

# Advantages and Disadvantages of Low VOC Vegetable Based Metalworking Fluids

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# Outline

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- Metalworking Types
- Potential Areas for Use
- Advantages and Disadvantages
- Summary

# Metalworking Fluids – Rule 1144

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Are:

- Metal Removal Fluids
- Metal Protecting Fluids
- Metal Forming Fluids
- Metal Treating Fluids

Coolants, cutting oils

Rust inhibitors

Stamping, drawing, forging

Quench oils

Are Not

- Metal Cleaning Fluids

Parts washing soaps, detergents

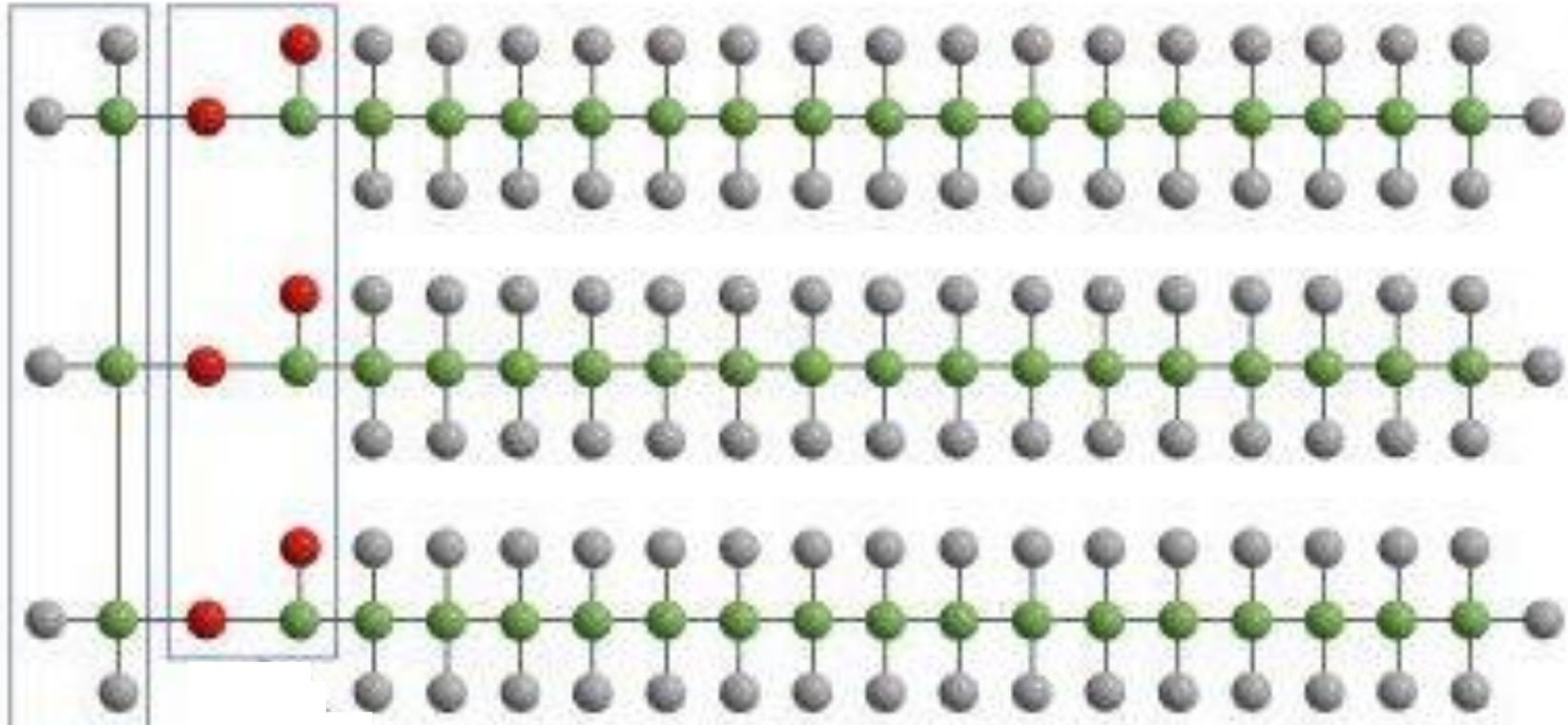
# Natural Vegetable Oils - Manufacturing

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- Canola , Rapeseed
- Soybean
- Sunflower
  
- Mostly triglycerides

# Triglycerides

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Glycerol

Three Fatty Acids

# Mineral Oil / Petroleum Oil

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- No fatty acids
- No glycerol
- Alkanes, cycloalkanes, and various aromatic hydrocarbons
- Contain nitrogen, oxygen, and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium
  
- Lubricating oil = 16 carbon atoms
- Paraffin wax = 25 carbon atoms
- Asphalt = 35++ carbon atoms

# Structures are Different

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- Vegetable
- Mineral

Therefore performance should be different

- AND IT IS – Each has advantages and disadvantages over each other

# Vegetable oil applications

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## Metalworking

- Metal removal fluids – emulsions, straight oils
- Metal protecting - Low VOC Rust Protectors
- Metal forming – wire drawing, stamping

## Other

- Conventional and Fire resistant hydraulic oils
- Gear oils
- Way oils
- Spindle oils

# Volatile Organic Compounds

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VOC expressed as grams / liter  
Per ASTM E1868-10

<b>Viscosity Grade cSt @ 40 Degrees C</b>	<b>Paraffinic Oil</b>	<b>Naphthenic Oil</b>	<b>Vegetable Oil - Canola</b>
4.4	400	718	NA
9.6	50	130	NA
20.5	10	64	NA
39.0	< 1*	5*	< 1**

\* Blended, two base stocks

\*\* Food grade

# Lubricity

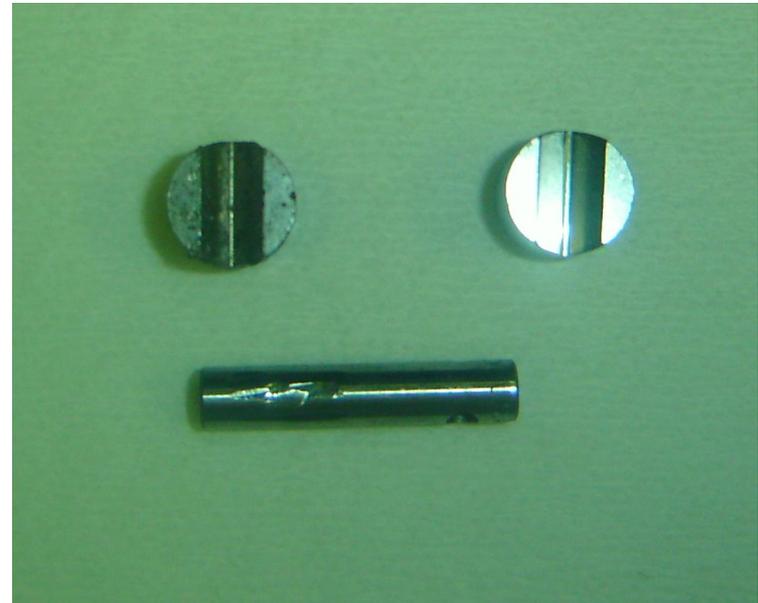
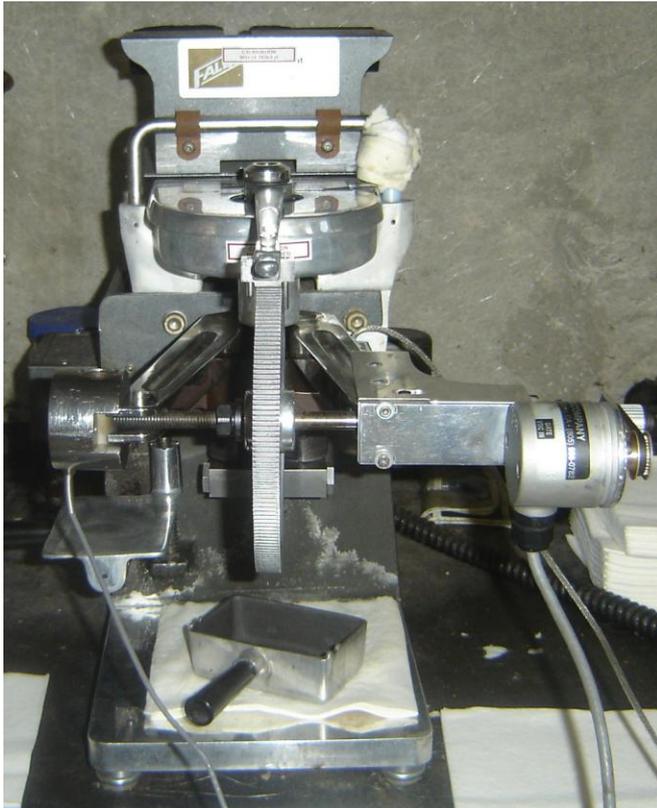
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- Determined by many standard lubricity tests
- Mineral oil = good
- Vegetable oils = better
- **Note: Without additive vegetable oils will generally outperform mineral oil in standard lubricity tests**
- Reference
  - Pin and V block
  - 4 ball
  - Tap torque
  - hydraulic pump/wear tests, such as ASTM D2882 and ASTM D2271

# Pin and V Block

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- V blocks are clamped around the spinning pin and pressure is increased until failure.



# Four Ball

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- One ball spins on top of three under pressure to scar the surface of the three.



# Tapping Torque

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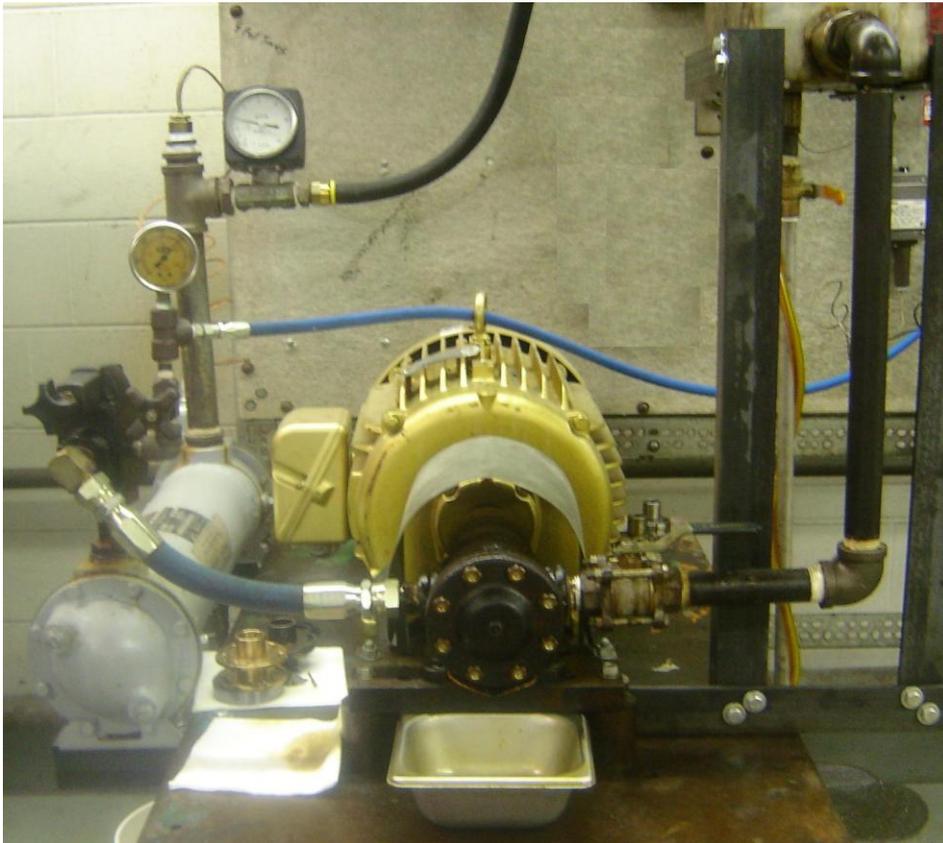
- Measures the amount of torque required to thread a standardized part.



# Hydraulic Pump/Wear Tests

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- ASTM D-2882 – V104C pump test



# Flash Point

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- Mineral Oil = 300°F – 400° F (typical 390°F)
- Canola Oil = 620°F - 625°F
- Soybean = 605°F - 615°F
  
- Method ASTM D92



# Biodegradability

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**Biodegradation** is a process of chemical breakdown or transformation of a substance caused by micro-organisms (bacteria, fungi) or their enzymes.

- Mineral Oil = Considered to be slow to biodegrade
- Canola, Soy = Considered readily biodegradable
- Reference: OECD 301 B (Organization for Economic Cooperation and Development)  
ASTM D-5864  
CEC EC-L-33-A-94 (Coordinating European Council)

# Biodegradable – both good and bad

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- Triglyceride – Breaks down into free fatty acids
- Fatty acids + Calcium + oil + alkali = grease
  - Especially problematic in wastewater treatment using Acid Alum treatment
- Can be so thick that it can be unpumpable
- Grease has no reclaimable potential!



# Aquatic Toxicity

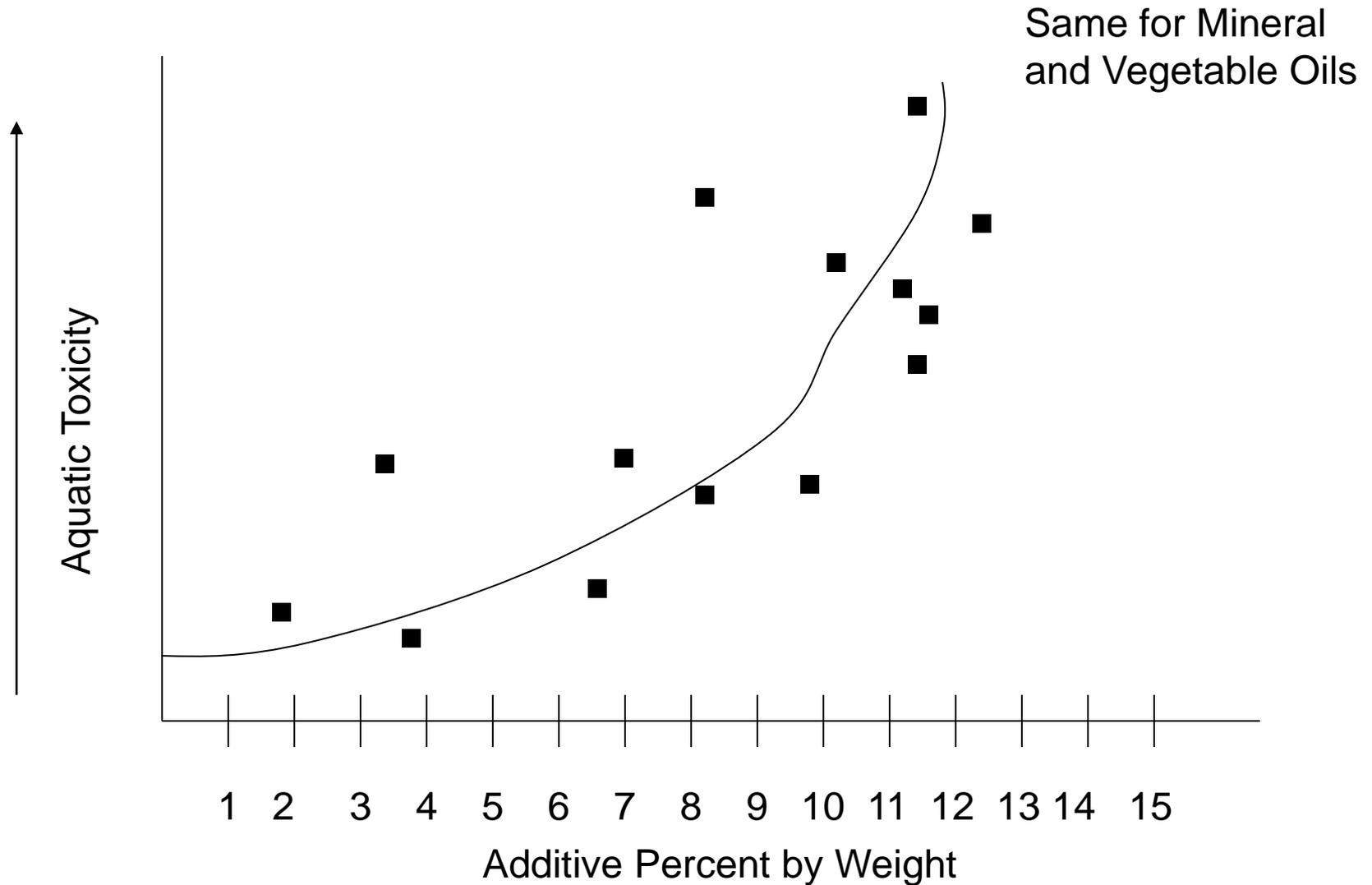
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- Daphnia
- Fat head minnow
  - LC50 > 100 mg/L – “Practically Non-toxic”
  - LC50 > 1,000 mg/L – “Relatively Harmless”
- **Note: Additive make or break toxic properties of fluids**



# Comment on Additives

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# Oil and Grease Measurement

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- EPA method 1664 and Standard Methods 5520B,F are used to determine oil and grease and hydrocarbons in wastewater – (hexane extraction, silica gel)

<b>Product Type</b>	<b>Dose mg/L</b>	<b>Response 5520B mg/L</b>	<b>Recovery %</b>	<b>Hydrocarbon 5520F mg/L</b>
Mineral Oil 20.5 cSt Naphthenic	<b>109</b>	<b>95</b>	<b>87.2</b>	<b>79</b>
Canola Oil 39 cSt Food Grade	<b>105</b>	<b>100</b>	<b>95.8</b>	<b>6</b>

# Visible Sheen

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- Mineral oil = Yes
- Vegetable oil = Yes



# Renewable Resource

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- Mineral Oil = no
- All vegetable oils = yes

# Competes with existing food crops

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- Mineral oil = no
- Vegetable oils = yes



# Oxidative Stability

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- Low oxidative stability: oil will oxidize rather during use, becoming thick and polymerizing to a plastic-like or tar-like consistency
- Mineral Oil = Good
- Vegetable oil = Poor

# Residue on Machines

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- No standard tests
- Mineral oil = low residue, cleanable
- Vegetable oils = poor oxidative stability – may form very sticky residues and be very hard to clean
- Some vegetable oils are more stable than others
  - As measured by iodine value
  - Monounsaturated based oils are better (75% or higher )

# Hydrolytic Stability

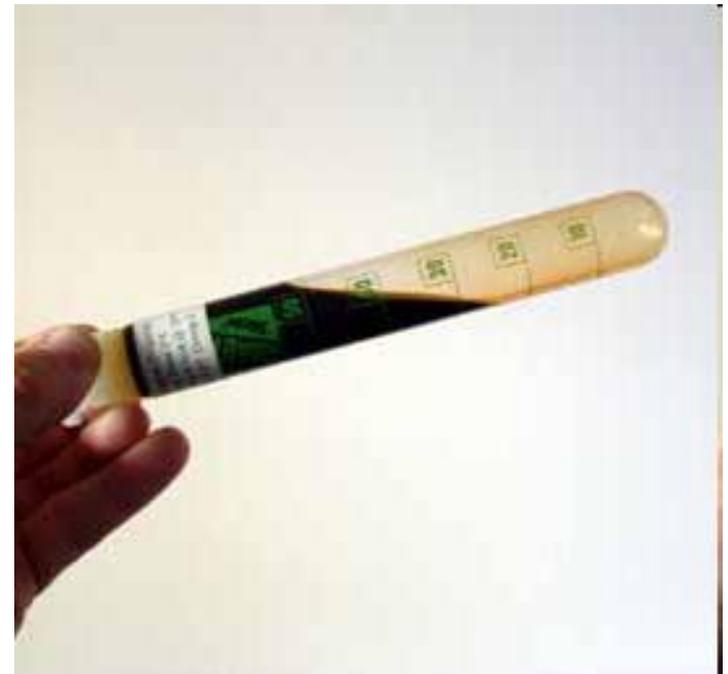
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- Stability when exposed to water
- Mineral = Good – may for invert emulsions
- Vegetable oil = poor, breaks down to release acids

# Pour Point

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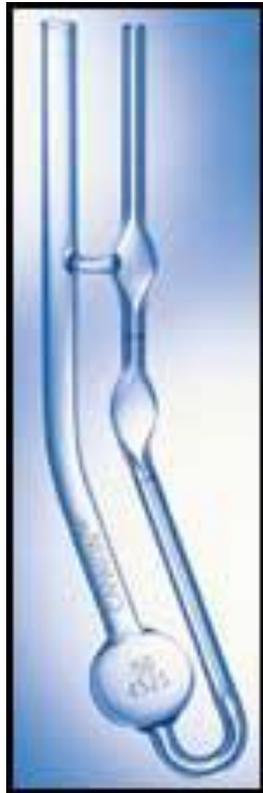
- Cold weather stability
  - Not really applicable to metalworking fluids
- Mineral Oil = minus 30 F
- Vegetable oils = +5 - +25F



# Viscosity Index

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- Maintains Viscosity at high temperature
- Viscosity Index (VI); for example, 223 for soybean oil vs. 90 to 100 for mineral oil
  - Higher number is better
- Mineral oil = fair
- Vegetable oil = very good



# Misting from Machining Operations

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- Mineral Oil = Medium
- Vegetable oil = low



# Dermal Sensitivity

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- Likelihood to cause Dermatitis
- Mineral oil = known to cause dermatitis
- Vegetable oil = minimal dermal issues
- Again – Additives can be irritants

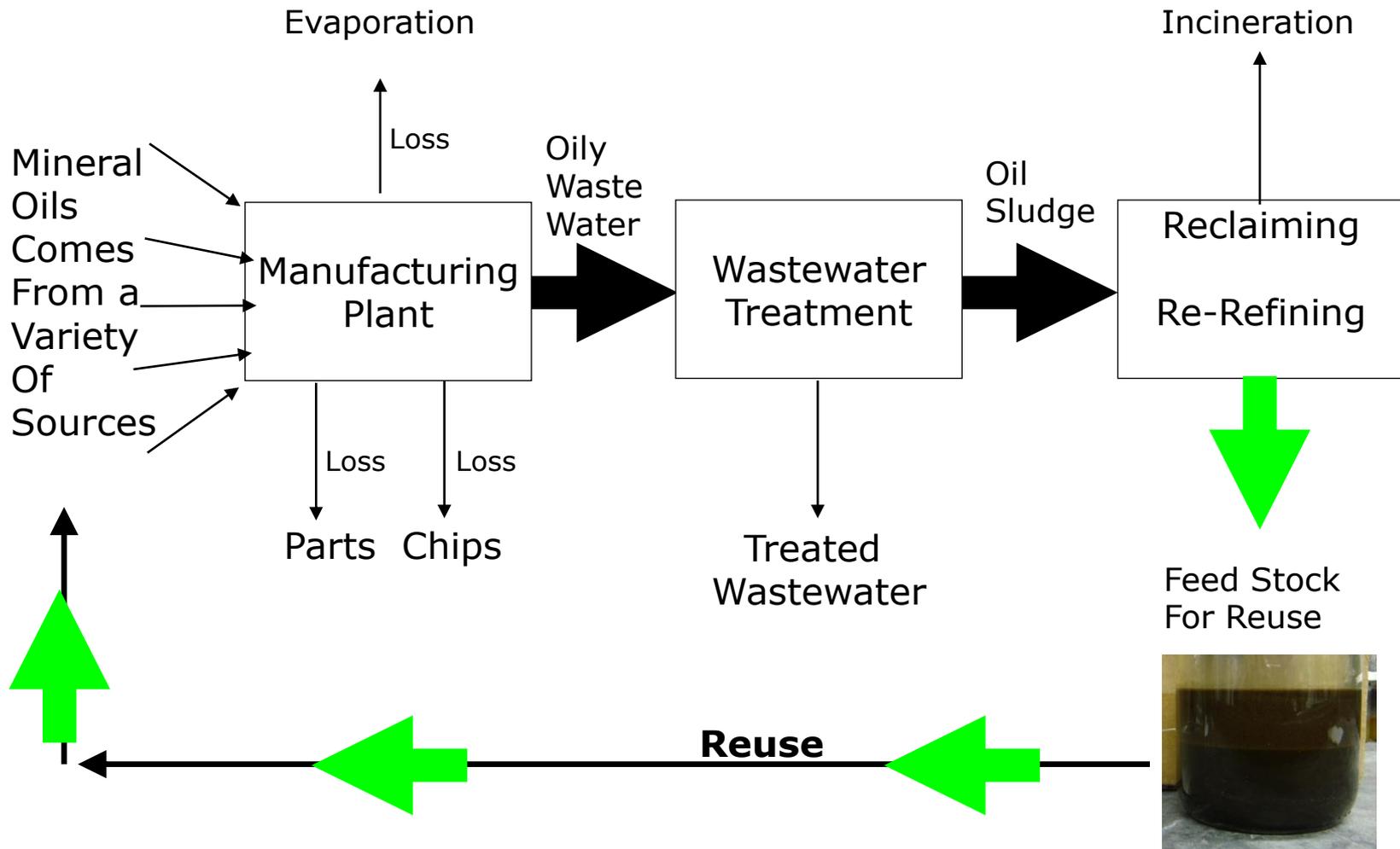
# Carcinogenicity Potential

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- Likelihood to cause cancer
- Mineral Oil = low if solvent refined and severely hydro treated
- Vegetable oil = naturally low

# Can be recycled

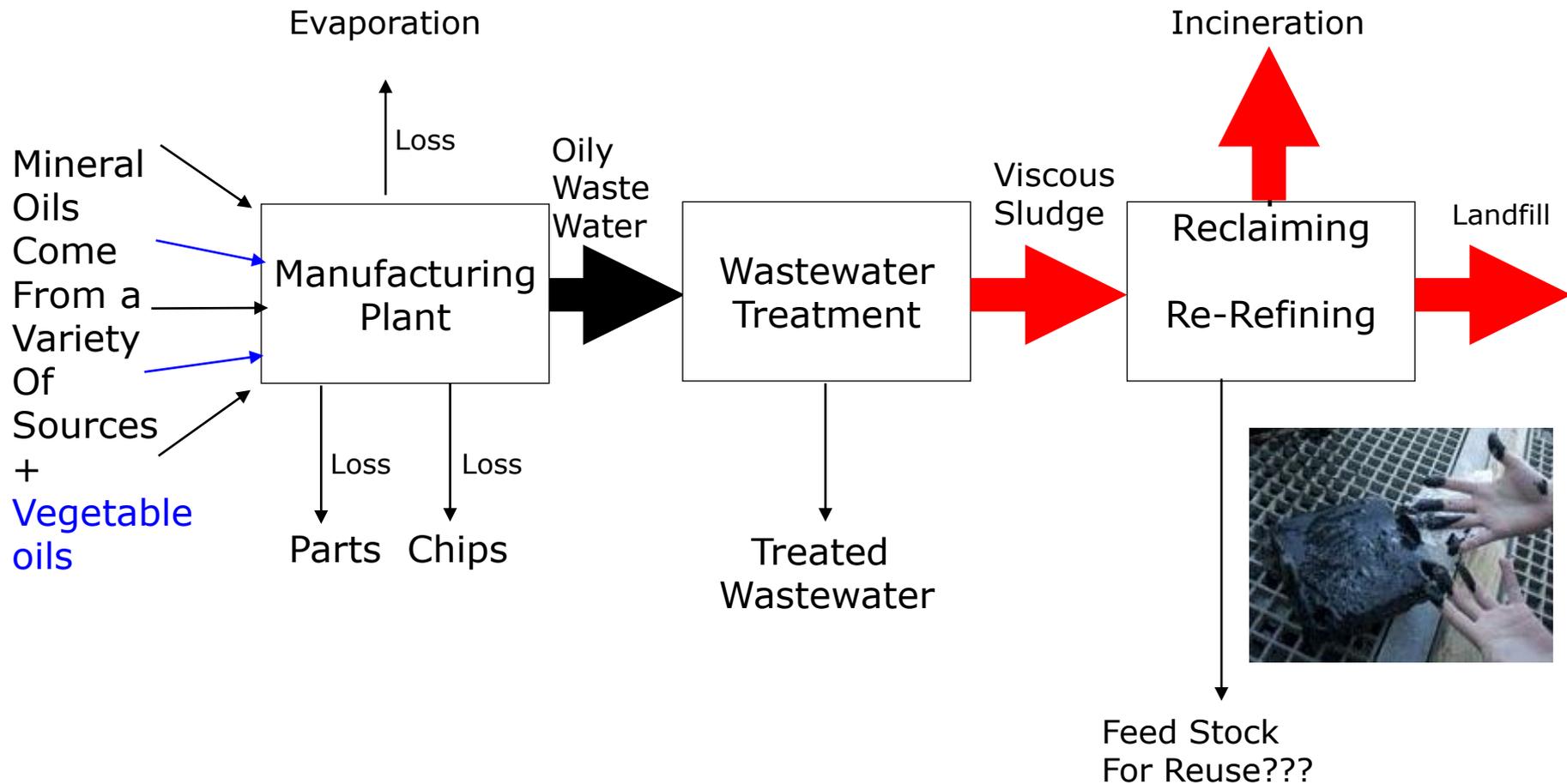
## Waste Infrastructure – Mineral Oil



# Can be recycled – Maybe not

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## Waste Infrastructure – Mineral Oil + vegetable oil



# What about cost

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- Base stock cost for vegetable oils generally track crude oil pricing
- Vegetable oils are generally more expensive
  - Mineral oil require multiple refining steps
  - Naphthenic oils are in limited supply, thus more costly
- Always exceptions to the rule
- Depending on the application and additive level, finished good price will vary

# Summary – Vegetable Oils

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- Vegetable Oils compete favorably with mineral oil
  - VOC, Lubricity, Dermal Sensitivity
- Additives needed to correct for
  - Pour point, oxidative stability, hydrolytic stability
  - Additives increase toxicity
  - Additive can increase dermal sensitivity
- May not be readily recycled

# Comparison Chart

Attributes	Vegetable	Mineral
VOC		
Lubricity		
Flash Point		
Biodegradable		
Aquatic Toxicity		
Oil and Grease		
Petroleum Hydrocarbons		
Visible Sheen		
Renewable Resource		
Food Crop - Compete		
Oxidative Stability		
Machine / Part Residue		
Hydrolytic Stability		
Pour Point		
Viscosity Index		
Misting		
Dermal Sensitivity		
Carcinogenic Potential		
Can Be Recycled		

Good

Fair

Poor

## SCORE

	Vegetable	Mineral
Good	10	6
Fair	4	7
Poor	5	5

# Summary

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- Vegetable oils are in use right now
- Can meet manufacturing demands
- Disposal of residuals needs research
- Costs are generally higher for vegetable oils than mineral oils

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## Thank You

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