

The Toxicity of Produced Water Discharges in the Amazon Basin, Ecuador

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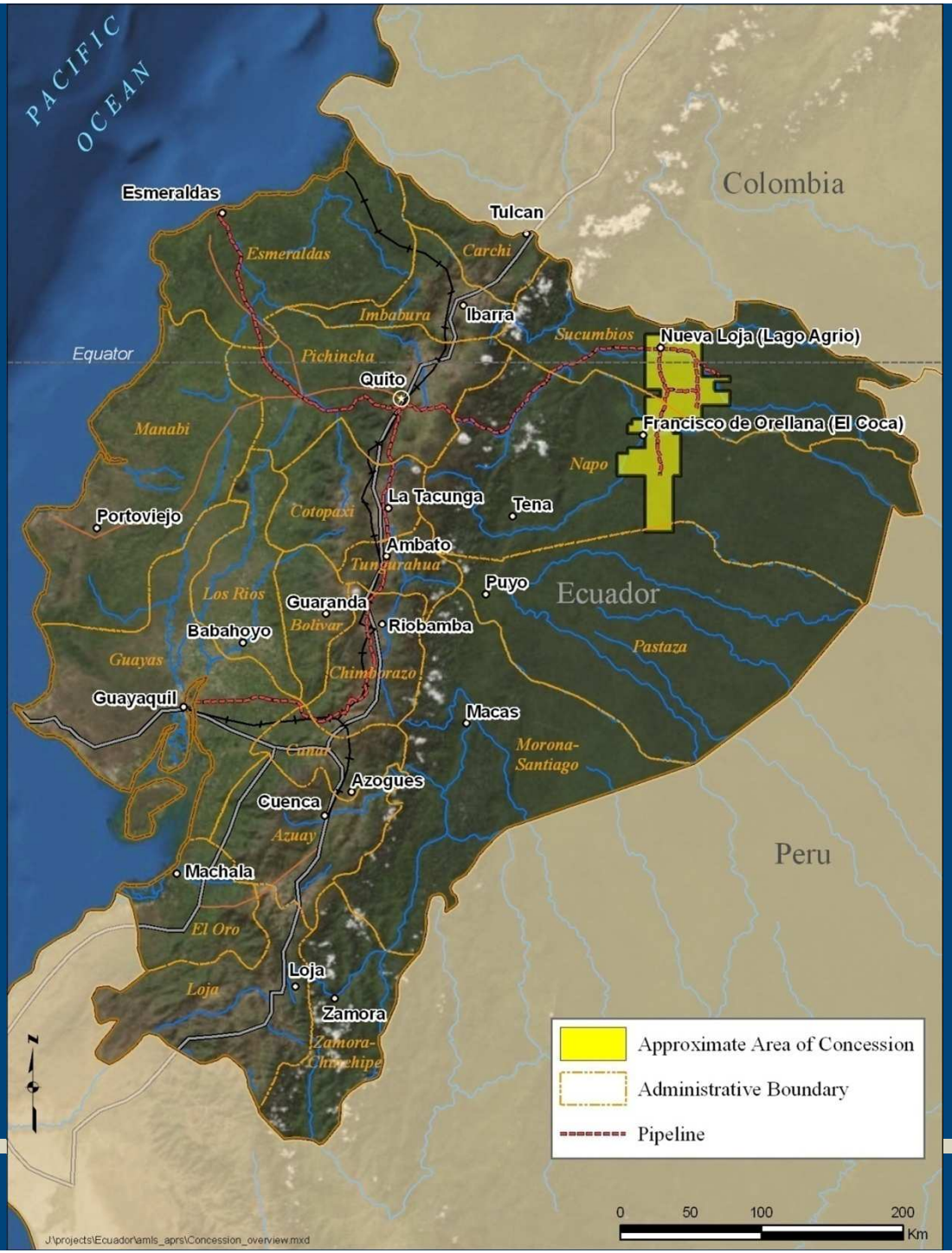

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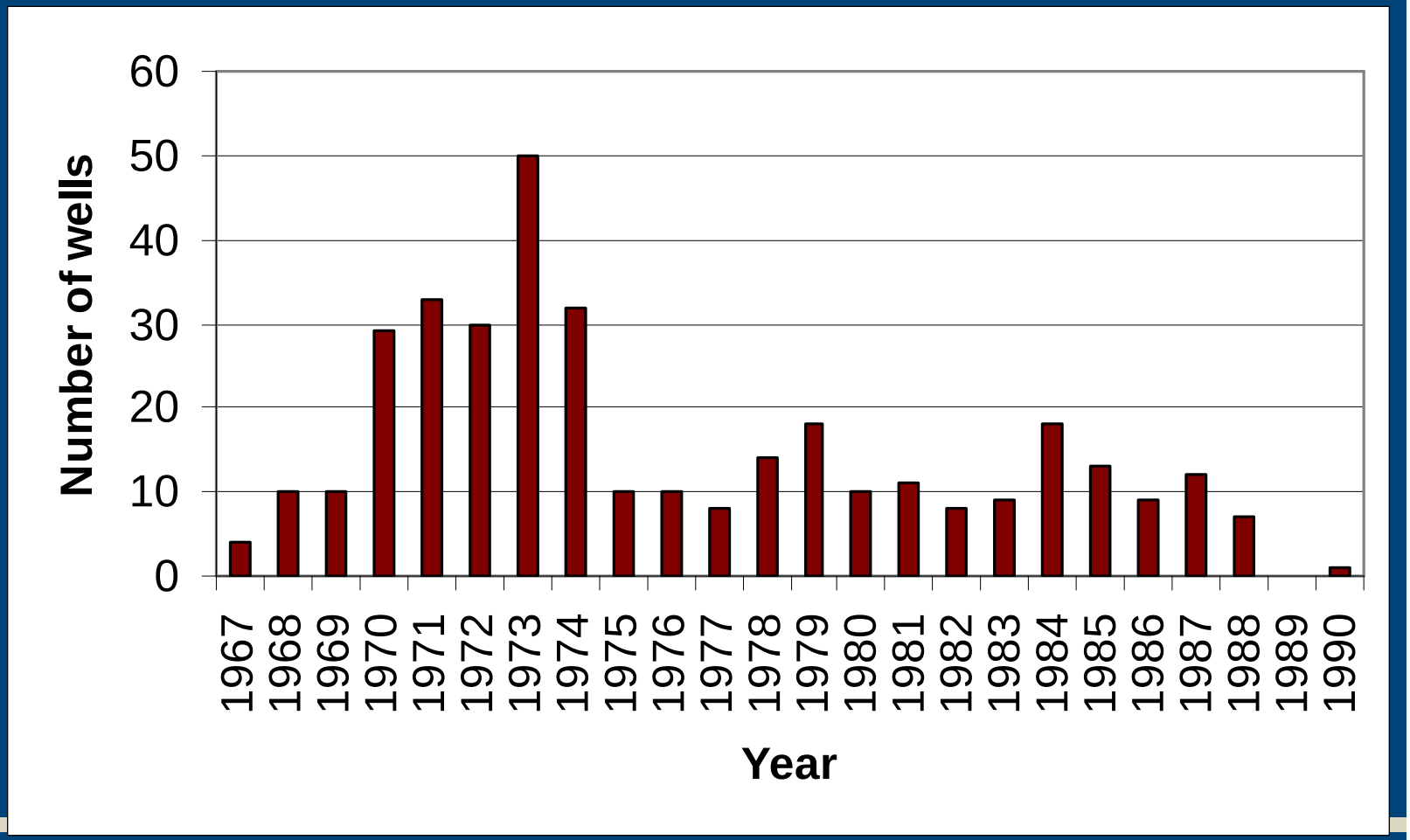
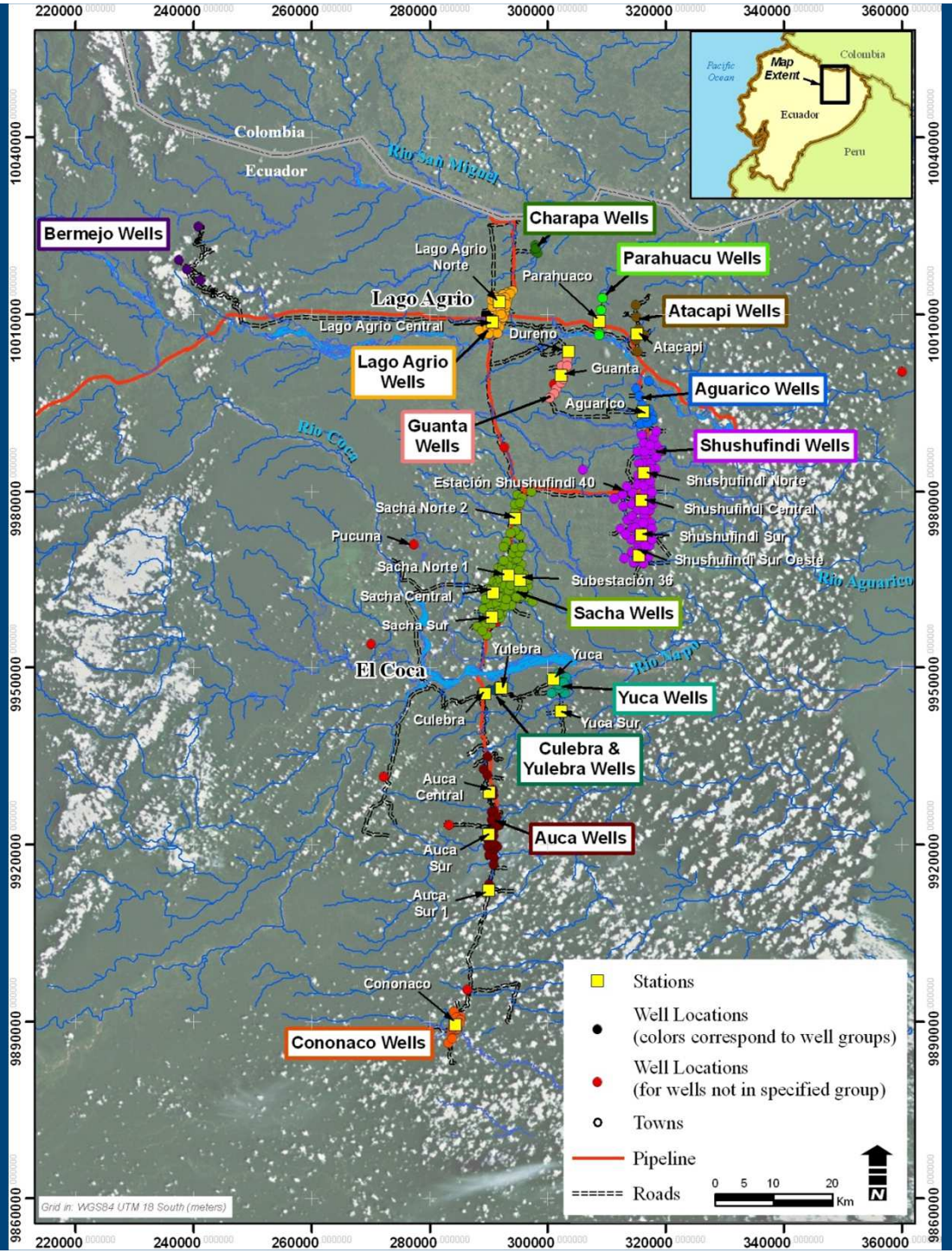
Texaco's Oilfield Operations in Ecuador

- Texaco drilled and operated 356 oil wells and built 22 production stations from 1967 to 1990
- Petroecuador took over operations in 1990
- Class action lawsuit brought by residents (including indigenous groups) against Texaco for pollution of the area
- Court expert recommends damages of $27 billion

Wells Opened and Operated by Texaco





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Primary Sources of Contamination

- 916 unlined, abandoned pits with wastes from wells (oil, drilling muds, other chemicals)

Photo credit:
L. Dematteis

Primary Sources of Contamination

- Oil spills from pipelines

Primary Sources of Contamination

- Oil poured on roads

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L. Dematteis, M. Pallares

Primary Sources of Contamination

- Air pollution from open burning of pits, flaring

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M. Pallares

Primary Sources of Contamination

- Discharge of produced water
  - Texaco audits show that they discharged ~18 billion gallons from 1972-1990 into streams and rivers

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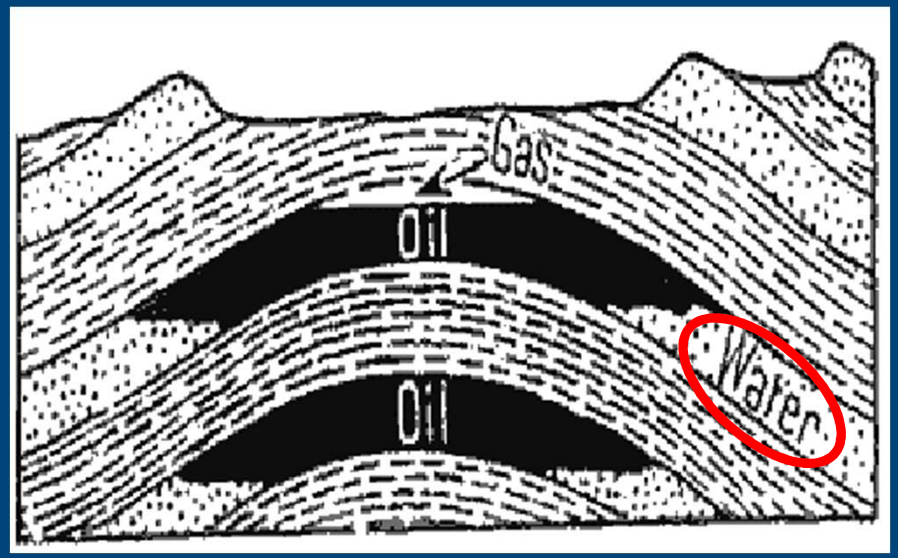
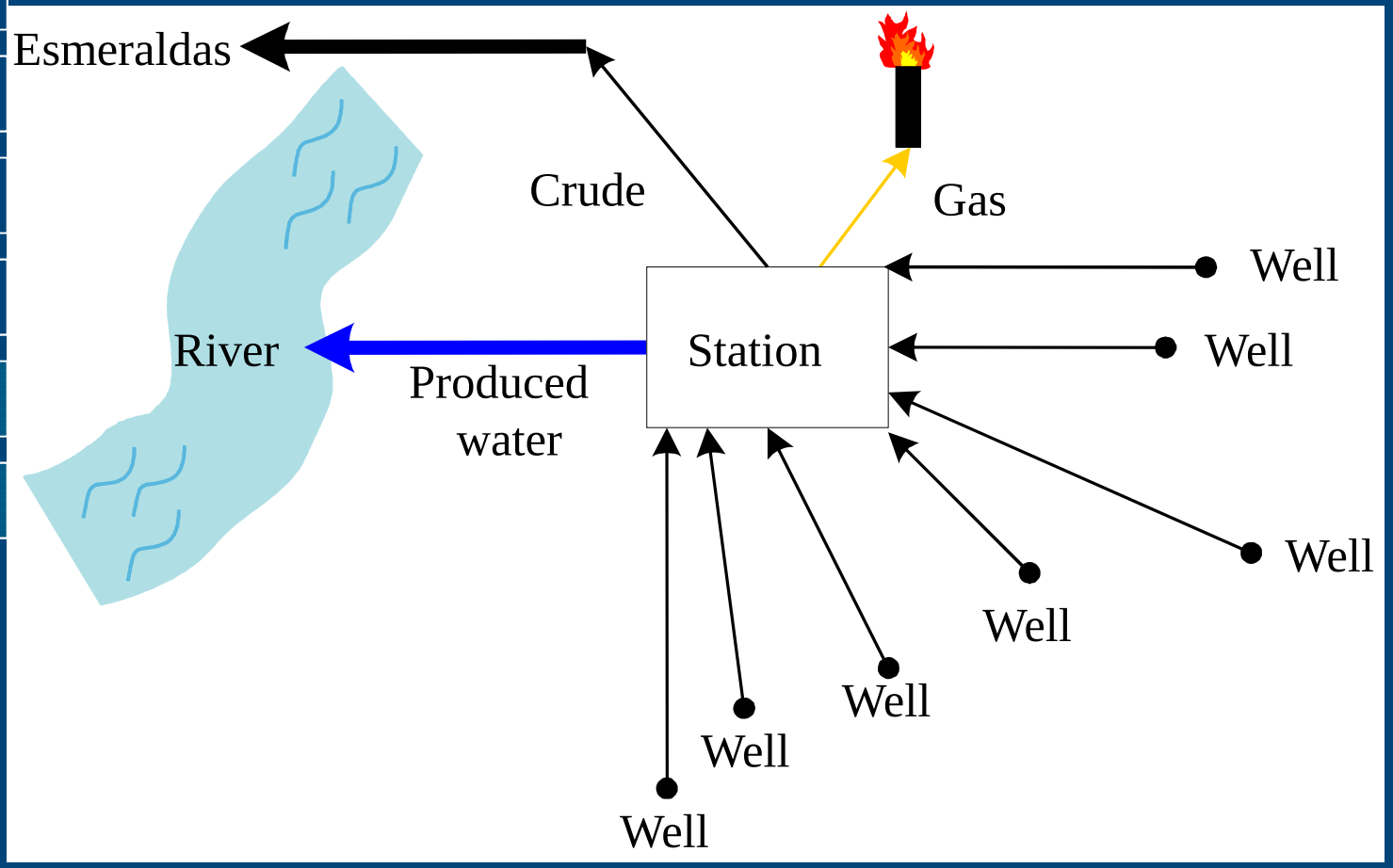
M. Pallares

Oilfield Produced Water

- Produced water occurs underground with oil and has to be separated from the oil at the surface



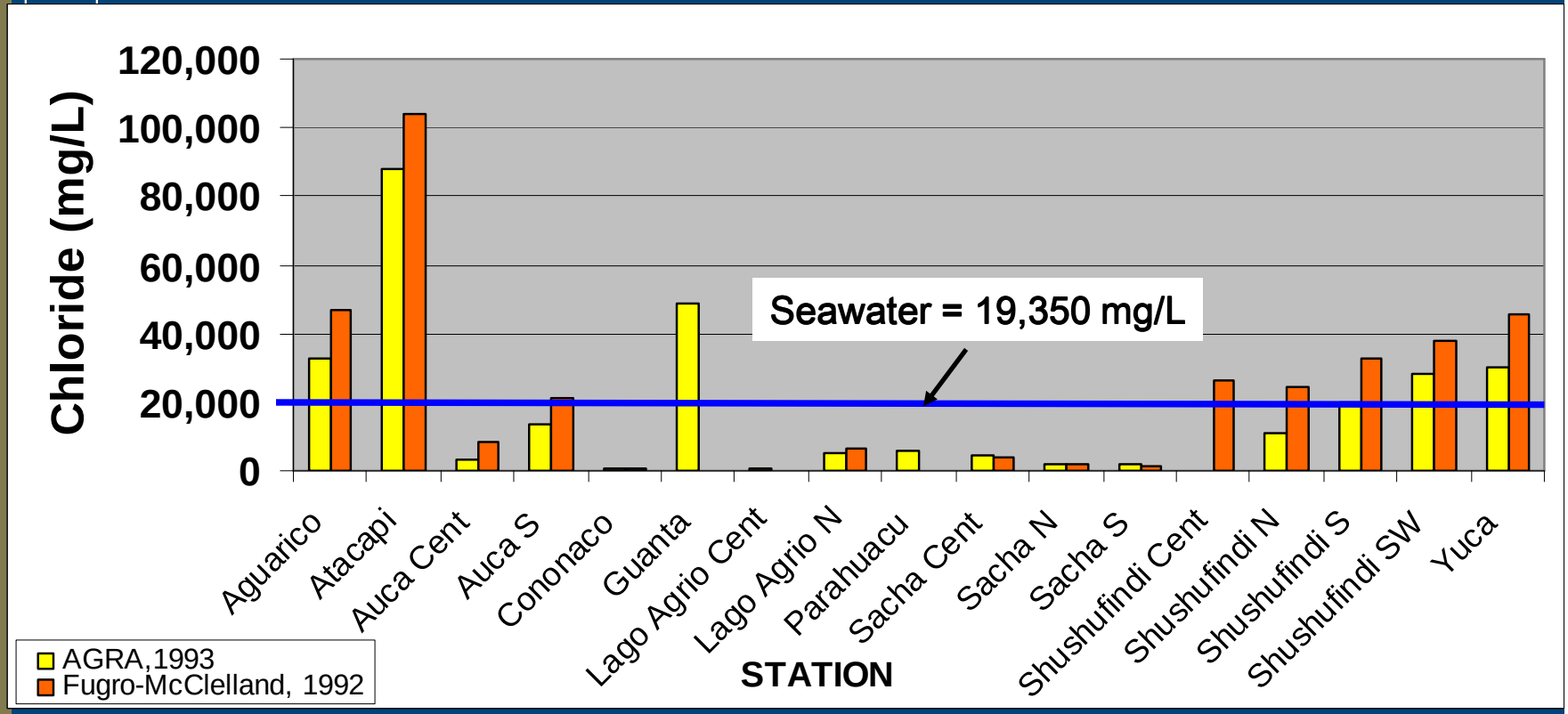
Texaco Operations



Oilfield Produced Water

- U.S. regulations for onshore discharge of produced water date back to the 1920s
- Onshore produced water is typically reinjected or treated to standards
- Since Petroecuador took over operations in 1990, produced water is now reinjected
- What was the toxicity of the water discharged by Texaco?

Chloride in Produced Water



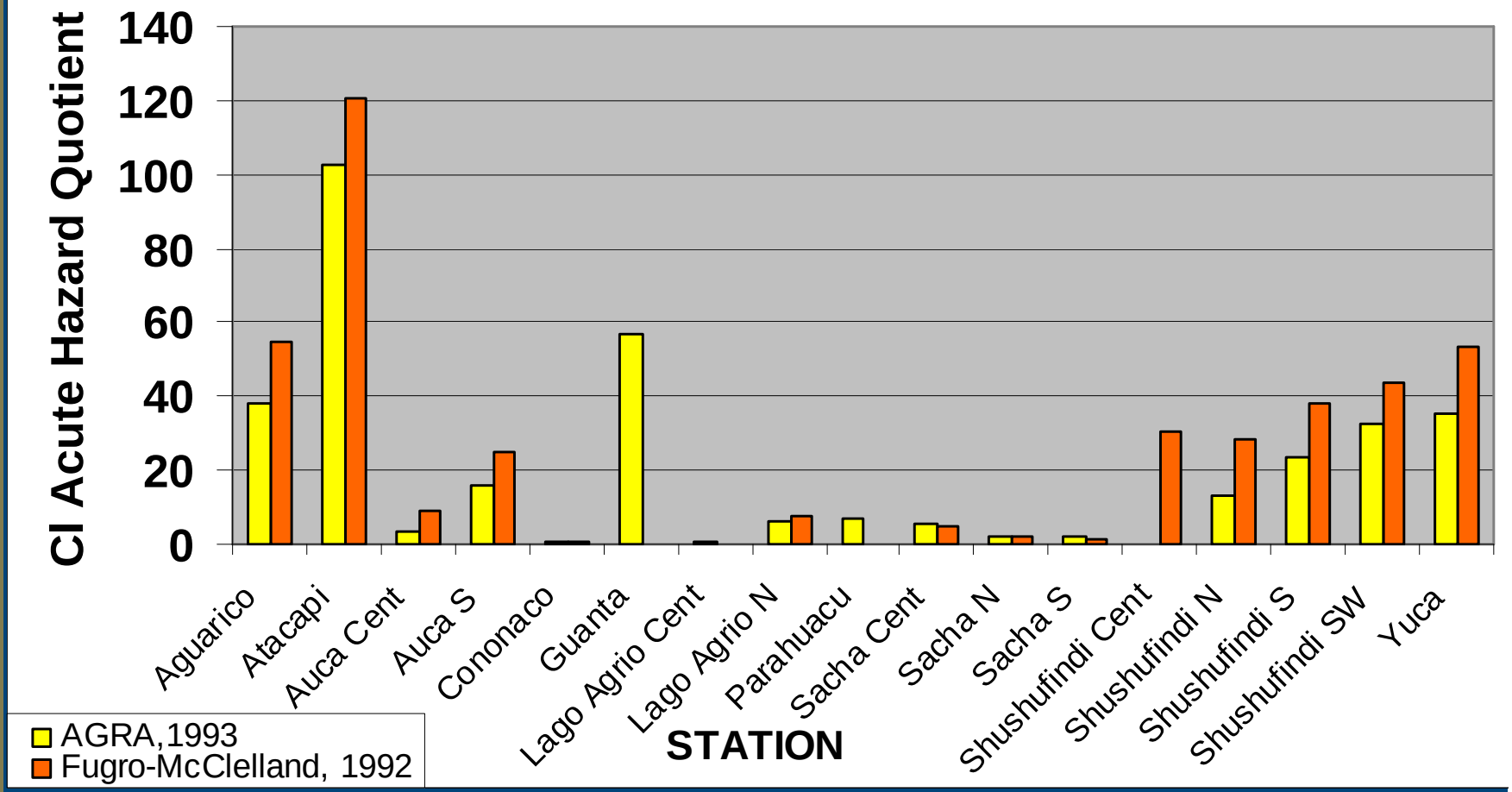
Chloride Toxicity to Aquatic Biota

- Chloride disrupts ionoregulatory processes of freshwater biota, causing ion imbalances
- No data available on toxicity to Amazon Basin aquatic biota
- Natural waters in the area have low ionic strength (~3 mg/L chloride), may influence susceptibility of aquatic biota to chloride toxicity

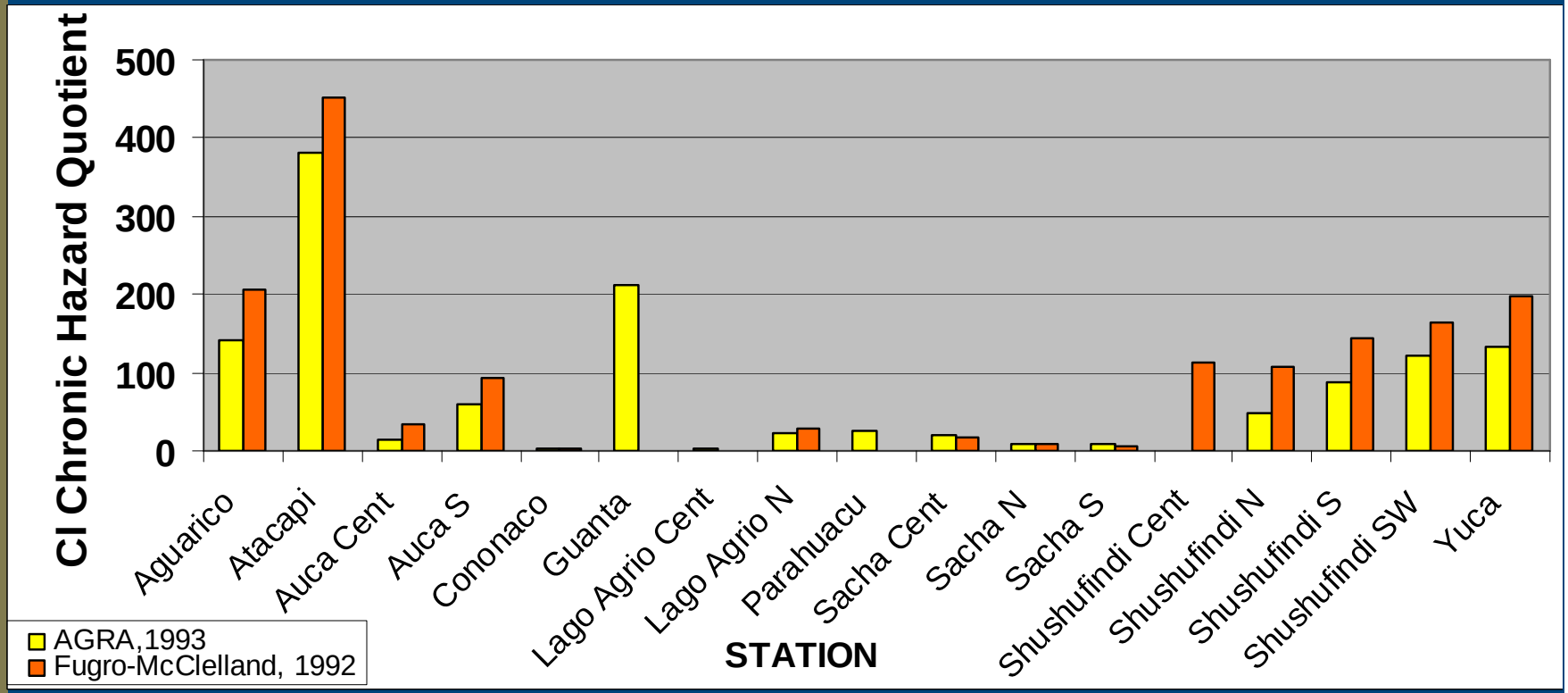
Chloride Toxicity to Aquatic Biota

- Acute LC50s
  - Inverts: ~2,000 to 6,000 mg/L Cl
  - Fish: ~6,000 to 12,000 mg/L Cl
- Chronic effects (growth, reproduction) at <1,000 mg/L Cl
- USEPA water quality criteria (USEPA, 1988):
  - Acute 860 mg/L
  - Chronic 230 mg/L
  - Driven by data for invertebrates taxonomically similar to those in the area (Gallo, 2007)
- Hazard Quotient (HQ) = concentration/criterion

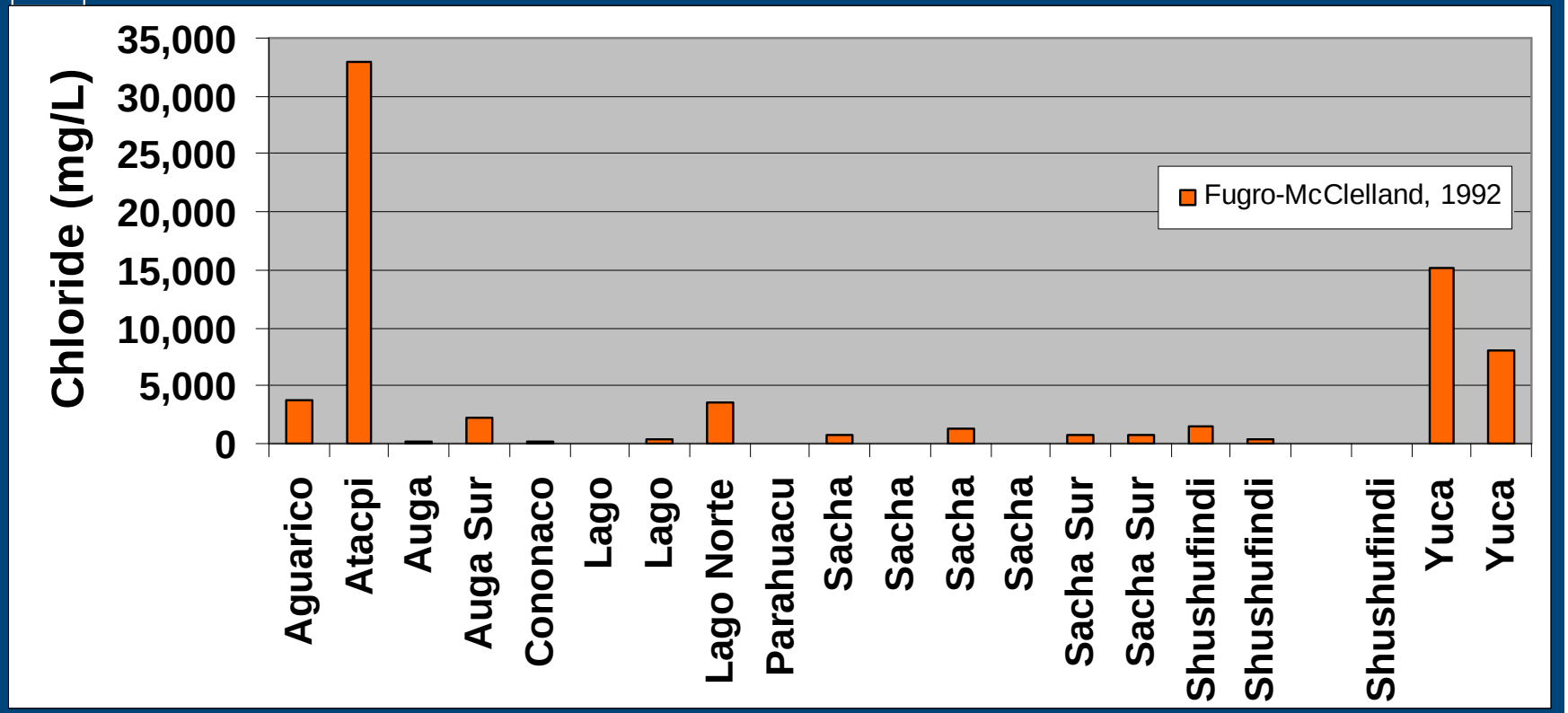
Cl Acute Hazard Quotient for Produced Water



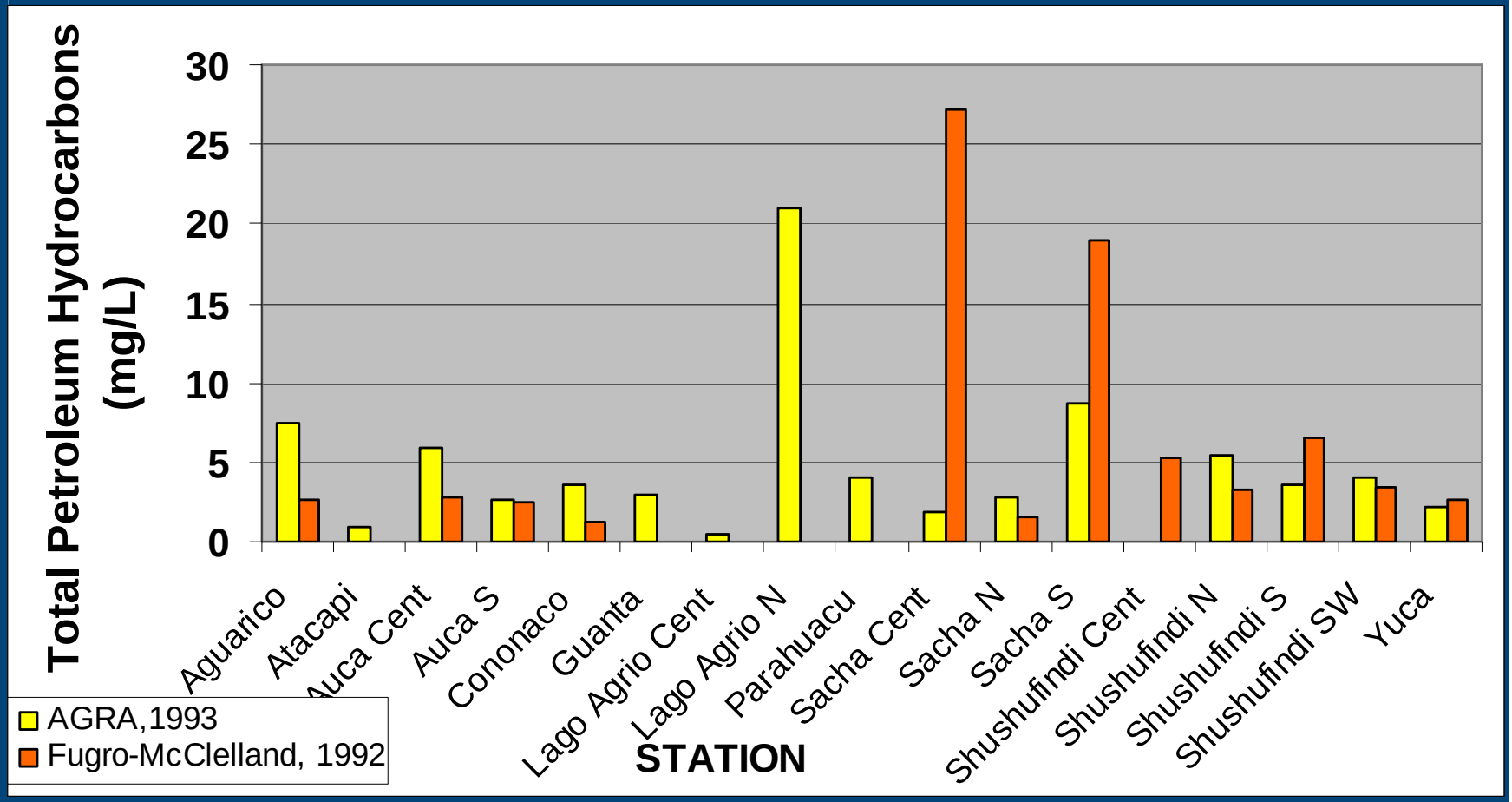
CI Chronic Hazard Quotient for Produced Water



Chloride in Streams Downstream of Stations



Total Petroleum Hydrocarbons in Produced Water

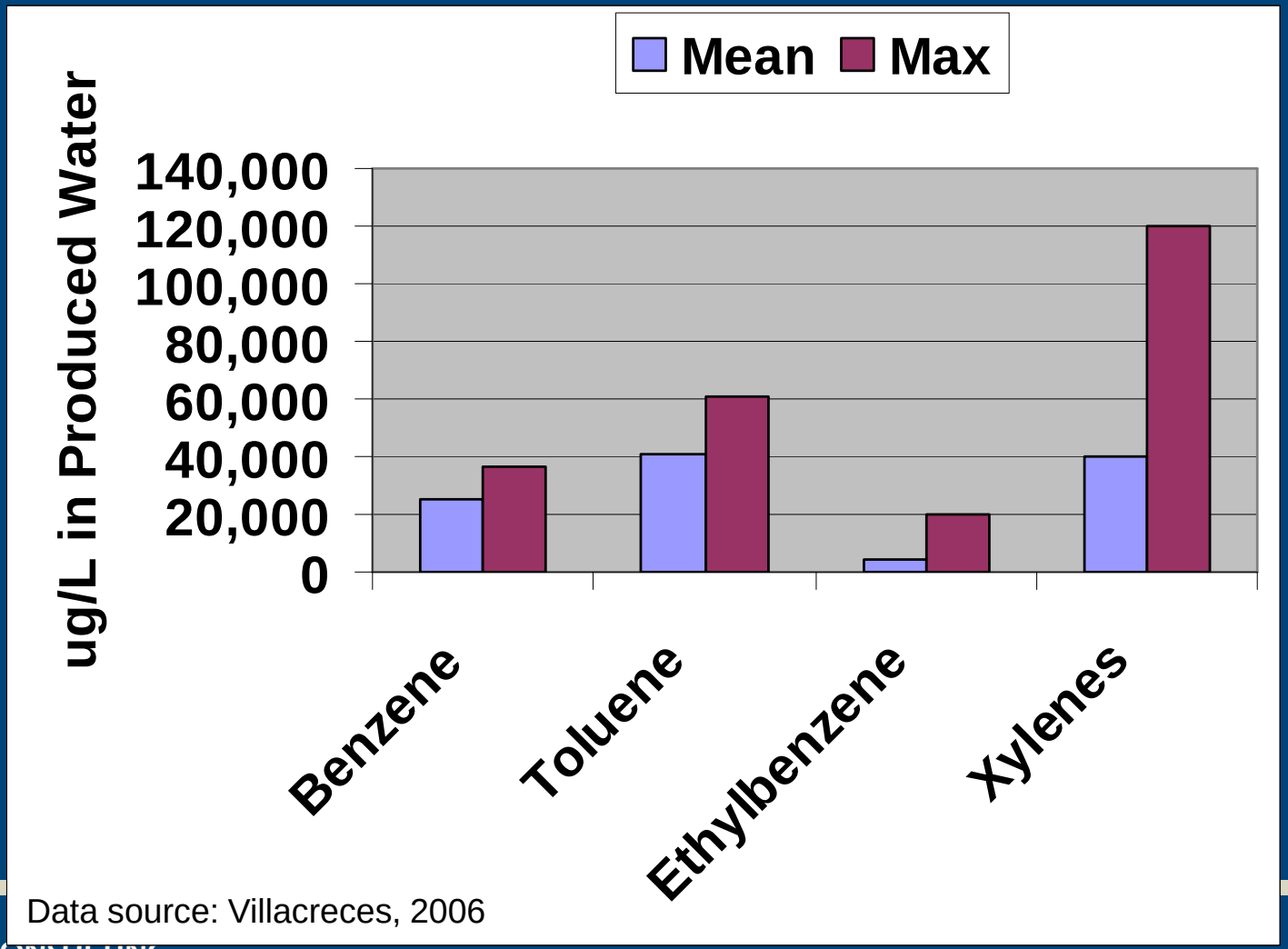


Total Petroleum Hydrocarbons

- Most water-soluble TPH from crude oil is BTEX
- From EPA AWQC database (ug/L):

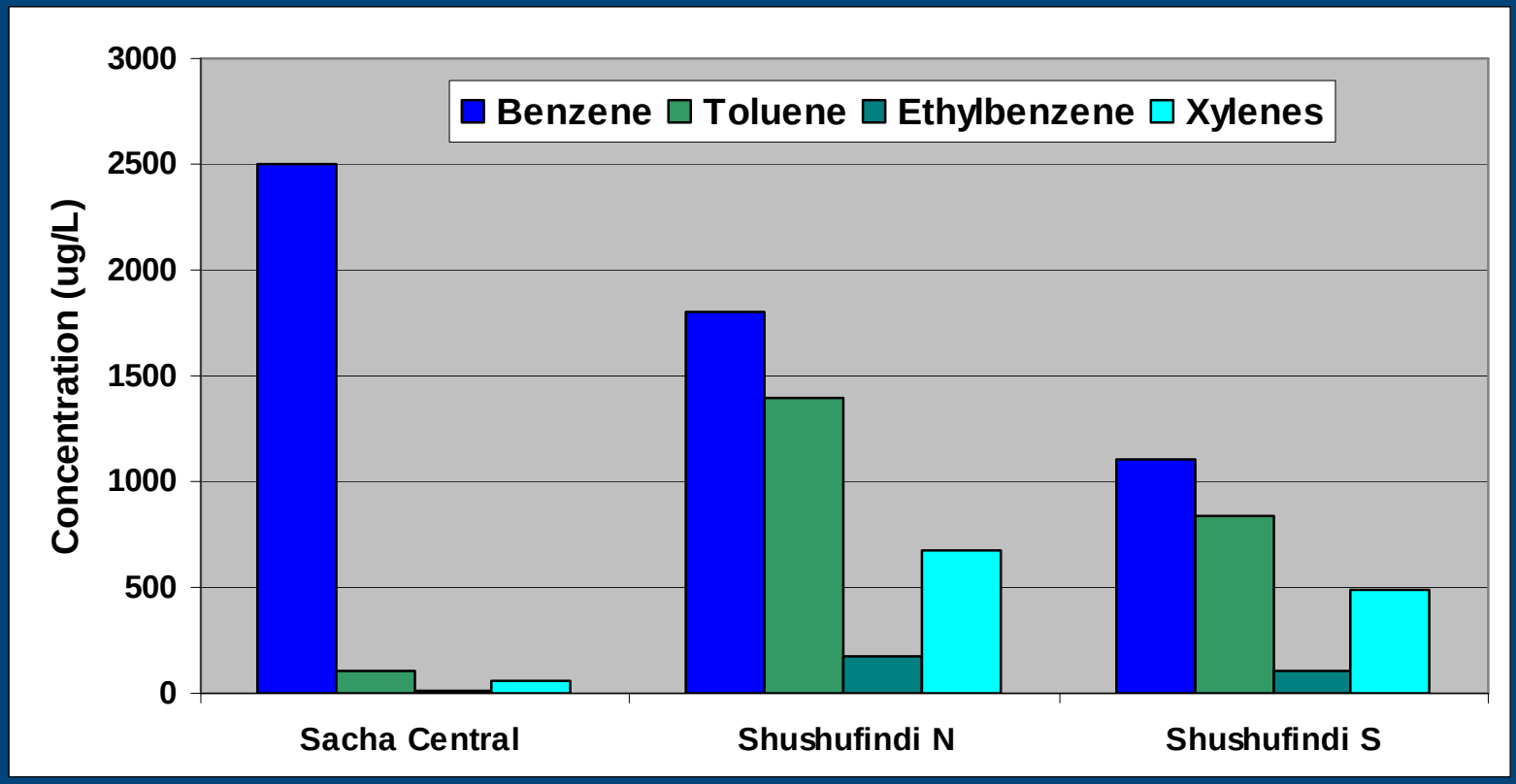
	Benzene	Toluene	Ethylbenzene	Xylenes
Acute	5,300	17,500	32,000	2,600
Chronic	262	110	1,800	30

Measured BTEX in Produced Water



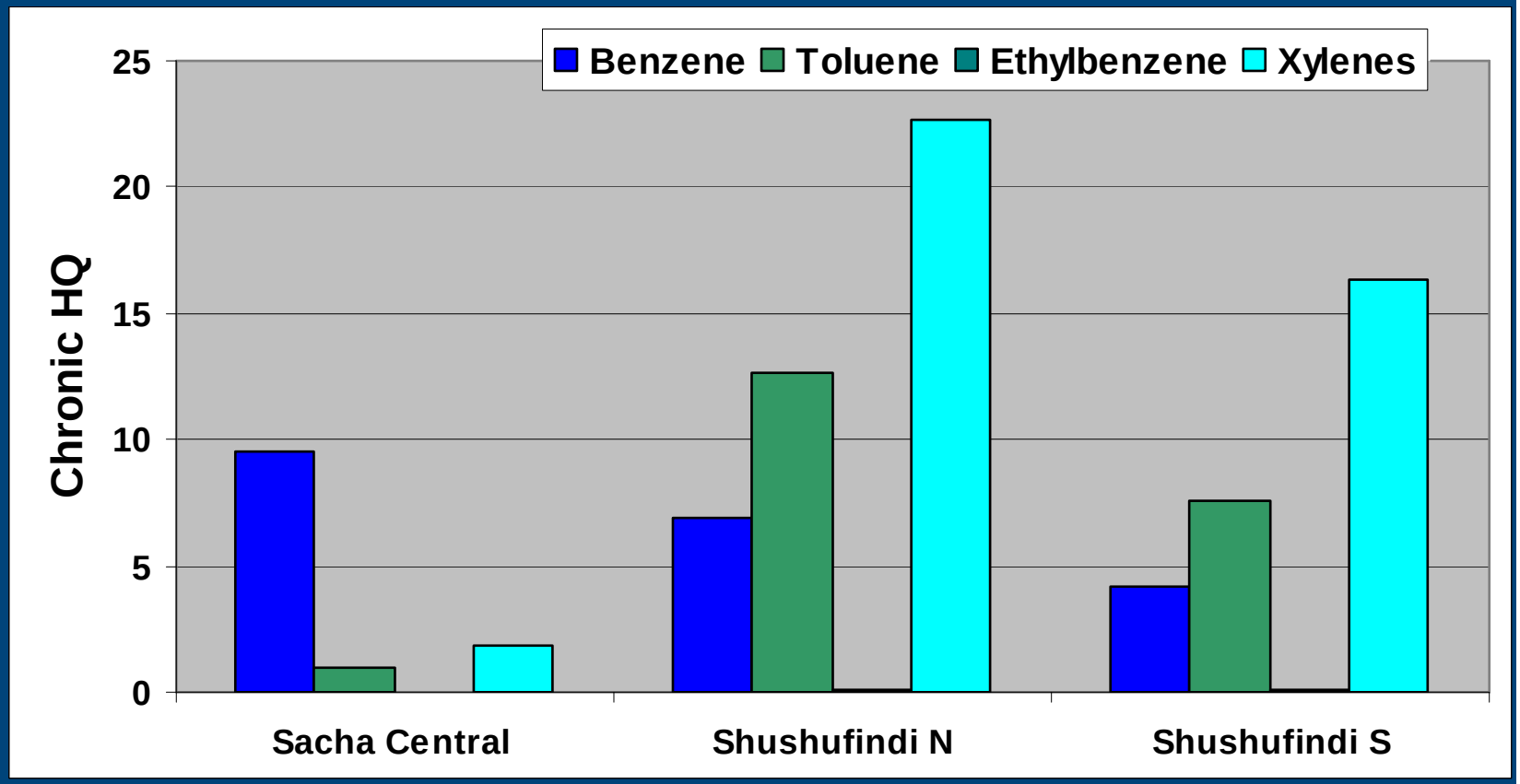
Data source: Villacreces, 2006

Measured BTEX in Produced Water



Data source: Jocknick et al., 1994

BTEX Chronic HQ for Toxicity to Aquatic Biota



Data source: Jocknick et al., 1994

Toxicity to Humans

BTEX concentrations in produced waters

	Mean (mg/L)	Range (mg/L)	Safe Drinking Water Act MCL (mg/L)
Benzene	25.1	18.9–36.4	0.005
Toluene	40.7	31.0–61.3	1.0
Ethylbenzene	4.7	1.8–19.9	–
p-, m-xylene	30.6	8.8–78.9	10[a]
o-xylene	9.5	3.7–40.8	10[a]

a. Maximum contaminant level for total xylenes.

Sources: Villacreces Carvajal, 2006, Table 2; U.S. EPA, 2007.

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M. Pallares

Sediment Contamination

- Sediments of rivers and streams downstream of oil operations, including production stations, are contaminated with oil
- Photoactivated toxicity of PAHs in sediment, water column

Photo credit:
L. Dematteis

Conclusions

- Texaco discharged 18 billion gallons of produced water directly into rainforest streams and rivers used by local people
- The produced water was acutely toxic to fish and invertebrates
  - Invertebrates more sensitive
  - Exposed biota may be susceptible to chloride toxicity
- The produced water contained benzene at concentrations many times higher than EPA drinking water standard

Photo credit:
L. Dematteis