Ice Melters and the Environment – Challenges and Opportunities

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Topics

- Introduction to the basics of environmental impact
- Overview of the environmental effects of the common deicers and additives
- Strategies to minimize environmental impact

Introduction – The 2nd Law of Thermodynamics

- "It is impossible to convert heat completely into work in a cyclic process."
- Translation: "You can't get somethin' for nothin"
- And you are always going to get less than you paid for!
- The difference is called entropy
- Entropy = disorder = waste (environmental impact)

2nd Law in real world terms

Before

After

You can't do anything without making a mess!

Entropy Unrestrained!

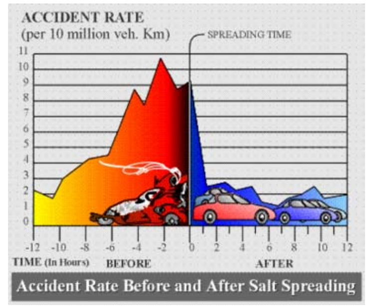
And this includes cleaning up a mess!

Cleaning up a mess **always** occurs at cost of making a **bigger** mess someplace else!

Ultimate Environmental Strategy

- *Understand* the environmental cost of any action
- Include the environmental impact as part of the *real cost* of any activity
- *Balance* the environmental cost with the benefit
- Maximize *efficiency* – accomplish the goal with the least amount of action

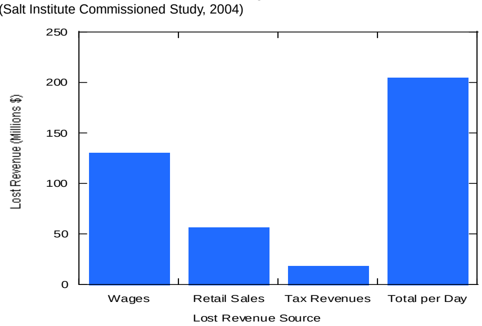
Benefits of Deicing



85% reduction in traffic crashes (SI/Marquette Study – graph courtesy of saltinstitute.org)

Projected Economic Cost of Roads Closed due to Snow and Ice for One Day in VA

(Salt Institute Commissioned Study, 2004)



All deicers present same basic environmental challenge

- We are dispersing chemical into the environment
- All chemicals affect the environment in different ways
- There is no "perfect" deicer chemical

Overview of Environmental Effects of Common Deicer Chemicals and Additives

Basic Ice Control Chemicals for Deicing Use

- Salt (sodium chloride)
- Calcium chloride
- Magnesium chloride
- CMA (calcium magnesium acetate)
- Potassium acetate
- Sand/abrasives

Commonly Used Performance Enhancing Additives

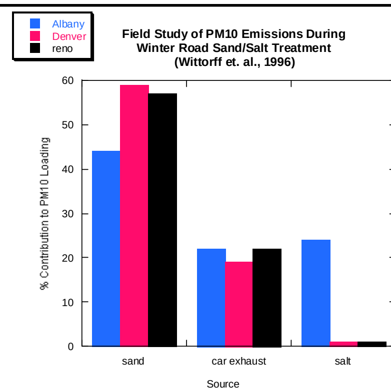
- "Agricultural Additives"
  - Molasses
  - Corn syrup
  - "beet juice"
  - Brewers condensed solubles
- Corrosion inhibitors
- Colorants
- Anticaking/Flow enhancers
  - YPS

Basic Types of Environmental Impact

- Soil
- Air
- Vegetation (particularly roadside)
- Ground water/wells
- Surface waters
- Aquatic/animal life
- Infrastructure corrosion

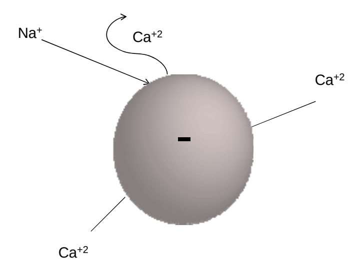
Effects on Air Quality

- Chief concern is particulate matter < 10 micron (PM10 emissions)
  - Respiratory problems
  - Eye/throat irritation
  - Regulated by EPA
- Sand/abrasives major source (Wittorff et. al.1996)
- Traffic makes an aerosol of sand
- Sand cannot dissolve in melt
- Mag and calcium chloride will suppress dust



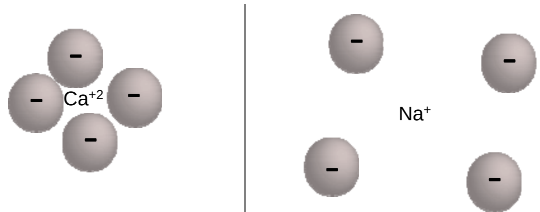
Effects on Soil – or - What do soil and water softeners have in common?

Soil behaves like resin in a water softener



Sodium can displace calcium in soil

Calcium and magnesium are important to soil structure



Strong charge on calcium bridges negative charged soil particles together

Weak charge on sodium cannot bridge soil particles together

Detrimental Effect of Sodium Salts on Soil Structure

- Inhibits soil aggregation
- Decreased permeability
- Decreased water availability to plants
- Decreased soil aeration
- Breakdown soil structure / increased erosion

Other Deicer Effects on Soil

- Highest Concentrations 6-10 feet from roadside
  - Elevated concentrations up to 33 feet from road, 3 feet deep)
  - Levels highest in spring, drop to background levels through summer and fall (Hofstra and Smith, 1984)
- CaCl2, MgCl2 may increase soil permeability / improve soil structure

Effect of acetate/organic deicers on soil

- Ca and Mg in CMA should have a beneficial effect on soil
  - Possibility that an excess of Ca in soil could create a nutrient imbalance for plants
- Acetates may mobilize trace metals from soil (conflicting reports)
- Acetates may cause temporary anaerobic conditions in soil due to BOD
- BOD can lead to soil acidity

Deicer Effects on Vegetation

- Greatest impact near heavily deiced roads
  - Damage can occur up to 650 feet from roadway (Environment Canada, 2000)
- Most resistant to salt
  - Grass, wetland species (spagnum moss and sedges)
  - Maple, pine, douglas fir, dogwood, peach, and plum trees
- Conifers generally more sensitive than desiduous trees (Hanes et. al., 1970)

Effects on Vegetation

- Highest at roadsides
- Toxicity rankings vary
  - KA > CMA > CaCl2 > NaCl > MgCl2 (Allium cepa root elongation and Duckweed Lemma growth inhibition tests – Anneli, et. al. 2003)
  - NaCl ~ NaFo > CMA (germination and growth of cress and barley – Robidoux et. al. 2001)
- High chloride may be more damaging than high Na, thus MgCl2 > CaCl2 > NaCl (Hanes, 1976)
- CMA < NaCl on 17/18 of tree species studied (Winters et. al. 1985)
- Rankings appear to be dependent on the plant and environment

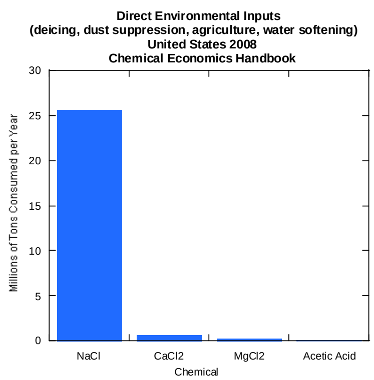
Deicers are not the only stress on roadside vegetation

- A variety of stress factors occur at roadsides
  - Soil compaction near road
  - Traffic stress (exhaust, petroleum residues)
  - Leachate from asphalt

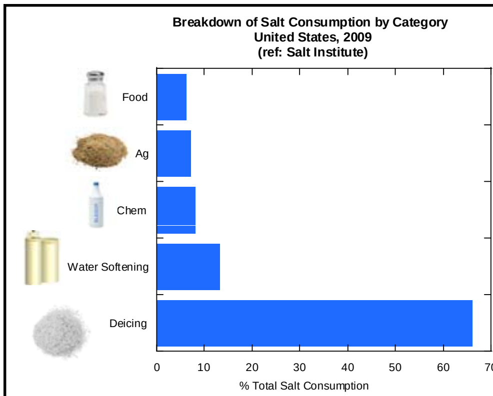
Ice Melters and the Environment – Challenges and Opportunities

Effects on Surface/Ground Waters

Ice Melters and the Environment – Challenges and Opportunities



Ice Melters and the Environment – Challenges and Opportunities



Ice Melters and the Environment – Challenges and Opportunities

Effects on Surface/Ground Waters

- Increasing density in lower layers – inhibition of mixing/oxygen distribution
- Elevated chloride levels measured in some small streams near highways – not seen in large bodies of water (dilution effect) – Cheng and Guthrie, 1998.
- Direct effects on aquatic life (complex)

Ice Melters and the Environment – Challenges and Opportunities

Sources of Chloride in Natural Waters

Deicers

H2O Softeners

Sewage/animal waste

Landfill leach

Fertilizer

Groundwater minerals

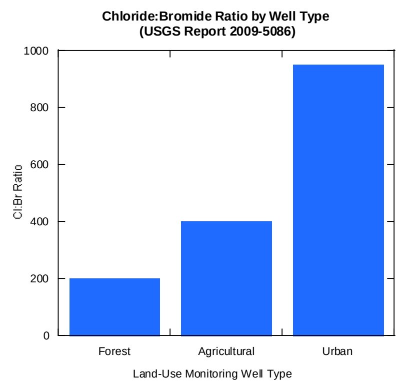
Ice Melters and the Environment – Challenges and Opportunities

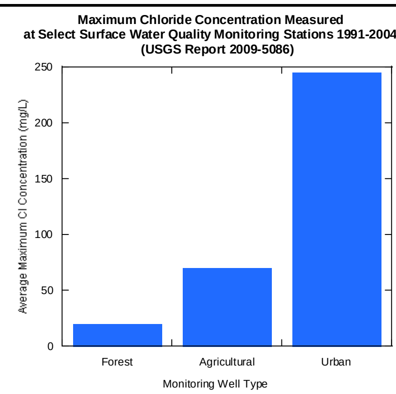
How important is deicing salt compared to other sources of chloride?

- Difficult to determine precisely
- USGS approach (2009) – look at chloride/bromide ratio in natural waters
- "natural" sources have lower Cl:Br ratios than "human activity" sources (e.g. deicers, water softeners)
- High Cl:Br ratios in waters would suggest influence of human activity

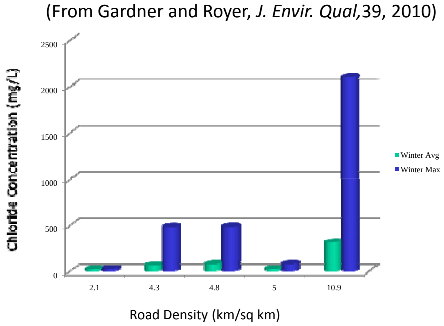
Typical Cl:Br Ratios (USGS Report 2009-5086)

- Deicing Salt = 1,000 – 10,000
- Sewage/Animal Waste = 460-1395
- Fertilizer = 510
- Landfill Leach = 164-193
- Natural Mineral Groundwater = 148





Chloride Levels in 5 Indiana Streams 2007-2009 (From Gardner and Royer, *J. Envir. Qual*,39, 2010)



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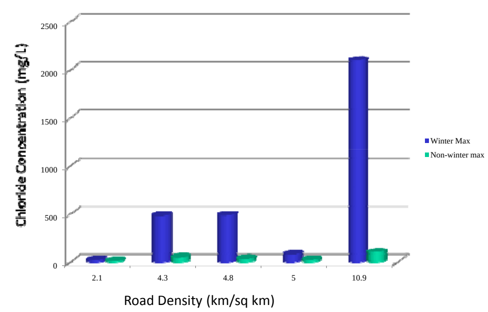


Observations from Indiana Stream Study (Garnder and Royer, 2010)

- Stream chlorides increase during winter months
- Spikes in chloride always associated with winter storms and deicing salt application
- Highest chloride observed at most urbanized site
- Elevated chloride occurred in discrete 24-48 hour pulses in all but most urbanized stream
- 5 periods in most urban stream showed 4-d average Cl > 230 mg/L (EPA guideline for potential chronic effects > once every 3 year)

Effect of Road Salt Chloride on Aquatic Life

- Current elevated chloride levels during winter in Indiana test streams unlikely to cause direct mortality to aquatic organisms (Gardner and Royer, 2010)
- 2002 loadings in Michigan streams not likely a risk to stream macroinvertebrate (= "fish food") communities (Blasius and Merritt, 2002)
- Chloride can affect pond amphibians at moderate concentrations – greatest negative effects limited to 50 m from road (Karraker et. al., 2008)

Effect of Road Salt Chloride on Aquatic Life

- Tests indicated catfish, bluegill, bass, trout, perch, and fathead minnows survived well a 24 hour Cl spike of 6100 mg/L (Walter, et. al., 1996)
- Urban streams in Wisconsin tested 1998-2008
- Toxicity to aquatic test organisms observed in 7 of 12 metropolitan area streams during deicer application
- Predict detrimental effects over numerous aquatic species
- Suggest a need for more detailed measurements to determine duration and range of road salt influence (Corsi, et. al., 2010)

Effect of acetate deicers on water

- Acetate (e.g. CMA) portion binds to soil – will tend to restrict it from ground and surface water (Horner, 1988)
- Acetates have high BOD and are considered likely to cause oxygen depletion of waters (Mussato and Guthrie, 2000)
- Another study concluded CMA unlikely to have negative effect for most application scenarios (McFarland and O'Reilly, 1992)
- No negative effects observed on bluegill and fathead minnows in pond field tests (Horner, 1988). Rainbow Trout??

Effects of Organic Deicers/Additives on Water


+

= oxygen consumption

- Chief effect is BOD (Biochemical Oxygen Demand)
- Bacteria feed on digestible organics as food
- Bacteria compete for oxygen with aquatic life

Other Effects of Organic Deicers/Additives on Water

- Organic nutrients and phosphorus can cause eutrophication (algae growth)
- Contributes to BOD

Environmental Impact of YPS

- Most deicing salt is treated with "sodium ferrocyanide"
- Common name YPS ("Yellow Prussiate of Soda")
- Not the same as cyanide
- YPS has FDA approval as a food additive
- YPS has a very unique effect on salt crystal growth!

Why cyanide in YPS is not toxic

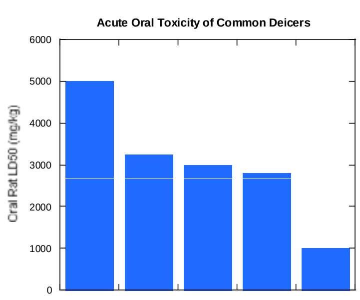
- Free cyanide is toxic because it LOVES to bind to iron
- It reacts with the iron compounds in blood involved in oxygen transfer
- Interferes with the body's ability to transport and utilize oxygen
- But in YPS cyanide is already completely bound to iron!
- However, sunlight will decompose YPS and release free cyanide in water

Practical Environmental Hazard of YPS in Deicing Salt Very Low

- Not persistent in either soil or water
- YPS only accessible to UV breakdown at surface of water
- Rapidly dissipates by evaporation and biodegradation
- Cyanide is acutely toxic, not chronically toxic

Alternatives to YPS?

- YPS probably not an environmental hazard except where runoff is isolated and not diluted
- Treated salt products containing MgCl2 or CaCl2 do not need YPS
- Some YPS substitutes exist, but are more expensive



Deicers Have Generally Low Aquatic Toxicity

Pesticide Toxicity Rating	LC50 (ppm)
Extremely Toxic	0.01 – 0.10
Moderately Toxic	1.0 – 10
Slightly Toxic	10 – 100
Minimally Toxic	> 100

- Common deicers typically LC50 > 500
- Commonly LC50 > 2000

Deicer Environmental Strategy

- Understand chemicals’ environmental effects
- Understand chemicals’ performance characteristics
- Choose the right chemical and application procedure for the right condition
- Maximize deicer efficiency!

Best Management Practices to Minimize Deicer Environmental Impact

- Non-structural BMPs – reduce amount of chemical applied to roadway
- Structural BMP’s – treat or mitigate deicer runoff after it leaves the roadway
- BMPs are effective – recent study was carried out at the University of Waterloo in Ontario with joint funding from the Salt Institute and Environment Ontario
  - groundwater monitoring data indicated that chloride levels in the “best practices” field locations were ~50% lower than for other locations.”
  - “a significant reduction in average soil Cl^- concentration occurred following the implementation of the best management practice activities.”

Non-Structural BMPs

- Managing service level expectations
- Use of snow fences
- Proper stockpile management
- Anti-icing/pre-wetting
- Use of slurries
- Use of non-chloride deicers
- Use of advanced snow plow technologies
- “sensible salting” – controlling application rates
- Data driven application rate optimization
  - RWIS
  - Friction monitoring
  - Decision Support Systems
- Use of non-chemical deicing technology (future?)

Structural BMP’s

- Use of salt tolerant plants to buffer roadways
- Controlled release of highway runoff to mitigate spikes in deicer concentration
- Use of ponds, wetlands, vegetated swales, filter strips, etc to reduce the rate and quantity of deicer runoff

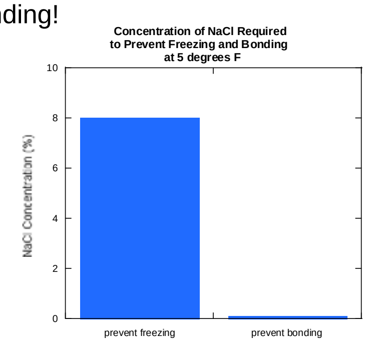
Basics of Sensible Salting

- Apply “just enough and no more” deicer
- Clear expectations of expected service level are required from local policy makers
- Plan ahead – choose application rates for the basic storm types
- Calibrate spreaders before the snow flies
- Apply deicer early in storm or pre-storm if possible
- Spread salt on upwind side of road if possible
- Spread salt on high end of banked curves if possible and let gravity flow work

Liquid Deicers – very important tool for minimizing chemical use

- Liquid deicers allow chemical to be spread in a very thin layer on the road
- Allows application of a small amount of chemical to prevent ice from bonding

Very little salt is required to prevent ice from bonding!



The Importance of Anti-Icing

Applying salt to an existing snow pack

- Often unavoidable
- Always inefficient

- Most of the salt is "wasted" melting through the snow pack to reach the pavement

The Value of Pre-wetting

- Pre-wetted salt permits 20-30% lower application rates of chemical
- Pre-wetting appears to make salt usable at colder temperatures
- Above 15 ^{0}F salt is most efficient ice melter
- Below 15 ^{0}F salt benefits from pre-wetting with mag or calcium chloride

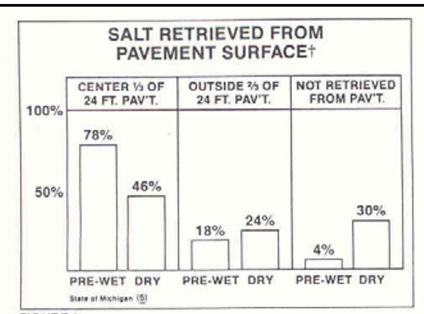


FIGURE 1

Salt pre-wet with liquid calcium chloride
From Michigan Dept. of State Highways Study 1972-73
H. Lemon, *Better Roads,* July, 1974, pp 20-21.

Faster Ice Melting at Colder Temperatures

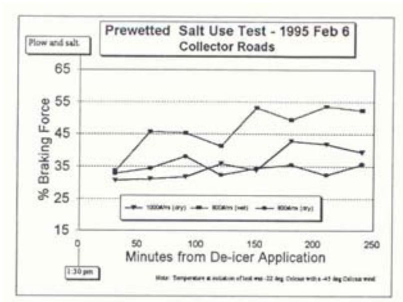
- "At 2^0 above zero (calcium chloride) wet salt section was cleared 4 to 6'. . .when dry salt was just starting to work" (Lemon, 1974)
- At 3 ^{0}F MgCl2 treated salt resulted in a markedly higher friction than NaCl wetted salt (Torgier Vaa, Norway field test, 2001-2002)
- At 14 ^{0}F pre-wetted salt showed significantly faster recovery of friction in lab tests over 6 different pre-wetting agents based on CaCl2 and MgCl2*

*C. Luker, B. Rokosh, T. Leggett, Transportation Research Circular, Number E-C063, June 2004, pp. 585-601

Michigan Field Ice Melting Observations (1974-75)

Prewet Salt*	Temperature	Dry Salt
• Starts immediately	28 ^{0}F – 32 ^{0}F	minor delay
• Starts immediately	25 ^{0}F – 28 ^{0}F	10-20 minutes delay
• Minor delay	Below 20 ^{0}F	> 30 minutes delay

* Prewet with liquid calcium chloride. H. Lemon, 1974-75 Prewetted Salt Report. Michigan Dept. of State Highways and Transportation, 1975



1994-95 Field Test by Ottawa Road Operations Division

M. Miner, "Ottawa Tests Low-Cost Salt Pre-wetting System," *Better Roads,* December, 1995, pp. 37-40.

Pre-wet = Less Salt Needed

- 15% less salt used (James Sprang, Milwaukee County, WI, 1975)
- 24-44% saving in salt consumption (Horst Hanke, Wiesbaden, Germany 1994)
- 40% less salt used at low temperatures (C.L. Huisman, Iowa State Highway Commission, 1973)
- 28-38% less salt used (S. Kahl, Michigan D.O.T., 1999-2002 field tests, Transportation Research Circular, Number E-C063, June, 2004, pp. 552-554)

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Proper Salt Storage

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Salt Storage Best Practices

- Provide good drainage away from stockpile
- Contain drainage in reservoir – use for prewetting if possible
- Outdoor piles must be securely tarped
- Leaching from pre-wetted salt piles can be minimized by using a viscous pre-wetting liquid

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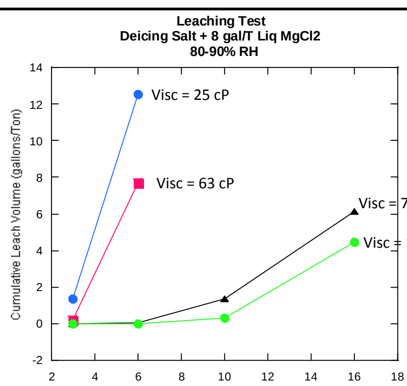

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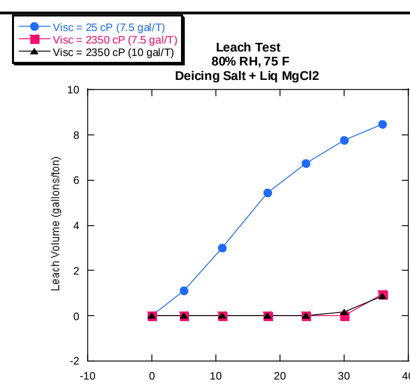

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Ice Melters and the Environment – Challenges and Opportunities

Conclusions

- Chemical deicers provide enormous value in preventing accidents, saving lives, and keeping transportation open in the winter.
- As urbanization increases, the possibility of increasing environmental impact exists
- Over application of chemical deicers can have a variety of potential negative environmental effects

Conclusions

- A major key to environmentally conscious deicing is minimizing application rates
  - Planning in advance
  - Spreader calibration
  - Apply early or pre-storm when possible
  - Use liquids when possible
  - Right chemical for right temperature
  - Store salt properly
  - Viscous prewetting agents minimize leaching in treated piles