



WaterTRACS

(Testing, Research, and Capacity Strengthening) Initiative

CHEMICALS AND HEAVY METALS IN DRINKING WATER IN KABAROLE DISTRICT, UGANDA

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With funding from the Conrad N. Hilton Foundation, the Aquaya Institute tested for chemicals and heavy metals in drinking water in Kabarole District, Uganda, in February 2024. Aquaya analyzed water samples from water points serving schools and healthcare facilities. This testing was part of the WaterTRACS initiative.

SUMMARY

- We tested water quality parameters at water points from a sample of schools and healthcare facilities.
- Some water points exceeded drinking water standards for parameters with low health implications, like pH, turbidity, and iron. These parameters do not directly affect health but may be unpleasant to users and can interfere with treatment efforts.
- Among parameters with high health implications, some water points exceeded drinking water standards for nitrite, nitrate, arsenic, and lead. All samples met drinking water standards for fluoride.
- Lead levels exceeded drinking water standards in one-tenth of samples, which may have severe health implications.

RECOMMENDATIONS

- Due to widespread acidic water, new water infrastructure should be constructed with corrosion-resistant materials, in line with national regulations.
- To address lead in drinking water:
 - Water suppliers should use lead-free materials and maintain a pH above 7.5 to prevent lead leaching.
 - Authorities should mandate regular lead testing of drinking water and raise awareness of lead-contaminated supplies.
 - Consumers should flush water points for at least 30 seconds before collecting drinking water following a period of non-use greater than 8 hours.
- While chemical contamination can be of great concern, most water-related health problems arise from microbial contamination¹; therefore, microbial surveillance should be prioritized



BACKGROUND

Globally, microbial drinking water quality remains a top health concern in low-and middle-income countries.¹ There are also health risks associated with chemicals like fluoride, arsenic, and nitrates, which may be present in drinking water.¹ Further, growing evidence indicates widespread lead contamination in drinking water supplies, often being introduced through lead-containing water system components.²

With funding from the Conrad N. Hilton Foundation, The Aquaya Institute is monitoring microbial water quality over time in two districts in Uganda (see prior [research briefs](#)). In February 2024, Aquaya also tested chemical water parameters at a subset of water points to get a more comprehensive picture of water quality, including contaminants with known health risks and physiochemical parameters affecting user acceptability.

METHODS

Aquaya visited 73 institutions, which were randomly selected among all public schools and healthcare facilities in Kabarole district. We identified 126 drinking water points at these institutions, including both primary and secondary sources. Twenty (16%) were unavailable for testing due to breakdown or other reasons. We collected drinking water samples from the remaining 106 water points – 74 at schools and 32 at healthcare facilities.

DRINKING WATER SAMPLES TESTED IN KABAROLE



106 Water points tested, including:



74 at Schools



32 at Healthcare facilities

A subset of these samples was analyzed for different water quality parameters. Some samples were omitted from analyses due to: reaching a quota for a specific water point type or parameter, inability to match results to surveys, or missing results from the lab.

Aquaya tested physicochemical parameters (pH, turbidity, and electrical conductivity) on-site with portable meters and collected samples to be tested for other parameters at the Uganda Ministry of Water and Environment (MWE) Regional Laboratory in Fort Portal or Central Laboratory in Entebbe. Anions (chloride, fluoride, nitrate-N, nitrite-N, phosphate as ortho-phosphate, and sulfate) were measured using ion chromatography following USEPA 300.1 Methods, hardness was measured by spectrophotometer or titrimetry following USPEA 130 Methods, and heavy metals (arsenic, iron, and lead) were measured using inductively-coupled plasma optical emission spectroscopy (ICP-OES) following USEPA 200.2 Methods. Samples for metals analysis were acidified with concentrated nitric acid.

For water points that could be shut off (e.g., piped systems, handpumps, rainwater collection), we asked operators to close water points overnight (for 8-18 hours³) and collect “first-draw” samples of the first water leaving the system in the morning. These samples were tested for iron and lead, with the purpose of identifying whether excess metals may be leaching from water system components after a period of water stagnation. We tested 43 first-draw samples.



RESULTS

PARAMETERS WITH LOW HEALTH IMPLICATIONS

A third of samples (34%) had pH below the Uganda National Bureau of Standards (UNBS) drinking water standard minimum value of 6.5, which may cause corrosion of metal parts in the water system. Two-fifths of samples (40%) had turbidity above the standard of 5 NTU, which may reduce chlorine’s treatment effectiveness and may be visually unpleasant to water consumers. One-fifth of samples (22%) had iron levels above the standard of 0.3 mg/L. Elevated iron does not represent a known health risk, but water consumers may not like the water’s taste or appearance. All samples had electrical conductivity, chloride, total hardness, phosphate, and sulfate within the standard range.

Table 1: Summary of drinking water standards and test results for parameters with low health implications

	Limit (Uganda National Bureau of Standards, UNBS ⁴)	N	% outside of limits	Likely origin	Implication of being outside limits
pH	6.5 – 8.5	106	36% (34% under, 2% over)	pH is determined from source water characteristics and treatment processes, and may be influenced by human activities such as mining	Low pH may corrode water system hardware; high pH may reduce effectiveness of chlorine treatment
Turbidity	5 NTU, max	106	40%	Naturally suspended or dissolved materials	High turbidity may look unpleasant, indicate presence of other contaminants, and reduce effectiveness of chlorine treatment
Electrical Conductivity	1500 µS/cm, max	104	0%	Dissolved salts, minerals, and metals	Water with high electrical conductivity may look or taste unpleasant (salty)
Iron	0.3 mg/L, max	58	22%	Naturally occurring in earth deposits; corrosion of iron-containing materials in water point components	High iron may be look or taste unpleasant, and may reduce effectiveness of chlorine treatment
Chloride	250 mg/L, max	57	0%	Naturally occurring in earth deposits	High chloride may look or taste unpleasant
Hardness (total)	300 mg/L, max	76	0%	Naturally occurring in earth deposits	High hardness may taste unpleasant, may irritate skin, may leave scale on cooking pots, and makes soap less likely to lather
Phosphates (as ortho-phosphate)	2.2 mg/L, max	57	0%	Contamination from agricultural activities (fertilizers) or poorly-sited or maintained latrines or septic tanks. Also added to prevent corrosion of metals into drinking water	None known
Sulfate	400 mg/L, max	57	0%	Contamination from agricultural activities (fertilizers) or poorly-sited or maintained latrines or septic tanks	High sulfate may look or taste unpleasant



PARAMETERS WITH HIGH HEALTH IMPLICATIONS

We analyzed a set of chemicals (fluoride, nitrate, and nitrite) and heavy metals (arsenic and lead) that have known negative health impacts. Fluoride and arsenic were included due to their recognition as priority chemicals by the international WHO/UNICEF Joint Monitoring Programme, nitrogen was included due to its persistence in rural areas, and lead was included due to national and global interest to reduce lead exposure from drinking water.⁵

All samples met the UNBS drinking water standard for fluoride. Over half (56%) of samples had nitrite above the UNBS standard of 3 µg/L; however, there were no nitrite exceedances with respect to the WHO guideline value of 900 µg/L. Few samples had nitrate (2%) and arsenic (3%) concentrations above UNBS standards.

Overall, **9% of samples had detectable lead levels** above 15 µg/L or 15 parts per billion (ppb). Due to its health impacts, we include more information about lead in the following section.

Table 2: Summary of drinking water standards and test results for parameters with high health implications

	Limit (Uganda National Bureau of Standards, UNBS ⁴)	N	% outside of limits	Likely origin	Implication of being outside limits
Fluoride	1.5 mg/L, max	57	0%	Naturally occurring in earth deposits	High fluoride may cause dental and skeletal fluorosis
Nitrite-N	3 µg/L, max*	57	56% (0%)*	Contamination from agricultural activities (fertilizers) or poorly-sited or maintained latrines or septic tanks	High nitrite may lead to negative blood or thyroid effects, especially in infants
Nitrate-N	45 mg/L, max	57	2%	Contamination from agricultural activities (fertilizers) or poorly-sited or maintained latrines or septic tanks	High nitrate may lead to negative blood or thyroid effects, especially in infants
Arsenic	10 µg/L, max	74	3%	Naturally occurring in earth deposits	High arsenic is carcinogenic and may lead to negative cardiovascular and neurodevelopmental effects
Lead	10 µg/L, max	45	9%**	Most commonly from lead-containing materials in water system components	High lead may lead to negative neurodevelopmental effects, particularly in children

* WHO guideline value for nitrite-N in drinking water is 900 µg/L, max

** We report detectable lead as above 15 µg/L (ppb) due to the reporting limit of the analytical method used (ICP-OES, USEPA Method 200.2). Because the UNBS drinking water standard is set at a lower level than we were able to detect (10 ppb), it is possible that a higher percentage of sampled exceeded the standard level



SPOTLIGHT: LEAD IN DRINKING WATER

In some cases, lead is present in drinking water from naturally-occurring sources. However, in most cases, **lead contamination in drinking water comes from lead-containing components in water systems, such as pipes, faucets, and plumbing fixtures.** Exposure to lead in drinking water may lead to negative neurodevelopment effects, with infants and children being most vulnerable.²

There is no safe level of lead in drinking water.² In this brief, we define detectable lead as above 15 µg/L (ppb) due to the reporting limit of the analytical method used (ICP-OES, USEPA Method 200.2). This is less conservative than the maximum level allowed by the UNBS drinking water standard and the WHO provisional guideline value of 10 ppb. In other words, it is possible that more samples exceed the 10 ppb standard than the percentage reported here that exceed the 15 ppb level.

One-tenth (9%) of drinking water samples had detectable lead (≥ 15 ppb), including **7% of school samples and 13% of healthcare facility samples.** Handpump samples had more detectable lead (29%, n=7) than piped system taps (9%, n=23) (Figure 1), though relatively small sample sizes limit robust comparisons.

Elevated lead in drinking water was more common when pH was low. Among samples with pH below 6.5, 20% (n=15) had detectable lead (≥ 15 ppb), compared to only 3% of samples with pH above 6.5 (n=30). Low pH promotes corrosion of water system components, which can release metals into the water, including lead if present.

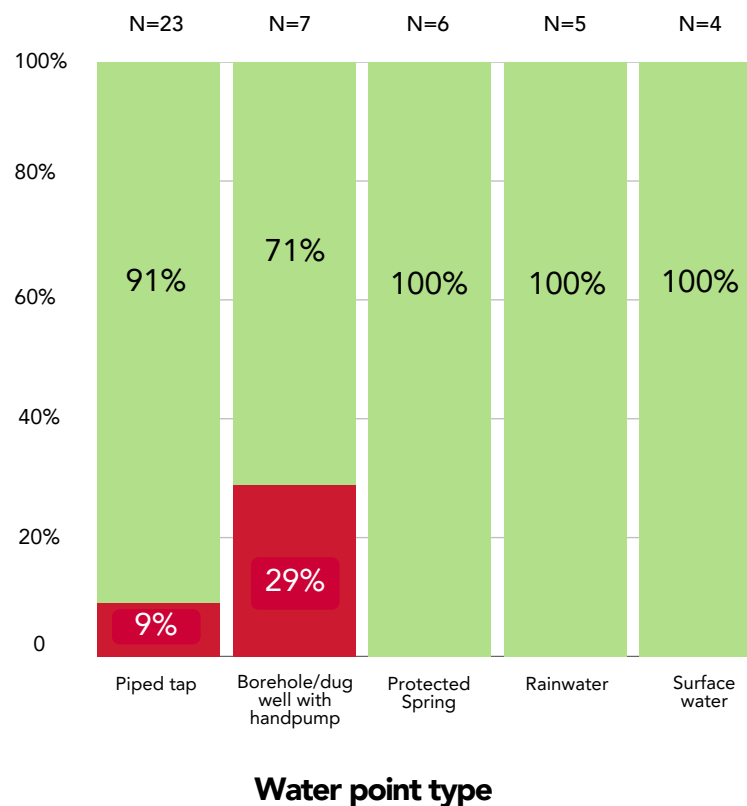


Figure 1: Lead concentrations by water point type. Water samples were collected during the daytime from a subset of institutional water points in Kabarole District.





Enumerators in Kabarole conducting water quality tests on drinking water

FIRST-DRAW SAMPLES

We tested 43 first-draw samples – 23 from piped system taps, 6 from handpumps, and 14 from rainwater collection. There was **more lead and iron in first-draw samples compared to random daytime samples** across all water point types. Among first-draw samples, 49% had detectable lead, and 56% had high iron; this was significantly higher than what was measured in random daytime samples where 9% had detectable lead and 22% had high iron.

Among first-draw samples, elevated iron and lead levels may be attributable to leaching from water system components, including taps, after sitting stagnant overnight.

LEAD IN RAINWATER

We detected lead in some rainwater samples. This may be attributable to lead in paint on roofs and gutters. However, sample sizes were small, and our data cannot confirm the source of lead in rainwater samples.

SUMMARY

PARAMETERS WITH LOW HEALTH IMPLICATIONS








Some water points did not meet the limits defined by the Uganda National Bureau of Standards. One-third of water points had acidic water (pH below 6.5), two-fifths were turbid (cloudy), and one-fifth had high iron. While these exceedances do not have direct negative health implications, they may be unpleasant to water users, may suggest presence of other contaminants, may interfere with treatment processes, and should continue to be monitored. All samples met drinking water standards for electrical conductivity, chloride, total hardness, phosphate, and sulfate.

PARAMETERS WITH HIGH HEALTH IMPLICATIONS

All samples met drinking water standards for fluoride, but some exceeded recommended levels of lead, nitrates, and arsenic, some of which may have severe health implications.



RECOMMENDATIONS

- 1** Given the widespread presence of acidic groundwater (pH is <6.5), new water infrastructure should be constructed with corrosion-resistant materials such as stainless steel or PVC (rather than galvanized iron), in line with national regulations.
- 2** To address lead in drinking water:
 -  Water suppliers should construct new infrastructure using certified **lead-free parts**.
 -  Piped water suppliers should consider maintaining pH above 7.5 and adding orthophosphate to minimize lead leaching from water system components.
 -  National authorities should mandate **regular lead testing of drinking water**.
 -  Local authorities should **raise awareness of lead-contaminated supplies** and alternative water sources among consumers
 -  New research should identify low-cost and practical lead removal strategies.
 -  Institutions employing rainwater collection should ensure that roofs and gutters are constructed with **lead-free materials**, including paint.
 -  Consumers should flush water points for at least 30 seconds before collecting drinking water following a period of non-use greater than 8 hours.
- 3** While chemical contamination can be of great concern, most water-related health problems arise from microbial contamination¹; therefore, **microbial surveillance should be prioritized**.

REFERENCES

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