicts of interest.
- Local community input is discouraged and ignored
- Lack of an easily accessible number where problems can be reported by the general public and neighbors
- Lack of investigation of abandoned or compromised wells
- Lack of periodic monitoring of neighboring drinking water wells for coliforms and nitrate

Need for restrictions

- Restrictions on barn construction in floodplain zone
- Restrictions on barn construction near most vulnerable surface waters (small lakes, streams)
- No barn construction in Precambrian Shield zone
- No barn construction in high water table zones (<3 meters below surface in "normal" precipitation years)
- No barn construction where permafrost within 5 meters of surface
- No barn construction in karst zones
- No barn construction adjacent to ecological preserves

Barns and manure spreading should be restricted where:

- Porous or sandy soils exist (in some cases operations are in gravel pits)
- Organic, acidic soils exist (in some cases manure is applied to bogs)
- The land slopes towards a watercourse
- TDS in water is <100 mg/L
- Bedrock outcrops exist and soils are shallow
- Other uses (including other barns) that impact on water already exist within a 2 km radius
- Drains and watercourses are likely to be contaminated during spring runoff or wet seasons
- The site is <10 km from Lake Winnipeg or other large lake
- Nitrogen and/or phosphorus levels are already high
- Aquifers are small or hydrological data are lacking

Other issues

- How much do the greenhouse gases produced by live pigs and by manure offset the gains in greenhouse gas reduction made by Manitoba in other areas?
- What impact do pharmaceuticals and vaccines in the waste have on wildlife and human consumers?
- What happens to the productivity of land that is continuously fertilized with manure over many years?
- Can certain aquifers sustain the high pumping rates required to service (often several) large hog barns?
- How will lagoons be decommissioned?
- How will the wastes from a projected Winnipeg slaughterhouse be handled by a sewage treatment plant that cannot cope with the present existing sewage loads?
- Why are boil water advisories not mailed to each household?