Breakthrough Technologies for Prevention of Acidification of Soils and Water

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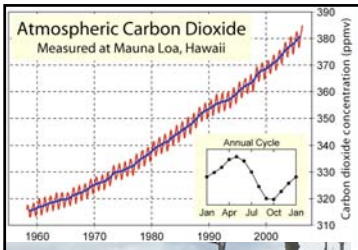
Fossil Fuel and Development

- Unprecedented economic growth
- Higher efficiency in crop yields by providing power to irrigate and produce fertilizers
- Allowed mechanization of agriculture
- Rapid transportation of goods, including food

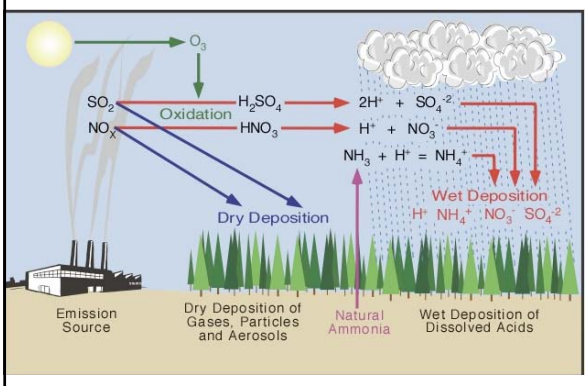


Environmental Impact

- Extraction and combustion of fossil fuels (coal, gas, oil) contributes to global, regional, and local environmental problems:

>Rise of carbon dioxide
>Acidification of rain
>Contamination of waters and soil by mine waste

Acidification of Rain



- Burning of sulfur in coal & oil leads sulfur oxides
- Sour gas releases hydrogen sulfide, which converts to sulfur oxide
- Sulfur oxide combines with water to produce acid

Global Susceptibility to Acid Rain

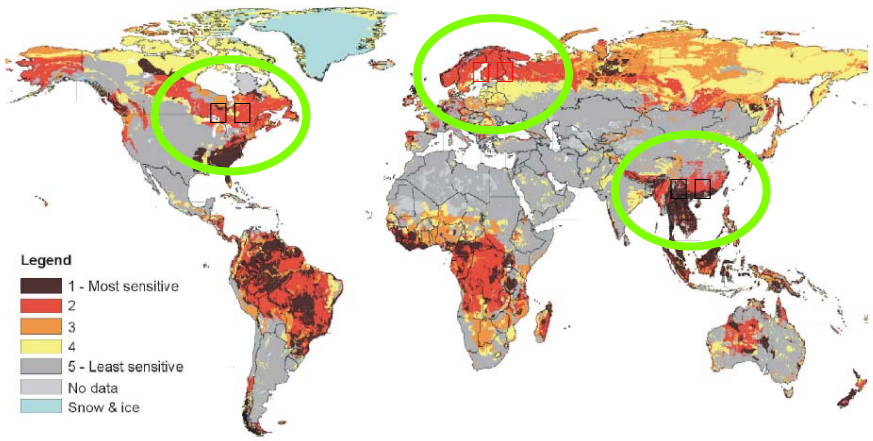


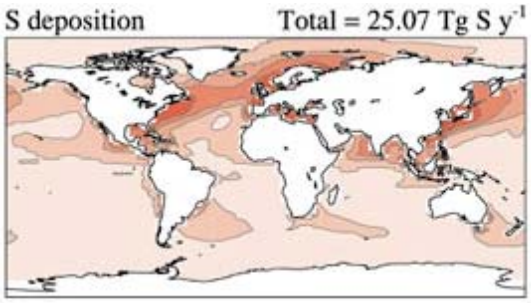
Figure: SEI Global Assessment of Ecosystem Sensitivity to Acidic Deposition (Kuylenstierna *et al.* 2001)

Some Implications of Acid Rain

- Soil degradation--Loss of calcium from root zone
- Loss of forests -- floods--soil
- Mobilization of Aluminum--toxic to fish

Impact on Coastal Waters

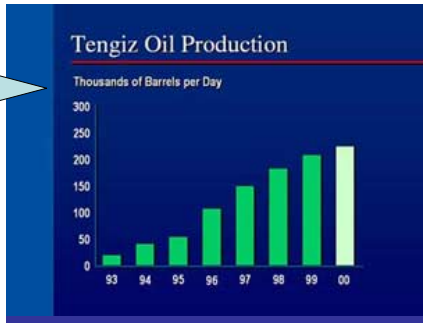
- Acid rain lowers pH of coastal waters
- Lower pH leads to loss of coral reef ecosystems
- Loss of plankton



Mitigation Strategies

- ***"End-of-Pipe"*** strategies, e.g. scrubbing of Sulfur Oxides, is dominant mitigation strategy in coal-fired power plants.
- Sour gas field present significant challenge to end-of-pipe strategies.
- New, pre-combustion mitigation strategies are needed
- Example Tengiz Field

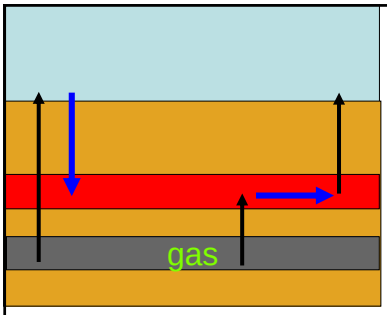
Caspian Sea Region



Tengiz accounts for 20-25% of output of region. Also significant gas production.

Further data and projections for largest oil field Tengiz: 2002 production 285k barrels/d, 2006 450k barrels/d, 2010 700k b/d; about 125 Bcf gas in 2002. Source: http://www.eia.doe.gov/emeu/cabs/caspian.html

- Tengiz contains about 10 to 16 wt% S
- Average for Caspian Sea 5 wt% S.
- At Tengiz each day 4500 tons of liquid S is poured onto football-size fields.
- With the projected increased production, the annual S production may reach about 5 million tons (5 Tg/a).
- 5 Tg S/a is equivalent to about 50% of global volcanic S emission and about 5% of current global anthropogenic S emissions

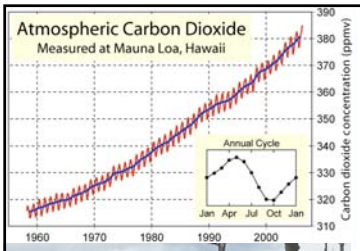


Alternatives to End-of-Pipe Technology

- Inject hydrogen sulfide into iron-bearing sand stones to sequester sulfur in the form of iron sulfide (pyrite).

Or

- Pass sour gas through iron-bearing sand stone before bringing it to surface
- Experimental work in our lab indicates that this is may work.



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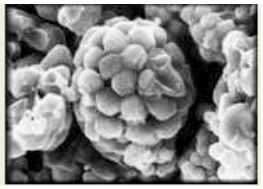
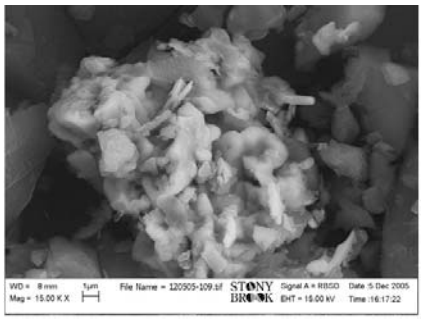
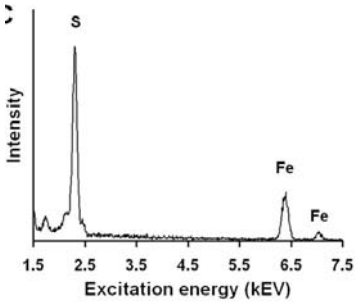
Sulfur in Coal



- Up to 5 % Sulfur by weight in coal
- Mostly as iron sulfide (FeS2)





Pyrite, Oxygen and Water

Reactions with Molecular O_2:

$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$

$2Fe^{2+} + 1/2O_2 + 2H^+ \rightarrow 2Fe^{3+} + H_2O$

Water critical reactant.

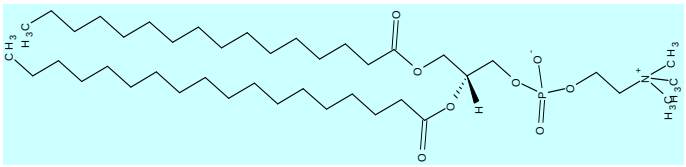
Pyrite is never pure and contains Arsenic, Selenium, Copper, Zinc and other metals.

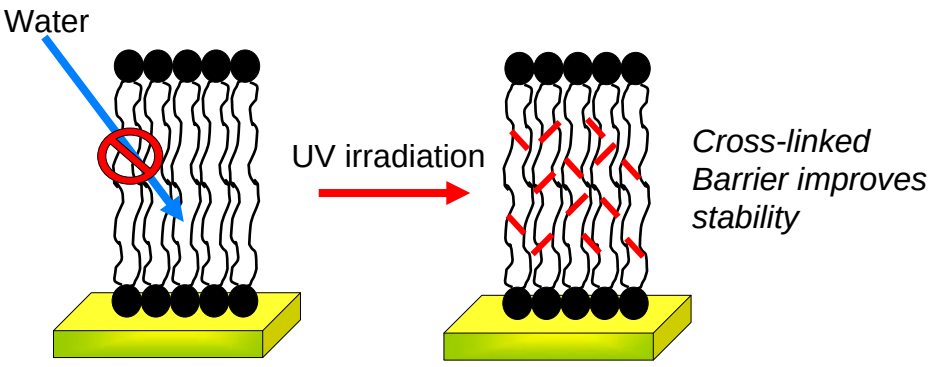
These impurities are released into waters with the dissolution of pyrite.

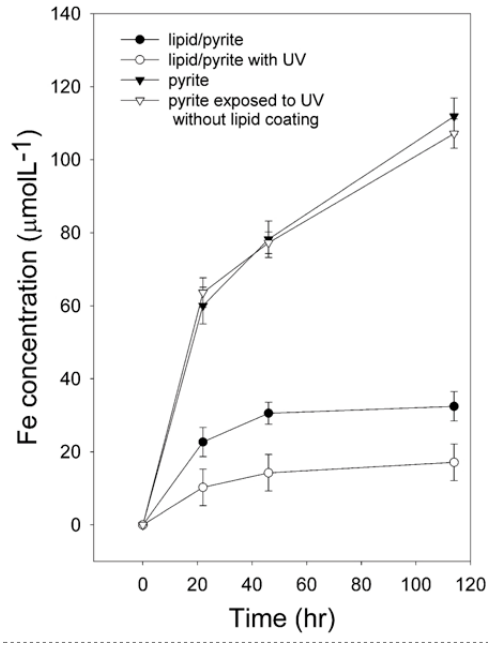
Mitigation Strategies

- “End-of-pipe” strategy, treat water to remove acidity and metals.
- Proactive strategy: stop oxidation by physically coating pyrite
- New alternative: deposit a molecular barrier to oxidation using lipids.

Excluding water from interface with two-tailed lipids



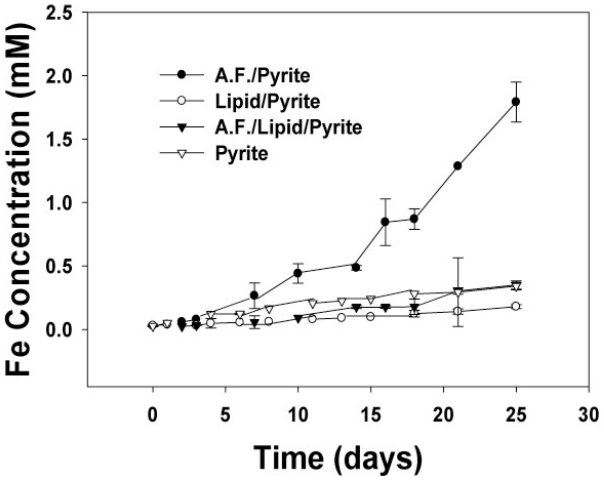




Adding lipids inhibits pyrite oxidation

Exposure to UV increases Inhibition.

Lipids in presence of bacteria



Bacteria increase rate of reaction

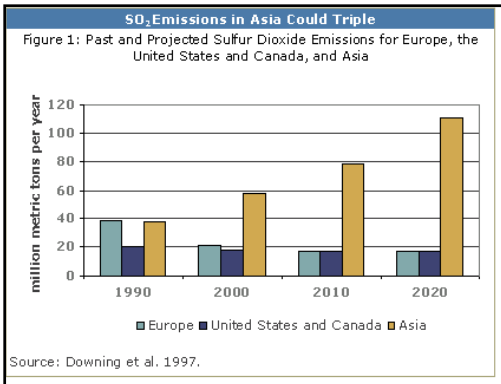
Lipids work in presence of bacteria

A.F. = Acidithiobacillus ferrooxidans

Advantages

- Lipids are natural products
- Self assemble on surface of pyrite
- Develop water-repellant (hydrophobic) barrier
- Stability of barrier can be enhanced by cross linking.

Currently working with Governmental Agencies to field-test and upscale technology



Outlook

- Fossil Fuel will be important for decades to come
- Environmental Impacts compromise soils, water, and coastal ecosystems.
- “end-of-pipe” technology needs to be replaced by pre-combustion technology
- New technologies are available but need to be field-tested.

Before Reclamation One Year After Reclamation

Photos above show the Nancy Lee Slowey Tailings (near Superior, Montana) http://www.deq.state.mt.us/Rem/MWCB/index.asp