Assessing corrosion risk for rural water supplies

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STOP THE ROT, 9/12/2025

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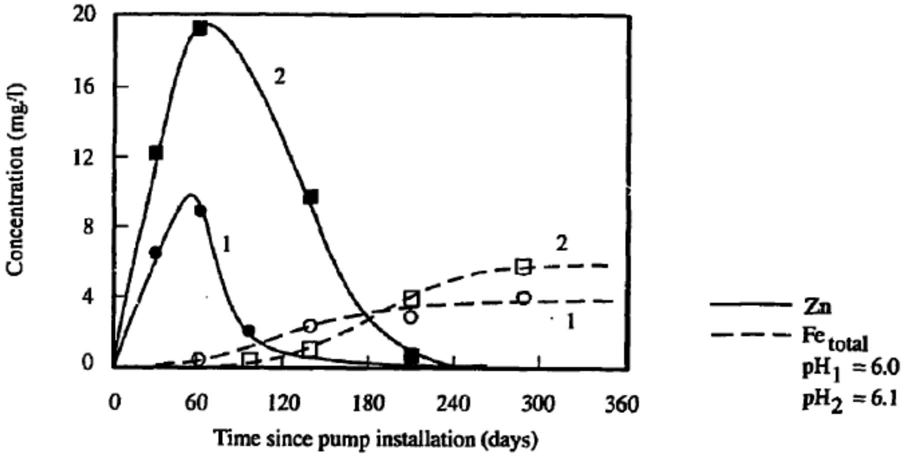
A long history of corrosion assessments in handpumps

- Langenegger (1989):
  - *"As a rule of thumb, galvanized iron or mild steel should not be considered as material for rising mains and pump rods where the pH of the groundwater is below 6.5."*
- Langenegger (1994):
  - *"Field observations have shown… where groundwater is moderately to highly aggressive (pH < 6.5), galvanization of mild steel rising mains and pump rods does not protect them from corrosion."*
- World Bank (2024) knowledge note proposes the use of the < 6.5 pH threshold in National regulations.



pH	Application of galvanized material	Diameter reduction (mm/y)	Rating of corrosion damage
pH > 7	suitable	< 0.1	negligible
6.5 < pH ≤ 7	limited	0.1 – 0.2	mild
6 ≤ pH ≤ 6.5	not recommended	0.2 – 0.4	mild
pH < 6	not recommended	> 0.4	moderate to severe (to extreme)

Stop the Rot research questions

- Are there better indicators of corrosion than pH?
- What is the probability of corrosion when pH < 6.5?
- Does more comprehensive assessment of water quality improve prediction of corrosion?

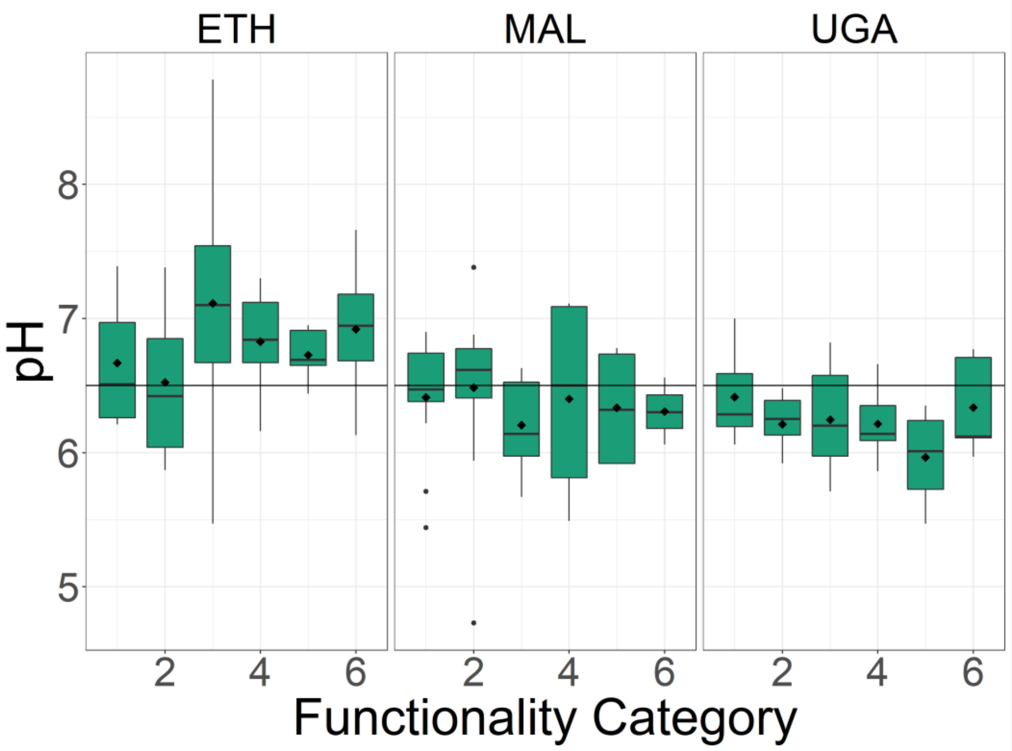
Hidden Crisis: unravelling failures for future success

- Interdisciplinary research in Ethiopia, Malawi, and Uganda to better understand determining factors of handpump borehole functionality.

- Physical survey of 145 handpumped boreholes:
  - **water chemistry,**
  - **observations and measurements of component condition,**
  - pumping test,
  - borehole construction survey,
  - questionnaires (reliability, downtime, quantity, quality).

Water chemistry and corrosion

- How did pH vary across our dataset?



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Langenegger (1994)

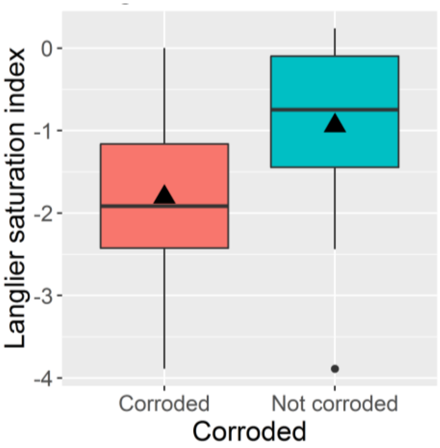
Functionality categories:

1. Functional
2. Low yield
3. Poor reliability
4. Low yield and poor reliability
5. Non-functional
6. Abandoned

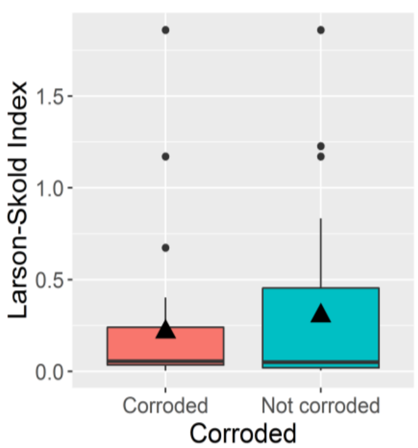
Handpump component condition

- India Mark II rising main:
  - Ethiopia:
    - 60% thickness below specifications (3.25 mm ±0.2 mm)
    - 55% galvanising thickness below specifications (70- 80 µm)
    - c.50% corroded.
  - Uganda:
    - 65%
    - 90%
    - > 80%

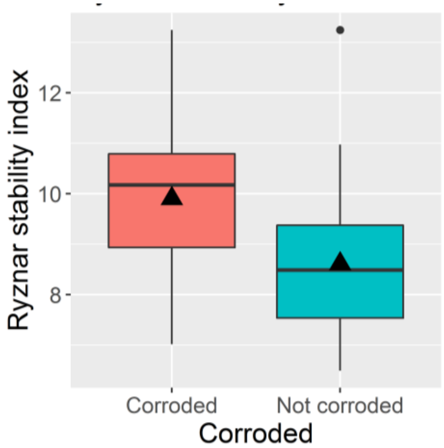
Corrosion indices and observation of corrosion



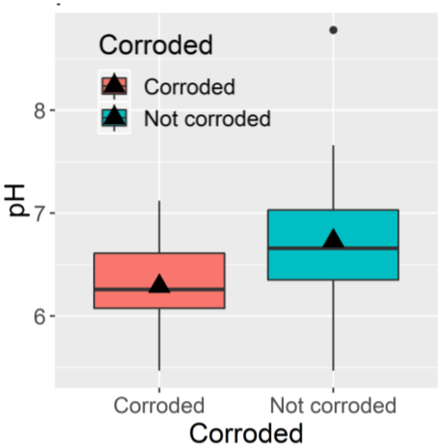
Super saturated > 0
Saturated = 0
Under saturated < 0



Low risk < 0.5
Intermediate risk: 0.5 - 1.2
Severe risk > 1.2



Corrosive > 7
Equilibrium: 6 - 7
Scaling < 6



Low risk > 7
Intermediate risk: 6.5 - 7
High risk: 6 - 6.5
Severe risk < 6

$$\text{LI} = pH - pHs^*$$

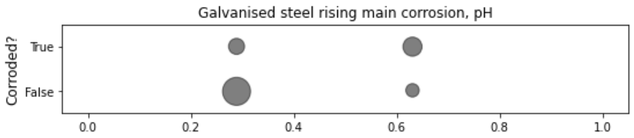
$$\text{LSI} = \frac{2SO_4 + Cl}{HCO_3}$$

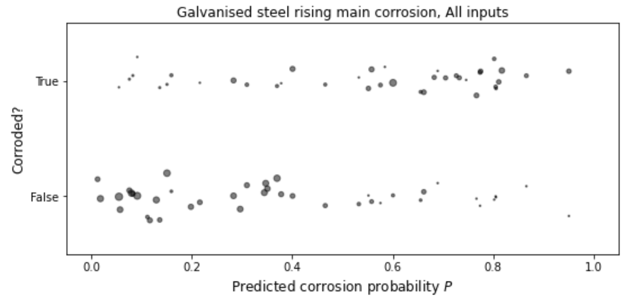
$$\text{RSI} = 2pHs - pH*$$

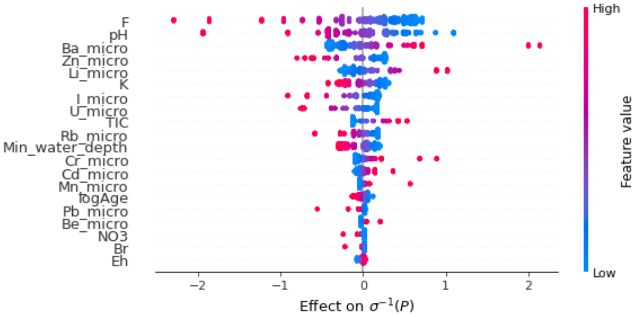
pHs – accounts for calcium concentration, alkalinity, temperature and total dissolved solids (i.e. salinity).

Predicting corrosion based on water chemistry

- Linear model for probability of corrosion, 114 water chemistry measurements, 3,046 observations of downhole components from 145 sites.
- **Most effective binary corrosion indicator:**
  - **pH < 6.5** for galvanised iron rising mains (RM) and rods.
  - corrosion probability **61% if pH < 6.5** for RM (61% for rods)
  - corrosion probability **30% if pH > 6.5 for** RM (50% for rods)
  - pH < 7 most effective indicator for stainless steel
- 13% improvement in prediction accuracy using all water chemistry measurements BUT coefficients can’t be interpreted causally.







So why is pH such an effective predictor of corrosion?

- **Accelerated Metal Dissolution:**
  - In environments with pH < 6.5 the high concentration of H^+ ions significantly increases the rate at which metals oxidize and dissolve.

- **Impeded Protective Layer Formation:**
  - Many metals form a thin, stable, passive oxide layer in near-neutral to slightly alkaline conditions (around pH 7.0 to 8.5) which naturally slows further corrosion. Below pH < 6.5, this protective layer cannot form or is quickly dissolved, leaving the base metal vulnerable to rapid, continuous corrosion.

- **Synergy with other factors:**
  - The corrosive effects of low pH are compounded by other factors. For example, water that is both soft (low in protective minerals like calcium carbonate) and acidic is highly corrosive. The combination of ***low pH and high chloride*** concentration is particularly aggressive. H^+ absorbed into the metal can also degrade its mechanical properties.

Implications

- **Statistical validation of empirical measurements by Langenegger (1989, 1994).**
- **pH < 6.5 is the most effective binary indicator of corrosion.**
  - The probability of corrosion of rising mains is still 30% when pH > 6.5 (50% for rods).
- **Importance of measuring pH accurately.**
  - This is not easy. Use of high accuracy probes and proper calibration. Stable measurements before recording values. More in our handpump diagnostics manual.
- **Interval for component replacement.**
  - In low pH water components need replacement more regularly.
- **Use of more appropriate materials** reduces or eliminates corrosion problems:
  - Stainless steel (expensive, not as widely accessible, needs to be good quality).
  - PVC or uPVC (wells < 45 m, but ongoing trials in wells > 45 m).
- **Adherence to pump standards is crucial.**
- **Implications for other technologies (e.g. solar pumps, piped water).**

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Thank you

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