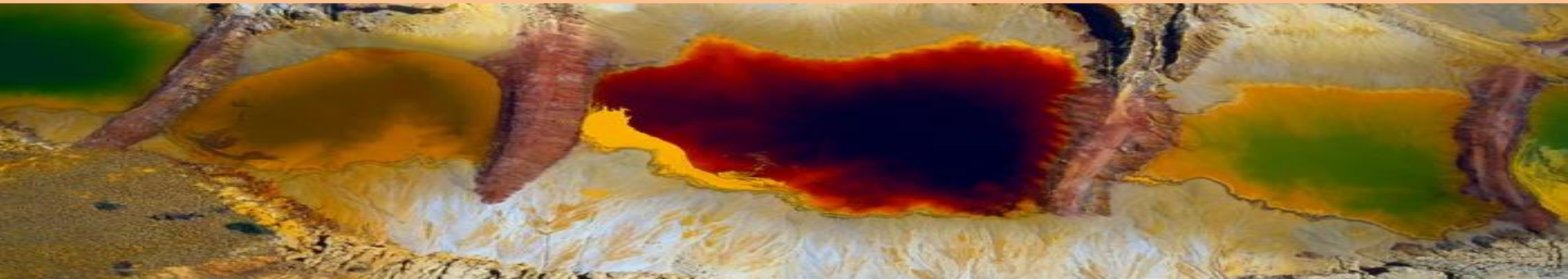
School of CHEMISTRY

the ENVIRO GEOCHEM lab

Artisanal Mining in South Africa

Sources & Impacts on the Environment

Dr Shaeen Chetty



140 YEARS OF CONFLICT

Gold was discovered in Johannesburg over a century ago, shaping the city's identity. However, as the urban landscape expanded, the legacy of mining became more complex.

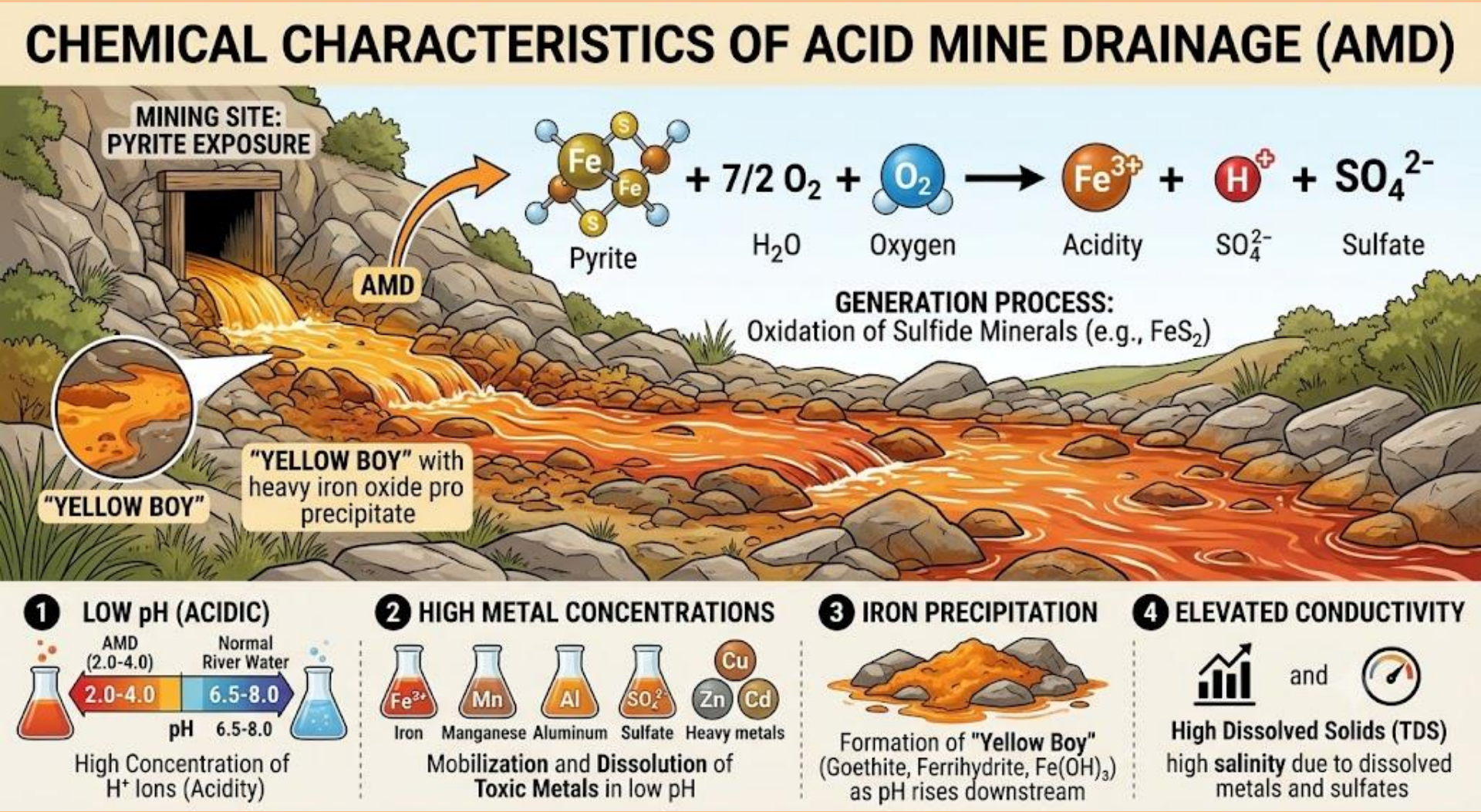
- **Historical Discovery:** 1886 Witwatersrand Gold Rush.
- **Urban Evolution:** Cities grew over abandoned mine networks.
- **Systemic Change:** Transition from individual seekers to organized syndicates.

SOURCES OF GOLD

Artisanal miners in Johannesburg do not usually dig new mines. Instead, they exploit the residual gold left in "waste" materials from industrial operations.

- **Abandoned Shafts:** Re-entering deep underground tunnels.
- **Tailings Dams:** Processing the yellow mine dumps that dot the skyline.
- **Residual Extraction:** Using primitive methods to catch fine gold particles.

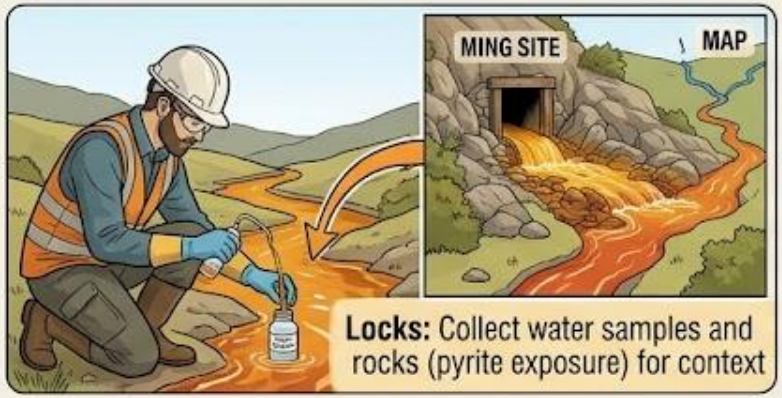
CHEMISTRY OF CONTAMINATION




northern suburbs
Johannesburg
Soweto
mine dumps
N

COMPLETE PROCESS FOR ACID MINE DRAINAGE ANALYSIS: FROM FIELD SAMPLING TO INTERPRETATION.

1 STEP 1: FIELD SAMPLING AND COLLECTION (THE SOURCE)

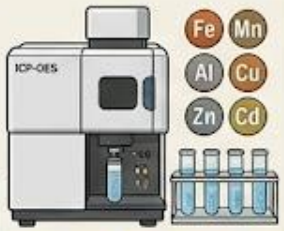


Locks: Collect water samples and rocks (pyrite exposure) for context

2 STEP 2: CHEMICAL ANALYSIS IN THE CHEMISTRY LAB

2A LAB ANALYSIS: LIQUID SAMPLES

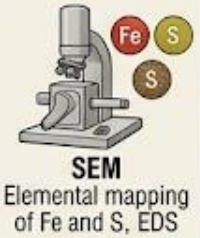
pH & Conductivity Measurement



Metal Analysis by ICP-OES

2B LAB ANALYSIS: SOLID PRECIPITATES

XRD
Crystal Phases



SEM
Elemental mapping of Fe and S, EDS

Characterization of Iron Precipitate (e.g., $Fe(OH)_3$, Fe_2O_3)

3 STEP 3: DATA PROCESSING & GEOCHEMICAL MODELING

QA/QC of calculatiions, algorithms

Professioal advanced visualization software

QA/QC of Analytical
Data. Input data for computer simulation and fate modeling

4 STEP 4: DATA INTERPRETATION & ACTIONABLE INSIGHTS

A Source Identification: Pyrite Oxidation FeS_2

B Plume Extent & Metal Loadings

Fe | Mn | Al | SO_4^-

D Remediation Strategy:
Passive & Active Treatment Options (e.g., neutralization tanks, constructed wetlands)

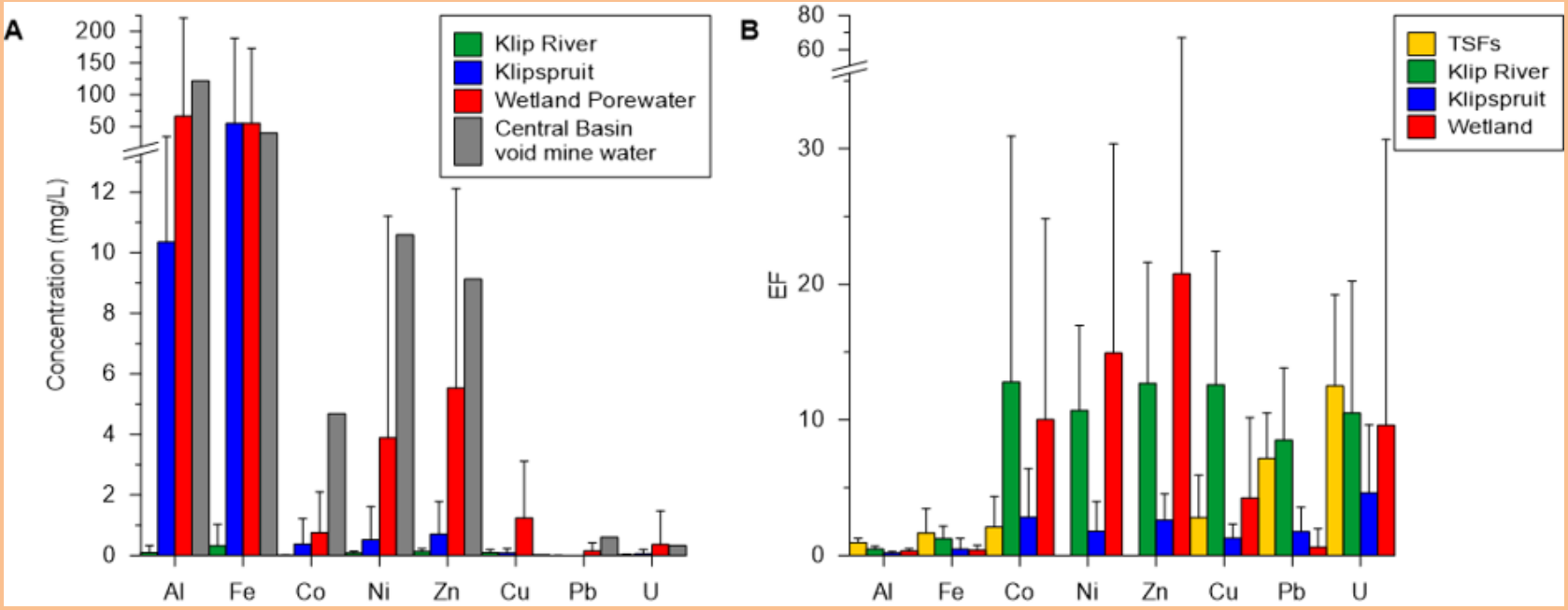
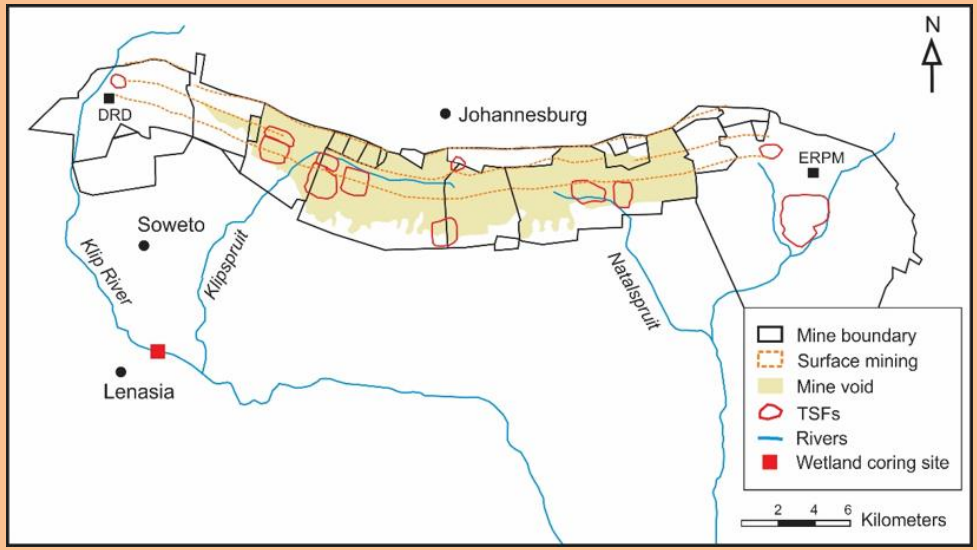


Figure: A) Comparison between average metal concentrations measured in water from the Klip River, Klipspruit, Klip River wetland (this study) and the Central Basin mine void (DWA, 2013) , and B) average metal enrichment factors (EF) measured in material collected from TSFs, Klip River, Klipspruit and wetland.



Chetty S, Pillay L, Humphries MS. Gold mining's toxic legacy: Pollutant transport and accumulation in the Klip River catchment, Johannesburg. S Afr J Sci. 2021;117(7/8), Art. #8668. https://doi.org/10.17159/ sajs.2021/8668

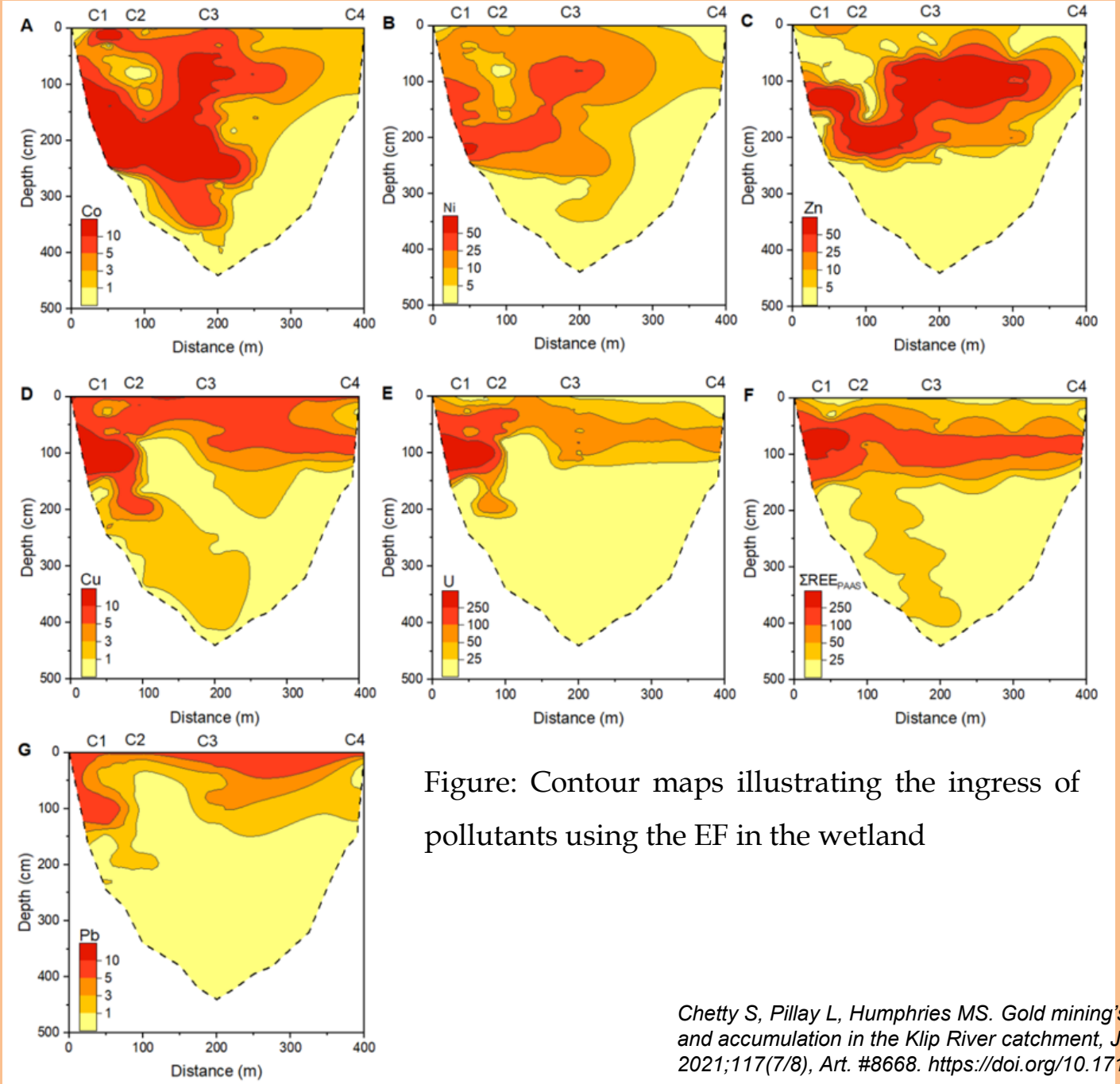


Figure: Contour maps illustrating the ingress of pollutants using the EF in the wetland

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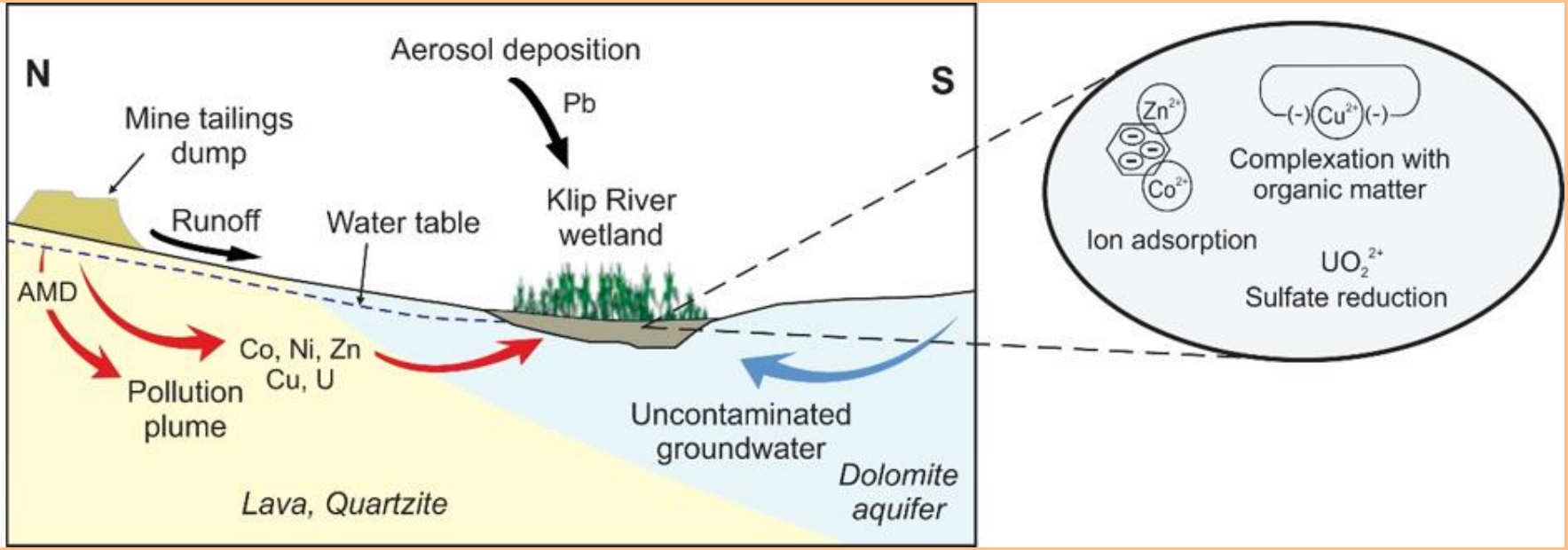


Figure: Conceptual hydrogeological model showing the main transport pathways of metal contaminants to the Klip River wetland (diagram not to scale).

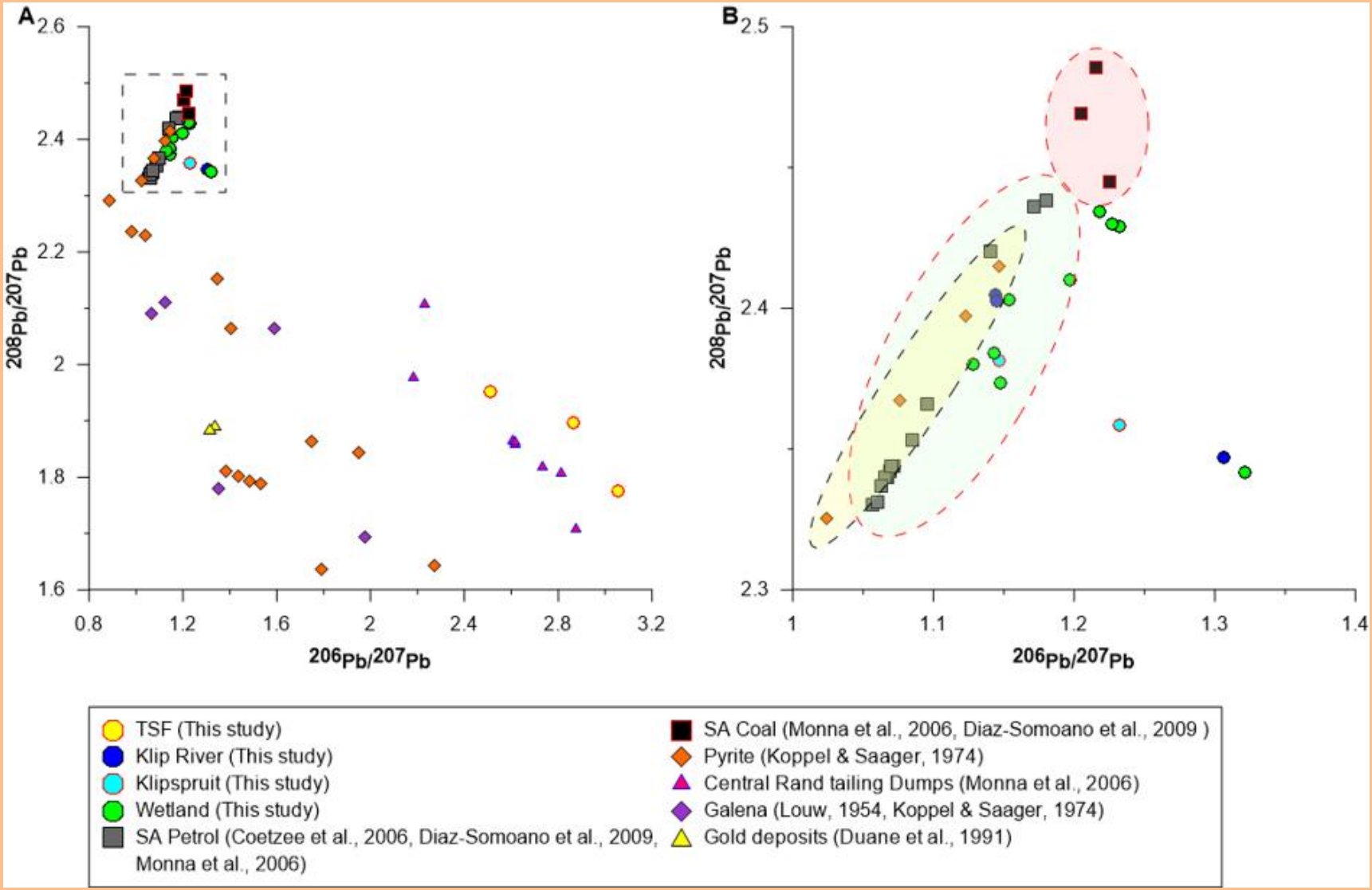
Chetty S, Pillay L, Humphries MS. Gold mining's toxic legacy: Pollutant transport and accumulation in the Klip River catchment, Johannesburg. S Afr J Sci. 2021;117(7/8), Art. #8668. https://doi.org/10.17159/ sajs.2021/8668

TOXIC ELEMENTS & IMPACTS

Element	Source	Environmental Impact	Health Risk
Mercury (Hg)	Amalgamation process	Water & soil poisoning	Neurological damage
Arsenic (As)	Pyrite association	Groundwater toxicity	Carcinogenic effects
Lead (Pb)	Mineral deposits	Bioaccumulation in plants	Developmental issues
Uranium (U)	Witwatersrand reefs	Radioactive tailings	Kidney damage

Chetty, Shaeen, Humphries, Marc S., Blümlein, Katharina, & Pillay, Letitia. (2023). An investigation into arsenic speciation in a wetland impacted by acid mine drainage. South African Journal of Chemistry, 77, 126-132. https://doi.org/10.17159/0379-4350/2023/v77a15

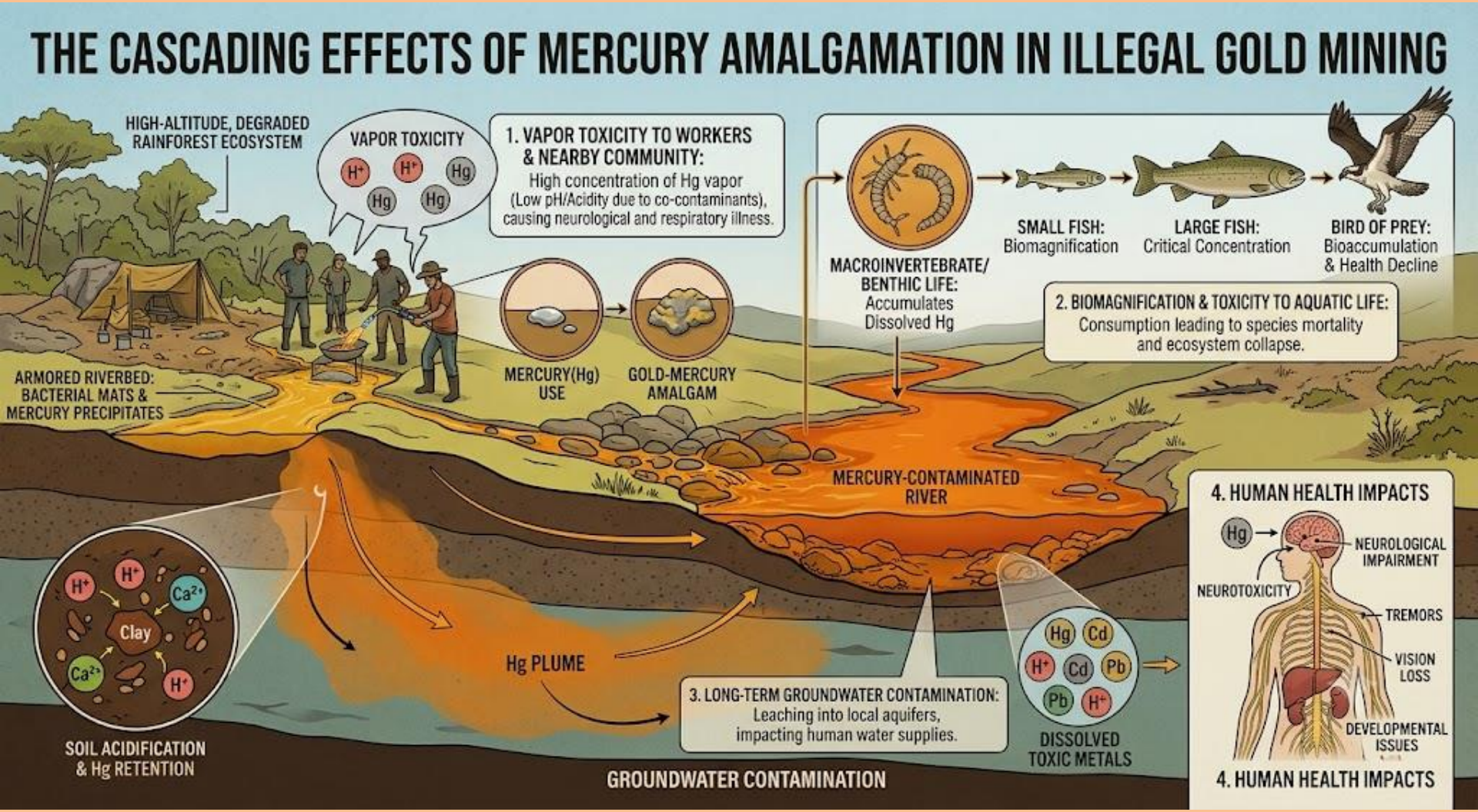
LEAD CONTAMINATION



Understanding the Speciation and Migration of Metal Pollutants in the Mining-Impacted Klip River Wetland, Johannesburg
Chetty, Shaeen. University of the Witwatersrand, Johannesburg (South Africa) ProQuest Dissertations & Theses, 2021. 31800548.

https://www.proquest.com/dissertations-theses/understanding-speciation-migration-metal/docview/3161869914/se-2?accountid=15083

MERCURY AMALGAMATION



IMPACT ON COMMUNITY HEALTH

Dust & Air Quality

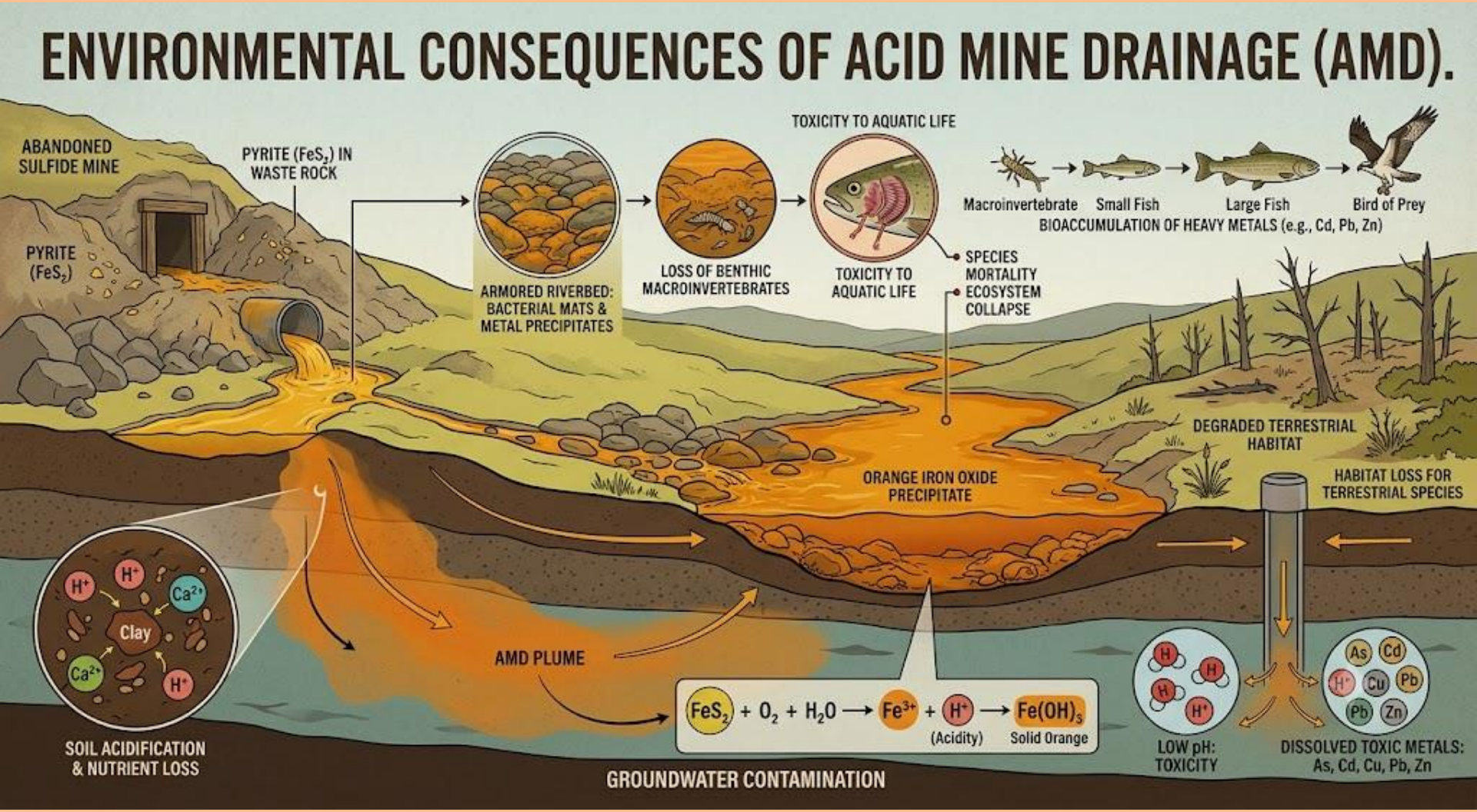
Fine silica dust from mine dumps leads to Silicosis and TB.

Radiation Exposure

Uranium-rich waste creates long-term radioactive hazards.

Water Contamination

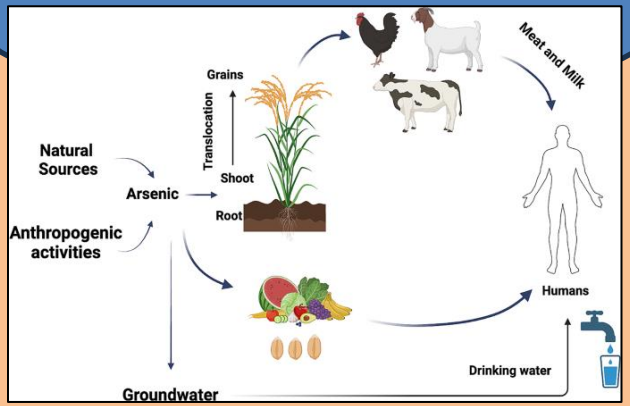
Toxic AMD prevents safe access to local water for communities.


ENVIRONMENTAL CONSEQUENCES OF ACID MINE DRAINAGE (AMD).
ABANDONED SULFIDE MINE
PYRITE (FeS_2) IN WASTE ROCK
PYRITE (FeS_2)
ARMORED RIVERBED: BACTERIAL MATS & METAL PRECIPITATES
LOSS OF BENTHIC MACROINVERTEBRATES
TOXICITY TO AQUATIC LIFE
TOXICITY TO AQUATIC LIFE
SPECIES MORTALITY
ECOSYSTEM COLLAPSE
Macroinvertebrate
Small Fish
Large Fish
Bird of Prey
BIOACCUMULATION OF HEAVY METALS (e.g., Cd, Pb, Zn)
DEGRADED TERRESTRIAL HABITAT
HABITAT LOSS FOR TERRESTRIAL SPECIES
ORANGE IRON OXIDE PRECIPITATE
AMD PLUME
Clay
SOIL ACIDIFICATION & NUTRIENT LOSS
$FeS_2 + O_2 + H_2O \rightarrow Fe^{3+} + H^+ \rightarrow Fe(OH)_3$
(Acidity)
Solid Orange
LOW pH: TOXICITY
DISSOLVED TOXIC METALS: As, Cd, Cu, Pb, Zn
GROUNDWATER CONTAMINATION

RESEARCH AT WITS CHEMISTRY

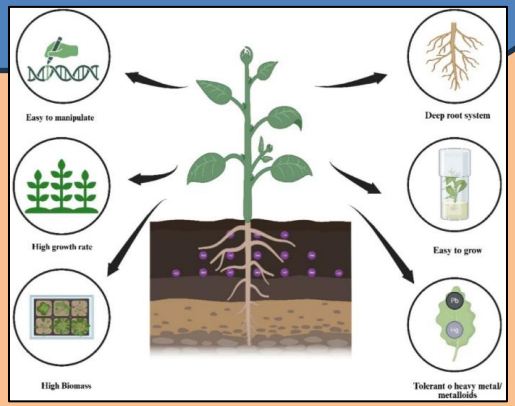
Environmental Speciation

The Wits team analyzes how metals like Lead and Arsenic change form (speciation) in the soil, which determines how toxic they are to humans and plants.



Remediation Strategies

Researching "Phytoremediation"—using specific plants to absorb heavy metals from contaminated mining soil as a green solution.



https://www.wits.ac.za/chemistry/research/

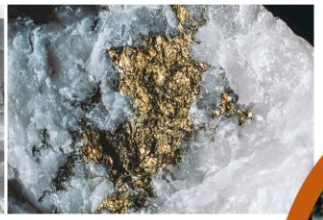
Acid Mine Drainage: An Unwanted Inheritance

@WitsChemistry

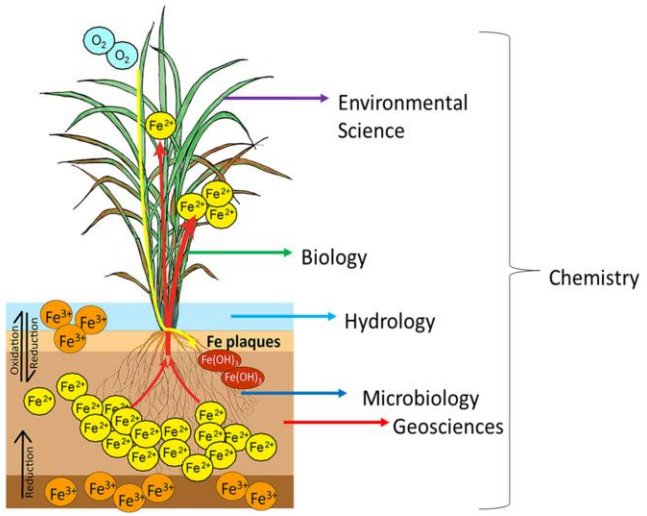
https://www.wits.ac.za/chemistry/

The Gold Rush!!!

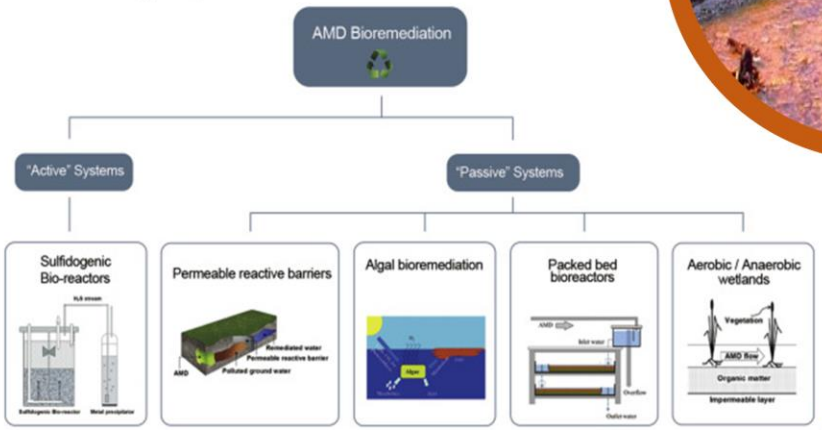
- South Africa is the primary producer of gold in the world since 1886, with the Witwatersrand producing 2⁄3 of the World's gold.
- Acid Mine Drainage (AMD) is a by-product of the mining sector.



Why is AMD chemistry important?



Cleaning up AMD



Research @ Wits

- Geochemical analysis of polluted ecosystems.
- Environmental remediation using membranes technology.
- Application of novel synthesised nanocomposite and biocatalytic materials for the remediation of various organic pollutants and pesticides in water.

EXPLORING ENVIRONMENTAL GEOCHEMISTRY AT WITS UNIVERSITY

UNDERSTANDING THE EARTH'S CHEMISTRY & OUR IMPACT

WITS

WHAT IS ENVIRONMENTAL GEOCHEMISTRY?

Studying the chemical processes that shape the Earth's surface and the impact of human activities

INVESTIGATING THE ENVIRONMENT

WATER QUALITY

- Testing equipment
- Analyzing pH
- Dissolved solids
- Heavy metals

SOIL HEALTH

- Layers
- Plant roots
- Nutrient cycling
- Degradation

ATMOSPHERIC PROCESSES

- Emissions
- Dust particles
- Air sampling

TRACKING CONTAMINANTS

HUMAN IMPACT & POLLUTION

MINING IMPACTS

- Acid mine drainage
- Tailings dams
- Heavy metal transport

INDUSTRIAL & URBAN WASTE

- Landfills
- Factory emissions
- Urban runoff

AGRICULTURAL RUNOFF

- Fertilizers
- Pesticides

RESEARCH SITES ACROSS SOUTH AFRICA

APPLYING KNOWLEDGE

FINDING SOLUTIONS

REMEDIATION STRATEGIES

- Cleaning up polluted sites
- Phytoremediation with plants

SUSTAINABLE PRACTICES

- Safe mining
- Waste management

INFORMING POLICY

- Environmental regulations
- Data-driven decisions

WHY IT MATTERS?

CLEAN WATER & SANITATION | HEALTHY ECOSYSTEMS | FUTURE SUSTAINABILITY

LEARN MORE: WITS.AC.ZA/CHEMISTRY/RESEARCH/ENVIRONMENTAL-GEOCHEMISTRY/

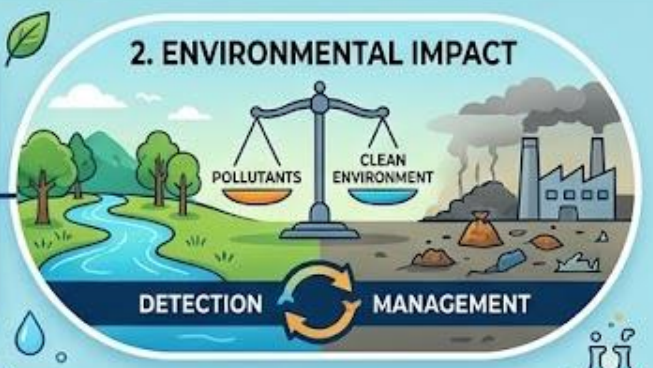
LANDSCAPE INFOGRAPHIC
HIGH SCHOOL STUDENTS

EXPLORING ENVIRONMENTAL & ANALYTICAL CHEMISTRY

UNDERSTANDING OUR PLANET, ONE CHEMICAL AT A TIME

UNIVERSITY OF THE WITWATERSRAND

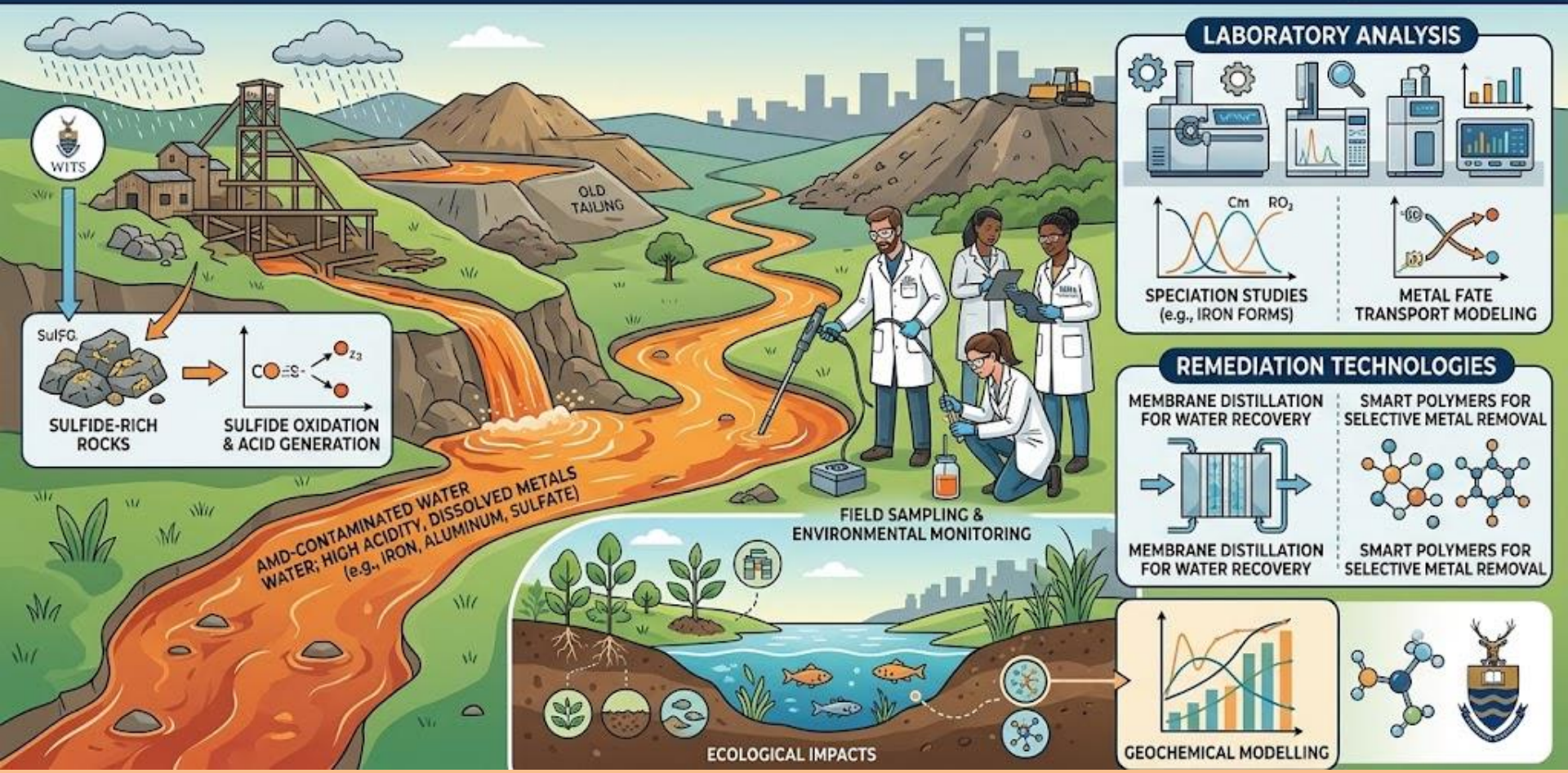
CORE FOCUS AREAS



APPLIED SOLUTIONS

ENVIRONMENTAL ANALYTICAL CHEMISTRY RESEARCH AT WITS:
ADDRESSING ACID MINE DRAINAGE (AMD) IN JOHANNESBURG

UNIVERSITY OF THE WITWATERSRAND



Questions?