

# Ecology and Sustainable Development.

## 5. Environmental Pollution:

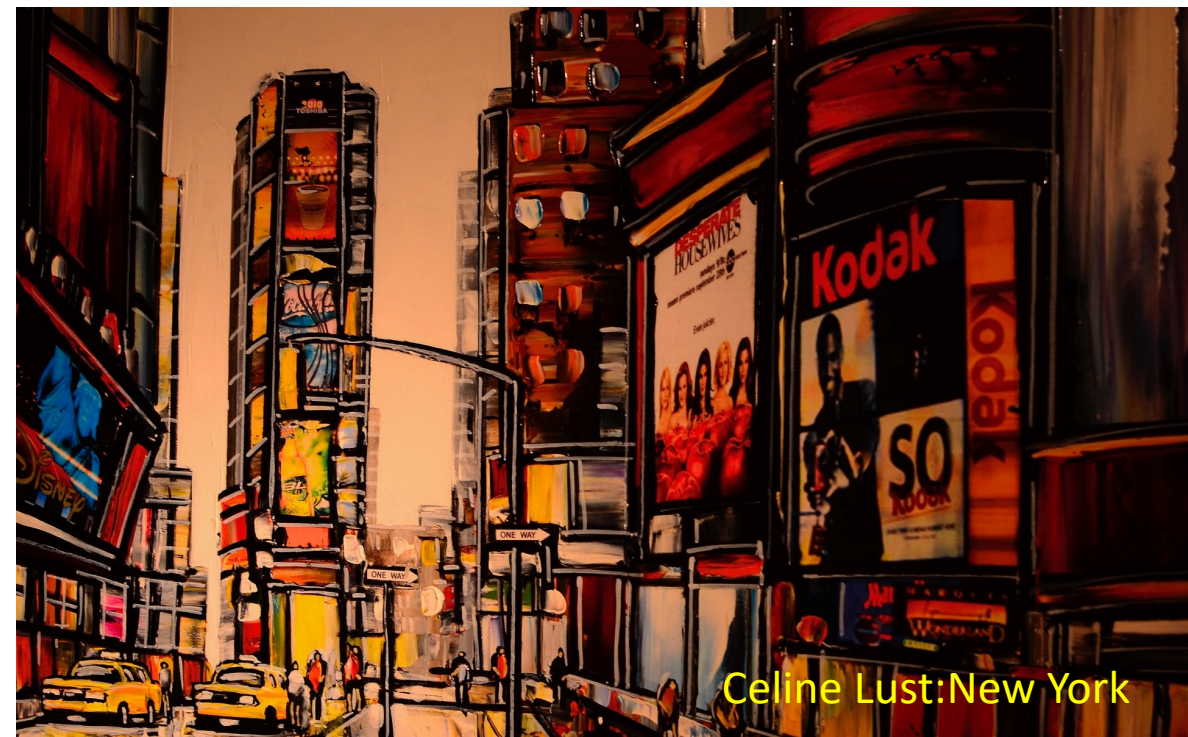
5.1 Air.

5.2 Water.

5.3 Soil.



Alfred Verwee: Schelde (1860)



Celine Lust: New York



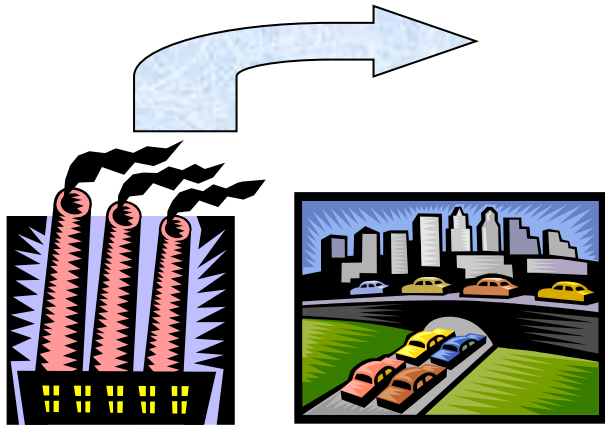
Claude Monet: Vetheuil 1880

## 5.1 Air Pollution: Relation Emissions - Air Quality - Health.

- **Major sources:**

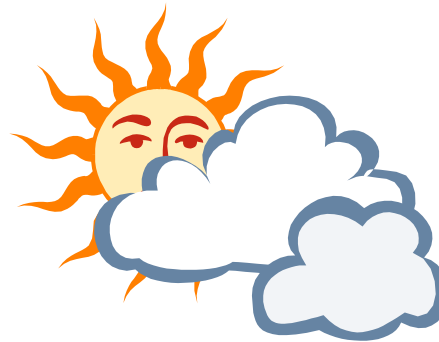
- Industry (production plants, power plants, waste incineration).
- Traffic (road, shipping).
- Small scale heating.

**Emissions:**  
measured as  
amounts [tons/year]



**Major primary air pollutants:**  
SO<sub>2</sub>, NO<sub>x</sub>, Particulate Matter (PM), Volatile Organic Compounds (VOCs)

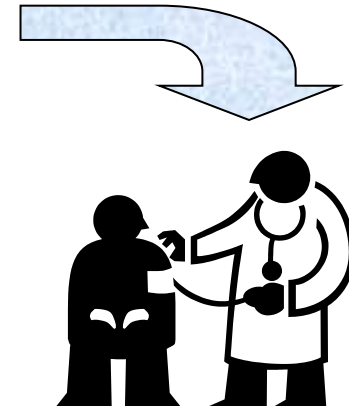
**Air Quality:**  
measured as  
immission  
concentrations  
[μg/m<sup>3</sup>]



**Primary pollutants:**  
SO<sub>2</sub>, NO<sub>x</sub>, PM, VOCs

**Secondary pollutants:**  
O<sub>3</sub>, ammonium sulfate  
and ammonium nitrate  
particles

**Health Effects:**  
measured as percentage  
of population suffering  
from a specific disease



**Chronic Diseases:**  
asthma, allergies, cancer

**Acute Diseases:**  
bronchial, cardiovascular  
diseases

**Transport of air pollutants:** Regional and global distribution of pollutants – effect depends on lifetime of a pollutant in the air.

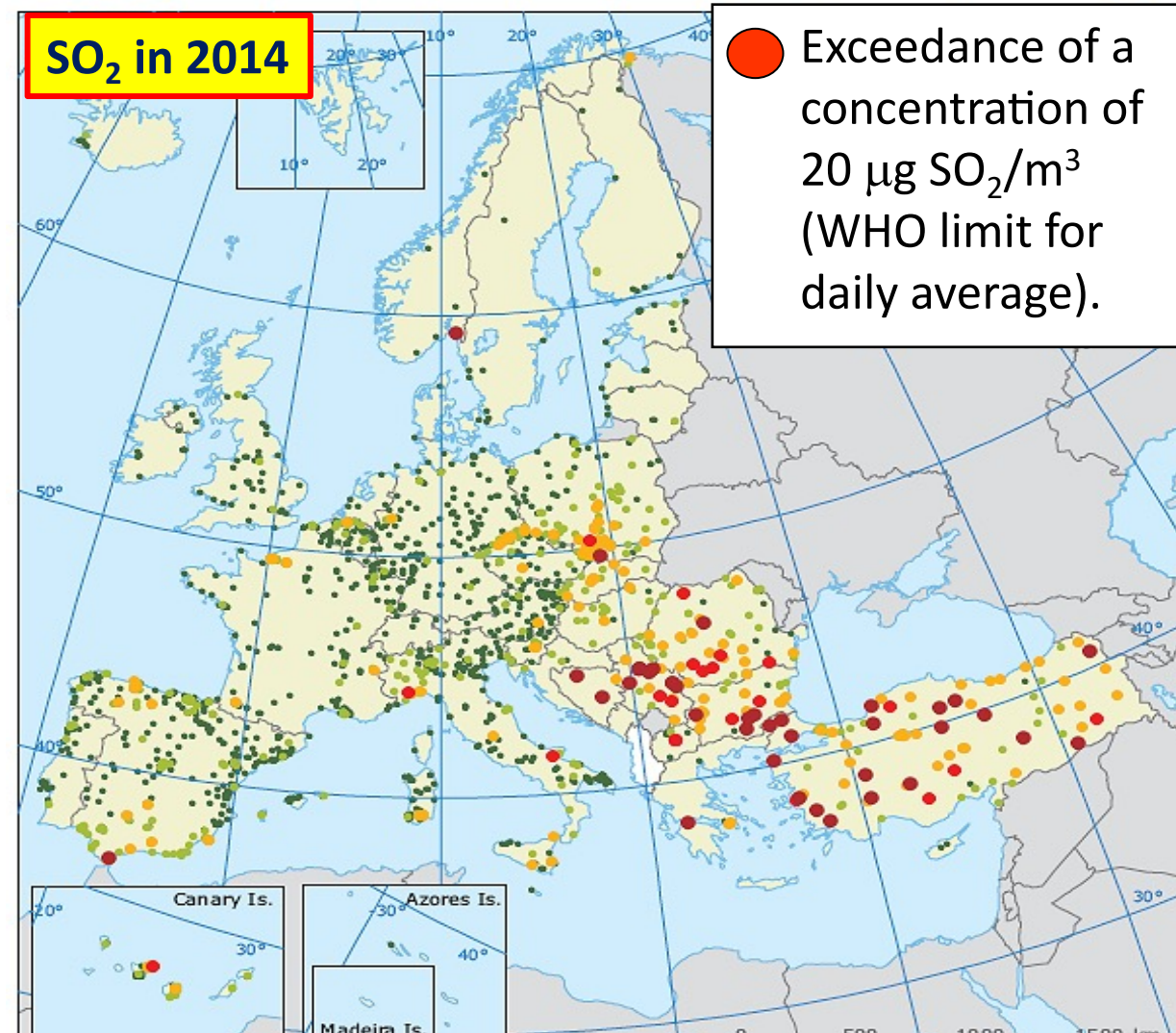
# Exposure of Urban Population to Air Pollutants in the EU.

- **Major pollutants: Particulate Matter (PM<sub>10</sub>, PM<sub>2,5</sub>), Nitrogen dioxide (NO<sub>2</sub>), Sulphur dioxide (SO<sub>2</sub>), Ozone (O<sub>3</sub>)**
- Pollution situation - percentage of **urban** population exposed to concentrations above EU immission limit values in 2020:
  - **Sulphur dioxide (SO<sub>2</sub>):** <1% in this period, (EU limit value 125 µg SO<sub>2</sub>/m<sup>3</sup> daily mean not to be exceeded more than three days a year).
  - **Particulate Matter (PM<sub>10</sub>):** 11% (EU limit value 50 µg/m<sup>3</sup> daily mean, not be exceeded more than 35 days a calendar year).
  - **Particulate Matter (PM<sub>2,5</sub>):** <1% (limit value 25 µg/m<sup>3</sup> yearly average)
  - **Nitrogen dioxide (NO<sub>2</sub>):** 1% (EU limit value 40 µg NO<sub>2</sub>/m<sup>3</sup> annual mean).
  - **Ozone (O<sub>3</sub>):** 12% (EU target value 120 µg O<sub>3</sub>/m<sup>3</sup> daily maximum 8-hourly average, not to be exceeded more than 25 times a calendar year).
- ❖ Note: ozone is not directly emitted, but formed by the reaction of hydrocarbons and nitrogen oxides under sunlight providing UV-radiation.
- Rural population usually not much effected by air pollution – „background immission concentrations“ below threshold levels.
- But: 80% of Europeans live in urban areas.

# Regional Exposure to Air Pollutants in Europe.

## SO<sub>2</sub> in 2014

● Exceedance of a concentration of 20 µg SO<sub>2</sub>/m<sup>3</sup> (WHO limit for daily average).

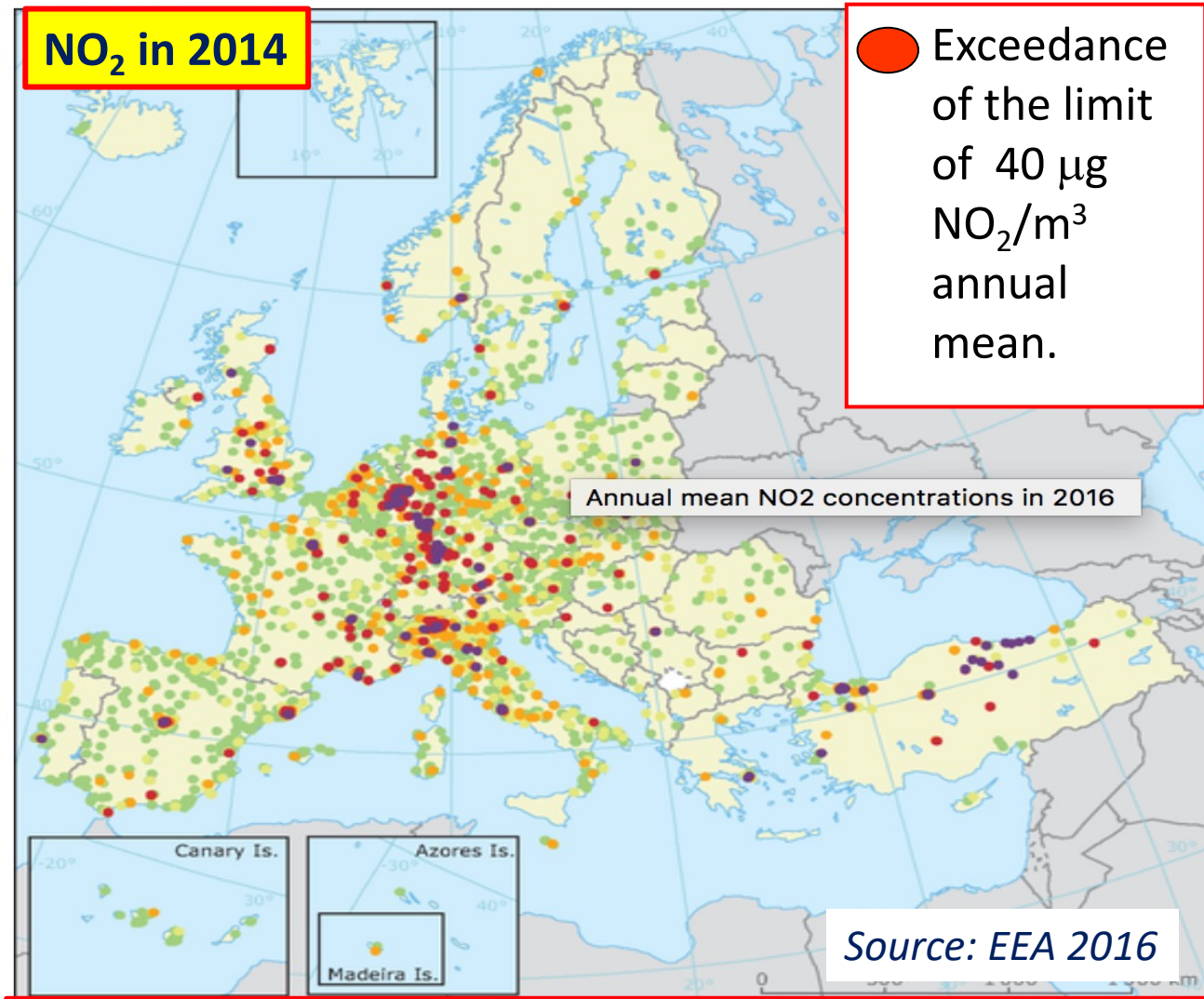


### Major sources for SO<sub>2</sub>:

- power stations (coal, oil), shipping

## NO<sub>2</sub> in 2014

● Exceedance of the limit of 40 µg NO<sub>2</sub>/m<sup>3</sup> annual mean.



### Major sources for NO<sub>2</sub>:

- road vehicle and ship emissions

Source: EEA 2016

# Regional Exposure to Air Pollutants in Europe.

## PM10 in 2016

● Exceedance of annual limit value ( $40 \mu\text{g}/\text{m}^3$ ) – mainly in winter.

## PM10 in 2020

Source: EEA 2018

Much improvement in E-Germany and CEE States (modernisation of energy and transport infrastructure).

## Major sources for PM<sub>10</sub>:

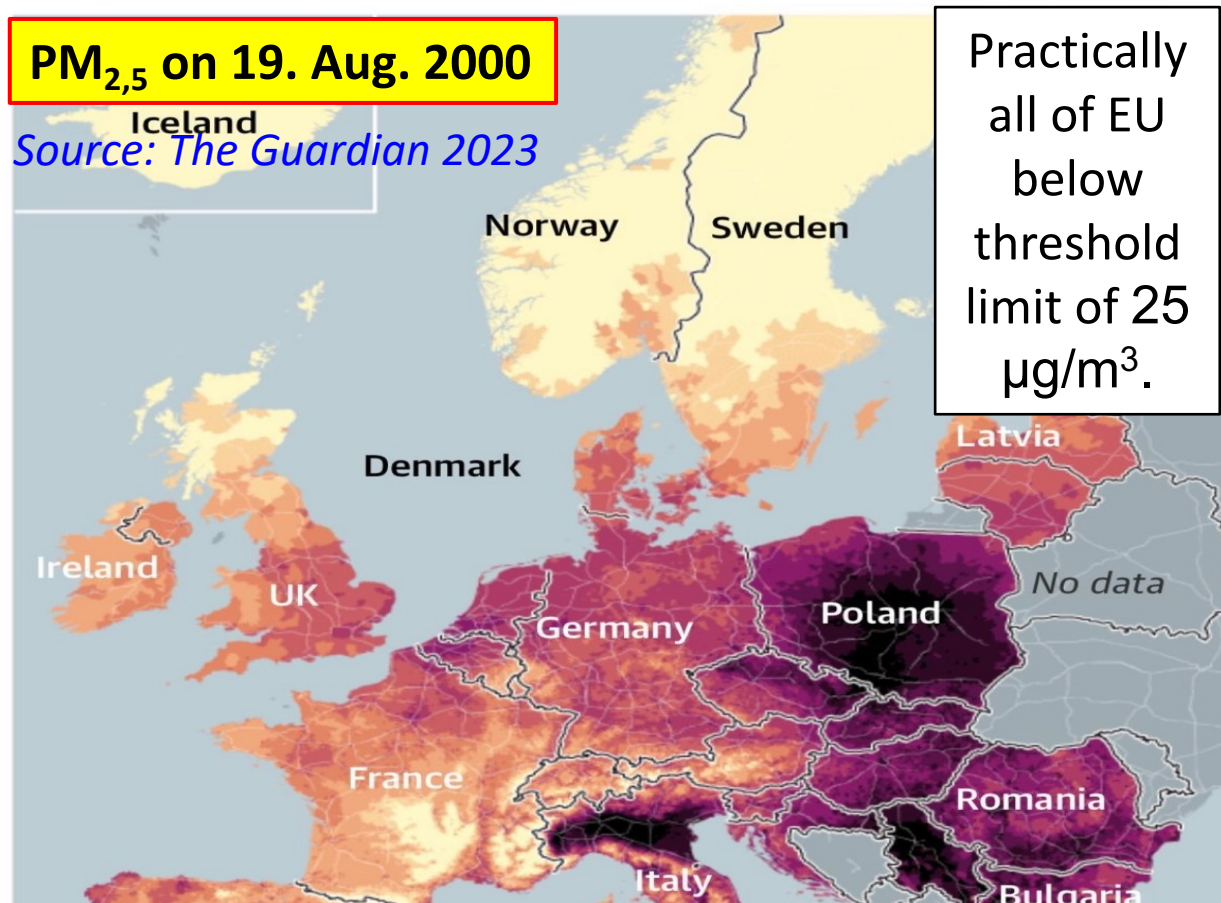
- dust from road traffic (minerals), vehicle emissions (carbon), small scale heating (carbon), regional transport of air pollutants (secondary particulate matter), industrial emissions

# Regional Exposure to Air Pollutants in Europe.



**PM<sub>2,5</sub> on 19. Aug. 2000**

Source: *The Guardian* 2023

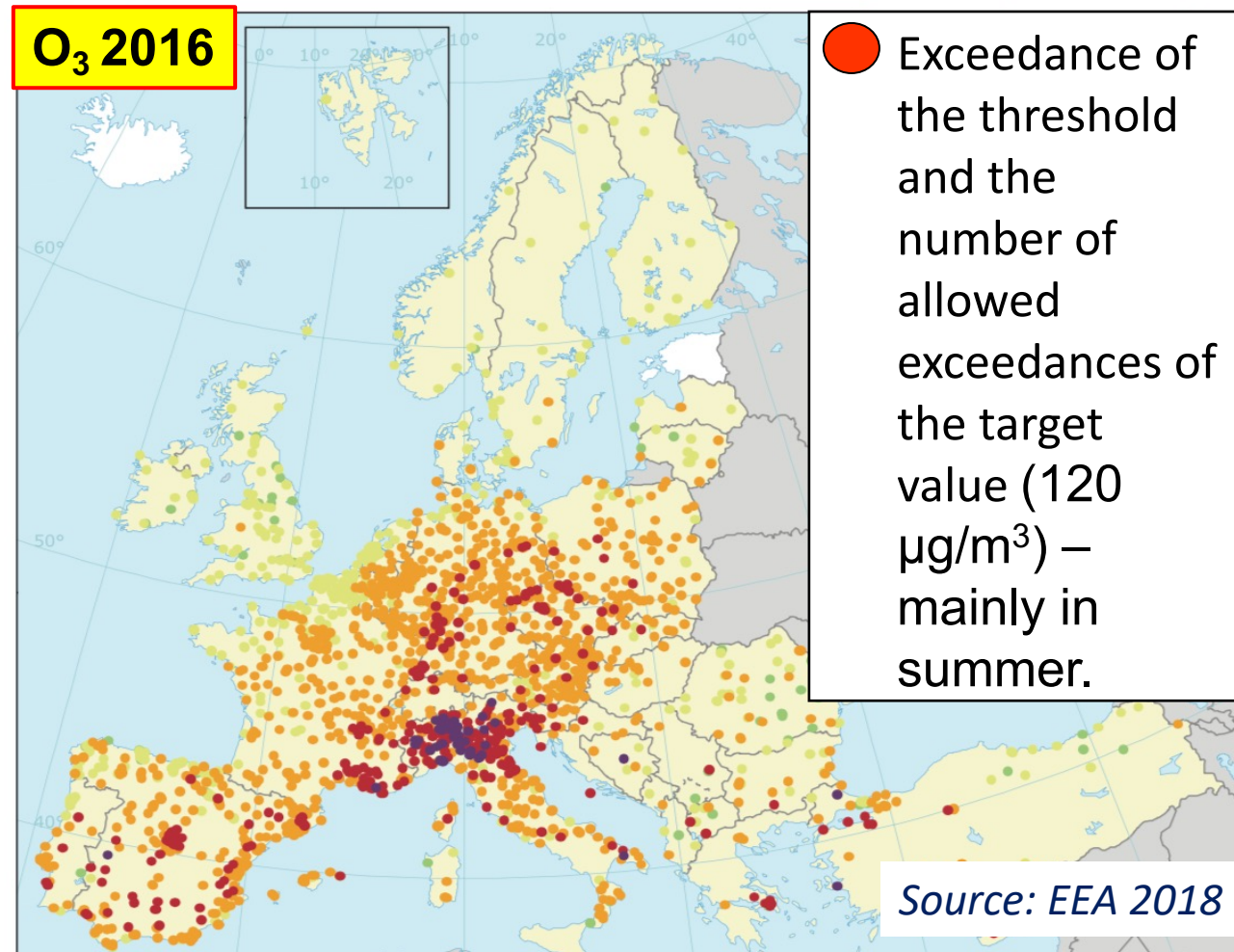


Practically all of EU below threshold limit of  $25 \mu\text{g}/\text{m}^3$ .

**Major sources for PM<sub>2,5</sub>:**

- vehicle emissions, small scale heating, regional transport of air pollutants

**O<sub>3</sub> 2016**



Source: *EEA* 2018

**Major reasons for elevated values of ozone:**

- road vehicle and ship emissions (VOCs and NO<sub>x</sub>)
- high UV radiation

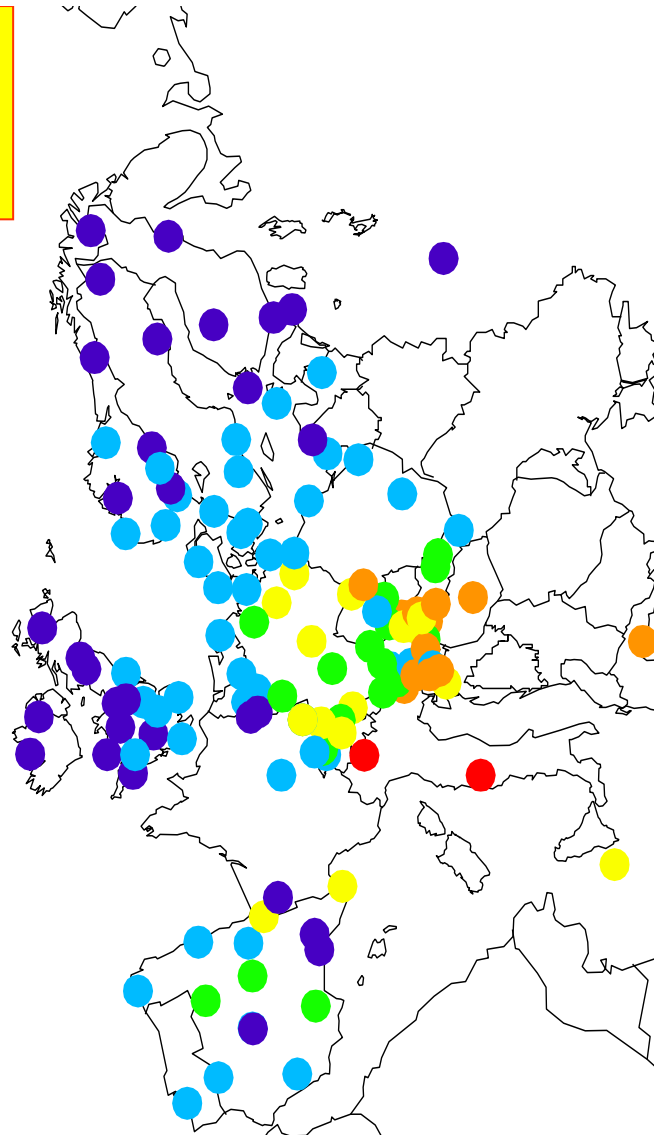
# Trends for the Emission of Air Pollutants in EU 1990 - 2014.

- **Driving force for emission reductions was EU-legislation:**
  - Euro Emission Standards for Road Vehicles 1970 – 2018 (emission limits for vehicles).
  - Air Quality Directives 1996 – 2008 (immission limits).
  - National Emission Ceilings Directive 2001 and 2016 (limits for maximum emission of pollutants like NO<sub>x</sub>, VOC, SO<sub>2</sub> and NH<sub>3</sub> for a Member State).
- **SO<sub>2</sub>/SO<sub>3</sub> reduction by 95%:**
  - Industrial abatement measures (cleaning of flue gas).
  - Elimination of sulfur from diesel and gasoline.
- **NO<sub>x</sub> reduction by 60% and NMVOCs (Non-Methane VOCs) by 65%:**
  - Reduction of small vehicle emissions (catalysts):
    - 2005 Euro4 with 0,08\*/0,25\*\* gNO<sub>x</sub>/km
    - 2011 Euro5 with 0,06\*/0,18\*\* gNO<sub>x</sub>/km
    - 2018 Euro6 with 0,06\*/0,08\*\* gNO<sub>x</sub>/km
- **PM<sub>10</sub> and PM<sub>2,5</sub> reduction by 35%:**
  - Industrial abatement measures (filters for smoke stacks).
  - Reduced emissions for diesel passenger cars:
    - 2005 Euro4 mass limit 25 mg/km
    - 2011 Euro5 mass limit 5 mg/km
    - 2018 Euro6 mass limit 4,5 mg/km
  - improved road management
  - reduction of small scale heating
  - fuel switch in heating from coal to gas

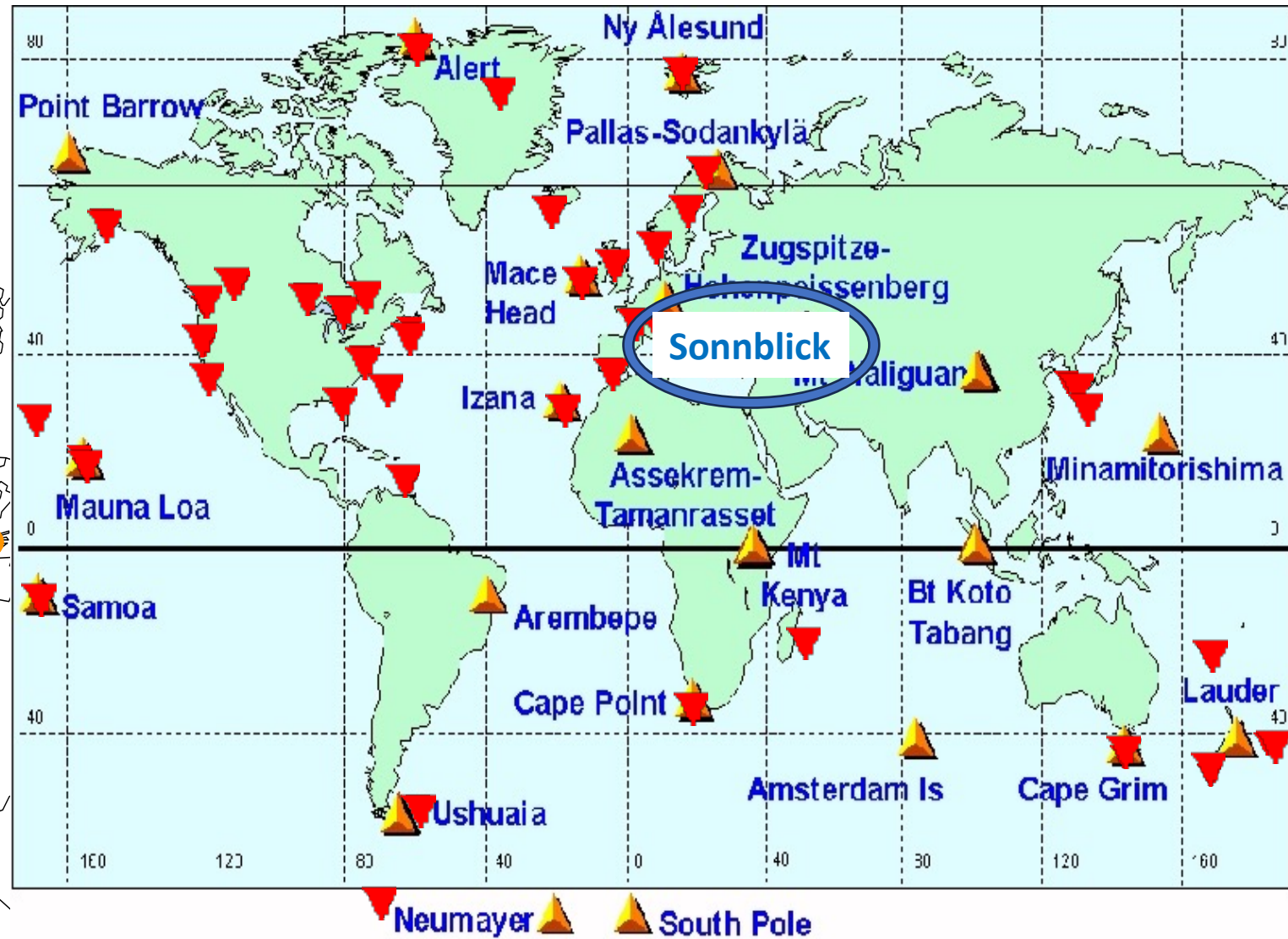
\* gasoline vehicles, \*\*diesel vehicles

# Regional and Hemispherical Transport of Air Pollutants.

Measurement  
of ozone  
in 2000.



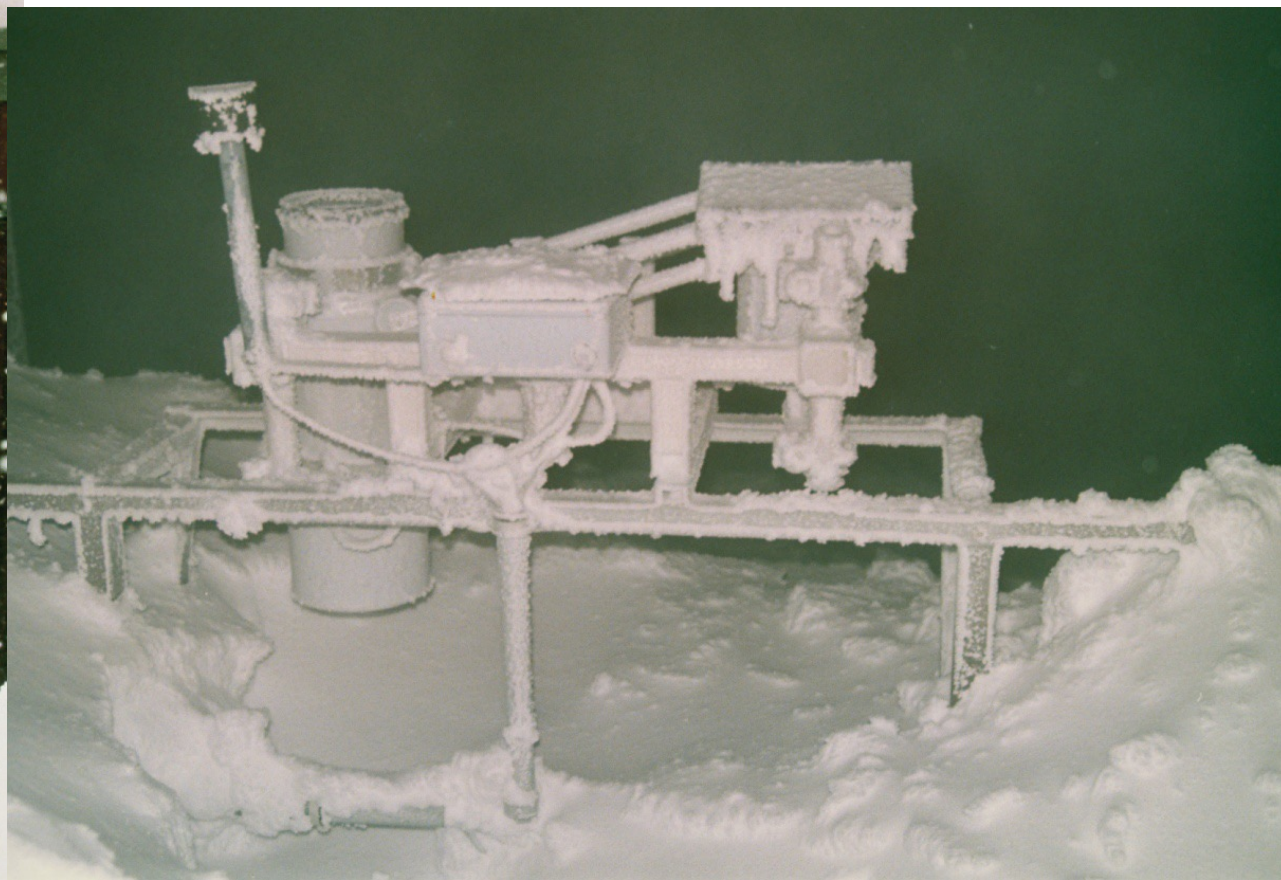
European Network for measuring the long range transport of air pollutants.



World Meteorological Organisation Global Atmospheric Watch Network (WMO-GAW)

# Hemispherical Transport of Air Pollutants

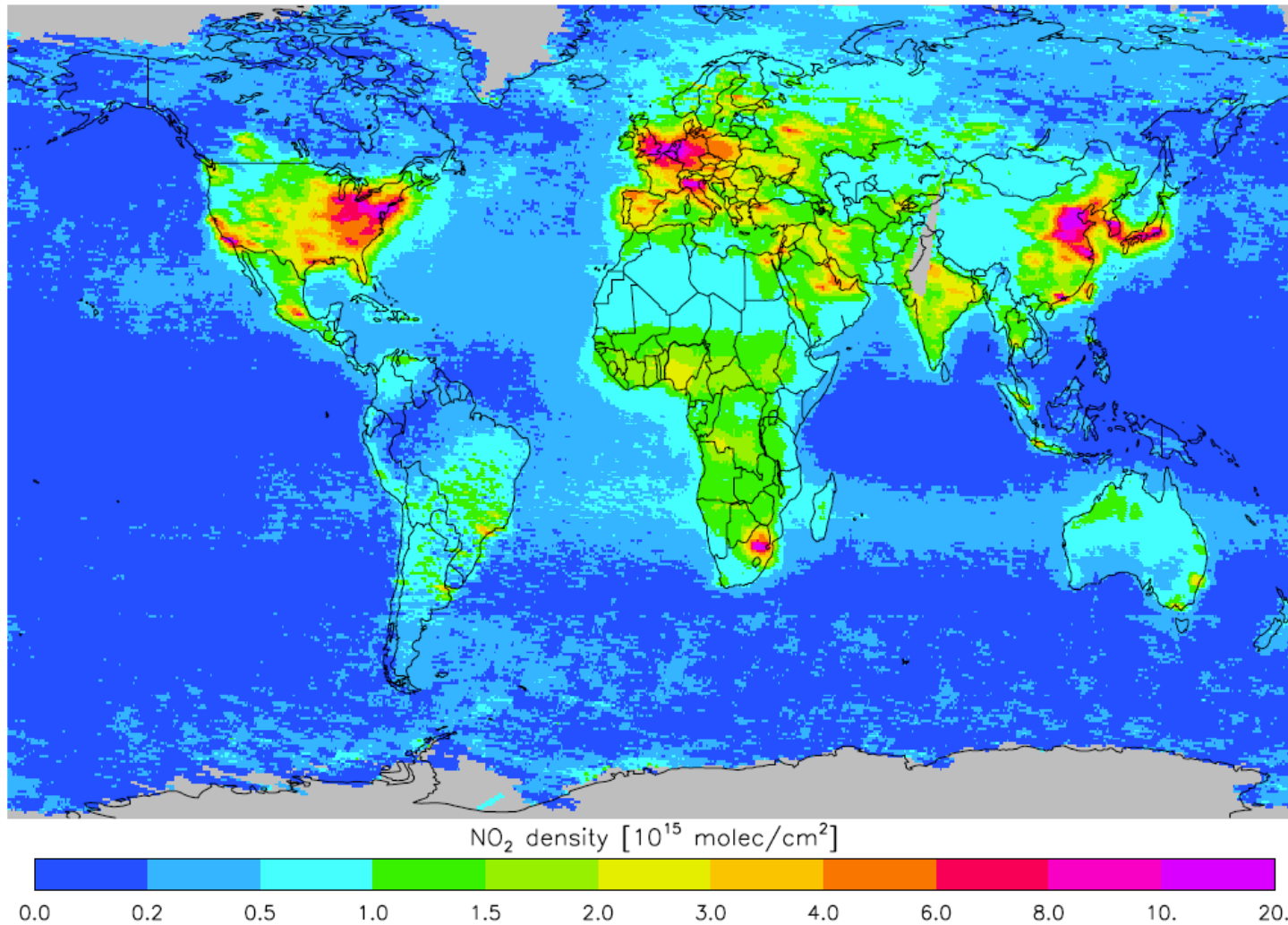
Measurements at the Austrian GAW  
Station Sonnblick, 3106 m a.s.l.



# Hemispherical Transport of Air Pollutants

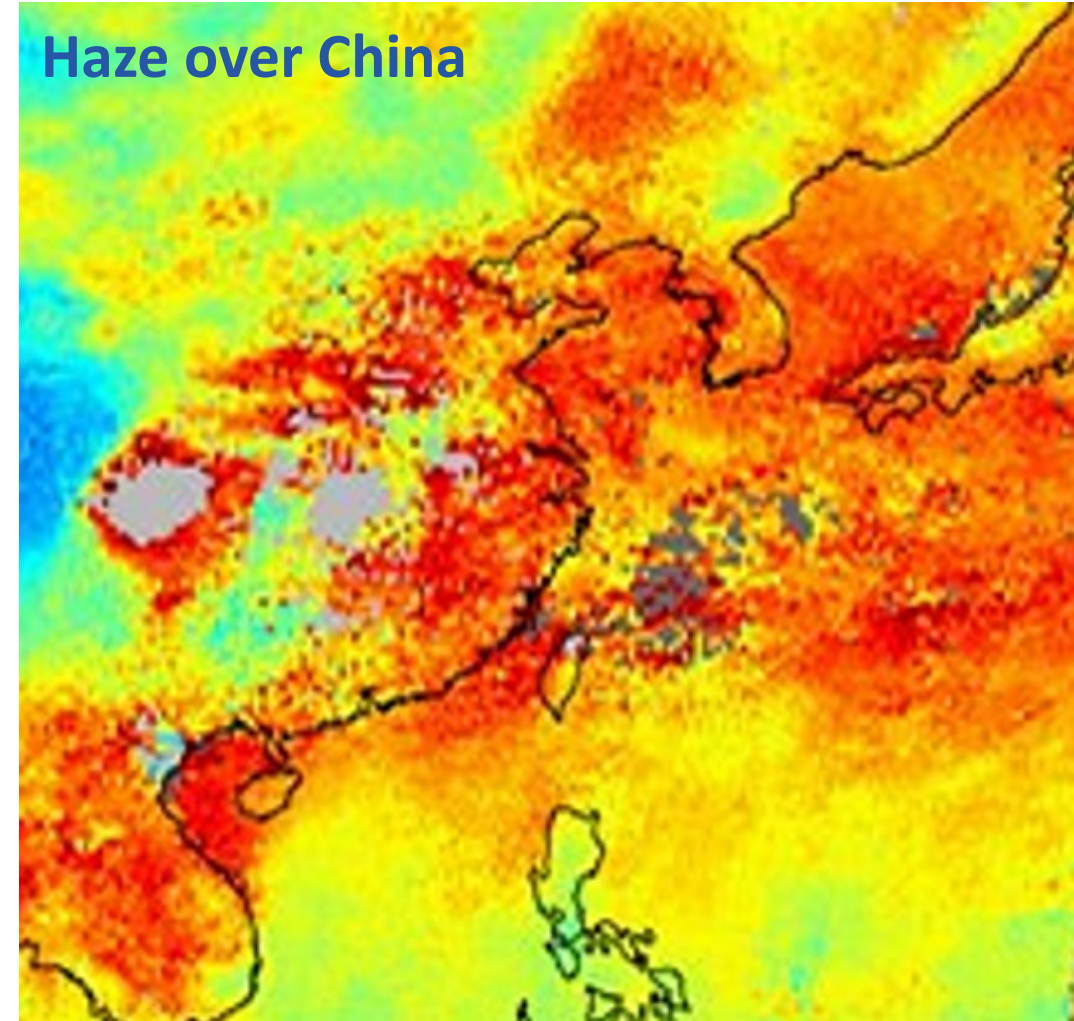
GOME mean tropospheric NO<sub>2</sub> – 2000

Mean of three retrievals



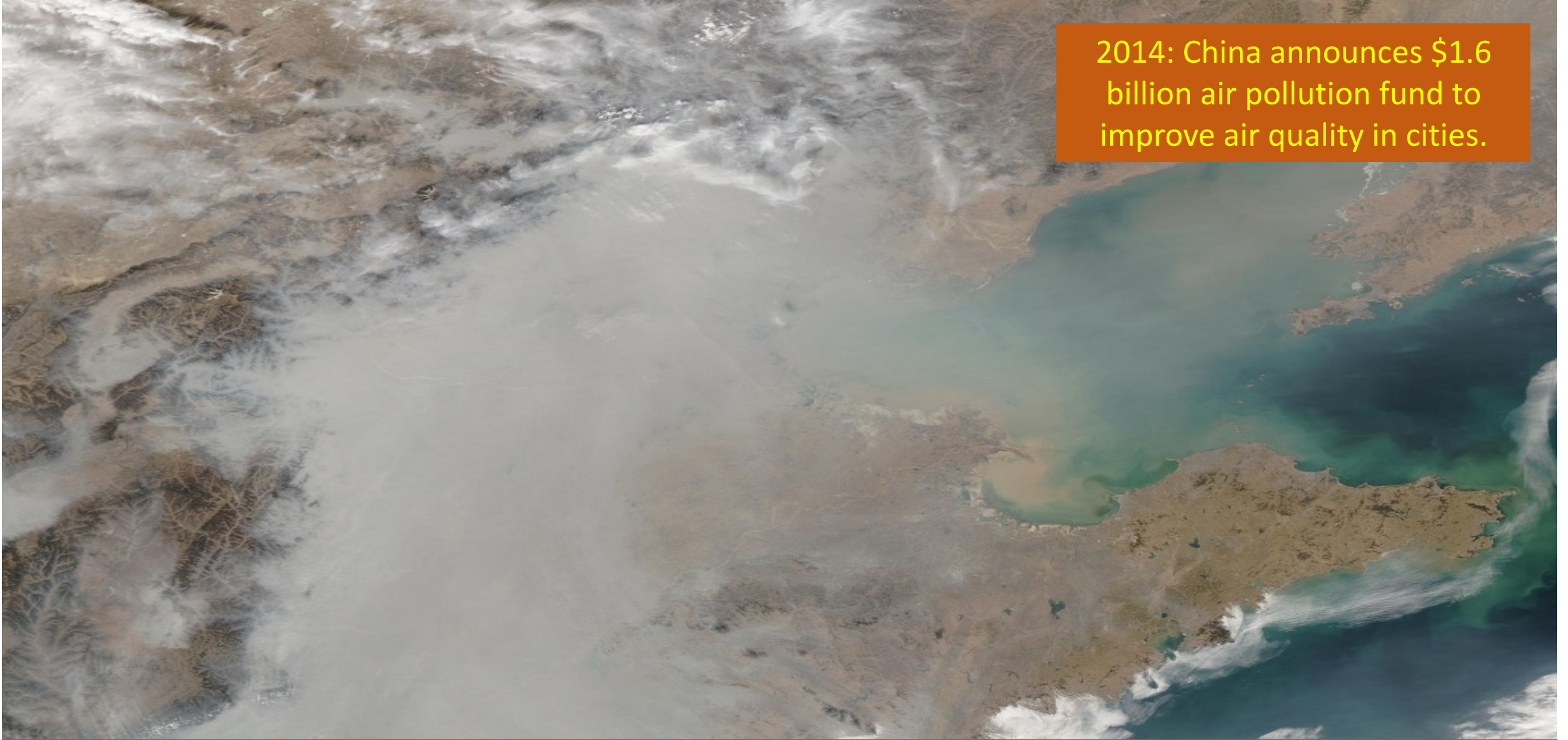
Global air pollution: Nitrogen dioxide in atmosphere.  
Lang range transport can increase ozone levels in Europe  
by a few ppb.

Haze over China



Carbon monoxide measurements March 2007,  
with NASA's Terra satellite. CO is a good  
indicator of urban and industrial pollution.

# Global Air Quality: Beijing



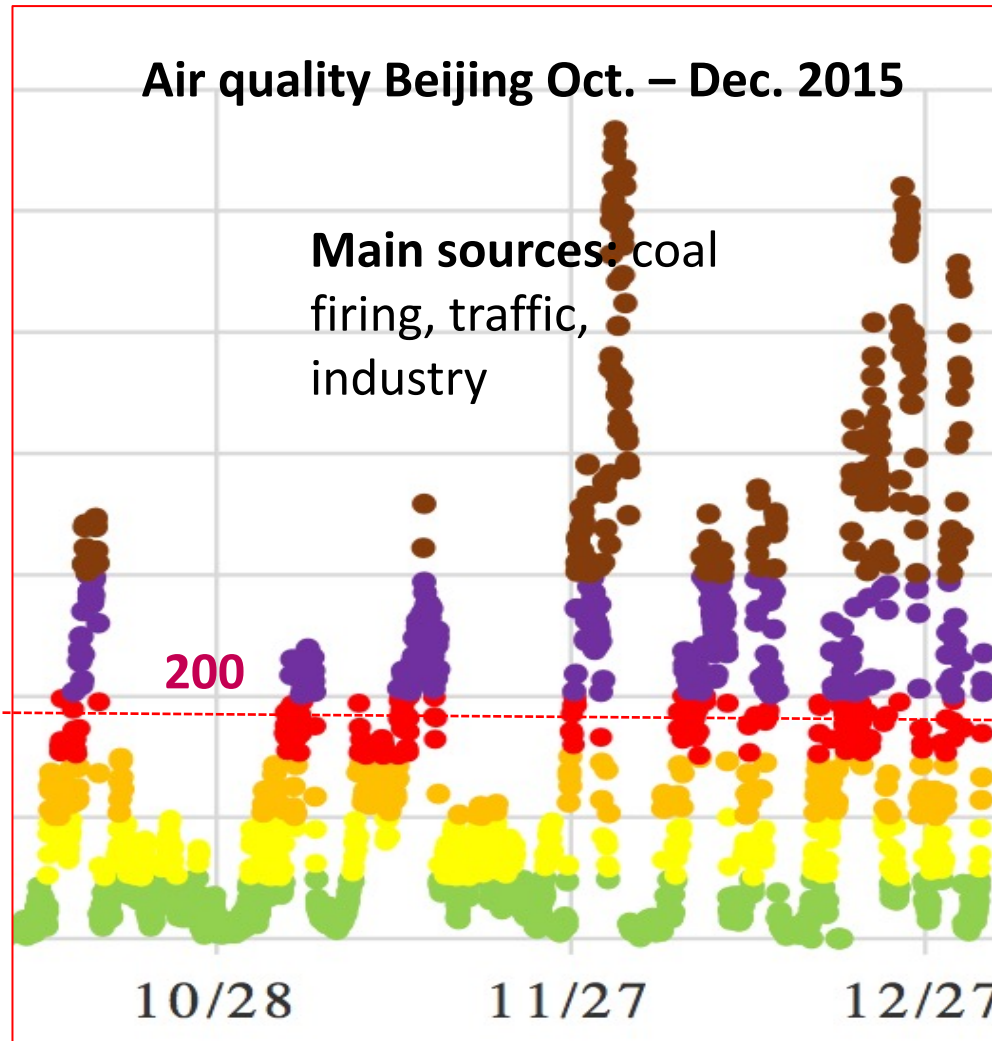
2014: China announces \$1.6 billion air pollution fund to improve air quality in cities.

Global air pollution: Urban haze in Beijing area. „Brown clouds“ can travel from SE-Asia to North America and Europe.

# Historical Air Pollution in Beijing.

- Air quality indicated as Air Quality Index (AQI) based on the levels of PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub> and CO. AQI related to health effects.

AQI	Air Pollution Level
0–50	Excellent
51–100	Good
101–150	Lightly Polluted
151–200	Moderately Polluted
201–300	Heavily Polluted
300+	Severely Polluted



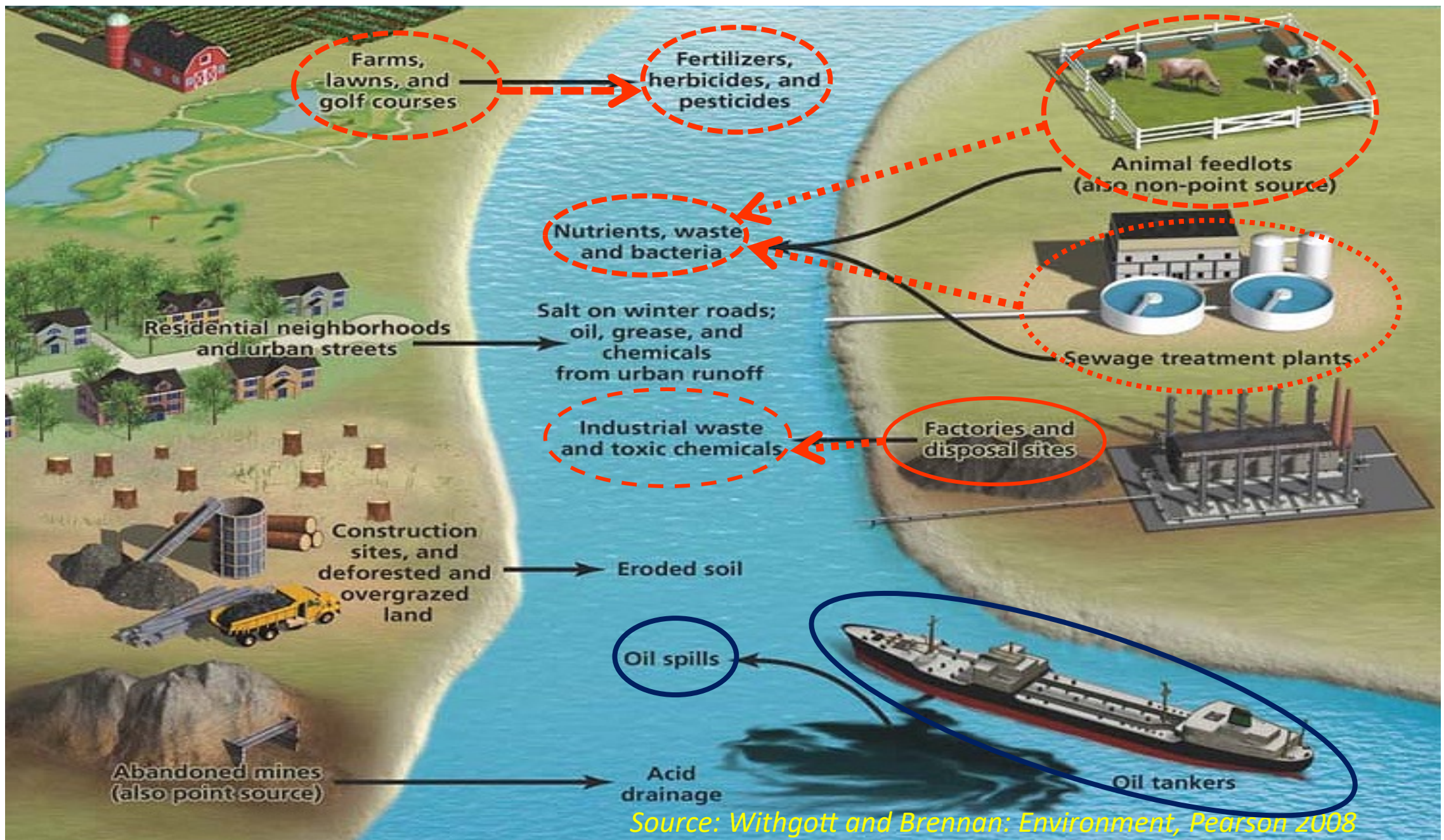
**Air Quality Index 3 Feb. 2024:**

**165**

**Clean air is a major driving force for development of transport technologies: 80% of the public transport in Chinese large cities is electric (BEVs).**

**PM10: 900 µg/m<sup>3</sup> in Jan. 2013 (EU limit 50)**

## 5.2 Water Pollution.



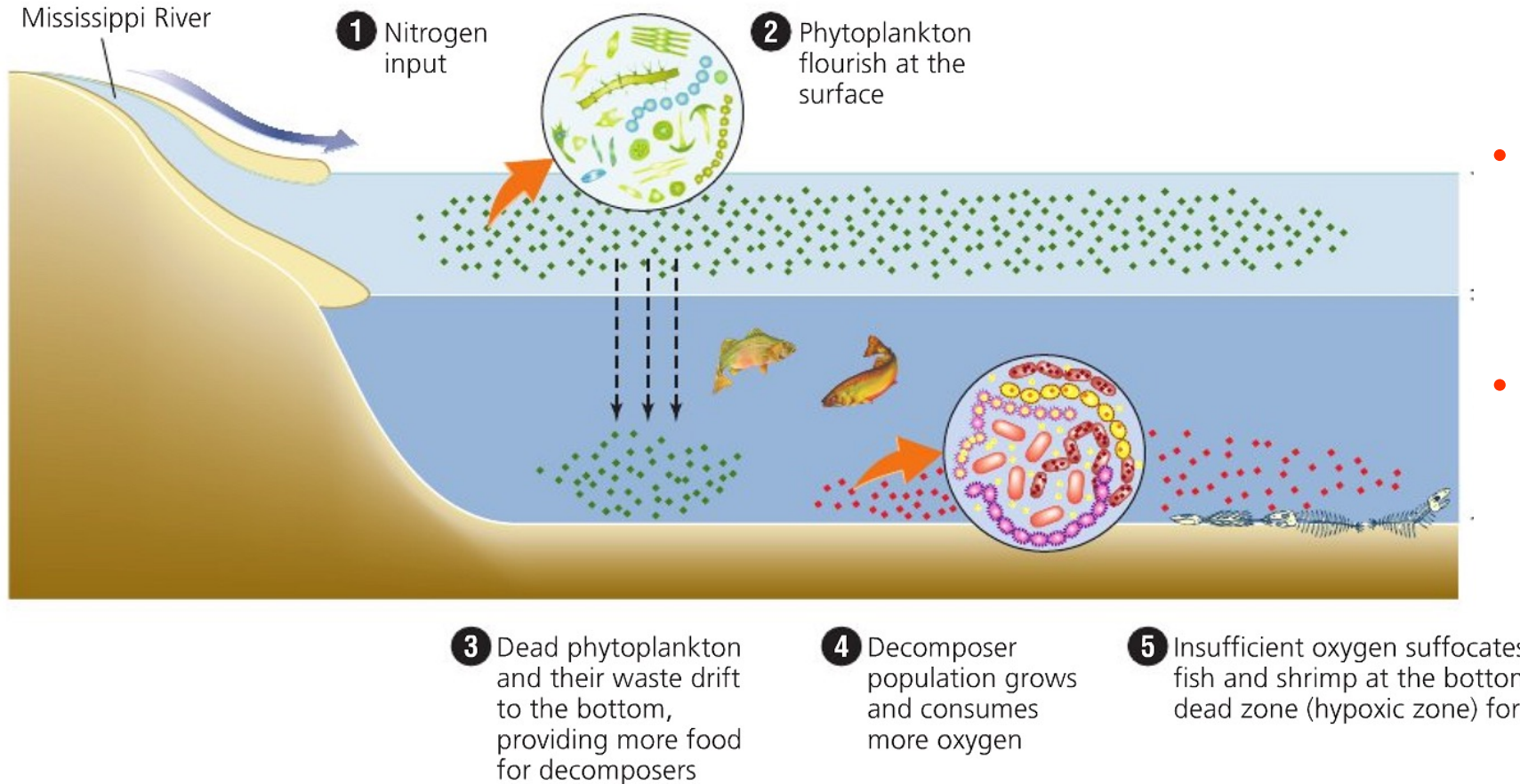
Source: Withgott and Brennan: Environment, Pearson 2008

# The Situation of European Waters.

- **Pollution - most important possible causes:**
  - ***Industrial waste water discharges:*** Heavy metals, organic toxins and oils. Now largely eliminated in EU, USA, Japan. Still a major problem in emerging economies and developing countries.
  - ***Agricultural effluents:*** Pesticides, herbicides leading to ground water pollution, nutrients from fertilisation leading to eutrophication, manure leading to bacterial contamination, but threshold values rarely exceeded.
  - ***Human waste water discharge, unprocessed or processed in sewage plants:*** Nitrates and phosphates leading to eutrophication and bacterial contamination, but most waste purification plants deliver relatively clean water to the rivers or sea.
  - ***Oil discharges:*** Oil spills due to accidents with tankers or in drilling or release of hydrocarbons due to intentional cleaning of oil tanks at the open sea – mostly eliminated now.
- **General problems with European waters:**
  - In hot summers excessive warming of surface waters: due to discharges of heated cooling water of thermal and nuclear power stations leading to a depletion of oxygen.
  - Seasonal eutrophication and reduction of biodiversity in European water bodies.
  - Coastal zones under heavy pressure due to aquacultures, settlements and industrial activities.
  - Over-consumption of water in the South of Europe due to irrigation in agriculture and tourism.
- **European waters – rivers, lakes and seas experience little damage compared to other continents.**

# Eutrophication.

• **Eutrophication:** high primary productivity (phytoplankton growth) due to a high nutrient input (particularly P and N from waste water and fertilizers).



- About half of the lakes in Europa, America and Asia show eutrification.
- In contrast an **oligotrophic lake** is a lake with low primary productivity, the result of low nutrient content.
- These lakes normally have very clear waters, some even with drinking-water quality.

- Eutrophic lakes: excessive algal blooms, murky water and poor water quality.
- The bottom waters of such lakes is deficient in oxygen (no fish).

Source: Withgott and Brennan: Environment, Pearson 2008



# Water Pollution: Sources of Nutrients.

- **Point sources:**

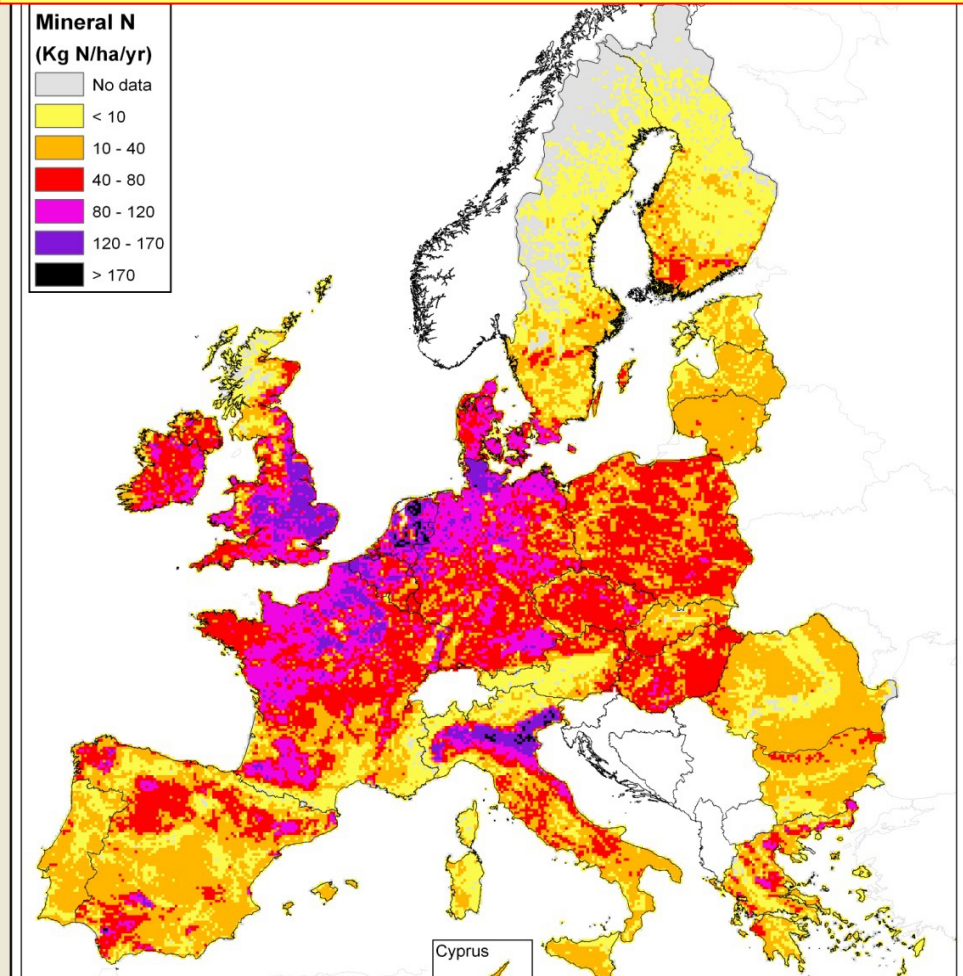
- Effluents of households and waste water treatment plants, mainly phosphates and nitrates.
- Phosphates can be eliminated with chemical processing of waste water, nitrates by treatment with bacteria (reduction to nitrogen).

- **Diffuse sources:**

- Nitrate and phosphate mainly from agricultural activity (manure, fertilisers).
- Agriculture is main source for nitrate input into ground water, rivers, lakes and coastal waters.
- Input subject to large spatial and temporal variations (season, precipitation, and other irregular events).
- High density animal raising can cause massive local and regional pollution of ground water.
- Use of fertilisers has dramatically increased in all parts of the world during the last 50 years to enhance agricultural yield.

Average application of mineral nitrogen fertilisers in the EU.

**Use of nitrogen fertilisers has increased 10-fold in EU during last 50 years!**

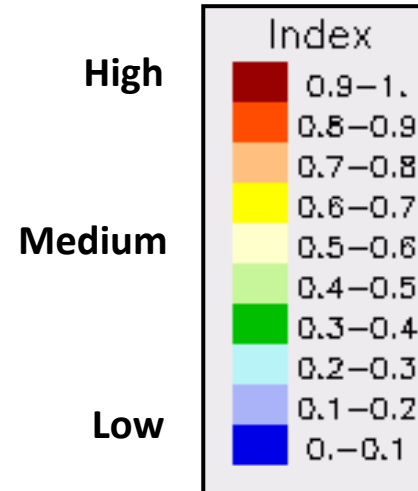
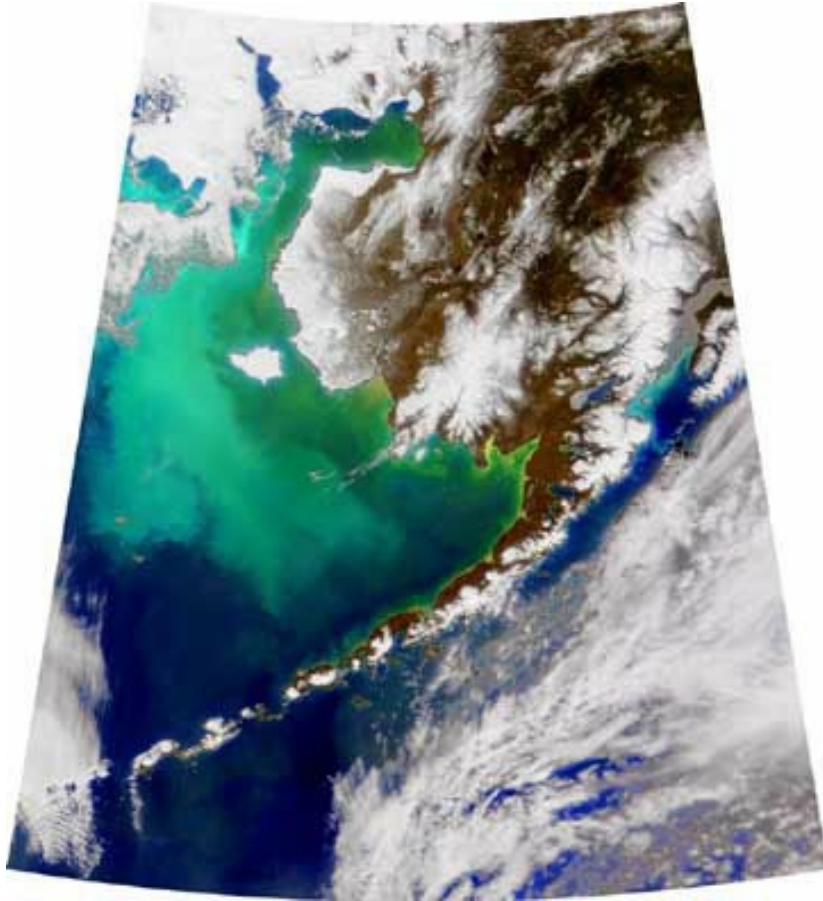


•Nitrates Directive 1991/676/EC

•Drinking Water Directive 98/83/EC

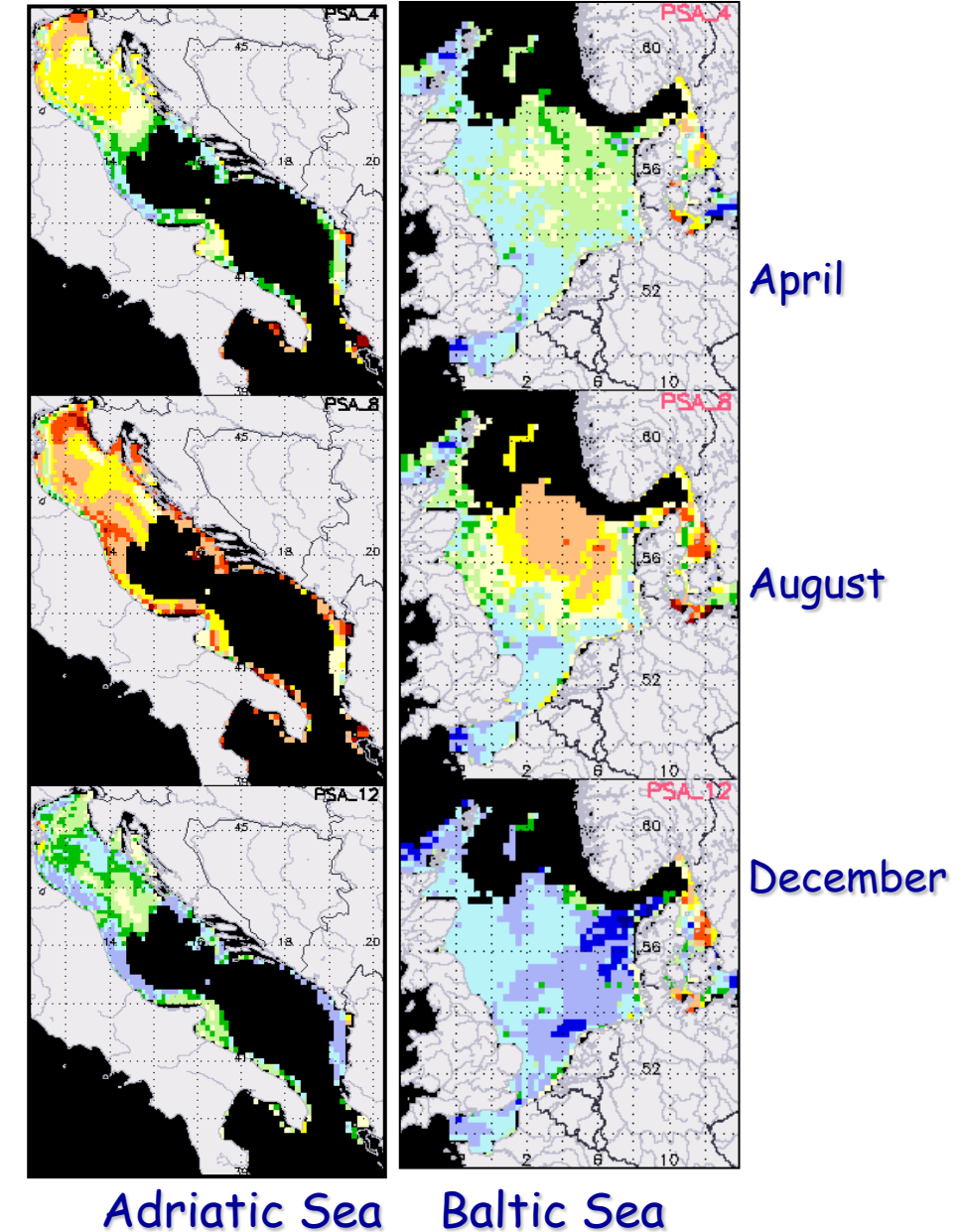
# Measuring Eutrophication.

- A widely-used measure of eutrophication is the determination of algal and cyanobacterial biomass from the chlorophyll concentration.
- Peak values of chlorophyll *a* for an oligotrophic lake are about 1-10  $\mu\text{g/l}$ , while in a eutrophic lake they can reach 300  $\mu\text{g/l}$ .



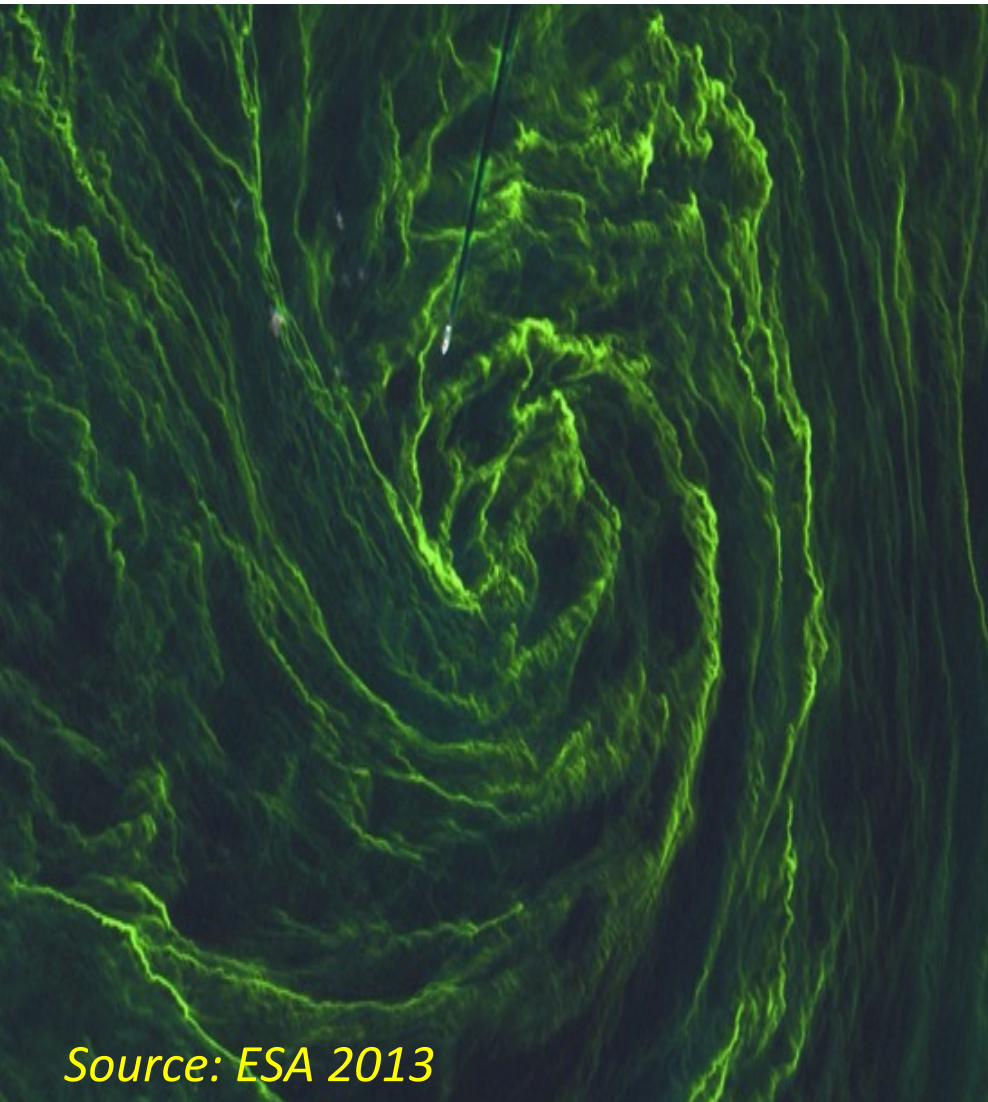
Satellite image of a large coccolithophore bloom in the Bering Sea in 1998.

## Seasonal eutrophication.



Source: ESA and JRC-IES

# Large Scale Eutrophication Events.



*Source: ESA 2013*

Algal bloom in the the Baltic Sea  
on 7 August 2015.



Algae carpet at Qingdao at Chinese coast covering 13.000 km<sup>2</sup>.

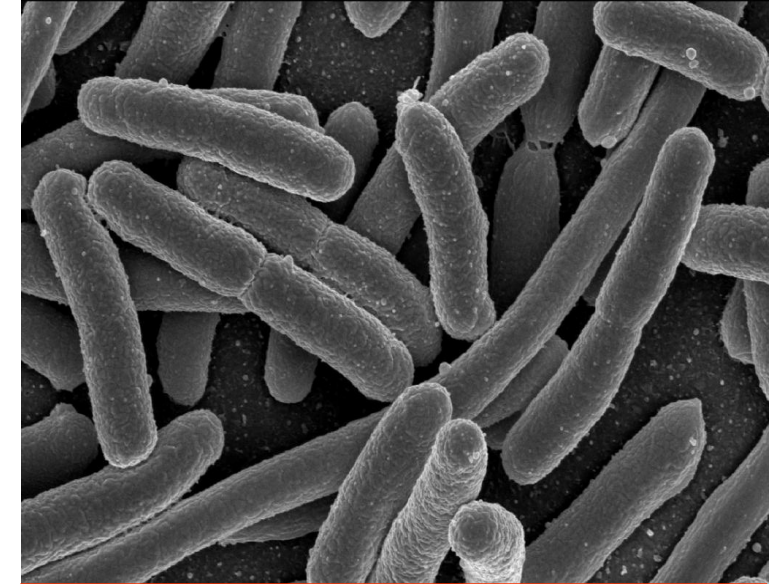
*Source: Spiegel On-line 20 July 2008*

# Water Pollution with Pathogens.

**Pathogens are protozoa, viruses or bacteria producing diseases.**

- **Bacterial infections are most important:**

- *E. coli* – gastrointestinal disorders
- Campylobacteriosis – one of the most common causes of human bacterial gastroenteritis with fever, headache, and myalgias.
- Legionellosis - cause Pontiac fever and Legionnaires' disease
- Salmonellosis - due to many Salmonella species. Water/food/direct contact borne.
- Typhoid - Salmonella typhi bacteria - gastro-intestinal water/food borne.
- Cholera - Vibrio cholerae bacteria - gastro-intestinal often waterborne.
- **Diarrheal diseases:** are attributable to unsafe water supply, sanitation and hygiene and account for 4% of the total daily global burden of disease (WHO).
- **Sources for bacterial infections:**
  - Mainly contaminated drinking water, used in the preparation of food.
  - Such infections are a massive problem in developing countries since 800 million people do not have access to clean drinking water.
  - Cholera outbreaks rather frequent.



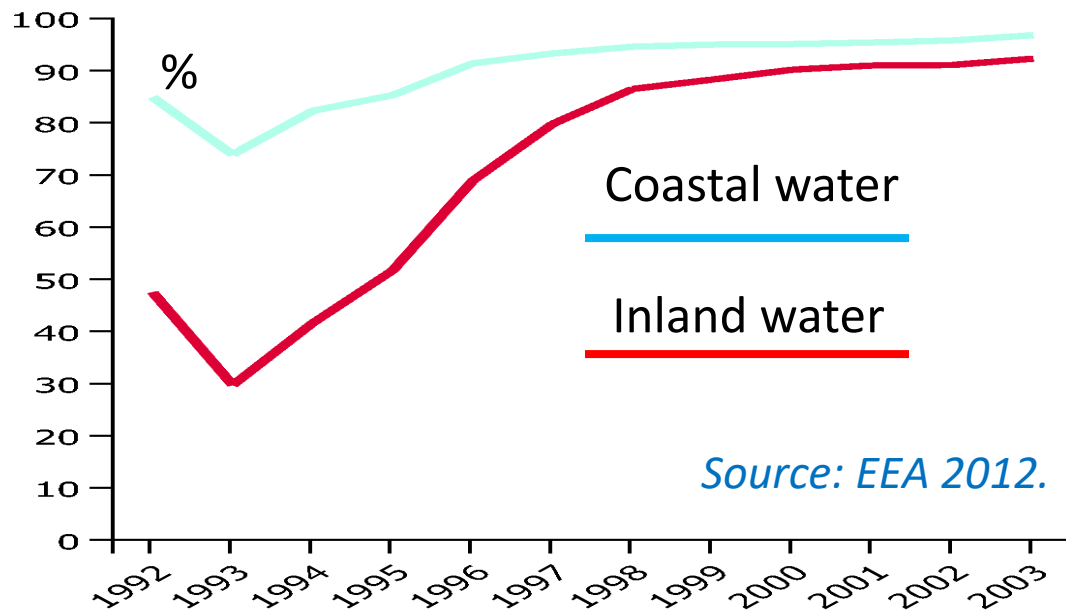
*Escherichia coli.*



*Salmonella typhimurium* (red)  
invading cultured human cells.

# Water Pollution with Pathogens.

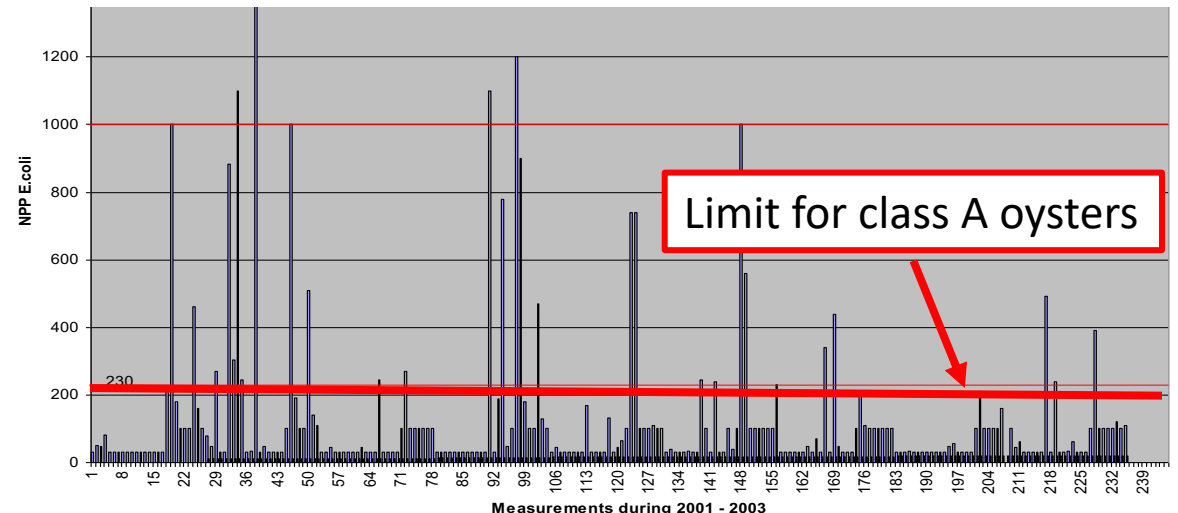
- Pathogens, particularly E. coli, determine to a large extent bathing water quality.
- Before the enactment of EU legislation about bathing water quality (Directive 76/160/EC, extended with 2006/7/EC) household effluents were directly pumped into rivers, lakes and coastal zones causing widespread contamination (in addition to the substantial eutrophication).
- To clean up the aquatic systems effluents were then processed in wastewater cleaning plants, leading to a rapid and massive improvement of the water quality.



Percentage compliance of EU coastal and inland bathing waters with the bathing water directive, 1992 to 2003 for EU-15.

- Bacterial contamination is also an issue for seafood production in coastal zones, like oyster growth.
- Bacterial contamination is strictly controlled.

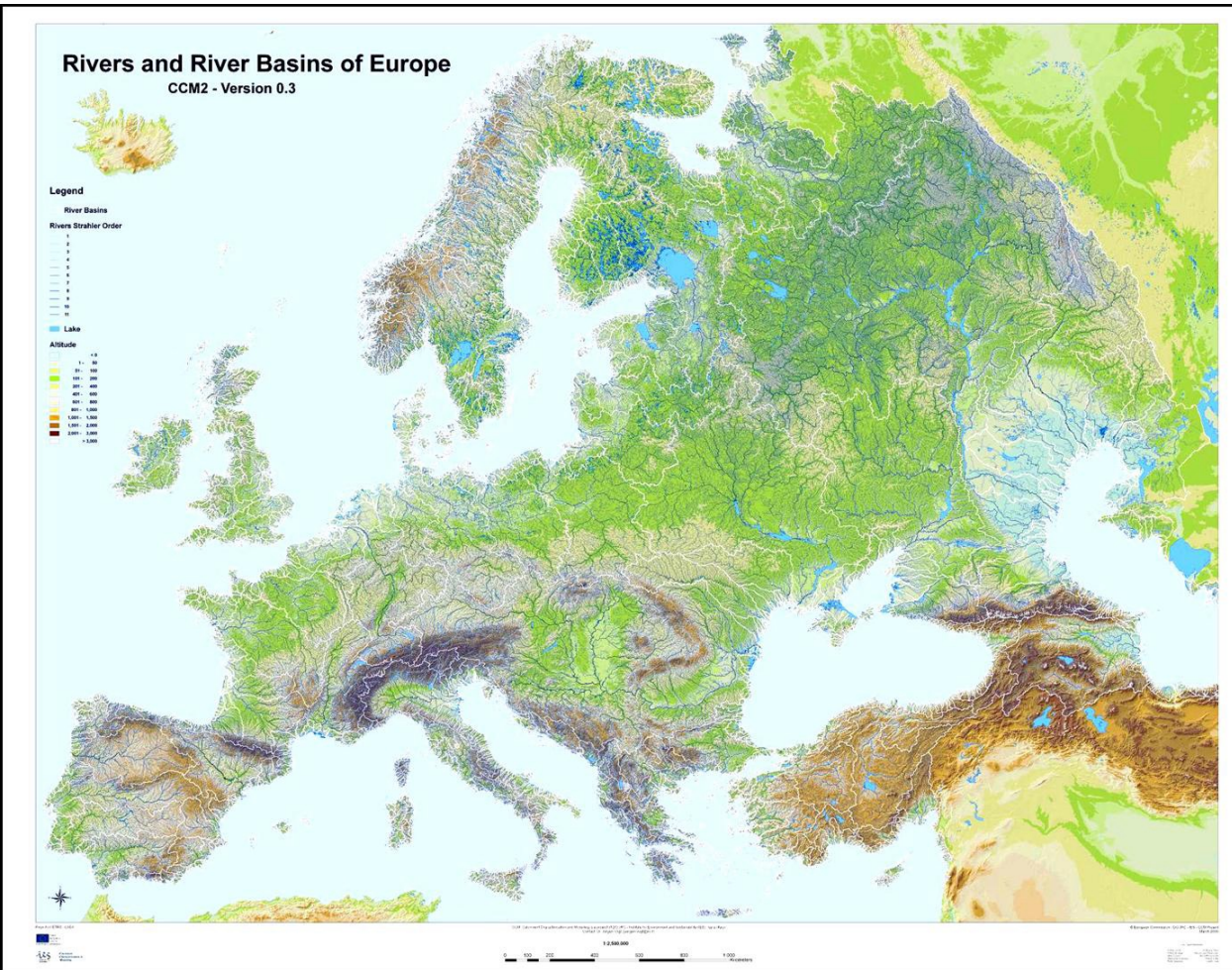
## E. Coli Bacterial Content of Oysters in Etang de Thau 2001 - 2003



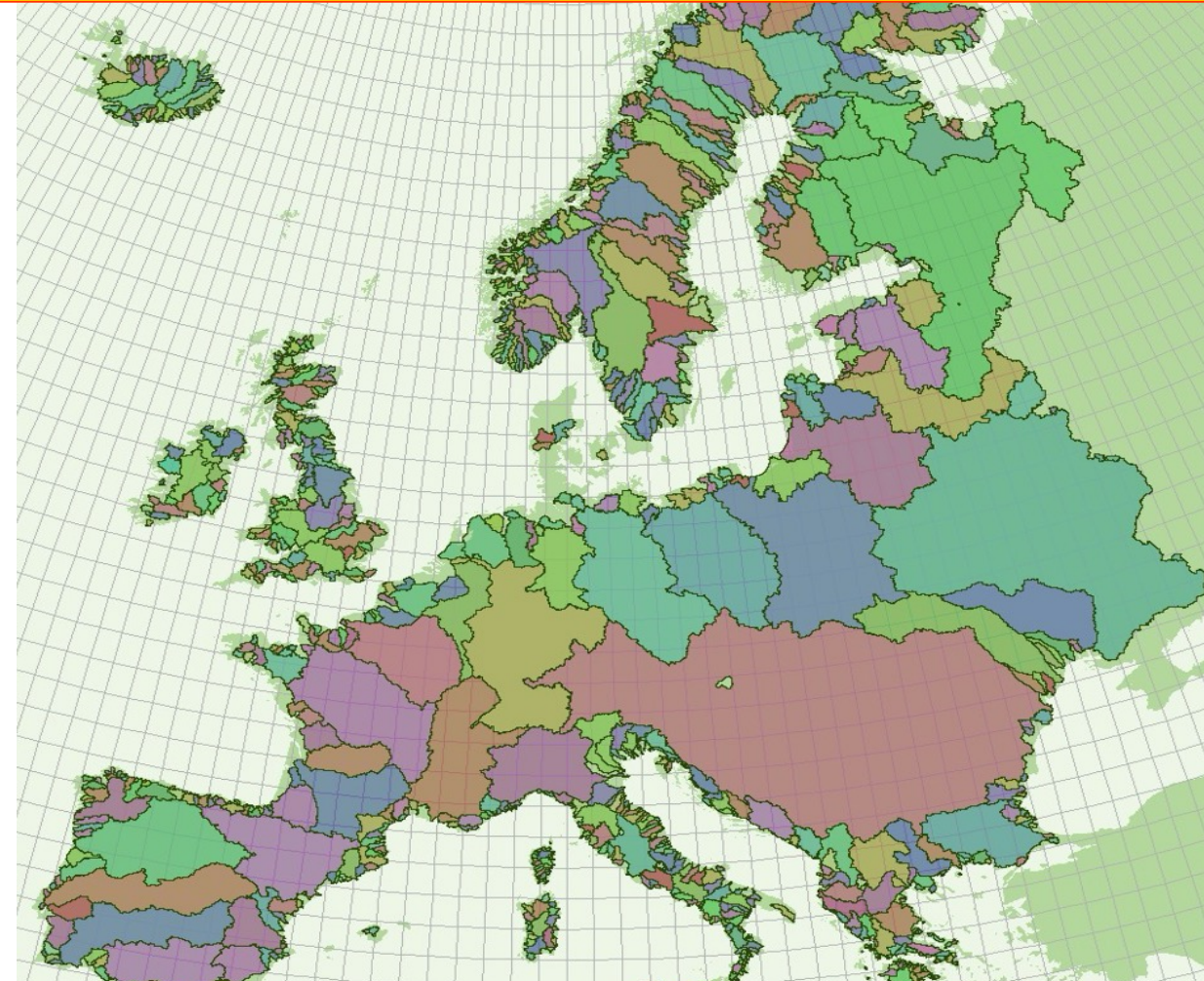
# Environmental Monitoring and Management of EU Waters.

## The Water Framework Directive 2000/60EC.

Integrated impact-based river basin management based on holistic assessment of surface water status.



European Rivers form a complex network of water bodies in direct contact with the coastal zones..



Ambitious objective:  
“good surface water status” by 2015.

# The Water Framework Directive 2000/60EC:

## Holistic Assessment of Surface Water Status.

### Chemical status (surface and ground water)

Levels of chemicals meet environmental quality standards in good status.  
32.000 monitoring sites.

More than 100 chemical substances with potential harmful effects monitored regularly, e.g. nitrates, phosphates, pesticides, solvents, PAHs, heavy metals.  
Millions of environmental data collected every year.

### Chemical Status.

Standards met.

Standards not met.

### Ecological Status

high

good

moderate

poor

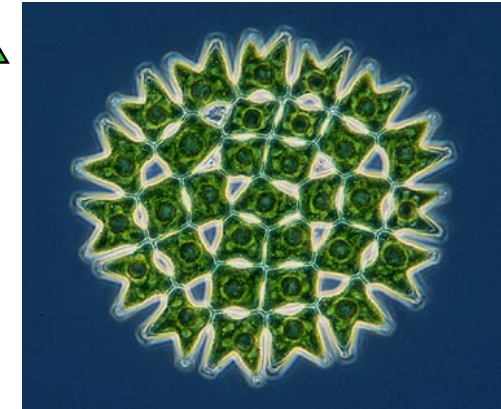
bad

### Ecological Status (surface water)

Based on biological quality indicators and ecological boundary setting.

52.000 monitoring sites.

Restore



Specific indicators for each of the 7 ecoregions in Europe.

**Ecosystem approach to water quality management.**

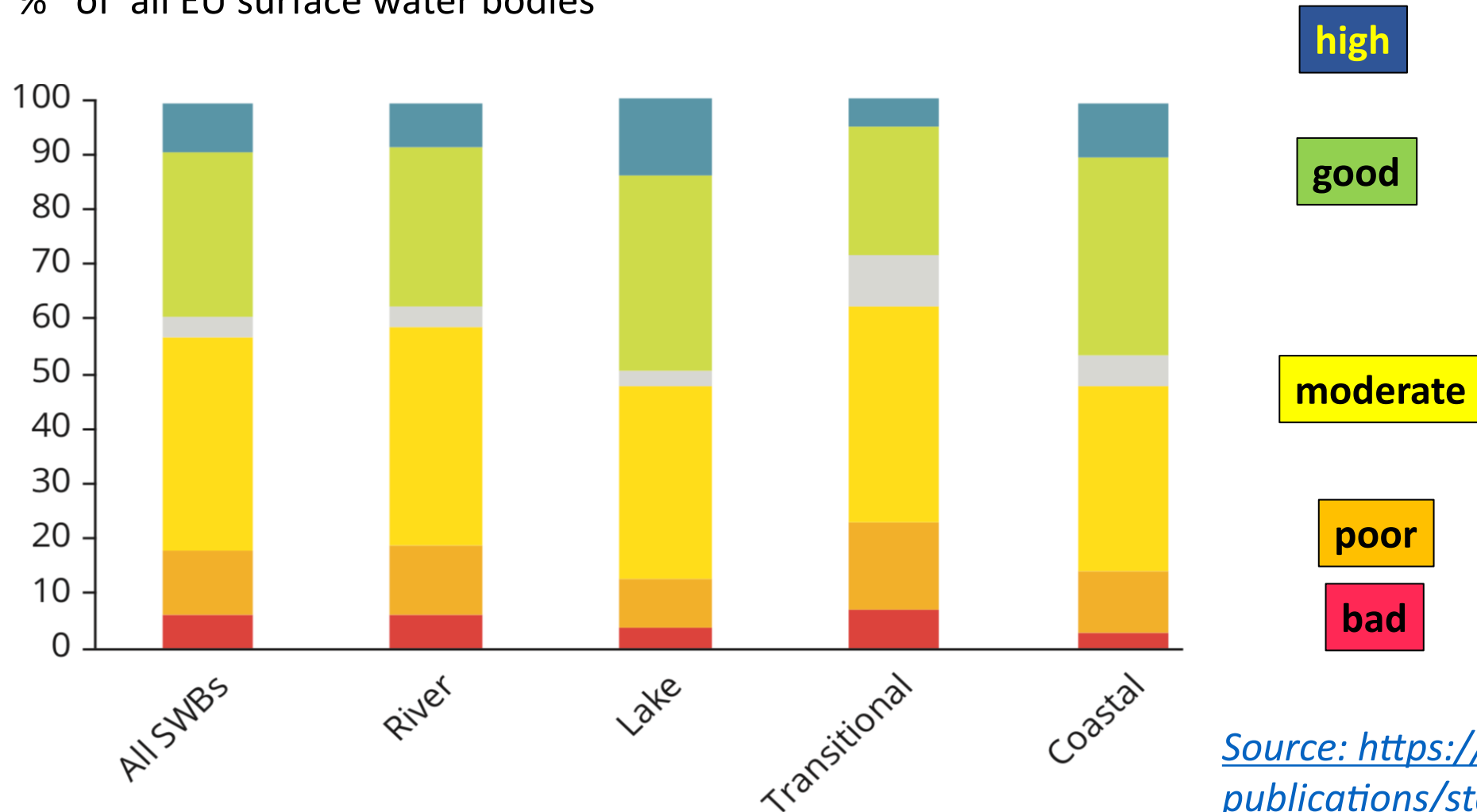


# The Water Framework Directive 2000/60EC:

## Holistic Assessment of Surface Water Status.

### Ecological Status of Surface Waters 2016-2017.

% of all EU surface water bodies

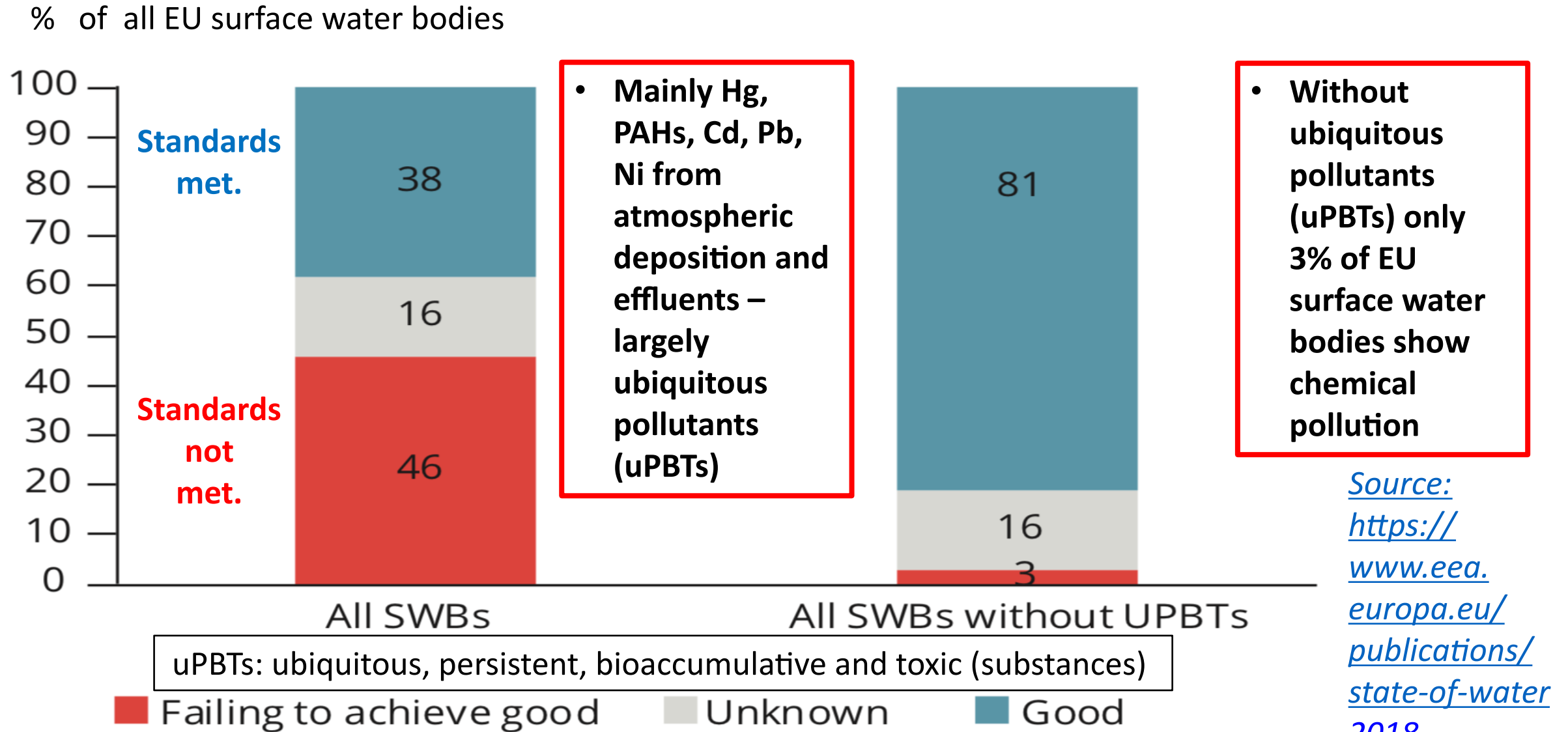


- 40% of the surface water bodies are in good or better ecological status
- 60% did not achieve good status.

Source: <https://www.eea.europa.eu/publications/state-of-water> 2018

# The Water Framework Directive 2000/60EC: Holistic Assessment of Surface Water Status.

## Chemical Status of Surface Waters 2016-2017.



A topographic map of the Danube River Basin, showing the river's course from the Alps in the west to the Black Sea in the east. The basin is outlined in black, and the river is shown in blue. The map uses a color gradient to represent elevation, with green for lower altitudes and brown/orange for higher altitudes. The surrounding regions of Central and Eastern Europe are visible in the background.

**Length of Danube River : 2.857 km  
120 tributaries**

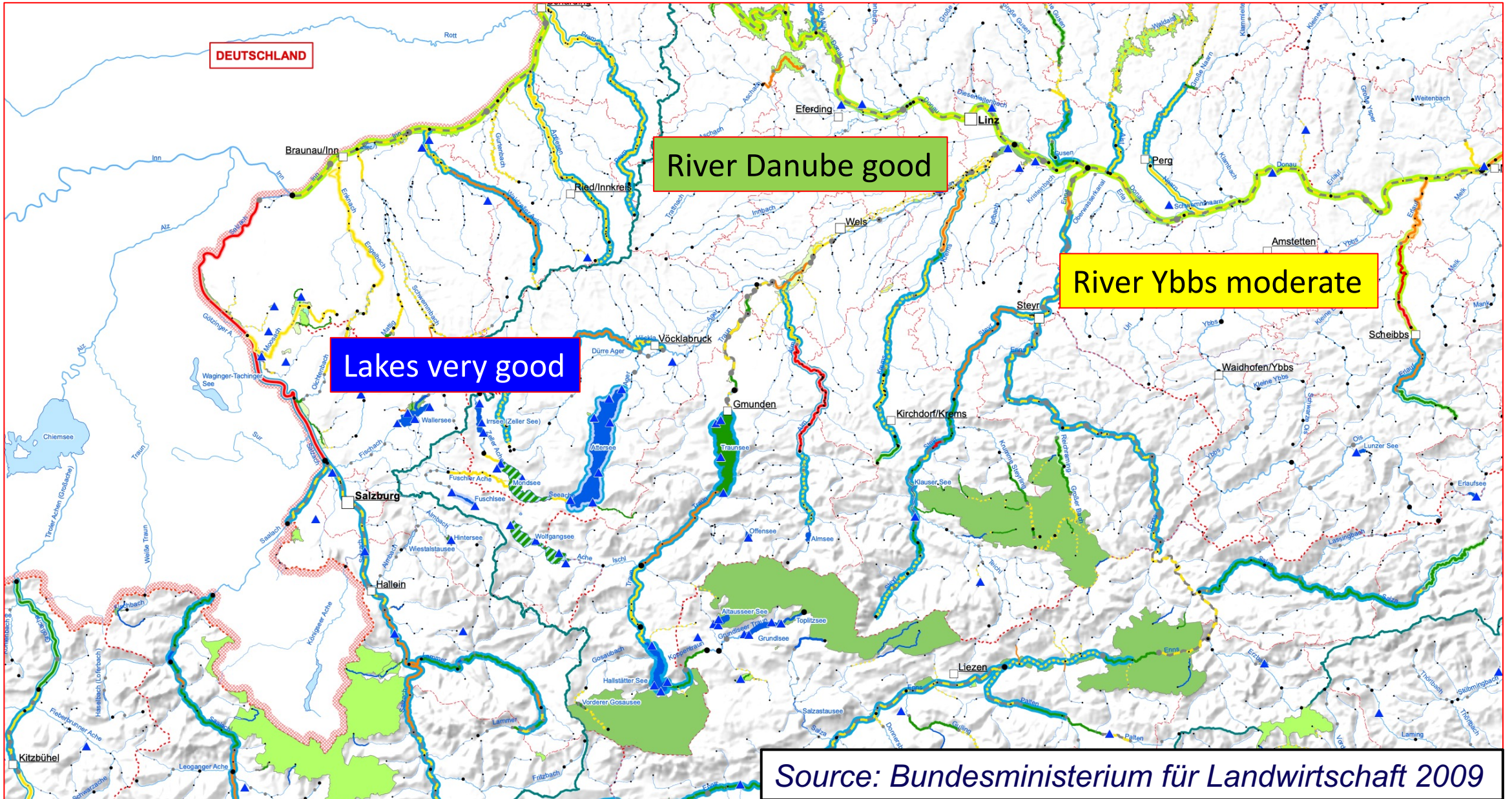
# **Environmental Monitoring and Management of EU Waters. The Danube Basin.**

## **Danube River Basin.**

801.463 km<sup>2</sup>,  
81 million inhabitants,  
19 countries.

**International  
Commission for  
the Protection of  
the Danube River  
(ICPDR).**

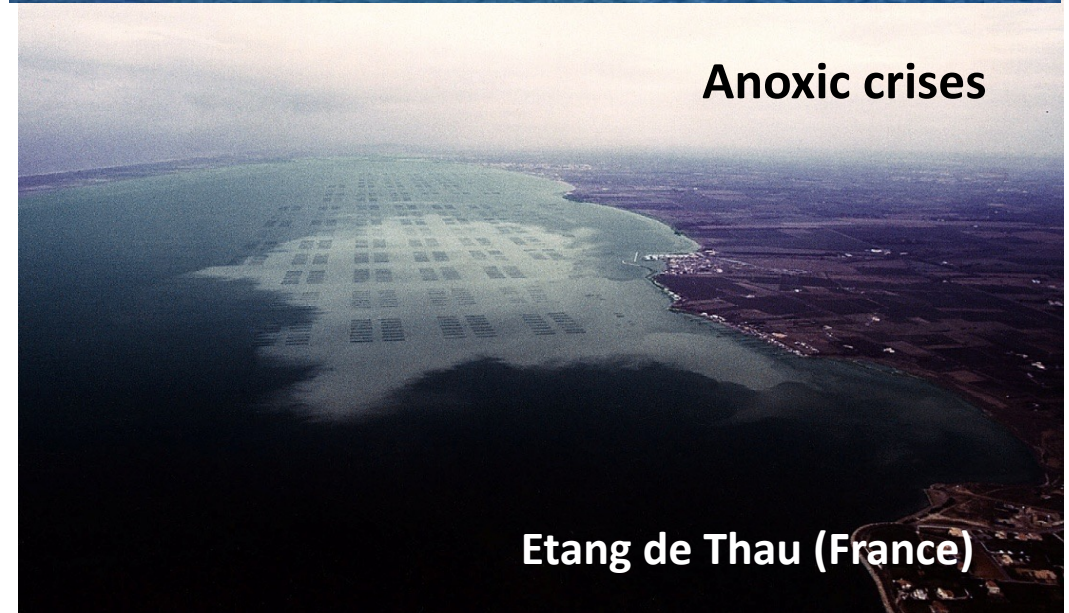
# Ecological Status Assessment Austria: Danube, Salzkammergut Region.



# Coastal Zones: Stressed Ecoregions.

- **Strong anthropogenic pressures:**
  - Freshwater inputs rich in nutrients and pollutants leading to algae blooms.
  - Population growth and tourism in coastal areas.
  - Fish and shellfish farming (500.000 tons of mollusks annually), leading to anoxic crises.

**Sustainable coastal zone management largely lacking.**

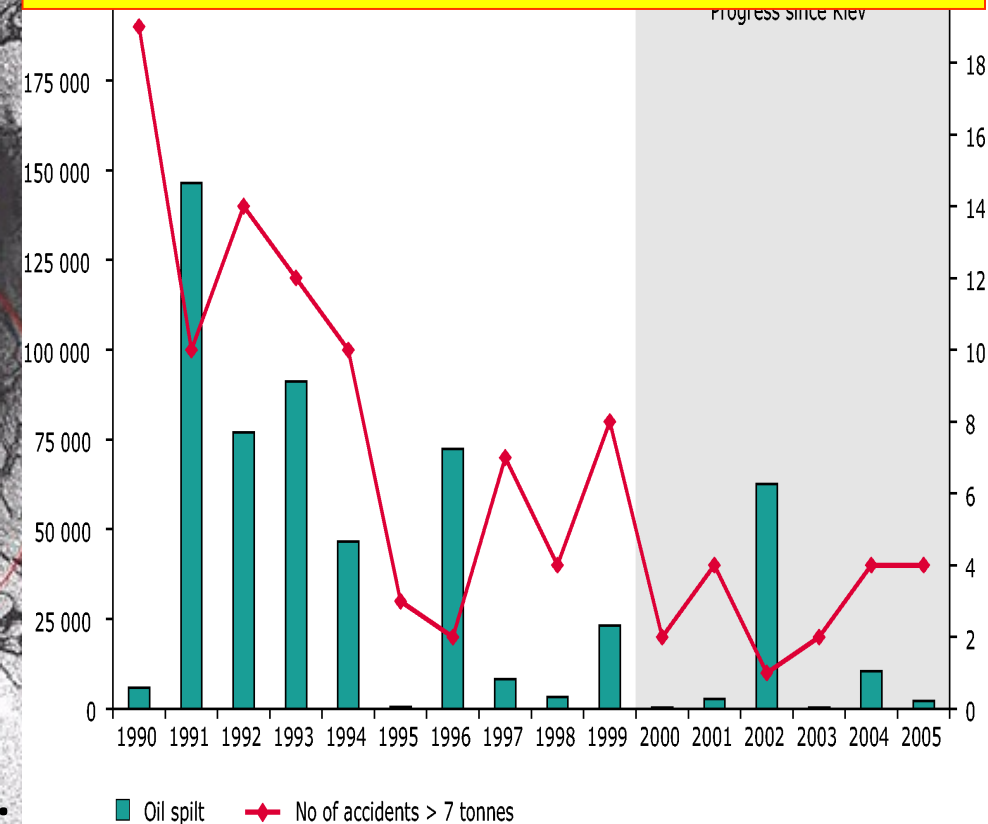
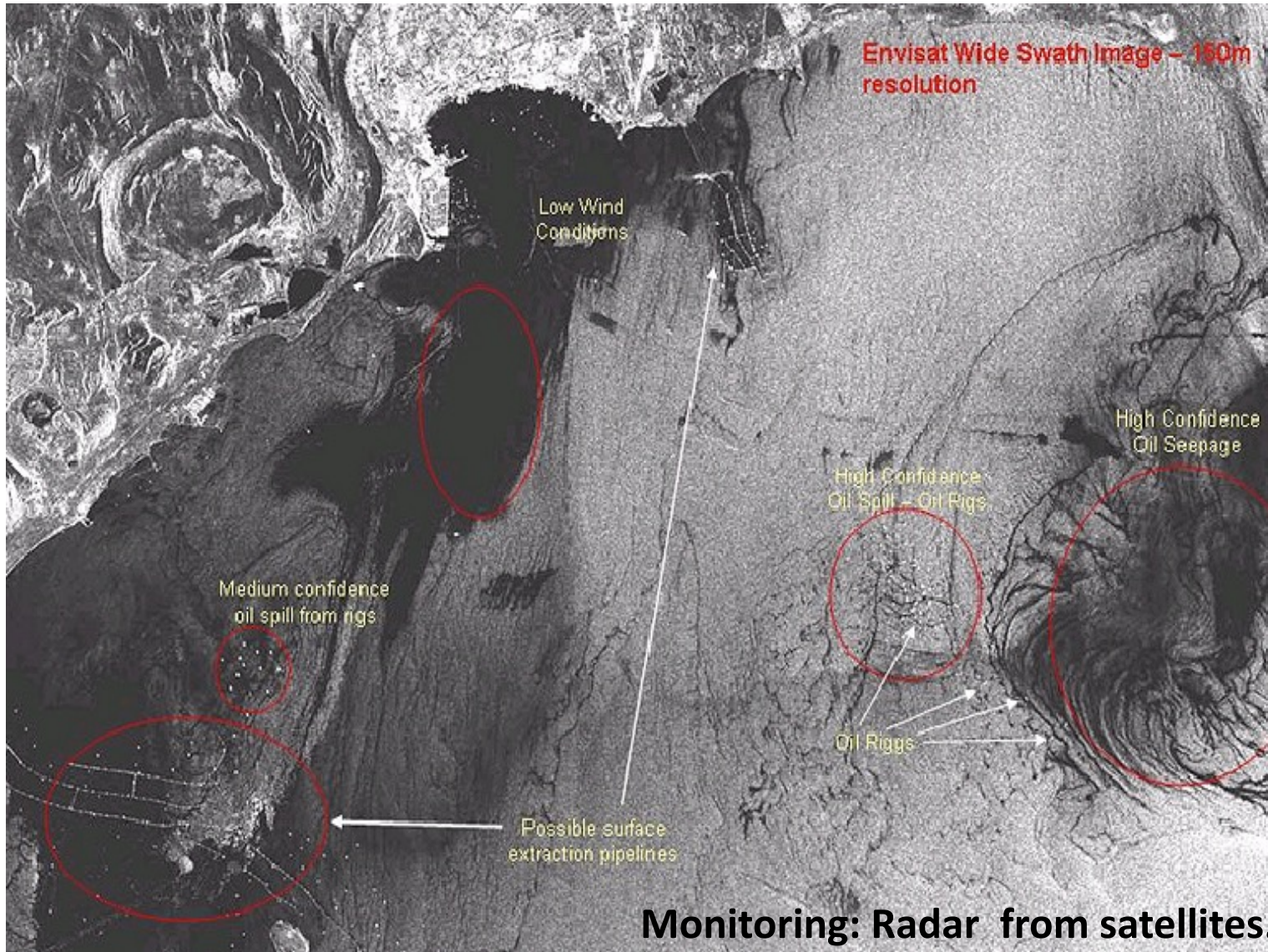


# Coastal Zones: Stressed Ecoregions.

Oil Contamination due to tanker accidents.



Accidental oil tanker spills in European seas.



# Global Pollution of Seas with Plastics.

Moses crossing the Red Sea  
by foot in 2024.



270.000 tons (5.000 billion pieces) of macro or  
'micro plastic floating in the seas.



## 5.2 Soil Pollution.

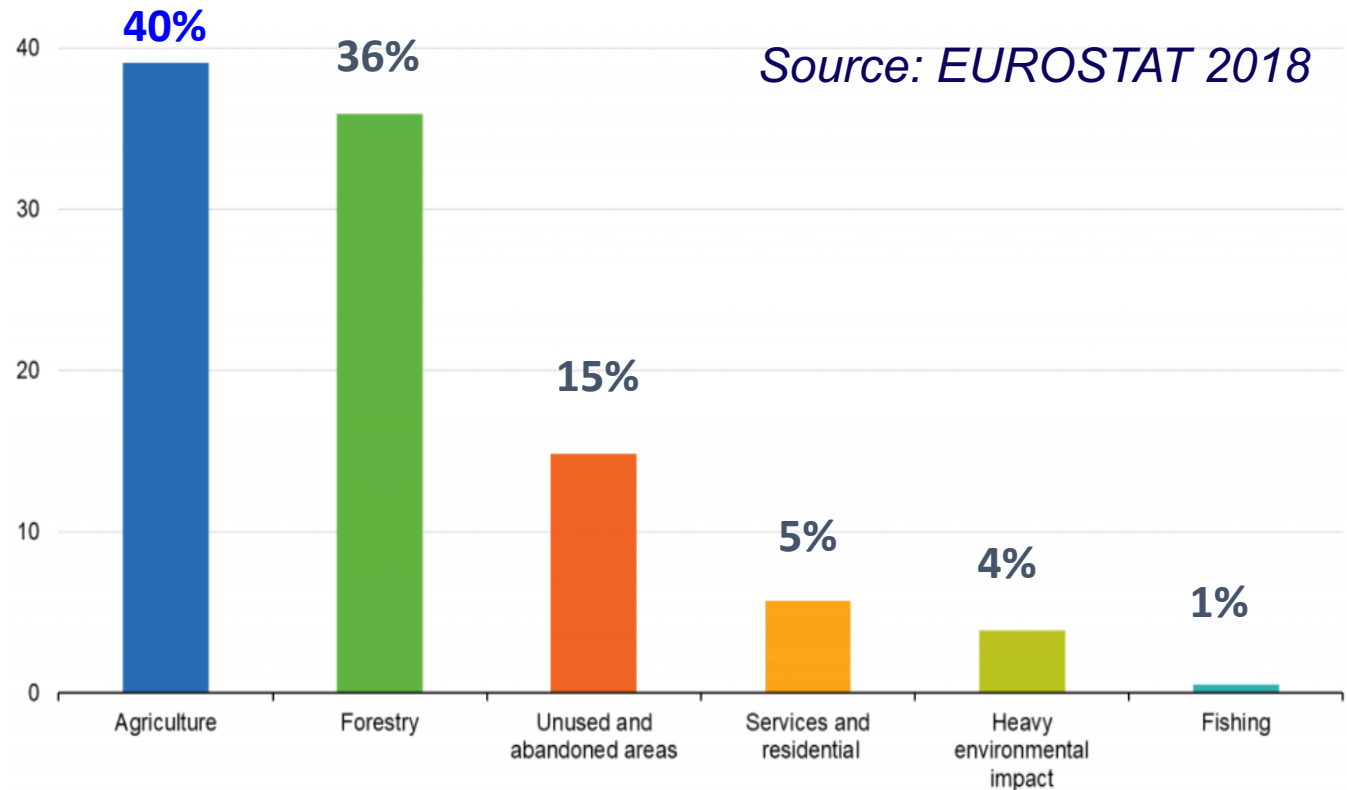
- **Significance of soil:**

“Man...despite his artistic pretensions and many accomplishments, owes his existence to a thin layer of topsoil ...and the fact that it rains”.

*Old Chinese Proverb*



**Main land use by land use type, EU 2018**  
(% of total area)



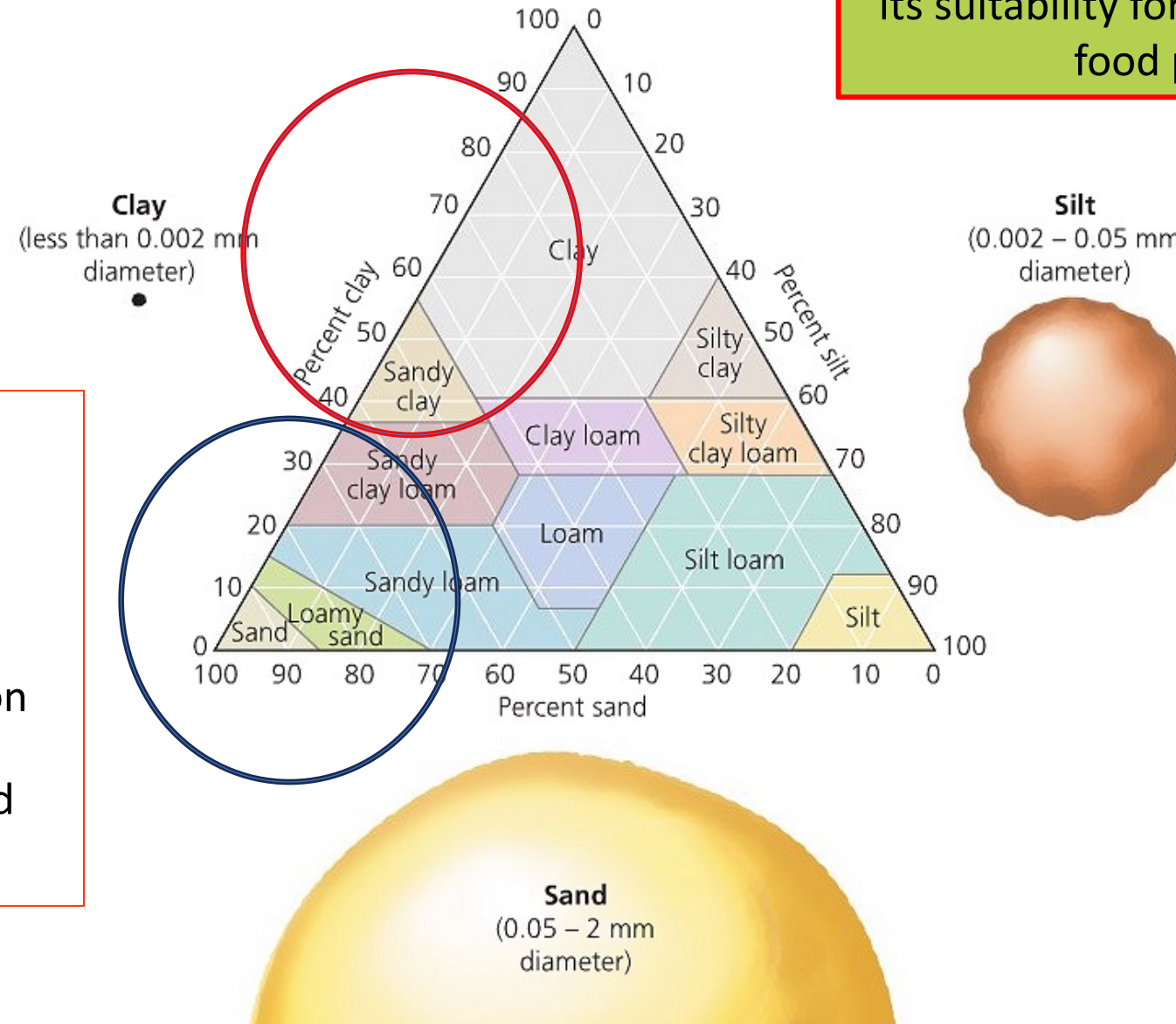
The soil of Europe is a diverse, valuable and non-renewable resource that should be safeguarded.



• Soil texture refers to sand, silt and clay composition affecting soil behavior, like the retention capacity for nutrients and water.

## Soil Texture.

The composition of the soil determines its suitability for growth of plants and food production.



wheat

wine

- Clay is the product of chemical weathering.
- Clay soil has high retention capacity for nutrients and water.

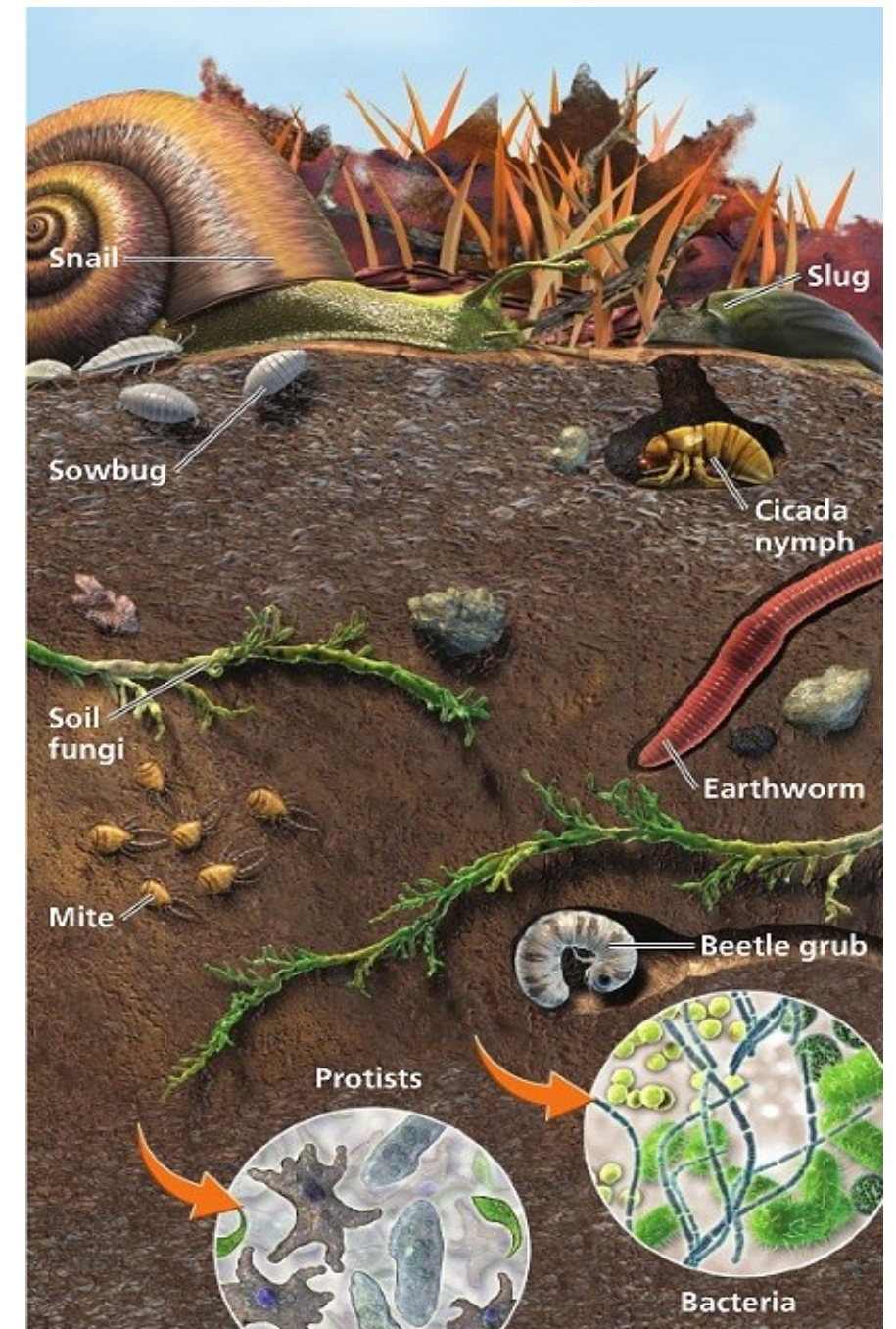
- Sand and silt are the products of physical weathering.
- Silty and sandy soils are more sensitive to erosion.

# Soil Functions.

- **Soil performs a number of key environmental, social and economic functions that are vital for life.**
  - Plants and crops depend on soil for the supply of water, nutrients and as a medium for growing.
  - Soil stores, filters, buffers and transforms substances that are introduced into the environment, crucial in protecting water supplies and regulating greenhouse gases.
  - Soil is a provider of raw materials.
  - Soil is an incredible habitat and gene pool.
  - Soil is a fundamental component of our landscape and cultural heritage.

1 g of soil contains 100 million bacteria.  
5 tonnes of live organisms can exist in  
a hectare of soil.

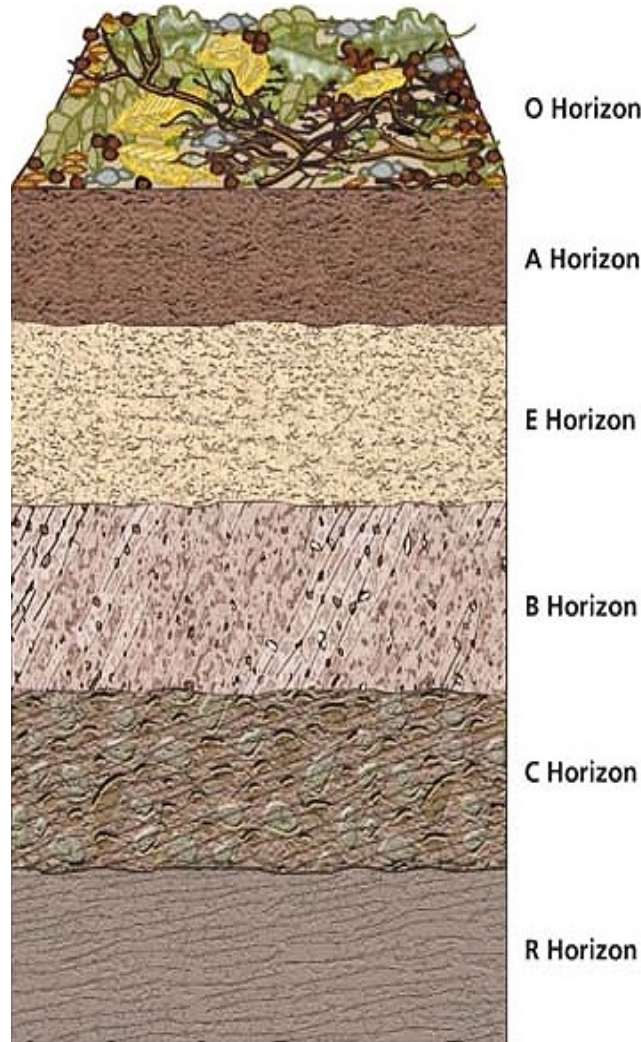
*Source: Withgott and Brennan:  
Environment, Pearson 2008*



# Soil Erosion and Contamination.

## Soil erosion:

- 12 % of Europe's surface affected by water erosion, 5 % by wind.
- **Reduced capacity for carbon storage:**
  - Function as carbon sinks degrading, loss of capacity to bind CO<sub>2</sub>
  - 45 % of European soils have a reduced organic carbon content (particularly in Southern Europe)
- **Urban sprawl:**
  - Continued loss of soil from sealing and replacement (e.g. by construction)
- **Intensification of agriculture:**
  - Increasing use of fertilisers and plant protection products harmful for soil biodiversity.



## Soil contamination:

### • Major causes:

- rupture of underground storage tanks
- application of pesticides
- leaching of wastes from landfills
- direct discharge of industrial wastes.

### • Most common chemicals:

- petroleum hydrocarbons and solvents
- pesticides
- heavy metals.

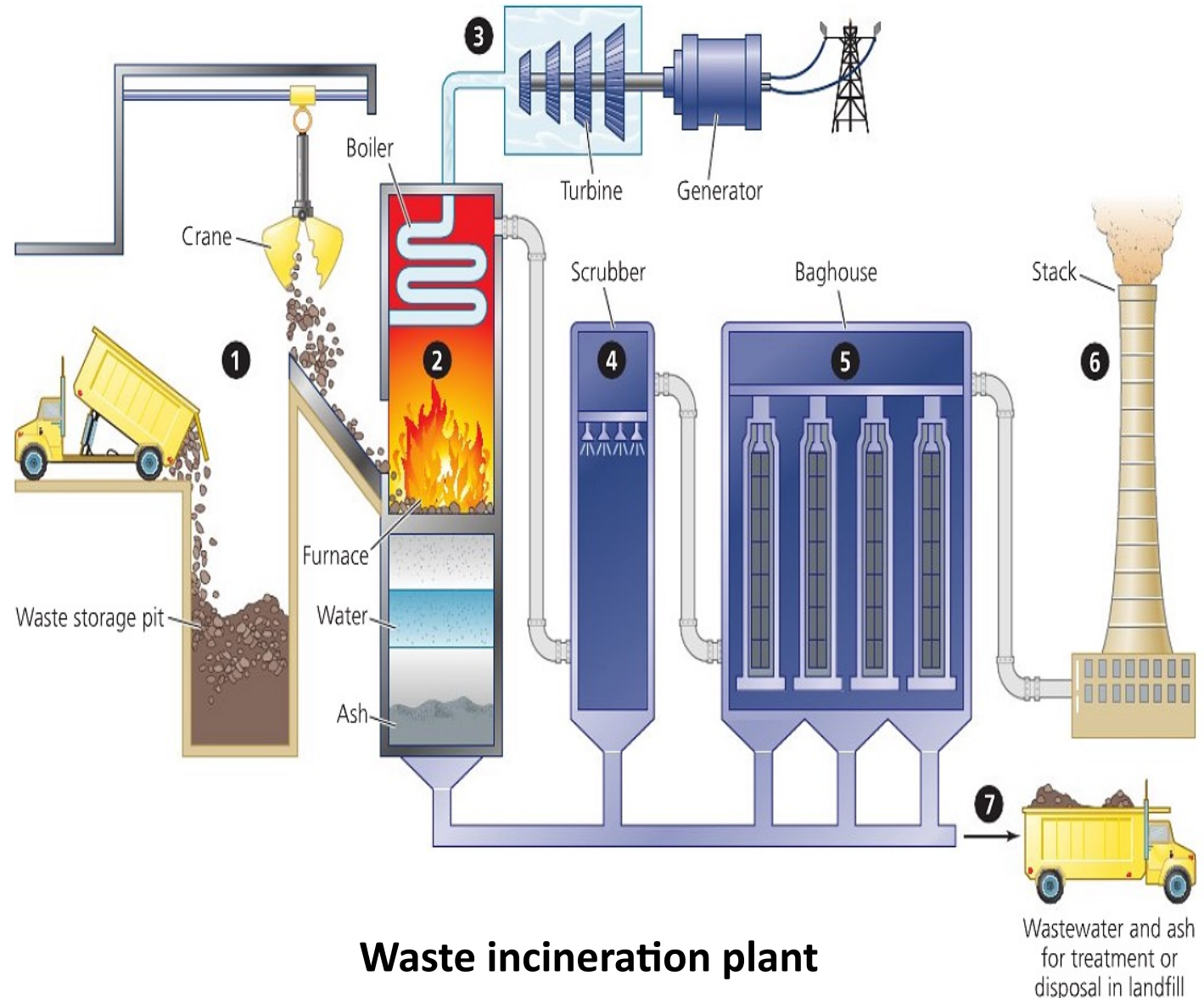
### • Concerns:

- health risks due to contamination of water, crops, feed and food.

There are about 150.000 contaminated sites within the European Union.

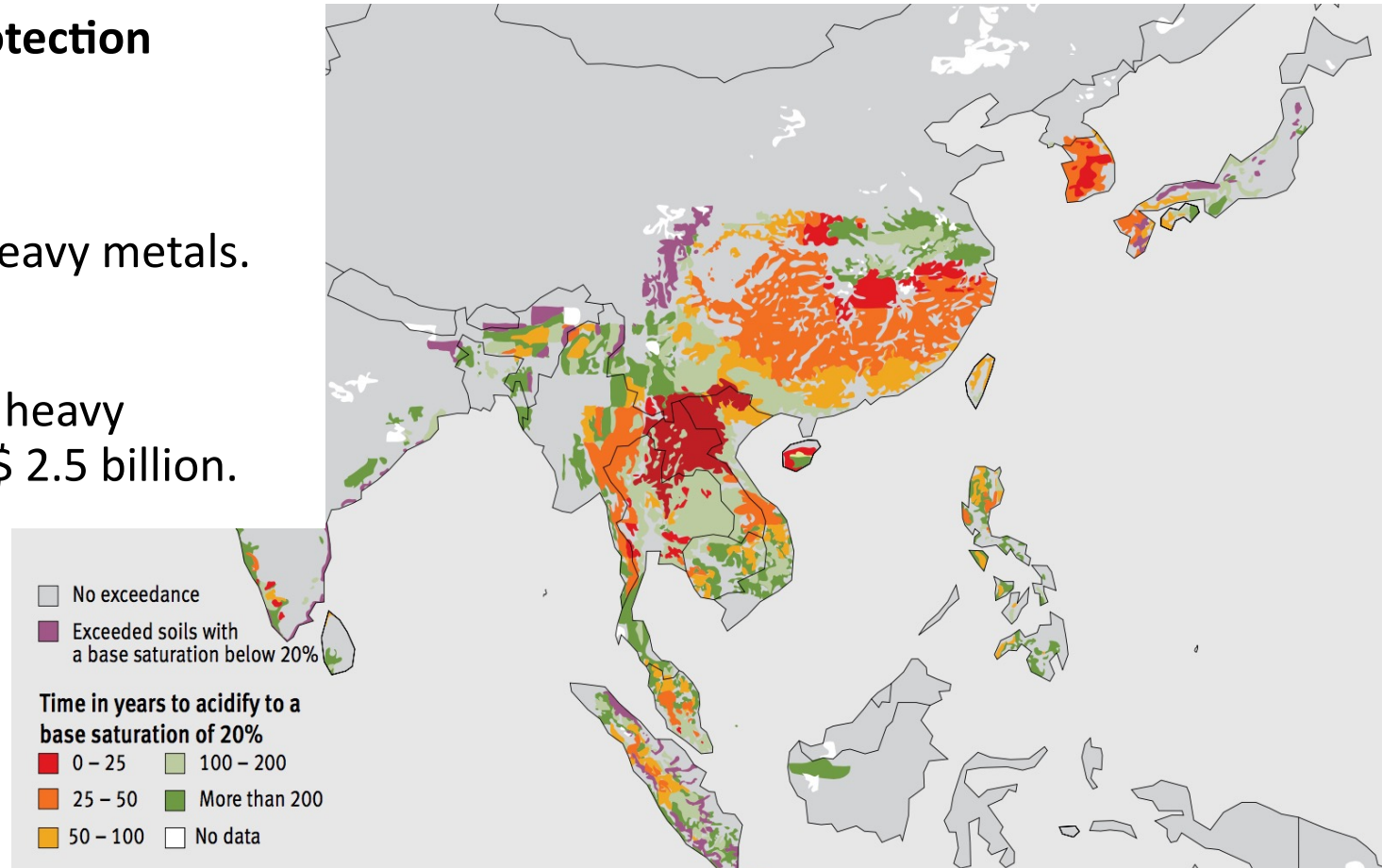
# Waste Management.

- Each European produces on average 500 kg waste per year.
- Possible effects of waste deposition by landfill operations:
  - Contamination of groundwater and/or aquifers by leakage.
  - Outgassing of methane (green house gas) from decaying organic wastes.
  - Harbours of disease vectors such as rats and flies.
  - Simple nuisance problems (e.g. dust, odour).
- **Mitigation:**
  - Waste reduction and recycling.
  - Incineration and pyrolysis.
  - Composting and mechanical biological treatment.
  - Banning of disposal of untreated waste in landfills (AT, DE, CH).



# Soil Contamination: Tiger Economies - Example China.

- **Economic growth without environmental protection resulted in massive soil pollution:**
  - Widespread damage of soil due to acid rain.
  - 20% of China's cultivated land polluted with heavy metals.
  - 60% of ground water contaminated.
  - >10 million tons of grain are contaminated by heavy metals every year, causing direct losses of US\$ 2.5 billion.



- Contaminated areas account for one-tenth of China's cultivatable land, and concern mostly economically developed regions.
- 1.300 km<sup>2</sup> are covered or destroyed by solid waste.