Keno Hill Environmental Audit – 2023
Hecla Mining Co.

Prepared for:

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Project No. 107840-01

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1.0 Introduction

1.1 Background

Alexco Keno Hill Mining Corp. (c/o Hecla Mining Corp) (Hecla) retained Ausenco Sustainability Inc. (Ausenco) to complete the 2023 Environmental Audit of the Keno Hill Silver District Mining Operations Project, in accordance with the requirements of Quartz Mining License QML-0009, issued November 17, 2019 by the Yukon Mineral Resources Branch (MRB). The focus and scope of the audit was described by the Director of the MRB, as enabled by Section 12.2(f) of the Licence. There were three areas of the site environmental monitoring program that the environmental audit was to be focused on:

- Evaluation of environmental monitoring instruments and equipment.
- Evaluation of the visual assessment of waste rock and field screening criteria.
- Evaluation of the water treatment facilities.

Ausenco made the following assumptions for the completion of this audit:

- The period under review for the audit comprises of the calendar years 2021 and 2022.
- All of the relevant documents and data were provided by Hecla.
- The relevant plans are the versions in effect in 2021 and 2022.

1.2 Audit Execution

The onsite audit was completed August 16th and 17th, 2023 by Ausenco staff member Devon Yacura. Devon was assisted by Ensero Solutions staff member David Meeker and onsite Hecla staff members Michael Rae, Ron Hordichuk and Andrew Paskaruk.

The Ausenco audit team consisted of:

- Devon Yacura, M.Sc., Lead Environmental Scientist.
- Journey Paulus, BScH, LLB. Sr. Technical Lead.
- Laura Pacholski, M.Sc. National Director Mining.
- Florian Reurink, PhD, Project Coordinator (Analytical Support)
- Jeff Warner, PhD Senior Specialist.

None of the audit team have had any prior involvement with the Keno Hill mine in any capacity.

1.3 Approach to Audit Completion

The audit team completed the following steps in the execution of the 2023 Keno Hill Mine Environmental Audit:

Evaluation of Environmental Monitoring Instruments and Equipment

- Reviewed all of the Plans listed in the proposal (scope of work).
- Established a list of sites to visit for the field site portion of the audit.

- Reviewed all monitoring activities, as presented in the monthly and annual reports.
- Reviewed all maintenance logs and operations records where available.
- Determined whether or not the existing environmental monitoring equipment and instruments are working as intended.
- Determined potential improvements to any of the currently approved plans.
- Determined potential recommendations for alternative environmental protection measures to be considered.

Evaluation of Waste Rock – Visual Assessment and Field Screening Criteria

- Reviewed the 2022 Annual Report, the KHSD QML-0009 Site Characterization Report and the Waste Rock Management Plan Revisions 6.5 and 6.6 as well as the Water License QZ18-044. Note that version 6.6 is an internal document and has not been submitted.
- Acid-base accounting data was reviewed as well as the most relevant waste rock associated monitoring well data.
- Determined possible improvements to the field screening and visual assessment of waste rock process.
- Determined better integration of field data from waste rock piles with the initial static and kinetic testing of leachate chemistry as well as the addition of a static test for waste rock (Net Acid Generation test).
- Determined potential improvements that could improve the performance or other aspects of geochemical testing.

Evaluation of Water Treatment Facilities

- Reviewed of effluent quality standard exceedances in the past two years (2021-2022), and an analysis of water treatment plant performance compared to its expected design performance.
- Reviewed of any investigations completed related to effluent quality exceedances and the effectiveness of associated action plans and recommendations including any analysis of water management system improvements (considered or implemented).
- Reviewed of the OMS manual(s) and any associated SOPs for the water treatment plants and their effectiveness and compliance with the documentation.
- Reviewed of the Adaptive Management Plan related to WTP operation, the YESAA and Water Licence applications related to what is already licensed.
- Reviewed of training, maintenance and operational records and reports for the water treatment facilities.
- Determined potential improvements and/or corrective actions that could enhance the performance or other aspects of the water treatment facilities.

2.0 Environmental Monitoring, Surveillance, and Reporting

2.1 Environmental Monitoring Equipment and Instruments

The following documents were requested and where provided were reviewed as part of the Environmental Monitoring Equipment and Instruments audit scope:

- 2021 Environmental Monitoring, Surveillance and Reporting Plan
- 2021 Dust Abatement and Monitoring Plan
- 2021 Noise Monitoring and Management Plan
- Annual Physical Inspection Reports (dated between 2010 and 2022)
- Water Licence QZ18-044 Schedule B and Monthly Reports for 2022
- Quartz Mining Licence QML-0009 and Water Licence QZ18-044 Annual Reports for 2021 and 2022
- Compliance Monitoring and Inspection Reports from 2021 and 2022, that are relevant to the monitoring equipment.
- Maintenance logs.
- Water treatment plant OMS manual and operational records.

Monitoring instruments at the site, and the planned inspection activities for each, are as follows:

- Surface water stations (with continuous hydrological monitoring) and other flow monitoring locations (such as adits) will be reviewed for appropriateness of location based on desktop review of permits and monitoring report. Field equipment (loggers, staff gauges) will be inspected for adequacy of physical installation (where accessible) and flow capture (i.e., installed location representative of stream flows).
- Groundwater wells and piezometers will be sounded for depth to confirm their integrity. A review of well logs, well development records, and previous sampling events including development, field.
- parameter monitoring and laboratory results will be evaluated to confirm the installations are.
- functioning as designed.
- Ground temperature cables.
- Slope inclinometers.
- Meteorological stations.

2.1.1 Operational Status

The following table summarizes the equipment that was inspected as part of the onsite audit, whether the equipment was functioning as intended, and any applicable comments relevant to the inspection.

Table 1 Operational status of environmental monitoring equipment and instruments.

Equipment Item	Functioning (Yes/No)	Comments
YSI	Yes	Functioning as expected. YSI calibration record was reviewed.
Dipper Tape	Yes	Functioning as expected.
Meteorological Station Components	Yes	Functioning as expected.
Meteorological Station Software	Yes	Functioning as expected.
Ground Temperature Cable Probes	Yes	All six GTC were operational. Sensor #9 from BH22-09 is likely malfunctioning.
Slope Inclinometers	No	BH36 was present but unknown whether it is still operational. Could not locate the other two inclinometers.
Barologgers	Yes	Functioning as expected.
Leveloggers	Yes	Logger @ KV-64 was not in water. Logger @ FM-MW-03 could not be retrieved from borehole casing. It's possible that rocks/gravel have filled in casing above the logger.
Staff Gauge	Partial	Gauge @ KV-64 needs replacement. Numbers near bottom of gauge have been worn off.

2.2 Surface Water Monitoring

Surface water stations with continuous hydrological monitoring, and other flow monitoring locations, were reviewed for appropriateness of locations based on desktop review of permits and monitoring report. Field equipment, such as loggers and staff gauges, were inspected for adequacy of physical installation and flow capture (i.e., installed location representative of stream flows).

The following continuous flow monitoring stations were visited during the field audit: KV-6, KV-7, KV-21, KV-41, and KV-64. It should be noted that site KV-64 is a sample site under the ERDC Water License, not a AKHM monitoring station. It was determined that each of these station locations was appropriate based on desktop review of permits and monitoring reports. Furthermore, field equipment such as loggers and staff gauges were inspected at each station for adequacy of physical installation and flow capture. It was determined that each of these stations was installed at an appropriate location to capture flow and the physical installation was done correctly and robust enough to withstand changes in stream conditions and seasonal variation. It was documented that the staff gauge and levelogger at site KV-64 were not operating as they should, as the levelogger was located above the water mark and the staff gauge was damaged so that accurate readings cannot be obtained (**Figure 1**). The Ensero field technician reported that a recent flood on Flat Creek had scoured the creek bed resulting in the active water level of the creek to drop and the levelogger to be stranded above the water line. It was assumed that rocks washing down the creek during the flood had damaged the staff gauge.

Figure 1 Damaged staff gauge and improperly installed data logger at Monitoring Station KV-64.

The following table summarizes the audit results of the surface water monitoring stations, which includes the site ID for each monitoring station, a description of whether the flow monitoring equipment was installed appropriately and functioning as intended, and any applicable comments.

Table 2 Audit results of the surface water monitoring stations.

Surface Water Monitoring				
Site ID	Description	Installed Appropriately (Yes/No)	Functioning (Yes/No)	Comments
KV-6	Christal Creek at Keno Highway	Yes	Yes	Functioning as expected.
KV-7	Christal Creek at Hanson Road	Yes	Yes	Functioning as expected.
KV-21	No Cash Creek at Silver Trail Highway	Yes	Yes	Functioning as expected.
KV-41	Lightning Creek u/s bridge at Keno City	Yes	Yes	Functioning as expected.

2.3 Groundwater Monitoring

As part of the onsite audit, groundwater wells were sounded for depth to confirm their integrity (**Figure 2**). Depth to bottom measurements collected during the audit were compared to historical records of depth to bottom observations. A review of well logs, well development records, and previous sampling events including development, field parameter monitoring, and laboratory results were evaluated to confirm that the installations are functioning as designed. Based on results of the onsite audit, sites KV-85D, KV-123, and BH39 had significantly different depths compared to those reported in the historical records (**Figure 3**). All other sites that were monitored had depths within 10% of the historical records. An investigation is required to determine why the depths are significantly different and the sites should be monitored to determine if the depths are changing over time.

Figure 2 Ensero field technician and Na-Cho Nyäk Dun First Nation member sounding groundwater well.

The following table summarizes the audit results of the groundwater monitoring stations, which includes the site ID for each monitoring station, a description of whether the groundwater well is functioning as intended, and a comparison of the historical records to the audit data.

Table 3 Audit results of the groundwater monitoring stations.

Site ID	Description	Functioning (Yes/No)	Historical Data – Depth to Bottom (m)	Audit Data – Depth to Bottom (m)
KV-108	Upgradient of DSTF Phase 2 Expansion Area	Yes	94.30	92.15
KV-87N	New 2020 Flame and Moth Site. GW Well #3	Yes	94.80	97.18
KV-84ND	Keno City Well #1	Yes	88.39	88.90
ON-MW-2	Keno City Well #2	Yes	66.30	70.51
KV-85S	Keno Hill Silver District Mill Site Groundwater Well #2 shallow	Yes	4.03	4.62
KV-85D	*Keno Hill Silver District Mill Site Groundwater Well # (PH2) deep*	*No*	*42.70*	*6.44*
KV-88S	Keno Hill Silver District Mill Site Groundwater Well #6 shallow	*Yes*	*4.11*	*4.68*
RB-MW-1	Ruby 400 Adit Monitoring Well	Yes	13.41	14.13
KV-127	Bermingham – upgradient of BH P-AML	Yes	27.61	25.34
KV-124	Bermingham – upgradient of BH SW pit	Yes	15.83	15.88
BH-MW-1	Historical Bermingham 200 Adit Monitoring Well	Yes	21.34	22.90
KV-125	Bermingham – downgradient of BH P-AML well #1	Yes	59.16	59.37
KV-126	Bermingham – downgradient of BH P-AML well #2	Yes	71.24	72.02
KV-122	Bermingham – downgradient of BH SW pit well #1	Yes	26.70	26.69
KV-123	Bermingham – downgradient of BH SW pit well #2	No	44.56	33.67
NC-MW-1	No Cash 500 Adit Area Well	Yes	35.70	35.34
KV-116	New Bermingham Waste Rock Disposal Area Well	Yes	12.90	14.03
BH-39	DSTF Phase 1 Area	Yes	7.50	5.84
KV-89S	Keno Hill Silver District Mill Site Groundwater Well #8 shallow	Yes	4.80	5.33
KV-109	Lightning Creek near KV-81	Yes	27.60	26.95

2.4 Ground Temperature Monitoring

Performance of the Dry Stack Tailings Facility (DSTF) is monitored by taking regular readings on the instrumentation installed during and after construction. DSTF instrumentation consists of ground temperature cables installed to monitor permafrost temperature. In the 2021 Annual Geotechnical Inspection report completed by Tetra Tech, it was reported that some critical instrumentation located within and adjacent to the DSTF is in need of repair and/or replacement.

In 2022, Tetra Tech replaced the existing ground temperature cables with new installations. Eight new technological holes were drilled and temperature sensors installed. So far, five of them are functioning in and around the Phase II expansion area and one hole inside the Phase I area was repaired. Monitoring ground temperature within each of these 6 boreholes is conducted biweekly by a Hecla onsite mine technician. Monitoring data is entered into a spreadsheet and the data is sent to Tetra Tech for confirmation and analysis.

On August 17th, Devon Yacura was accompanied by Michael Rae and Arthur Mokwena to each of the six boreholes to obtain the temperature data (**Figure 3**). A total of 16 readings are collected at each monitoring station. The real-time readings are recorded in kilo-ohms, which are ultimately converted to Celsius using computer software. All 16 readings were obtained for each of the six monitoring stations during the field trip. It appeared that sensor #9 for borehole BH22-09 was malfunctioning, as the data output value was not consistent with the values for the other 15 sensors. However, this may have been a one-off error as the historical data for that sensor appears to be correct. Moving forward, the data for this sensor should be monitored closely to observe whether it continues to be inconsistent with the remaining 15 sensors. It appeared that all six boreholes were operating as intended and recording meaningful data (**Table 4**).

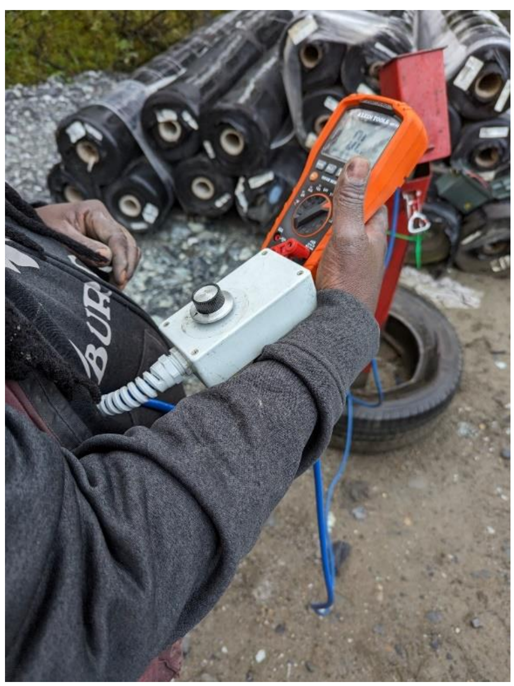


Figure 3 Mine Technician collecting real-time readings from the Ground Temperature Probes.

The following table summarizes the audit results of the ground temperature cable monitoring stations, which includes the site ID, a description of whether the ground temperature cables are functioning as intended, and any applicable comments.

Table 4 Audit results of the ground temperature cable monitoring stations.

Cable ID	Status	Comments
BH 22-01	Functioning	Cap won't close. PVC sticking up. PVC filled with water/oil mixture.
BH 22-05	Functioning	Good condition
BH 22-06	Functioning	Base of casing is loose
BH 22-07	Functioning	Good condition
BH 22-09	Functioning	Sensor #9 appears to be malfunctioning
BH 22-40B	Functioning	Good condition

2.5 Slope Inclinometer Monitoring

During Phase 1 Design and Construction, three slope inclinometers were installed to monitor lateral movement of the foundation soils under the DSTF. Through years of operations, two of these instruments have been damaged beyond repair (Tetra Tech, 2023). The remaining instrument, BH36 is located just north of the mill building (**Figure 4**). Lateral movement data was last collected from BH36 in 2021, when 50 mm of lateral movement was recorded since the last measurement. Tetra Tech reported that this amount of movement was not a concern, however, annual monitoring should continue.

No slope inclinometer data was obtained from BH36 during the audit (**Table 5**). Onsite staff members had limited knowledge of the slope inclinometers and were not able to comment on the current status of the monitoring stations.

Figure 4 Slope inclinometer station, BH36.

The following table summarizes the audit results of the slope inclinometer monitoring stations, which includes the site ID, a description of whether the slope inclinometer stations are functioning as intended, and any applicable comments.

Table 5 Audit results of the slope inclinometer stations.

Cable ID	Functioning (Yes/No)	Comments
BH36	No	TetraTech attempted to collect data from this instrument in August 2022 but was unsuccessful due to equipment issues.
BH38	No	As of 2021, the monitoring equipment is not accessible.
BH28	No	This instrument has been non-operational for several years and needs to be replaced.

2.6 Meteorological Station Monitoring

Meteorological data has been collected for the Keno Hill Silver District since 2007. There are currently three operating meteorological stations installed at the Keno Hill Mine: Calumet weather station installed in 2007, District Mill weather station installed in 2011, and Valley Tailings weather station installed in 2012. The location for the District Mill station was changed in 2022 and it is now located adjacent to the Duncan Creek Road at the Flame and Moth mine vent raise. Each of the stations is monitoring a variety of weather data including temperature, relative humidity, precipitation, wind speed and direction, etc.

Each of the meteorological stations were visited during the audit to inspect the operational status of the monitoring equipment and instruments (**Figure 5**). Data was downloaded from each of the meteorological stations to show that the instruments are operating and collecting data as intended.

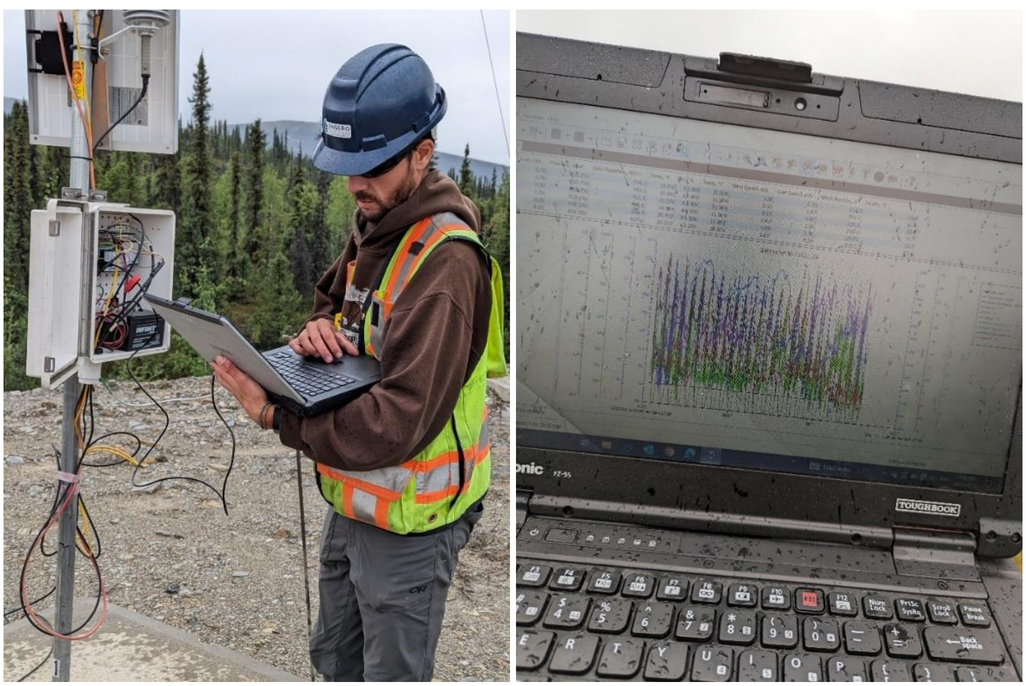


Figure 5 Ensero field technician downloading data from Calumet weather station on August 16th, 2023.

2.6.1 Calumet Station

The Calumet weather station is an automated Onset HOBO station installed on Galena Hill. The following table provides a list of the station's complete component list and a description of the operational status of each component.

Table 6 Summary of Calumet Weather Station Components

Component	Functioning (Yes/No)	Comments
Datalogger	Yes	Functioning as intended.
Air Temperature and Relative Humidity Sensor	Yes	Functioning as intended.
Soil Temperature Sensor	Yes	Functioning as intended.
Pyranometer	Yes	Functioning as intended.
Rain Gauge	Yes	Functioning as intended.
Wind Speed & Direction Sensor	Yes	Functioning as intended.
BP Sensor	Yes	Functioning as intended.
Solar Panel	Yes	Functioning as intended.

2.6.2 District Mill Station

The District Mill weather station is an automated Campbell Scientific station originally installed in 2011 above the DSTF and below the old Keno City dump. In 2022, the station was disassembled, and components were sent to the manufacturer for maintenance, replacement, and calibration. The station was moved to the Flame and Moth vent raise where it was reinstalled.

Table 7 Summary of District Mill Weather Station Components

Component	Functioning (Yes/No)	Comments
Datalogger	Yes	Functioning as intended.
Air Temperature and Relative Humidity Sensor	Yes	Functioning as intended.
Pyranometer	Yes	Functioning as intended.
Rain Gauge	Yes	Functioning as intended.
Wind Speed & Direction Sensor	Yes	Functioning as intended.
Solar Panel	Yes	Functioning as intended.
Battery	Yes	Functioning as intended.

2.6.3 Valley Tailings Station

The Valley Tailings weather station is an automated Onset HOBO station installed near the Valley Tailings. The following table provides a list of the station's complete component list and a description of the operational status of each component.

Table 8 Summary of Valley Tailings Weather Station Components

Component	Functioning (Yes/No)	Comments
Datalogger	Yes	Functioning as intended.
Input Expander Kit	Yes	Functioning as intended.
Solar Panel	Yes	Functioning as intended.
AC Power Adaptor	Yes	Functioning as intended.
HOBOware	Yes	Functioning as intended.
Air Temperature and Relative Humidity Sensor	Yes	Functioning as intended.
Solar Radiation Shield	Yes	Functioning as intended.
Pyranometer	Yes	Functioning as intended.
Rain Gauge	Yes	Functioning as intended.
Light Sensor Bracket	Yes	Functioning as intended.
Light Sensor Level	Yes	Functioning as intended.
Wind Speed & Direction Sensor	Yes	Functioning as intended.
Full Cross Arm	Yes	Functioning as intended.
BP Sensor	Yes	Functioning as intended.
Soil Moisture Sensor	Yes	Functioning as intended.
Tripod	Yes	Functioning as intended.

2.7 Recommendations for monitoring equipment/instrument repair, recalibration or decommissioning

The following are recommendations for addressing the current equipment/instruments:

- The slope inclinometers are not functioning as intended or unable to obtain data. The geotechnical inspection report for 2023 should be addressing this aspect to determine whether additional/replacement stations are warranted.
- Two of the groundwater wells (*KV-85D* and KV-123) were unable to get to the depths required in the groundwater monitoring plan. Efforts should be made to determine whether the repairs are possible and if not these stations should be replaced unless a qualified professional determines otherwise.

2.7.1 Improvements to any of the currently approved (and relevant) environmental monitoring plans

Monthly reports

No summary of information collected is provided for physical inspections and monitoring. It is not clear from the summary what was completed and whether the plan (Physical Inspection and Reporting Plan) is compliant with the requirements. Similarly for the waste rock monitoring section, a summary of monitoring completed would be helpful and then the reference to results being issued as part of the Annual Report. For example, a reference is made to “no seepage was observed during February”, which does not provide any information on which locations were checked, the frequency of monitoring, and the conditions that may provide context for absence of seepage (e.g., frozen conditions). Summary tables that provide the frequency of sampling required, number of samples taken in that time period and rationale for why sampling events were missed would be helpful.

Additional information would be beneficial in the management response summary. For example, failed acute toxicity tests could result in adverse effects to the receiving environment, therefore, details should be provided on the type of test (i.e., single concentration 96-hour Rainbow Trout LC50), summary of water quality, immediate response actions, etc.

The water quality conditions summary does not provide any information on method deviations, missed samples, concentration exceedances, monitoring locations. In Attachment A, there are blank cells in the table; it is unclear if this was missed sampling or another reason for no data. Improvements could be made to the monthly reporting of information to present sufficient information to the reader.

Water Management Plan 2019

Section 3.7.2 would benefit from more information about sediment and erosion monitoring. For example, is turbidity and total suspended solids part of monitoring and at what concentration would there be a trigger for mitigation.

Additional information could be provided on how water levels and flow volume is recorded. More details on the water balance models would also be useful for the reader to understand assumptions and limitations of the models. Additional information on water treatment facilities (what parameters are being treated via what mechanisms) and the related operational protocols related to when water is discharged to what locations would be helpful.

Monitoring, Surveillance and Reporting Plan 2021

Table 11-1 and the report in general is insufficient to capture environmental monitoring data:

- More information should be given about the event (I.e., quantify the change, parameters, concentrations, frequency, duration, geographical extent, comparison to historical data and guidelines/standards).
- The narrative trigger does not provide enough information for the reader. Summary tables and graphical representation of parameter concentrations by station and comparison to standards would be more helpful.
- Indicators column is particularly vague and relies on reader looking up or being aware of effluent quality standards or similar. Specific indicator information should be provided.
- Similar to the event column, the final three columns (I.e., thresholds, monitoring locations, monitoring parameters) should include substantially more data as suggested for the event column.
- No information is provided on response actions, mitigation, follow up. Some of the items in Table 11-1 have the potential for significant environmental changes and should be adequately explained.
- Tabular and graphical representation of the data would be helpful to clearly show the temporal and spatial trends in data.

Figures should be updated to include all watercourses where sampling stations are located.

No results were provided for the updated meteorological information collected and any expected changes to the meteorological/hydrological information and water balances as a result of the updates.

The groundwater levels collected as part of the program are said to be used to prepare groundwater contours maps twice per year and refinements to the groundwater models as required. No information on these updated maps or models is provided. There is also no summary of the groundwater level data collected.

The report could include information on any deviations from established methods and missed sampling.

Similarly, the reporting on exceedances related to water treatment plants is extremely limited and insufficient to be able to understand what has occurred. The monthly reports reference the notification reports as containing the necessary information. It would be more appropriate to provide a summary of the relevant information as well as given the current challenges to provide charts demonstrating the trend information on relevant criteria. For example, ammonia and TSS internal and external results for a relevant time frame (e.g., current year or past year if it is Q1). This information would provide transparency on the current status of water treatment and provide relevant context for interpreting the exceedances. Similarly, it would be helpful to have a comprehensive list of exceedances provided in a table for the current year.

2021 and 2022 Annual Reports

There was insufficient data presented to adequately assess the efficacy of environmental monitoring. These reports direct readers to links where data must be sought, rather than a summary of data in the actual reports. For example, Section 6.1.1 reports on what was done for the water quality surveillance network but no results, summary, or interpretation of the program are provided. Similarly, Section 6.1.2 reports on environmental effects monitoring and direct readers to a separate report; no summary of data, conclusions, or response actions and mitigation is provided.

2021 Dust Abatement and Monitoring Plan

Additional information would be helpful to describe existing climatic conditions. For example, the ten-year mean measured temperature of -23.1 °C to 15.1 °C is provided but doesn't speak to temporal or seasonal ranges, that would more adequately provide the reader with information. Similarly, the average total precipitation of 340.9 mm is provided but does not describe how this may have varied by year or seasonally.

A summary of results observed to date could be helpful for the reader to assess the adequacy of existing monitoring methods. In addition, no information is provided on how the results will be analyzed and presented i.e., graphical, statistical, tabular interpretation and summaries.

Updates to the monitoring plan are provided in Section 6.2 in response to concerns raised. However, no details are provided on what the concerns were, which makes it difficult to assess whether the updates would be sufficient to address the concerns.

There is no information provided on when the dust disturbance register was implemented and whether and to what degree it is actively used by Keno City residents.

In the additional mitigation measures, there is no discussion on when and if these measures would be implemented. An evaluation of effects or details of an approach to assess potential effects would be useful to determine how any exceedance of the air quality standards would be addressed.

Noise Monitoring and Management Plan

In section 1, it would be helpful to direct the reader to where there is a summary of the Noise Impact Assessment (NIA) findings. Additional information about how the informal communication referred to in Section 1.4 is captured, would be helpful. It is not clear from the current report how this and other formal community meetings are reported on.

In Section 2, the noise sources identified in the NIA are listed but no additional detail is provided on the expected noise levels and duration or frequency, and contributions from individual noise sources (e.g., mine operation noise from portal fan, compressor, blasting, etc).

In Section 3, it would be informative to include the rationale for noise receptor locations to adequately assess whether this monitoring is sufficient.

Additional mitigations are listed should there be a noise complaint investigation. There is no information about how an investigation is initiated, completed, and reported on.

Reporting is said to be provided on a quarterly basis; however, the MRB website does not have the reports for 2021.. More information could be provided on how the monitoring results are interpreted and what noise levels are compared to. Furthermore, additional information could be provided on what triggers might result in additional mitigation measures.

Section 5.4 refers to effects monitoring but this section appears to discuss results monitoring and not necessarily effects of increased noise levels. One reference is made to potential effects on a person's business but no reference to well being or other influences increased noise levels may result in (e.g., wildlife deterrence/avoidance).

2.7.2 Alternative environmental protection measures that should be considered by AKHM and the Director

Provision of the additional supporting information in reporting documents outlined above, will help provide a foundation for assessment of the adequacy of the current environmental monitoring programs. Three initial recommendations for consideration include:

1. The air quality stations appear to be effective in measuring particulates. However, consideration could be given to dustfall stations to more adequately measure potential deposition contributions from unpaved roads. The implementation of dustfall stations would be worth considering where exceedances are observed (e.g. unpaved roads that may be the cause of PM exceedance).
2. A surface water modelling exercise to determine the potential for continued effects to the receiving environment from the discharge points would be helpful. A robust operational water management model with inputs to a receiving environment model, would provide a holistic view of constituent movement from mine sources. Data from the models would help in identifying constituents of focus for the water treatment plans, optimize timing of discharge for effluent, preventative measures for protection of downstream receiving environments. Ausenco understands that in 2023 water attenuation studies were conducted and models were updated. These have not been reviewed as part of the audit.
3. As part of environmental management system, a thorough statistical re-evaluation of current monitoring programs (including all available data) is recommended. This would determine the adequacy of current programs, the suitability of sampling locations, optimum frequency of data collection, potential increase or reductions in monitoring, considerations for improvement.

3.0 Evaluation of Waste Rock Management

As a condition of the current water license QZ18-044, Hecla Yukon is required to characterize waste rock and monitor waste rock storage areas for acid generation as well as metal leaching. The geochemical characterization of waste rock to determine the potential for acid rock drainage and/or metal leaching (ARD/ML) is critical in order to prevent, attenuate or potentially treat ARD. This is achieved through a well-designed sampling program that aligns with the mine plan and that incorporates appropriate field-based and laboratory testing. A monitoring program is essential to validate predictions and results from laboratory or smaller scale field trials.

One approach to waste rock management is to segregate the waste rock based on its potential for ARD (acid rock drainage). An established approach is to use acid-base accounting (ABA) tests and the neutralization potential ratio (NPR) in combination with either NAG (net acid generation) pH or sulphide weight percent to assess whether a sample is PAG (potentially acid generating) rock or NPAG (not potentially acid generating) rock. The PAG rock pile will typically consider both hydrologic and geochemical controls in order to contain any impacts from acid generation.

Characterization of waste rock has been on-going since 2006 when Alexco Keno Hill Mining (AKHM) Corp. initiated exploration. Geochemical characterization studies targeted the mineralized zones at Bellekeno, Onek 990, Lucky Queen, Flame & Moth, Silver King and New Bermingham. Samples were obtained from exploration drill holes.

3.1 Field Screening Criteria and Visual Assessment

AKHM proposes to field classify rocks as P-AML (potentially acid generating and/or metal leaching) or N-AML (non-acid generating and/or metal leaching) by visually estimating the carbonate and sulphide content for major lithologies at the face after blasting. Face sheets were reviewed from August 2023, a total of 10 face sheets were given for both N-AML and P-AML sample designations. Face sheets contained sketches with lithology designations and sample id numbers as shown in the workflow (WRMP, Rev. 6.5). It was not clear if these corresponded to all the blast rounds in the month of August. In addition, there was no evidence of photographs being taken of the rock face or follow-up sampling, although these could be present in other documentation. The following recommendations relate to the field screening and visual assessment process.

- Inorganic carbonate content is estimated visually. This is not considered a conservative approach as many types of carbonate rock do not contribute to acid rock neutralization (e.g. Fe-carbonates). Fizz tests and ratings, though subjective because they depend on the normality and volume of the acid used as well as the coarseness of the sample, could be introduced as an added approach to identifying carbonate rock that contribute to acid rock neutralization. Operational confidence in the visual identification of carbonate rock could be strengthened if AKHM developed a site-specific fizz rating or visual identification process that was calibrated against more advanced techniques.
- Acid rock drainage is mainly produced by the oxidation of iron-bearing sulphides, primarily pyrite and pyrrhotite. Other iron-bearing sulphides, chalcopyrite, arsenopyrite and iron-bearing sphalerite can also oxidize to generate acidity. AKHM include several criteria addressing metal leaching concerns for lead (visual estimated galena ≥ 0.5%) and zinc (visual estimated sphalerite ≥ 0.75%). This process would also benefit from a site-specific calibration process against laboratory methods, such as x-ray diffraction.

- The current P-AML classification scheme as written does not seem to allow for an uncertain category. While the goal should be to reduce the number of samples classified as uncertain, it is unrealistic to not allow for an uncertain category. Once the category exists, it can be decided what to do with those samples, e.g. classify as P-AML or subject these rocks to further tests.

3.2 Confirmatory Sampling and Geochemical Testing

Analytical screening criteria are applied to data from the waste rock drill hole databases. Static geochemical tests are currently used to confirm waste rock analytical screening criteria. These tests are acid-base accounting (ABA), trace metal analysis conducted by inductively coupled plasma mass spectrometry (ICP-MS) techniques (after solids digestion) and shake flask extraction (SFE) for determining soluble constituents (after a 24 hr leach). These methods are widely used to classify samples for their acid generating potential. AKHM is also using a siderite-corrected Sobek method as well as sulphide sulphur determined by difference (total sulphur (Leco) minus sulphate sulphur (HCl digestion)) that minimize the limitations of ABA methods. The neutralizing potential in ABA methods does not provide an indication of the relative reactivity of the acid neutralizing component of the sample or if the rate of neutralization matches the acid generation rate.

Most external laboratories will also conduct net acid generation (NAG) tests, which are useful in establishing an upper limit of acid generation by pulverizing the sample and completely oxidizing any sulphide present with hydrogen peroxide. The single addition NAG test will give a final pH and a NAG titrated acidity resulting from the complete oxidation of any sulphides. A NAG pH of less than 4.5 indicates the sample is acid generating. This has been performed on tailings in the past at KHSD but does not seem to be a routine test for waste rock.

Kinetic tests performed are typically performed on samples representative of the amount of excavated rock at the site with perhaps a heavier weighting towards samples that are suspected of being acid generating. Kinetic tests are useful for obtaining times for the onset of acid generation, sulphide depletion rates and data on metal leaching within the confines and limitations of humidity cell testing procedures.

Previously three (3) humidity cell tests were performed on samples from Flame & Moth (1), and New Bermingham (2). All three HCTs were performed on non-potentially acid generating (NPAG) samples. Field barrel tests were also focused on NPAG material with only one out of the four field barrels containing NPAG material. This particular barrel was damaged in 2020 making any results obtained afterwards questionable. Kinetic tests are most useful when attempting to predict behaviour at new sites or new lithologies but are not as useful for predicting drainage chemistry from an existing waste rock pile as directly sampling the existing site.

3.3 Recommendations

The following are recommendations for improvements on waste rock management:

- Waste rock facilities seem to have different names across different documents (storage facilities, waste dumps, P-AML facilities, storage areas, New Bermingham #1 or #2). It would be helpful to standardize on a single name for each facility across all documents.
- It would improve the clarity of the document if at the outset the waste rock storage areas were listed with their current inventories, waste rock type (P-AML or N-AML), relevant monitoring wells, footprint, etc.

- Visual waste rock classification scheme should be validated by a site-specific calibration process that confirms accuracy of the process under site conditions and at different percentage contents of carbonate, pyrite, galena and sphalerite.
- The waste rock classification scheme should allow for an uncertain category. The uncertainty would be determined from the laboratory calibration and would specify steps to categorize those uncertain samples. For the visual classification this would typically be to just include them in the P-AML category.
- AKHM should report the accuracy of “face calls” and efforts of continual improvement.
- It would be valuable to indicate that kinetic testing is performed in accordance with ASTM D5744-18, if true.
- Comprehensive NAG (net acid generation) pH tests (single addition or sequential) should be conducted for all waste rock samples.
- Static and kinetic testing are important predictive strategies to pursue for solids obtained during active mine development but it is important to sample and test seepage water from existing waste rock facilities. This water is representative of the pore water chemistry within the waste rock pile and more accurately represents the constituents of concern from acid rock or neutral drainage as well as representing the field behaviour and not laboratory leaching rates.

3.3.1 Improvements to Waste Rock Management Plan

The Waste Rock Management Plan Revision 6.5 contains all the required components. At the time of writing, revision 6.5 was more complete than revision 6.6. Less reliance on laboratory studies and improved monitoring of seepage, surface water and groundwater would improve understanding of longterm waste rock geochemistry.

4.0 Evaluation of Water Treatment Facilities

The water treatment facility audit included analysis of the New Bermingham, Bellekeno, and Flame & Moth Water Treatment Plants:

- A review of effluent quality standard exceedances in the past two years (2021-2022), and an analysis of water treatment plant performance compared to its expected design performance.
- A review of any investigations completed related to effluent quality exceedances and the effectiveness of associated action plans and recommendations including any analysis of water management system improvements (considered or implemented).
- A review of the OMS manual(s) and any associated SOPs for the water treatment plants and their effectiveness and compliance with the documentation.
- A review of training, maintenance and operational records and reports for the water treatment facilities.
- A review of the Adaptive Management Plan related to WTP operation, the YESAA and Water Licence applications related to what is already licensed.

The following documents were reviewed as part of the audit of the Water Treatment Facilities:

- Water Management Plan
- Bermingham WTP Operations Manual 2021
- Bermingham WTP Construction Completion Report 2021
- Bermingham WTP Design Report 2021
- Flame&Moth WTP Design Report 2017
- Flame&Moth WTP Operators Manual 2018
- Flame&Moth WTP As Builts 2018
- Bellekeno WTP Design Report 2007
- WTP Maintenance History 2021 to 2022 (primarily corrective actions)
- March 27, 2019 WTP Performance (Information as part of water licensing process)
- July 30, 2018 Memo on Bermingham WTP (Information as part of water licensing process).

4.1 Review of Exceedances

The objective of the Bermingham, Bellekeno, and Flame&Moth Water Treatment Plants (WTPs) is to discharge water compliant with the Water Licence namely:

Discharge from the Bellekeno 625 water treatment systems at KV-43 must not exceed the following limits:

Parameter	Maximum Concentration in a Grab Sample (in mg/L unless otherwise noted)
pH	6.5 to 9.5 pH units
Total Suspended Solids	25
Ammonia Nitrogen as N	5
Arsenic (total)	0.1
Cadmium (total)	0.01
Copper (total)	0.1
Lead (total)	0.2
Nickel (total)	0.5
Radium 226	0.37 Bq/L
Silver (total)	0.01
Zinc (total)	0.5
96-hour Rainbow Trout LC_{50} at 100% concentration	Non-toxic

Discharge from the Flame and Moth water treatment systems at KV-104C must not exceed the following limits:

Parameter	Maximum Concentration in a Grab Sample (in mg/L unless otherwise noted)			
Discharge Rate	0-10 L/s	10.1-20 L/s	20.1-30 L/s	30.1-35 L/s
pH	6.5 to 9.5 pH units			
Total Suspended Solids	15			
Ammonia Nitrogen as N	6.5	3.7	2.7	2.4
Arsenic (total)	0.042	0.022	0.017	0.012
Cadmium (total)	0.0080	0.0060	0.0044	0.0042
Copper (total)	0.043	0.026	0.021	0.019
Lead (total)	0.043	0.023	0.018	0.016
Nickel (total)	0.5			
Radium 226	0.37 Bq/L			
Silver (total)	0.001	0.00064	0.00053	0.00052
Zinc (total)	0.5	0.46	0.42	0.40
96-hour Rainbow Trout LC_{50} at 100% concentration	Non-toxic			

Discharge from the Flame and Moth water treatment systems at KV-104L must not exceed the following limits:

Parameter	Maximum Concentration in a Grab Sample (in mg/L unless otherwise noted)			
Discharge Rate	0-10 L/s	10.1-20 L/s	20.1-30 L/s	30.1-35 L/s
pH	6.5 to 9.5 pH units			
Total Suspended Solids	15			
Ammonia Nitrogen as N	10	10	9.0	8.1
Arsenic (dissolved)	0.035	0.020	0.015	0.013
Cadmium (dissolved)	0.0012	0.00072	0.00055	0.00050
Copper (dissolved)	0.043	0.023	0.017	0.015
Lead (dissolved)	0.036	0.020	0.014	0.012
Nickel (dissolved)	0.50	0.50	0.44	0.40
Radium 226	0.37 Bq/L			
Silver (dissolved)	0.0029	0.0016	0.0012	0.0010
Zinc (dissolved)	0.23	0.13	0.095	0.085
96-hour Rainbow Trout LC_{50} at 100% concentration	Non-toxic			

Discharge from the New Bermingham water treatment systems at KV-114 must not exceed the following limits:

Parameter	Maximum Concentration in a Grab Sample (in mg/L unless otherwise noted)
pH	6.5 to 9.5 pH units
Total Suspended Solids	25
Ammonia Nitrogen as N	5
Arsenic (dissolved)	0.061
Cadmium (dissolved)	0.01
Copper (dissolved)	0.024
Lead (dissolved)	0.048
Nickel (total)	0.37
Radium 226	0.37 Bq/L
Silver (dissolved)	0.00062
Zinc (dissolved)	0.5
96-hour Rainbow Trout LC_{50} at 100% concentration	Non-toxic

In 2021 and 2022, there were exceedances from all three WTPs primarily related to: TSS, ammonia, arsenic and lead. In most cases, as is demonstrated in the table below, the issue was determined to be related to quality of water pumped from underground or equipment being broken or not yet installed.

Exceedances in 2021

Date	Parameter	Cause of Exceedance	Action Taken/Remedy
05-Jan-2021	Bermingham effluent exceeded As EQS		Interim results of treatment show improvement in settling and treatment
23-Jan-2021	Bermingham effluent exceeded ammonia EQS		
25-Jan-2021	Bellekeno effluent exceeded TSS		Re-running sample to validate the data as expected to be a reporting error
26-Jan-2021	Bermingham effluent exceeded ammonia and TSS EQS		
25-Feb-2021	Bellekeno effluent exceeded Pb and As and Bermingham effluent exceeded As EQS	PM was the issue at Bellekeno while Bermingham issue was related to pH	Implementation of additional measures
28-Feb-2021	Bellekeno effluent exceeded TSS max monthly mean concentration		
03-Mar-2021	Bermingham effluent exceeded As EQS	TSS and total metals high, which is consuming ferric sulphate that was previously used to keep concentrations down	Increase in ferric solution, change to fresh ferric sulphate reagent
09-Mar-2021	Bermingham effluent exceeded ammonia EQS and Flame & Moth effluent exceeded As EQS	Operator error, discharge amounts too high for Flame & Moth WTP	Flow rate reduced for Flame&Moth and ammonia treatment plant was delivered and installed March 18 for Bermingham
29-Mar-2021	Bellekeno effluent exceeded TSS EQS		Actions taken to improve settling
12-Apr-2021	Bellekeno effluent exceeded TSS EQS	fluctuations in underground mine pumping rates and short circuiting of treated water	Underground pumping reduced, modified, pond 1 desludged to provide additional retention capacity to reduce short circuiting, geotextile curtain installed at the discharge of pond 2

Date	Parameter	Cause of Exceedance	Action Taken/Remedy
14-Apr-2021	Bermingham effluent resulted in acute toxicity in LC50 Rainbow Trout test	variability in the plant influent from underground reaching breaking point system	Ammonia plant influent changed to recycle, recycle will also assist treating residual chlorine, investigation of dechlorinization, setup and calibration onside daily chlorine measurements
02-May-2021	Bermingham effluent exceeded As EQS		Lab testing in progress to optimize reagent treatment
25-May-2021	Bermingham effluent exceeded As EQS	influent arsenic concentrations from underground increased	Lab testing in progress to optimize reagent treatment
12-June-2021	Bermingham effluent exceeded As EQS		
20-June-2021	Bermingham effluent exceeded As EQS		Ferric sulphate and chloride added to both mixing tanks and the clarifier
28-June-2021	Flame & Moth effluent exceeded un-ionized ammonia and As		Ferric sulphate and chloride added to both mixing tanks and the clarifier, second addition point being commissioned in July
10-Aug-2021	Bermingham effluent exceeded TSS EQS	due to some remaining particulates from maintenance activities	
24-Aug-2021	Bellekeno effluent exceeded Pb EQS	Short-term condition of pH at the low end of operating conditions	System modified to ensure rapid calibration
06-Sept-2021	Bermingham effluent exceeded TSS EQS	particulate matter in the sample	
14-Sept-2021	Bermingham effluent exceeded TSS EQS and Flame & Moth effluent exceeded TSS EQS	particulate matter in the sample	Site reviewing the mine water management practices
15-Sept-2021	Bermingham effluent exceeded TSS EQS		Site reviewing the mine water management practices
20-Sept-2021	Bermingham effluent exceeded TSS EQS		Changed to operating practice implemented, sediment reduction measures implemented
27-Sept-2021	Bellekeno effluent exceeded TSS EQS		Changed to operating practice implemented, sediment reduction measures implemented
28-Sept-2021	Flame & Moth effluent exceeded TSS EQS		Changed to operating practice implemented, sediment reduction measures implemented

Date	Parameter	Cause of Exceedance	Action Taken/Remedy
05-Oct-2021	Bellekeno effluent exceeded TSS and Pb EQS	particulate matter introduced to the sample for TSS aspect	Work continues to implement operational changes
06-Oct-2021	Bellekeno effluent exceeded Pb EQS and Bermingham effluent exceeded TSS and Pb EQS	particulate matter introduced to the sample for the TSS aspect	Work continues to implement operational changes
12-Oct-2021	Bermingham effluent exceeded TSS EQS		
20-Dec-2021	Bermingham effluent exceeded pH EQS	from the underground workings, failure of sump pump, lime overdosing	Rate of acid addition increased, sump pump replaced

Exceedances in 2022

Date	Parameter	Cause of Exceedance	Action Taken/Remedy
27-Jan-2022	TSS at KV-114 (Bermingham)	Unforeseen ground support measures implemented underground	
09-Feb-2022	TSS at KV-114 (Bermingham)		
09-Feb-2022	TSS at KV-104L (Flame&Moth)		
21-Mar-2022	TSS at KV-114 (Bermingham)	Potential issues with the decant system used to settle solids from the drill exploration system reporting to the mine's water sumps	A change in substance being used to condition the drill holes may be required in future programs
09-May-2022	TSS at KV-114 (Bermingham)	Failures of geotextile sediment bag which resulted in solids entering the bag discharge pipe	Modifications to sludge bag system made to address issue
02-June-2022	TSS at KV-114 (Bermingham)	Underground cleaning activity, sump cleaning which resulted in increased sediment content	Long-term underground water management infrastructure, scheduled for fall 2022
24-Oct-2022	TSS at KV-104L (Flame&Moth)	Underground cleaning activity, sump cleaning which resulted in increased sediment content	Mew underground mine water practices being implemented
12-Dec-2022	Failed Rainbow Trout LC50 at KV-114 (Bermingham)	Nitrate combined with ammonia in low chloride environment	

EDI performed an investigation into the 96-hr Rainbow Trout LC50 exceedance in December 2022, concluding that elevated concentrations of nitrite, and to a lesser degree, ammonia were responsible for the acute toxicity test result. Based on two different Rainbow Trout LC50 acute test responses, a conservative approach would be to establish a threshold for action for nitrite in low chloride water equal or lower than the BC approved water quality guideline for maximum nitrite in low chloride water (0.06 mg/L nitrite-N, when chloride concentrations are < 2 mg/L). This could be in combination with a threshold for ammonia. Reducing nitrite can be done with BPC or an ion exchange system; however, may require further refinement of the process including consideration of holding times to allow nitrite to convert to nitrate. Ausenco was informed that the use of Ferric Chloride in the WTP has increased the chloride concentration in the effluent to an average of 55 mg/L for 2023.

Watertectonics has been commissioned by Hecla to conduct a WTP optimization study at Bermingham WTP. Thus, Hecla has already engaged in a process to improve the performance of the Bermingham WTP and if the process is successful then the other WTPs will be examined.

4.2 Evaluation of Design Criteria compared to Actual Results

The audit has focussed mainly on the Bermingham WTP where the majority of 2022 and 2023 exceedances occurred. The Bermingham WTP has design flow rates and established processes based on design specifications. Ausenco examined the internal daily flow rates and water quality to determine whether the design rates are being met. Note that Flame and Moth has design effluent criteria; however, not water quality from dewatering Flame and Moth mine. Bellekeno has no design specifications for either influent or effluent. The data on water quality and flow rates for all three WTPs is located in Appendix A. It would be helpful to conduct modeling of water quality to predict the requirements for future water treatment prior to contemplating any significant design changes.

On average, the expected flow rates from the new Bermingham adit were expected to range from 3 to 10 litres per second (L/s). Alexco proposed that the Bermingham WTP be built to accommodate a maximum flow of 14 L/s to accommodate peak flows. The licence limit on discharge is 13.9 L/s so slightly below maximum flow. For 2021 and 2022, the average rate for the decline at Bermingham was 5.2 L/s with a maximum flow of 10.2 L/s. Thus, the 2021-2022 flow rates are within the design specifications. If the WTP is able to achieve 14 L/s then it may be possible to recirculate the water that is not meeting discharge criteria where rates are below 7 L/s which over the past two years would be over 75% of the time (3rd quartile rate was 6.2 L/s).

The influent chemistry design basis was provided in Table 2-1 of the February 2021 Updated Design Report for the Bermingham WTP:

Table 2-1: Influent Chemistry Design Basis

Parameter	Units	Min	Median	Max	Expected Treatment Efficiency	EQS
pH	pH Units	6	8	7	n/a	6.5 to 9.5 pH Units
Total Suspended Solids	mg/L	4.2	140	2356	75-99%	25
Ammonia Nitrogen (as N)	mg/L	0.01	1.5	18.5	0.2-0.4 g ammonia as N/m3/day	5
Arsenic (dissolved)	mg/L	0.007	0.05	0.11	80-95%	0.061
Cadmium (dissolved)	mg/L	0.023	0.08	0.67	93-98%	0.01
Copper (dissolved)	mg/L	0.0002	0.001	0.009	0-90%	0.024
Lead (dissolved)	mg/L	0.0006	0.03	0.19	0-90%	0.048
Nickel (total)	mg/L	0.005	0.014	0.37	65-98%	0.37
Radium 226	BQ/L				n/a	0.37
Silver (dissolved)	mg/L	0.0001	0.0001	0.0003	0-90%	0.00062
Zinc (total)	mg/L	0.66	1.85	124	95-99%	0.5
Acute Toxicity Testing						
96-hour Rainbow Trout						Non-toxic, LC_{50} (100%)

The Appendix A has a comparison of the 2021 and 2022 data to the design criteria and an evaluation of % removal over time to understand whether performance is improving over time.

For Bermingham WTP, the conclusions are that:

- The TSS from the adit and effluent water is consistently below the maximum design criteria; except for one outlier exceeding the maximum design criteria in the effluent water in 2021. The values are generally not significantly different from random selected values within the design criteria for the adit water quality. The TSS removal percentage (comparison of the adit to treated water) is within design parameters and typically more than 80% removal; however, the effectiveness of removal has decreased over time.
- The arsenic concentrations in the adit and effluent water have exceeded the maximum design criteria on a few occasions in early 2021; but are generally trending downwards and the values are not significantly different from random selected values within the design criteria.. The removal effectiveness has improved over time with two events where arsenic concentrations increased as a result of treatment.
- Ammonia concentrations in the adit and effluent water are consistently below the maximum design criteria, which the exception of one occasion in effluent water in early 2021. The values are generally not significantly different from random selected values within the design criteria. Treatment effectiveness has not changed over 2021-2022 likely due to recent implementation of additional treatment targeting ammonia.

- pH in the adit and effluent water has mostly been below the maximum design criteria; however, it exceeded the maximum a couple of time in 2021. The adit values were also significantly higher than random selected values within the design criteria. The removal effectiveness did not significantly change over time.
- Lead in the adit and effluent water is trending well below the maximum design criteria and is significantly lower than random selected values within the design criteria. Removal effectiveness has also improved over time.

Thus, although the water quality, for all key parameters, has been above the median design criteria, recent results are below the maximum design criteria except for lead. This is particularly relevant for the parameters which led to exceedances in 2022, namely TSS and ammonia.

For Flame&Moth WTP, there is no design criteria and therefore the analysis focused on performance of the plant compared to EQS requirements and understanding the changes in performance over time. The conclusions are:

- The TSS effluence values are consistently below the maximum design criteria except for one occasion in late 2022. TSS removal on the other hand has improved significantly over time and is consistently better than 90% removal.
- Arsenic effluence values have remained below the maximum design criteria, and arsenic removal has significantly improved over time .
- Ammonia effluence values have exceeded the maximum design criteria multiple times and are significantly higher than random selected values within the design criteria. increased compared to the adit water quality. Ammonia removal has not improved over time.
- Lead effluence values have been well below the maximum design criteria and are significantly lower than random selected values within the design criteria. Lead removal has also improved over time.

Note that a number of outliers were removed during the analysis of the effectiveness of removal. These outliers were cases where the amount increased from adit water quality to effluent water quality by a significant margin.

4.3 Evaluation of WTP Operations

The Bermingham WTP Operations Manual Table 8 includes the following potential process issues and actions to resolve the issue:

Table 8: Anticipated Process Issues that Could Impact Plant Performance

Potential Issues	Troubleshooting Guide
Elevated Zn in plant discharge (pH normal)	**Key indicators:** • Site AA assay returns a zinc measurement >0.4 mg/L. **How to resolve the issue:** • Resample the settling pond decant to check for anomalous sample. Look for suspended solids in the sample, filter a portion of the sample and comparing the total and dissolved metals. • Check sludge level in the pond and schedule removal if necessary. • If solids are present and appear to be very fine, $FeSO_4$ addition may be required to resolve the issue. Ask for advice before either adding $FeSO_4$ or changing the dosing rate.
Elevated As concentration in pond decant	**Key indicators:** • External lab assay returns an arsenic measurement >0.05 mg/L. **How to resolve the issue:** • Increase ferric sulphate dosing rate into the mixing tank. • Add an additional dosing point for ferric sulphate just prior to the clarifier overflow. • It may become necessary to purchase an additional AA lamp in the future since there is a week delay between sampling and receiving results from the external assay lab.
Elevated ammonia concentration at pond decant	**Key indicators:** • Site handheld meter HQ40d returns an ammonia concentration >0.3 mg/L. **How to resolve the issue:** • Contact the mill manager or designate to confirm if the ammonia treatment plant should be turned on.
Chlorine concentration at pond decant	**Key indicators:** • Site handheld DR300 meter returns a total or free chlorine concentration >0.2 mg/L. • External bio-assay is failed. **How to resolve the issue:** • Contact the Mill Manager or designate to identify if the ammonia treatment plant can be turned off. • Evaluate the concentration of ammonia entering the ammonia treatment plant and compare against the hypochlorite dosing rate. • Evaluate the pH in the ammonia treatment plant to ensure it is being maintained within the target range of 8 – 8.5 • It is expected the conditions in the ammonia treatment plant can be managed such that chlorine concentration can be maintained below the toxicity limit for rainbow trout; however, it may become necessary to install a dechlorination system in the future.
pH at pond decant	**Key indicators:** • pH at Pond decant >9.3 **How to resolve the issue:** • Contact the Mill Manager or designate to identify if the ammonia treatment plant should be used to provide pH correction. Note: if ammonia treatment is not required the acid pump can be used to reduce the pH to a lower set point than 8 - 8.5. • Consider adding small amounts of sulphuric acid or ferric sulphate to the settling pond at the point where lime water treatment plant effluent flows into the pond.

Potential Issues	Troubleshooting Guide
Variable influent conditions to ammonia treatment plant	**Key indicators:** • The flow to the water treatment plant is inconsistent due to variable feed rates from the underground. • High variability in ammonia concentration in the plant feed. **How to resolve the issue:** • Change the ammonia plant feed from the lime treatment plant to come directly from the settling pond. This change was completed in May 2021 and has improved the consistency of the ammonia treatment plant feed.
Elevated TSS in lime plant feed	**Key indicators:** • Water entering the clarifier is dark. • Site TSS measurement is >250 mg/L. **How to resolve the issue:** • Increase flocculant dosing rate. • Adjust clarifier underflow dump frequency to send a higher proportion of the water to the sludge bags. • Change the feed pump from the underground sumps to a VFD instead of a float cell. This change was made in April 2021 and improved water quality from the underground has been observed.

This table illustrates that there are limited options for addressing ammonia or TSS exceedances. Thus, even if there are different "set points" to force earlier action, it may be that there are limited available options in this WTP.

4.3.1 Review of Training, Maintenance and Operational Records

The audit has focussed mainly on the Bermingham WTP where the majority of 2022 and 2023 exceedances occurred. The procedures and design specifications are slightly different at each location; however, the overall approach is similar enough that audit recommendations can be applicable to all three WTPs. The same personnel are responsible for all three WTPs.

Ausenco had intended to review a random sample of Bermingham WTP Daily Operator Checklists to compare to the required checklist in Table 6-1 of the WTP design report; however, was informed that the current process is "informal" and there are no daily checklists to review. Given the challenges in WTP performance, it would be valuable to have this information.

Table 6-1: Daily Operator Checklist

Parameter	am	pm	Parameter	am	pm
Reactor pH			Incoming Flowrate lps		
Clarifier pH			Sludge Discharge lps		
Lime Feed Pump Hz			Polymer Mix tank Level %		
Lime Slurry Feed lpm			Lime Tank Level %		
Polymer Feed Pump Hz			Iron Tank Level %		
Polymer Feed Pump lpm			Acid Tank Level %		
Ferric Feed Pump Hz			Clean Water Tank Level %		
Ferric Feed Pump lpm			Desludge Air Compressor Pressure psi		
Hypochlorite Feed pump Hz			Sodium Hypochlorite Tank level %		
Hypochlorite Feed pump lpm			Sulphuric Acid Tank Level %		
Acid Feed pump Hz			Chlorination system flow lps		
Acid Feed pump lpm			Free chlorine concentration		
Chlorination system pH			Total chlorine concentration		

The maintenance requirements for the Bermingham WTP are identified in the **Table 6-2** of the Design Report as:

Table 6-2: Equipment Maintenance Schedule

Equipment/Device	Maintenance Requirements				
	Daily	Weekly	Monthly	3 Months	6 Months
Reactor Agitator	Ensure it is rotating			Check gear box lube level	
Lime slurry peristaltic feed pumps	Check to ensure remote setting		Check wear on tubing	Change feed tubes	Oil bearings
	Check for frozen lines/blockage			Lubricate hosing	
Air compressors	Drain standing water				
	Check to ensure compressors on and valves in correct setting				
Reactor tank mixers	Ensure it is rotating				
Floc zone rake	Ensure it is rotating				
Clarifier plates	Clean off sludge build up				
De-sludge pneumatic valve	Check for proper air pressure				
Floc peristaltic feed pump	Check to ensure remote setting		Check wear on tubing	Change feed tubes	Oil bearings
	Check for line blockage			Lubricate hosing	
Floc tank agitator mixer	Check for proper rotation				
pH probes	Clean electrodes	Calibrate as necessary			
Turbidity meter	Drain, ensure proper flow in/out	Check incoming line for blockage			
		Calibrate as necessary			
Hypochlorite pumps	Check to ensure remote setting		Check wear on tubing	Change feed tubes	
	Check for frozen lines/blockage/leaks		Check diaphragm wear	Lubricate hosing	
Sulphuric acid pumps	Check to ensure remote setting		Check wear on tubing	Change feed tubes	
	Check for frozen lines/blockage/leaks		Check diaphragm wear	Lubricate hosing	
Chlorine probes	Clean electrodes	Calibrate as necessary			

Hecla has identified that this maintenance schedule is inaccurate and there is limited information available on maintenance in 2021 and 2022. For example, there is currently no access to the reactor agitator so an access is currently being engineered. The plants are not utilizing peristatic feed pumps, there are no air compressors, and there are no turbidity meters. Ausenco recommends that the maintenance procedures be updated and evaluated to determine what maintenance is required. It is currently not possible to evaluate whether plant maintenance is contributing to WTP operational challenges. Maintenance records were provided for 2021 and 2022. These records were primarily related to corrective actions. The "preventative" type of actions as envisioned in Table 6-2 were limited to: clarifier 6-month service in 2022.

4.3.2 Review of Adaptive Management Plan (AMP) and YESAA Application

The AMP has the following actions if there is a significant change in water quality:

Depending on the results of the evaluations, the MRP may consider the following measures:

- Reduce WTP discharge rates until corrective actions are implemented.
- Storage of water in underground sumps or the mill sediment pond to the extent practical to limit discharge until root causes have been identified and a solution implemented.
- If a root cause can be identified, plans will be implemented to manage the water quality, which may include modification of the WTP design or operating approach.

For a moderate "action level trigger" (e.g., WTP effluent exceeds EQS on weekly sample), the following is the management response:

- Engage a QP
- Initiate implementation of recommendations of the QP upon receipt.
- Update the MRP to include the mitigation options evaluated and the selection of the preferred response should the trend continue, and high action level triggers reached.
- Prepare a conceptual design of the preferred mitigation option and assess permitting requirements.
- Where appropriate, implement mitigation measures intended to manage water quality.

Based on changes to water quality related to ammonia, Hecla has already implemented a breakpoint chlorination (BPC) system to address the issues. Re-occurring exceedances for ammonia in 2023 are attributed to fine-tuning of the breakpoint chlorination (BPC) system and blasting practices resulting in higher ammonia concentrations in the underground water (since improved). While the YESAA and water licencing applications envisioned the use of ion exchange process, BPC is a well-established water treatment process for ammonia so is a suitable alternative. However, ion exchange remains a possibility. Installing an ion exchange system would require a short fine-tuning period in addition to the considerable lead time.

Similarly, for TSS at Bermingham WTP, Hecla has commissioned a study to determine potential actions. Ausenco advises that it is appropriate to wait for the conclusions of that study prior to enacting further changes related to TSS beyond the day-to-day actions already identified. In the meantime, it would be helpful to provide additional details on the AMP responses in the exceedance notifications. For example, the trend information to establish context for the exceedance and demonstrate the analysis required in the AMP is being conducted.

While the actions in the AMP do not include a consideration of changing the size of the settling pond. This should be evaluated as enabling the re-circulation of water that does not meet the requirements would be helpful combined with longer hold times. The current pond has only a maximum capacity of 1,205m^3 with a freeboard of 0.5 m. The original YESAA application (during exploration) proposed a 16m x 32m x 2m pond. Thus the size of the pond has already been altered meaning that another alternation may be possible within the existing YESAA assessments.

4.4 Recommendations

Based on a review of the design criteria compared to the water quality received by the Bermingham WTP, the conclusion is that outside of lead, the water is within the design specifications. As a result of the informal operations checks and maintenance, it isn't possible to determine whether the WTP is being operated within the design specifications. Thus, the first step would be to formalize the operations process to enable a daily checklist that is reasonable and then establish the correct maintenance protocols to ensure that there are logs and data available to review for future assessments.

Ausenco has reviewed the operating manuals for all three WTPs and concluded that a clear decision making flowchart for the parameters listed in the Water Licence would be helpful to ensure that all staff are clear on the procedures and that thresholds are set to limit exceedances. The current chart for Bermingham WTP Process Targets and Alarms illustrates that not all parameters in the Water Licence have thresholds:

Table 5: Bermingham WTP Process Targets and Alarms

Parameter	Units	Target	High alarm	Low alarm
Underground Water				
pH*	pH Units	6.5-9.5	9.8	None
Ammonia*	mg/L	<3	5	None
Lime Treatment Plant Effluent				
Reactor pH	pH units	9.2-9.6	9.8	8
Ferric sulphate*	Fe:As ratio	10:1	30:1	5:1
Turbidity	NTU	<2.5	3	None
Ammonia Plant Effluent				
pH In	pH units	8.2 - 8.5	8.6	7.9
pH Effluent	pH units	None	None	None
Total Chlorine	mg/L	<1.5	8	0
Free Chlorine	mg/L	0.1 - 0.5	5	0
ORP	mV	TBD	TBD	TBD
Ammonia Effluent*	mg/L	<1.5	1.5	None
Pond Decant				
Total chlorine*	mg/L	<0.1	0.2	None
Free chlorine*	mg/L	<0.1	0.2	None
Ammonia*	mg/L	<3	3	None
pH*	pH units	7-9	9.5	6.5
Zinc*	mg/L	<0.3	0.45	None
Arsenic*	mg/L	<0.004	0.004	None

*Parameters not actively measured using inline sensors

For example, the exceedances for Bermingham have been related to TSS, arsenic and lead which are not listed in this table. While there is a process for responding once there is an exceedance, there is not a threshold set prior to an exceedance to provide time to proactively address challenges prior to an exceedance occurring. Ausenco recommends that a threshold be set for nitrate and potentially nitrite to ensure that no acute toxicity effects are observed (i.e., samples pass the 96-hr Rainbow Trout LC50 test).

The current process for investigation of exceedances should be codified and records maintained. Greater details should be provided in the monthly reports including charts demonstrating performance of key parameters that have resulted in exceedances since 2021. This would enable all stakeholders to understand the relevant context.

The investigations have frequently concluded that underground activities are consistently resulting in exceedances. As a result, improved communication between the team responsible for underground activities and WTP operations is necessary. While there is limited capacity to retain water underground or in the settling ponds, advance notice could result in changes to WTP operations such as increasing BPC or flocculant dosing. Based on the current flow rates, it may be possible to re-circulate the treated water to improve performance. Alternatively, the size of the settling pond should be evaluated to increase holding times.

Given that a company has been retained to review the Bermingham WTP, it would be beneficial to implement the recommendations of Watertectonics and then re-evaluate after sufficient time to determine whether these recommendations are sufficient or further action is required to address the other parameters. It would be helpful to conduct modeling of water quality to predict the requirements for future water treatment prior to contemplating any significant design changes.

5.0 Summary and Recommendations

In summary, the majority of the environmental monitoring equipment and instruments are functional with a few exceptions such as the slope inclinometers, the one logger and staff gauge and the depths of two groundwater wells. It is recommended that the surface water flow station and groundwater stations be repaired.

A review of the reports and plans concluded that there is insufficient analysis and information presented to reach conclusions. It is recommended that a comprehensive re-evaluation be undertaken along with the development or refinement of the existing surface water model.

The current WROMP is sufficient; however, the review of waste rock management concluded that the following recommendations would be helpful:

- It would improve the clarity of the document if at the outset the waste rock storage areas were listed with their current inventories, waste rock type (P-AML or N-AML), relevant monitoring wells, footprint, etc.
- Visual waste rock classification scheme should be validated by a site-specific calibration process that confirms accuracy of the process under site conditions and at different percentage contents of carbonate, pyrite, galena and sphalerite
- Static and kinetic testing are important predictive strategies to pursue for solids obtained during active mine development but it is important to sample and test seepage water from existing waste rock facilities. This water is representative of the pore water chemistry within the waste rock pile and more accurately represents the constituents of concern from acid rock or neutral drainage as well as representing the field behaviour and not laboratory leaching rates.

For Bermingham WTP, the design specifications were compared to the current water quality for the influent and effluent. Predominantly the parameters are within design specifications. Due to a lack of records, it is not possible to determine whether operations and maintenance were performed as required. It is recommended that the processes for operations, maintenance, exceedance tracking and reporting be formalized and regularly tracked. Hecla has hired a water treatment expert to analyze and improve the performance at Bermingham WTP. After this evaluation and implementation of the changes, it would be beneficial to re-evaluate at regular intervals until compliance is regularly achieved.

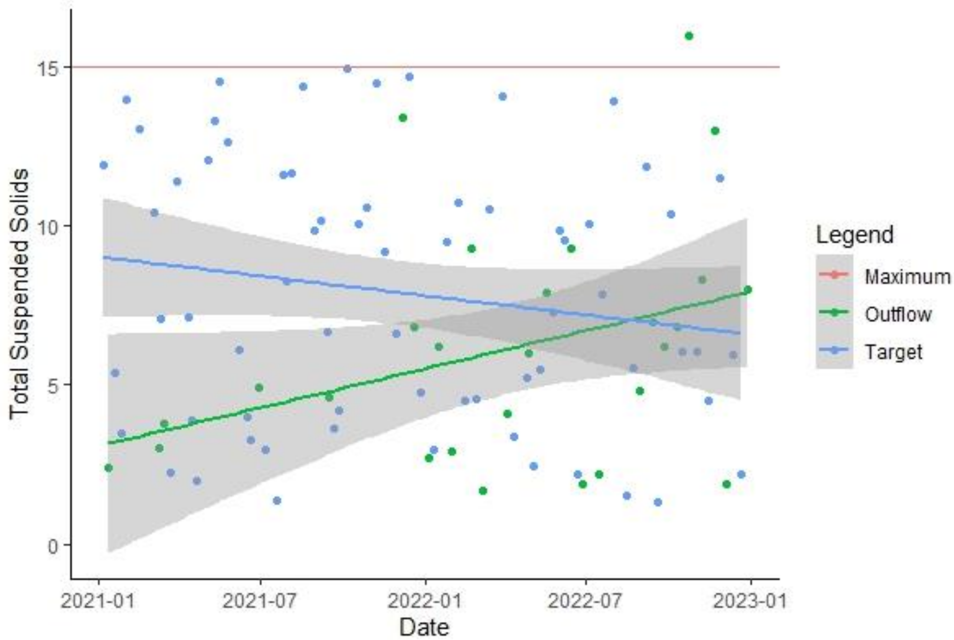
Appendix A

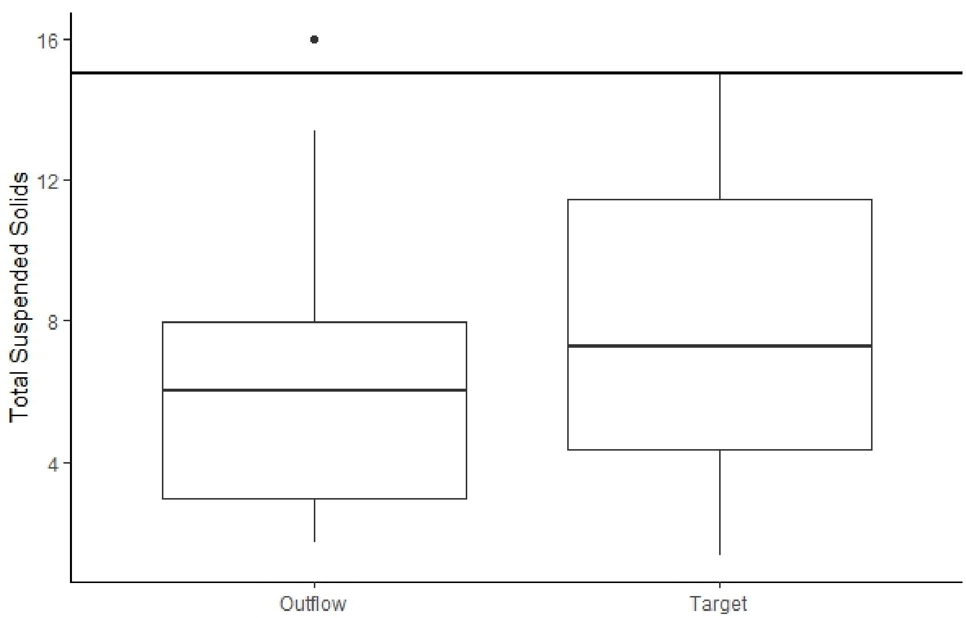
Statistical Analysis of Water Treatment Facilities

Note: Target is a random distribution between the EQS value and the lowest recorded value for each parameter.

Flame and Moth (FM), Outflow vs Target

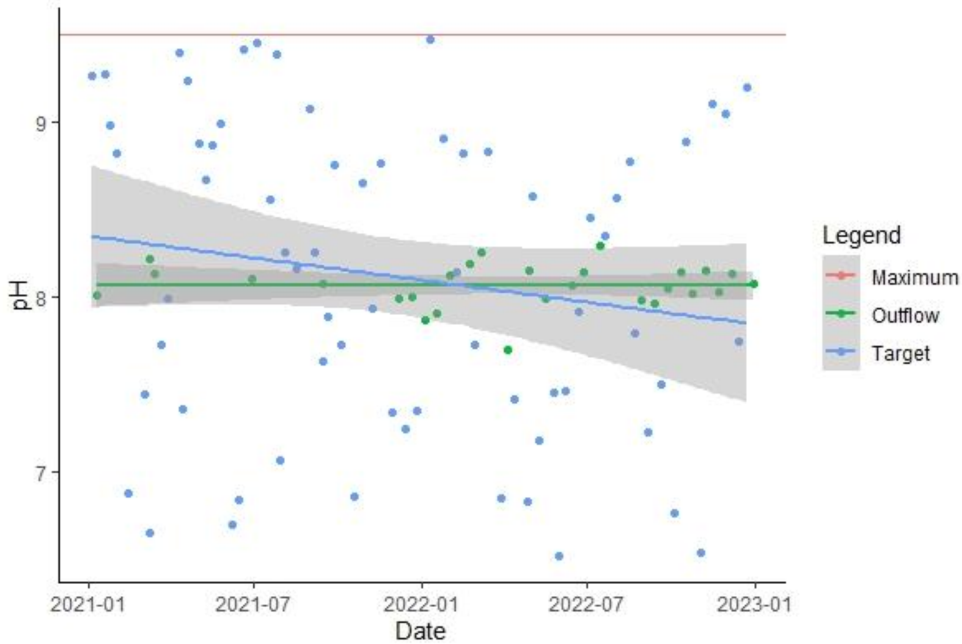
Total Suspended Solids (TSS)

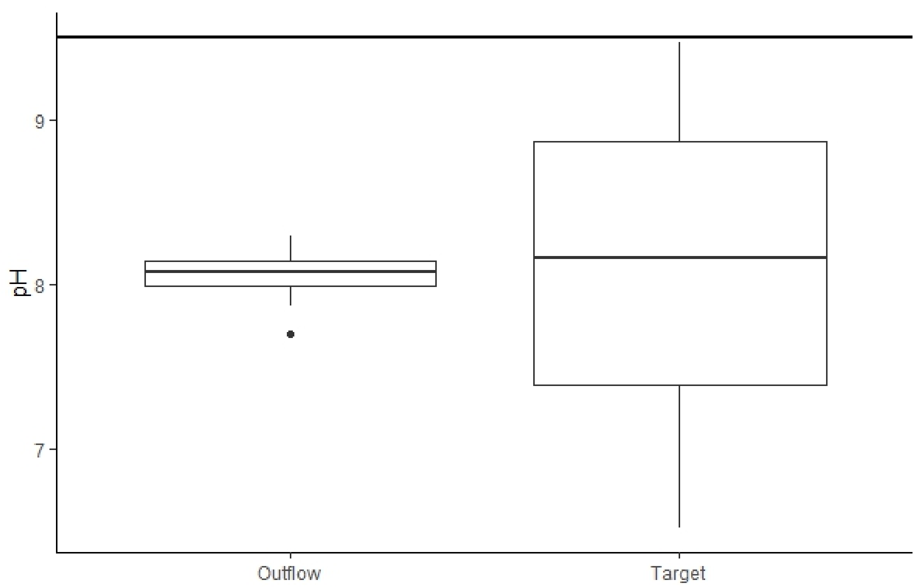





```
                    Wilcoxon rank sum test with continuity correction

data:  TSSFM by Flow
W = 871, p-value = 0.08627
alternative hypothesis: true location shift is not equal to 0
```

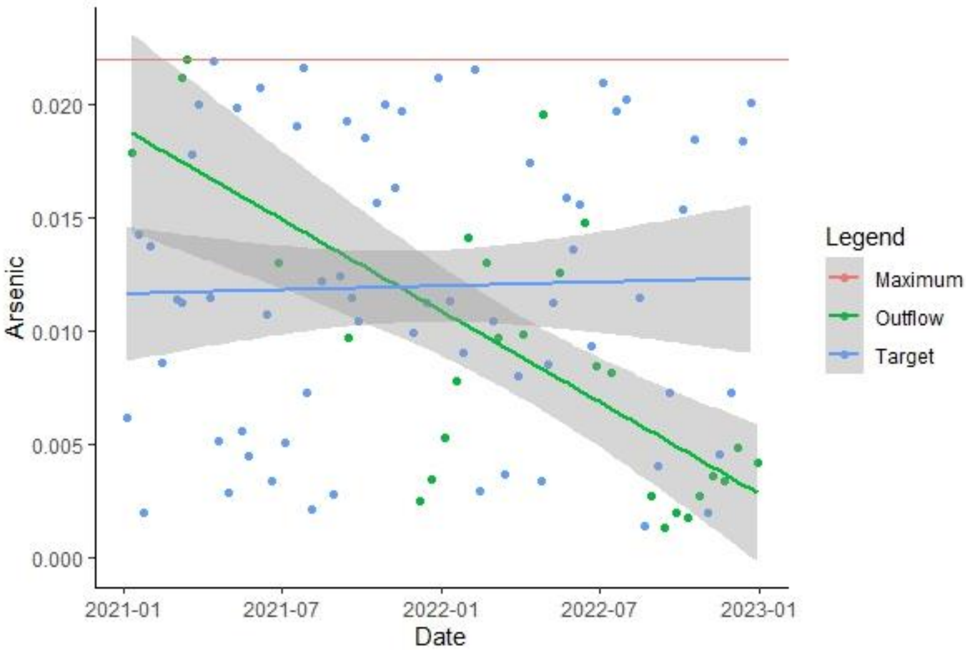
pH

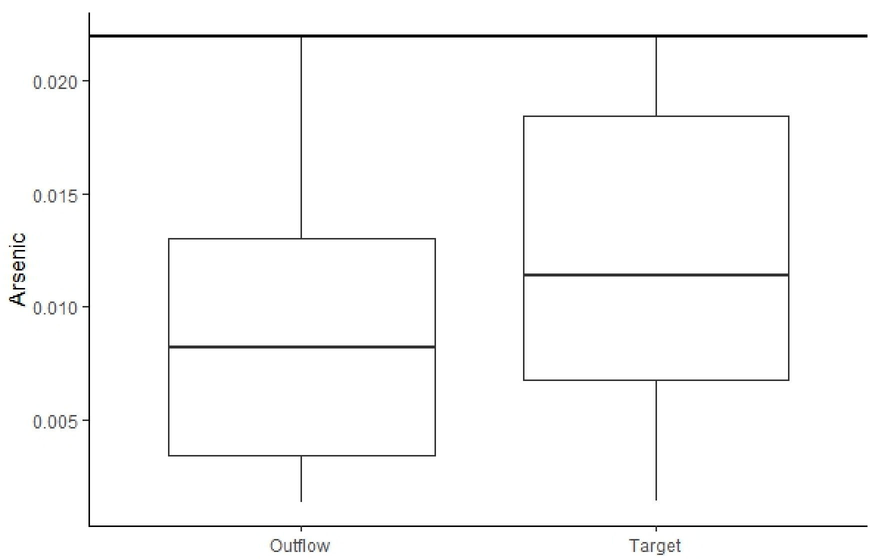





```
        Wilcoxon rank sum test with continuity correction

data:  pHFM by Flow
W = 1051, p-value = 0.6922
alternative hypothesis: true location shift is not equal to 0
```

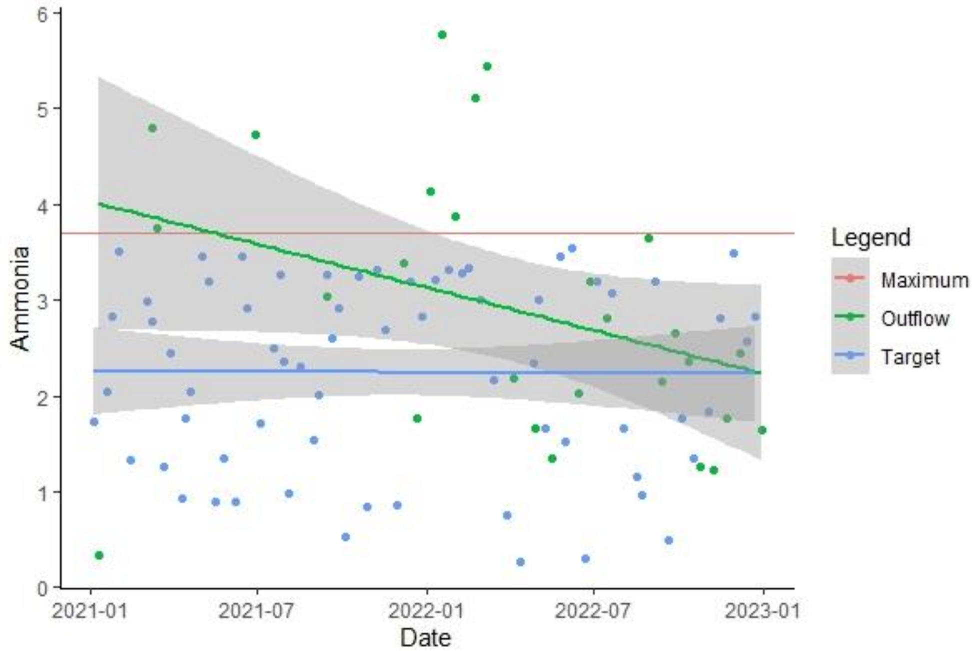
Arsenic (As)

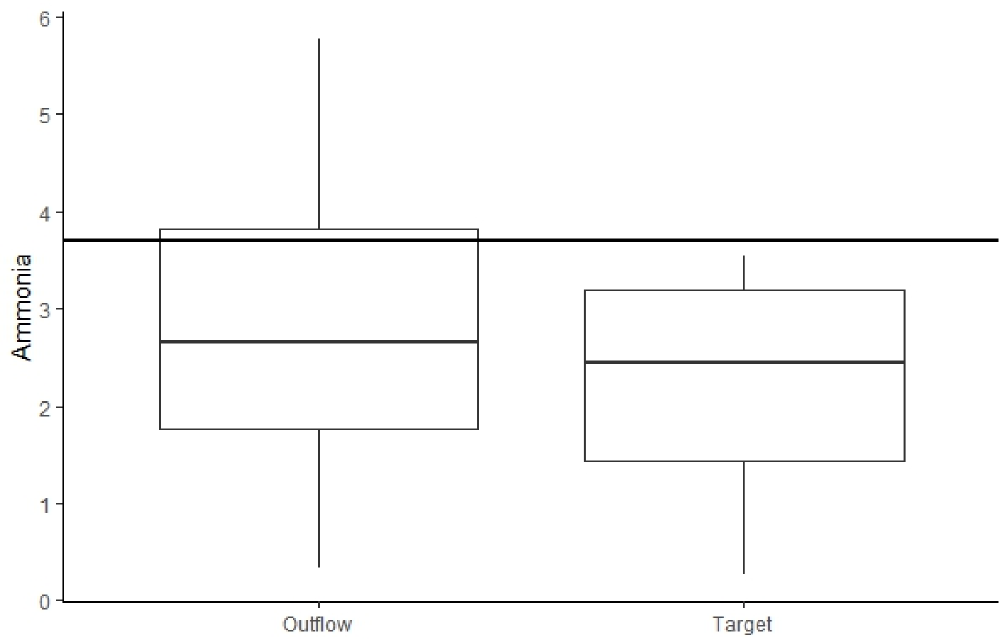





```
        Wilcoxon rank sum test with continuity correction

data:  AsFM by Flow
W = 813, p-value = 0.03231
alternative hypothesis: true location shift is not equal to 0
```

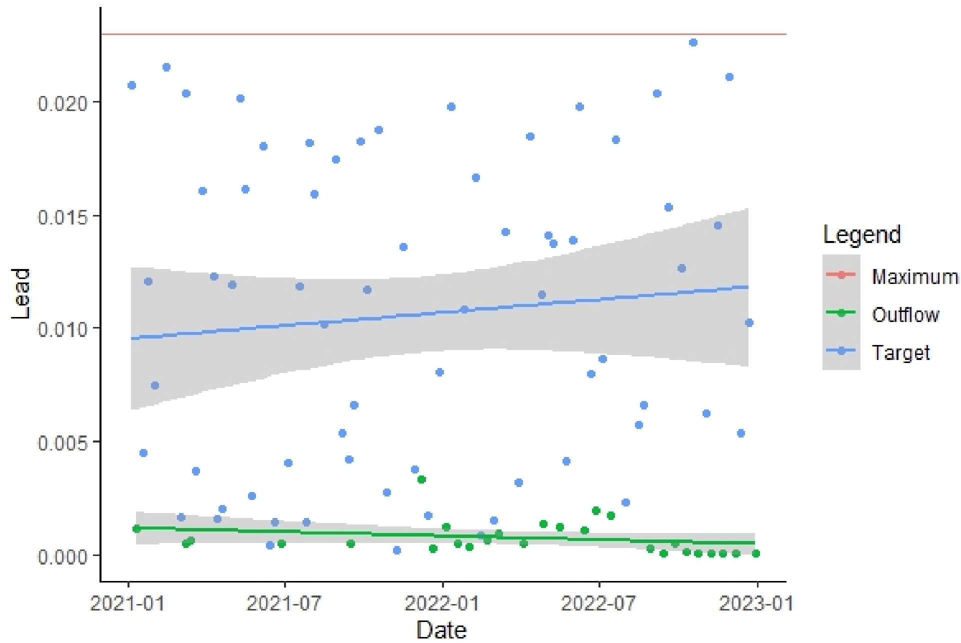
Ammonia (Am)

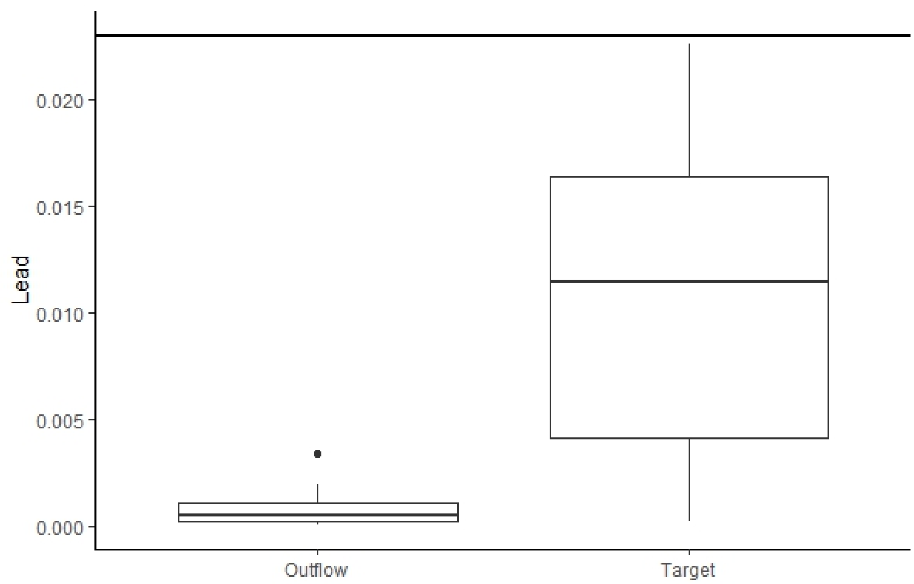





```
Wilcoxon rank sum test with continuity correction

data:  AmFM by Flow
W = 1353, p-value = 0.03586
alternative hypothesis: true location shift is not equal to 0
```

Lead (Pb)

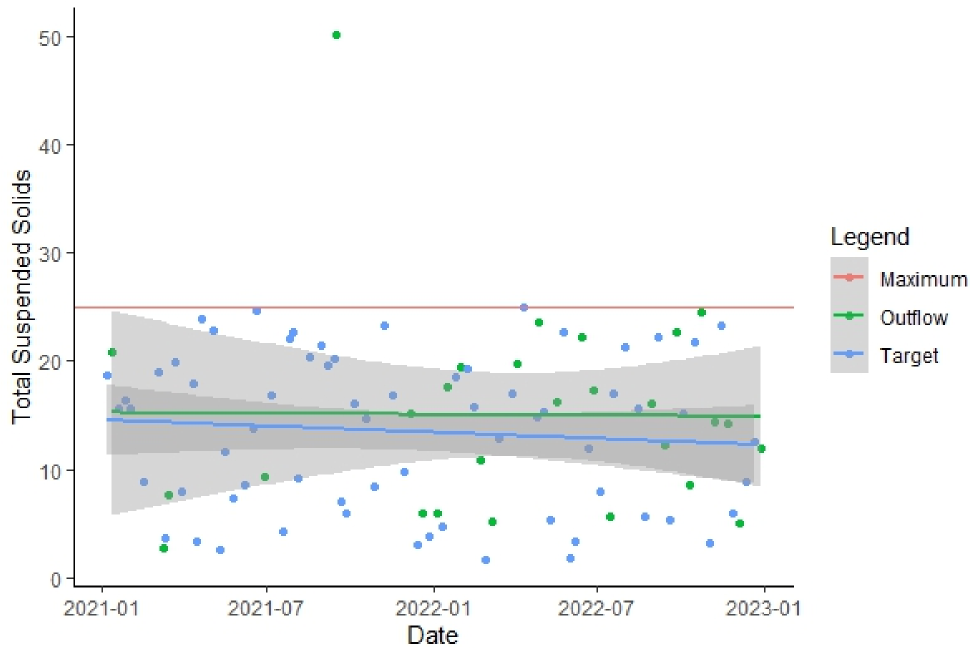


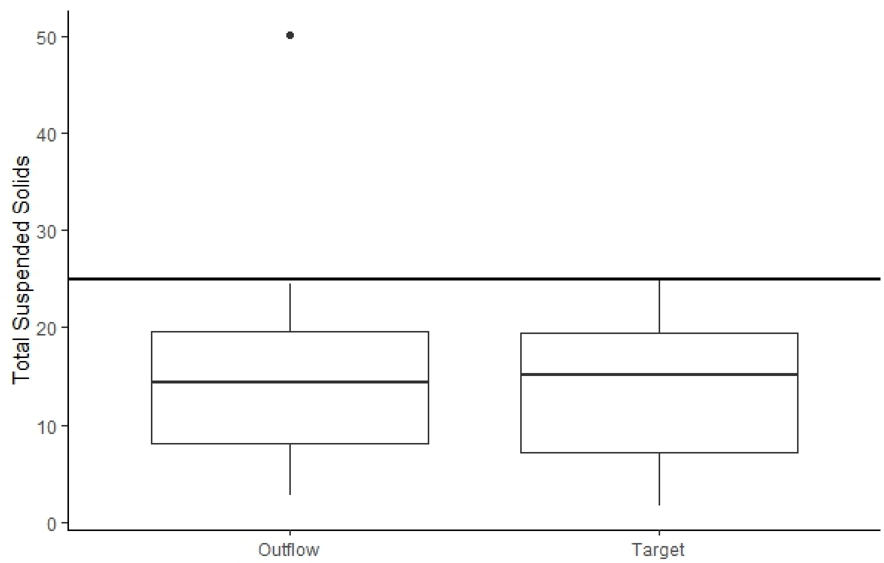



```
        Wilcoxon rank sum test with continuity correction

data:  PbFM by Flow
W = 108, p-value = 2.7e-13
alternative hypothesis: true location shift is not equal to 0
```

Bermingham (BH), Outflow vs Target

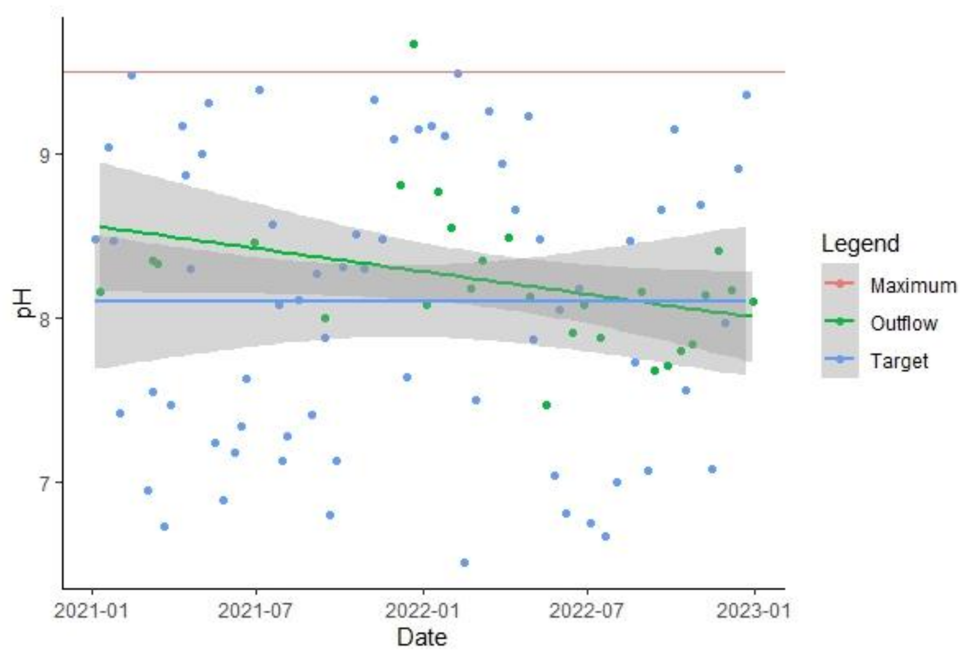
Total Suspended Solids (TSS)

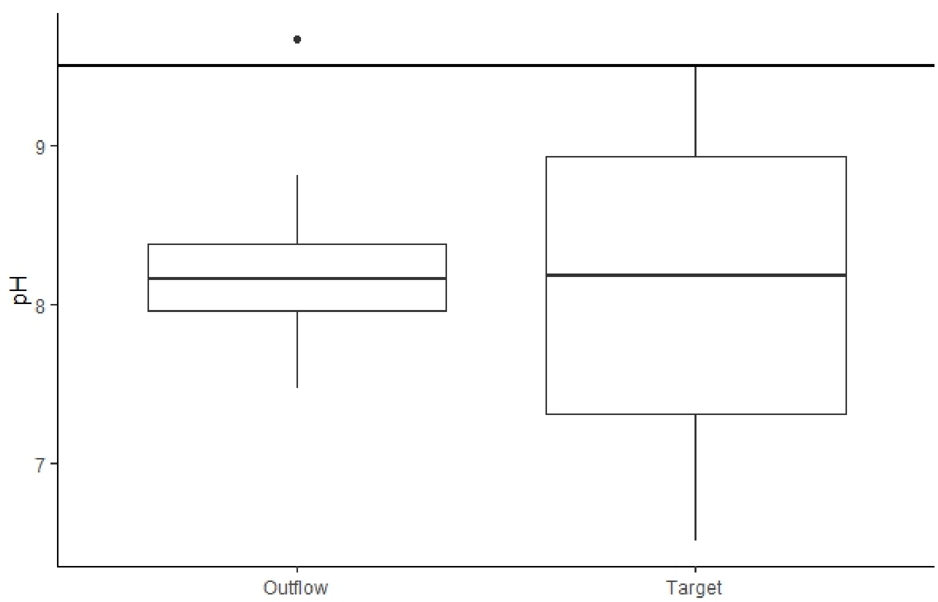





```
        Wilcoxon rank sum test with continuity correction

data:  TSSBH by Flow
W = 1795, p-value = 0.9439
alternative hypothesis: true location shift is not equal to 0
```

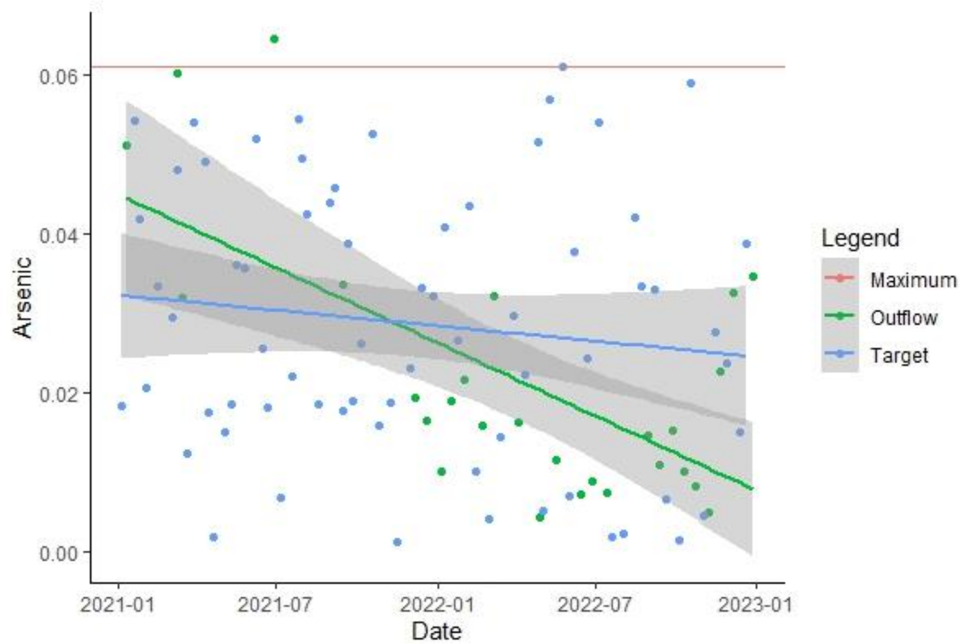
pH

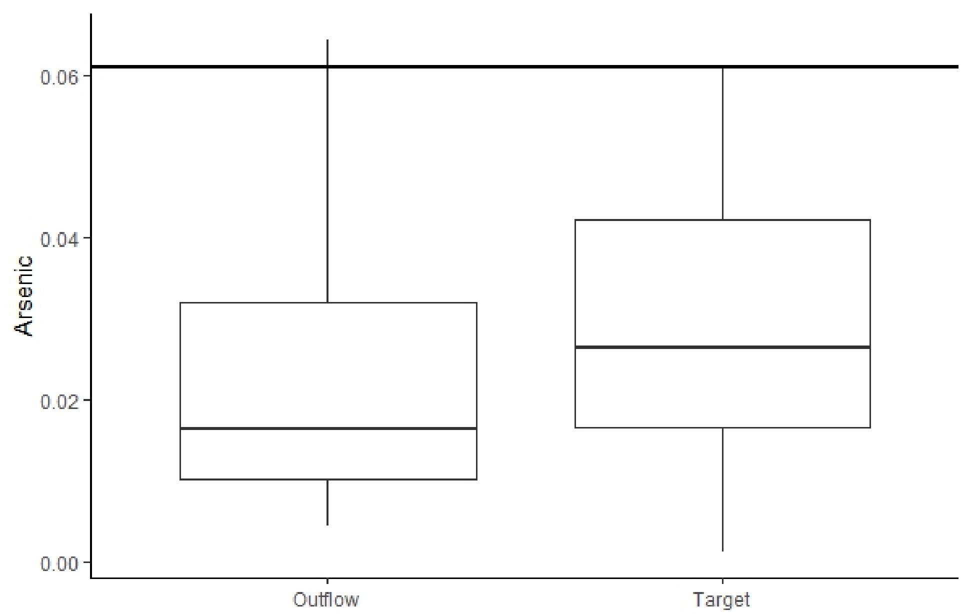





```
        Wilcoxon rank sum test with continuity correction

data:  Phbh by Flow
W = 1909, p-value = 0.6039
alternative hypothesis: true location shift is not equal to 0
```

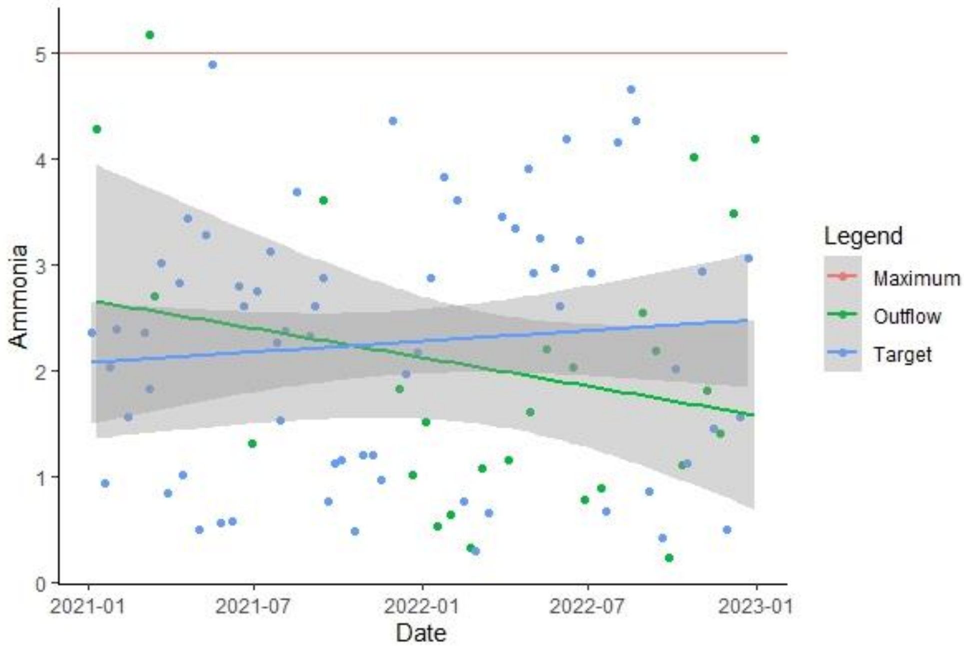
Arsenic (As)

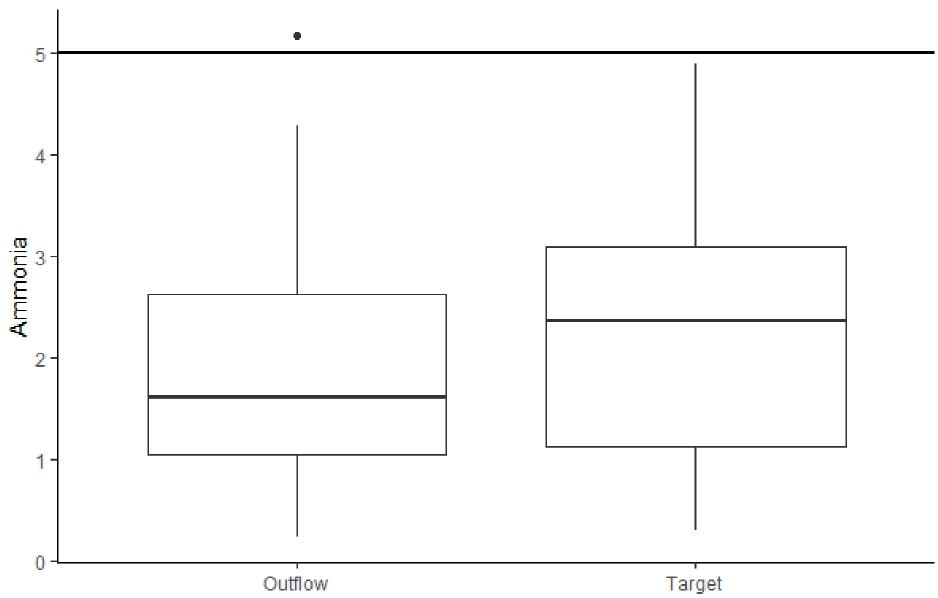





```
        Wilcoxon rank sum test with continuity correction

data:  AsBH by Flow
W = 1619, p-value = 0.3231
alternative hypothesis: true location shift is not equal to 0
```

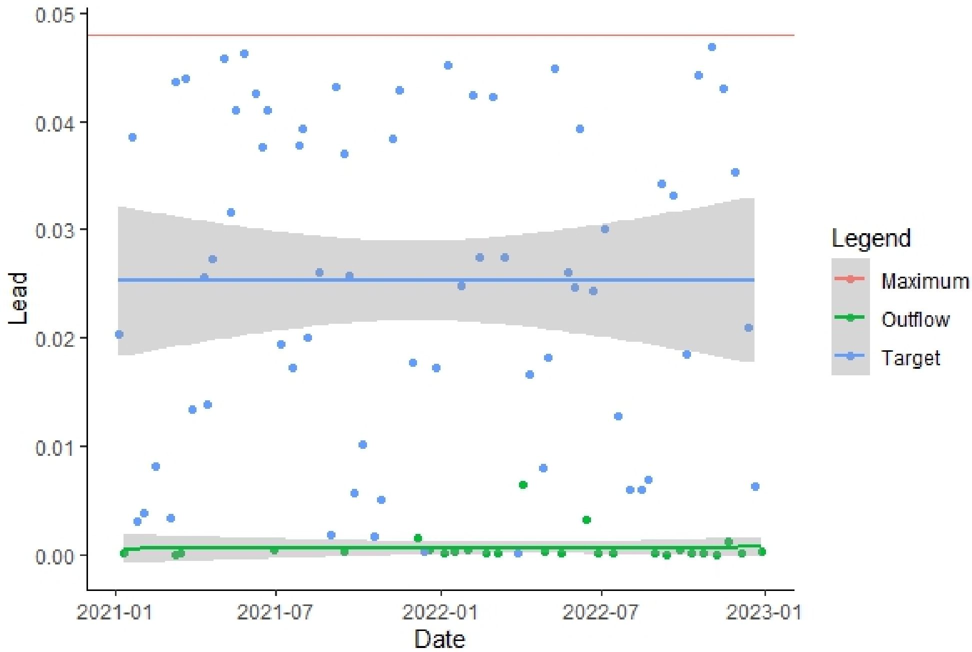
Ammonia (Am)

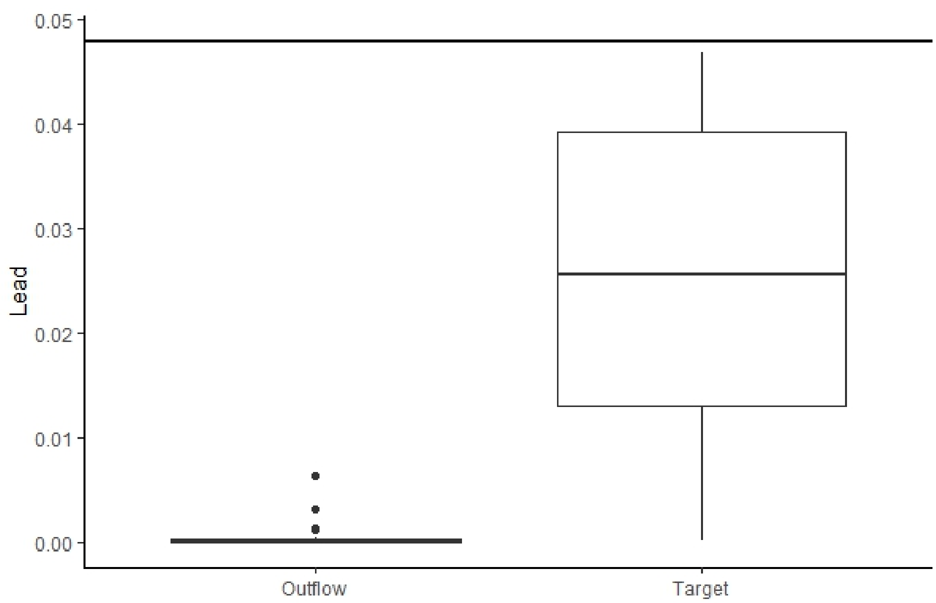





```
                 Wilcoxon rank sum test with continuity correction

data:  AmBH by Flow
W = 1713, p-value = 0.7432
alternative hypothesis: true location shift is not equal to 0
```

Lead (Pb)



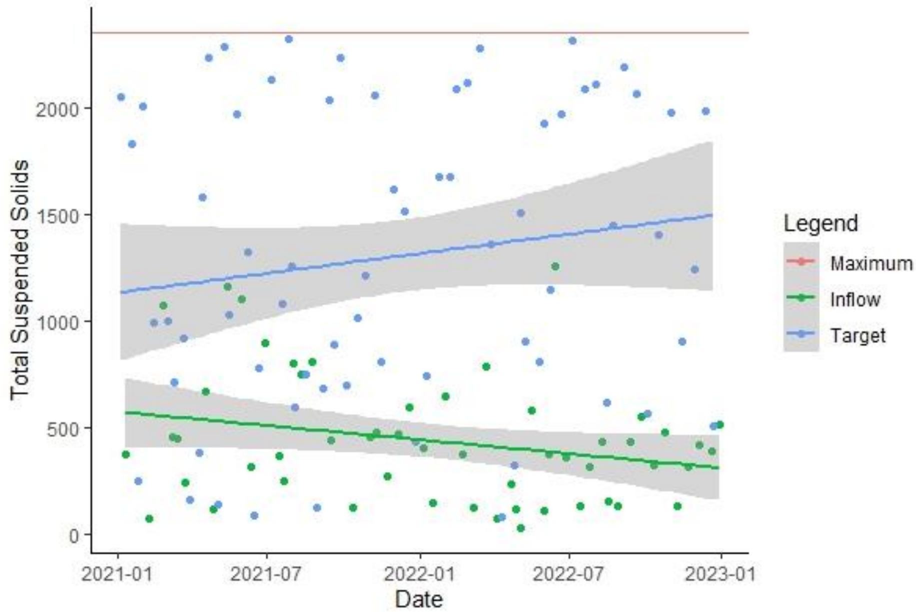


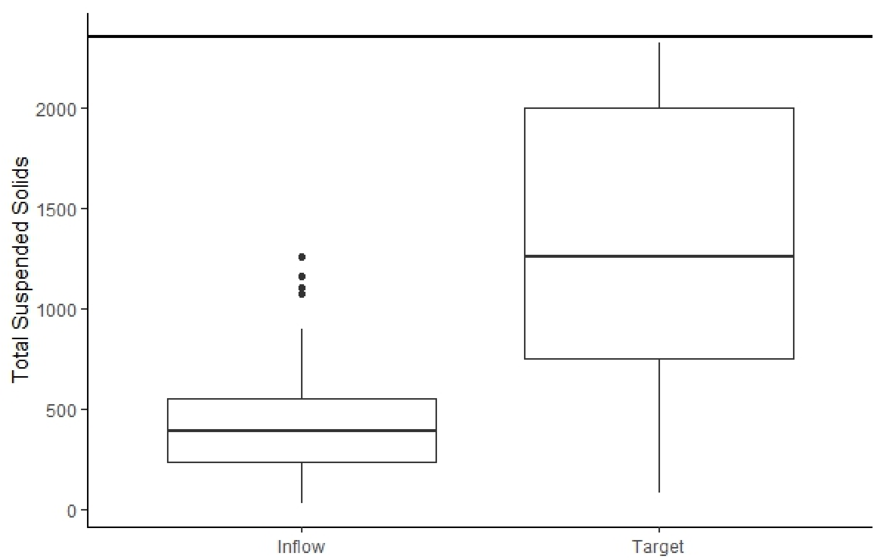

```
        Wilcoxon rank sum test with continuity correction

data:  PbBH by Flow
W = 116, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

Bermingham (BH), Inflow vs Target

Note: The target values are a random distribution between the minimum and maximum design criteria.

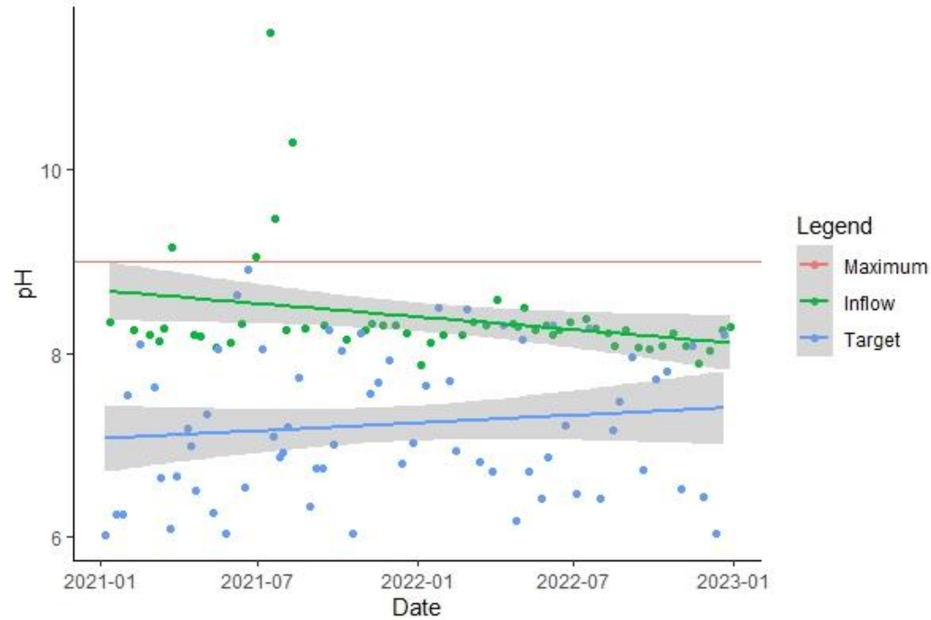
Total Suspended Solids (TSS)

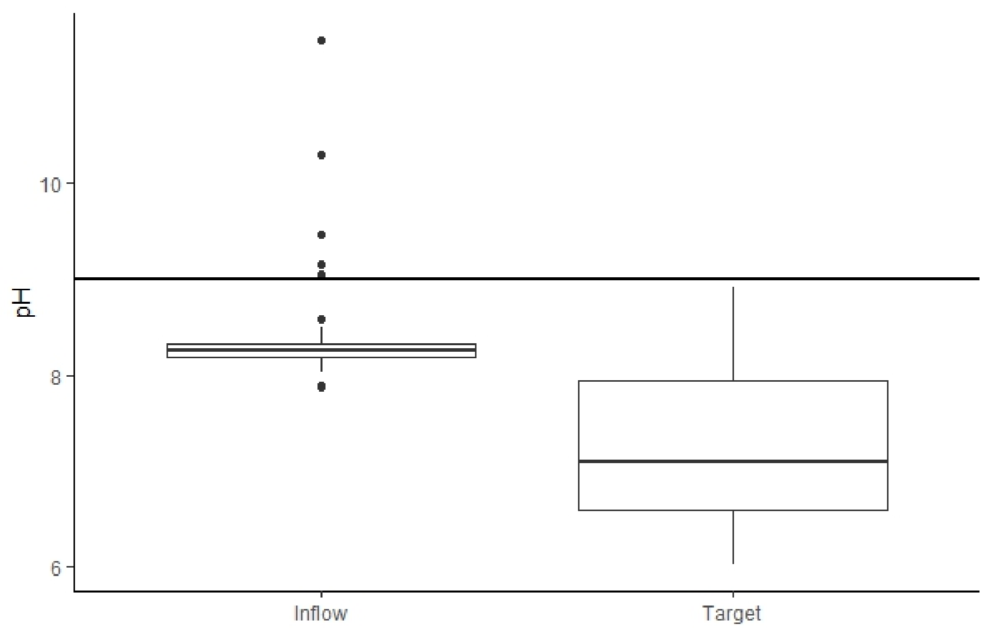





```
        Wilcoxon rank sum test with continuity correction

data:  TSSBH by Flow
W = 499, p-value = 1.548e-11
alternative hypothesis: true location shift is not equal to 0
```

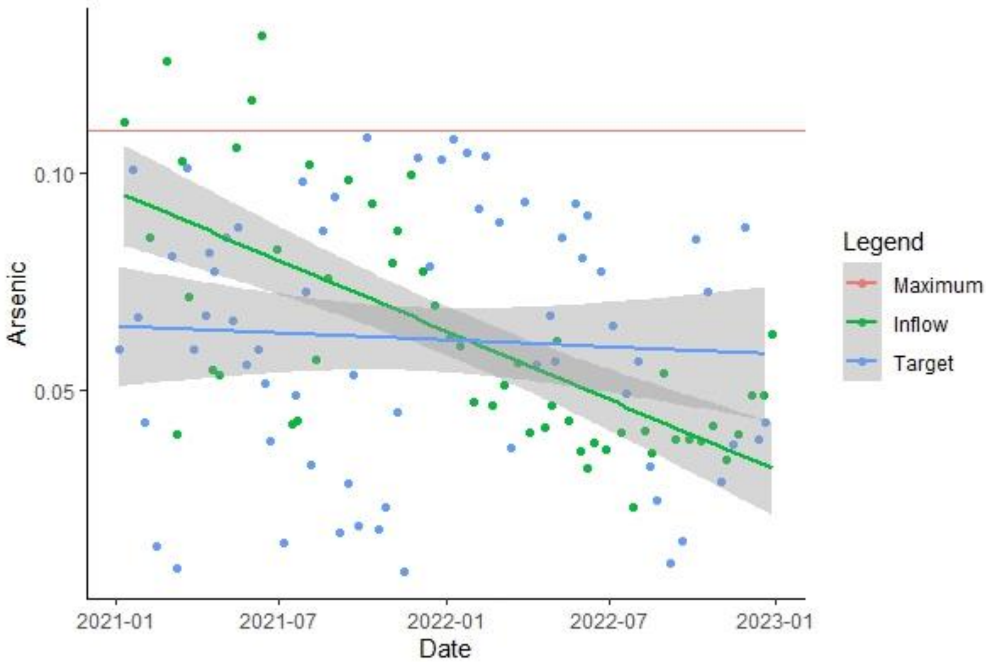
pH

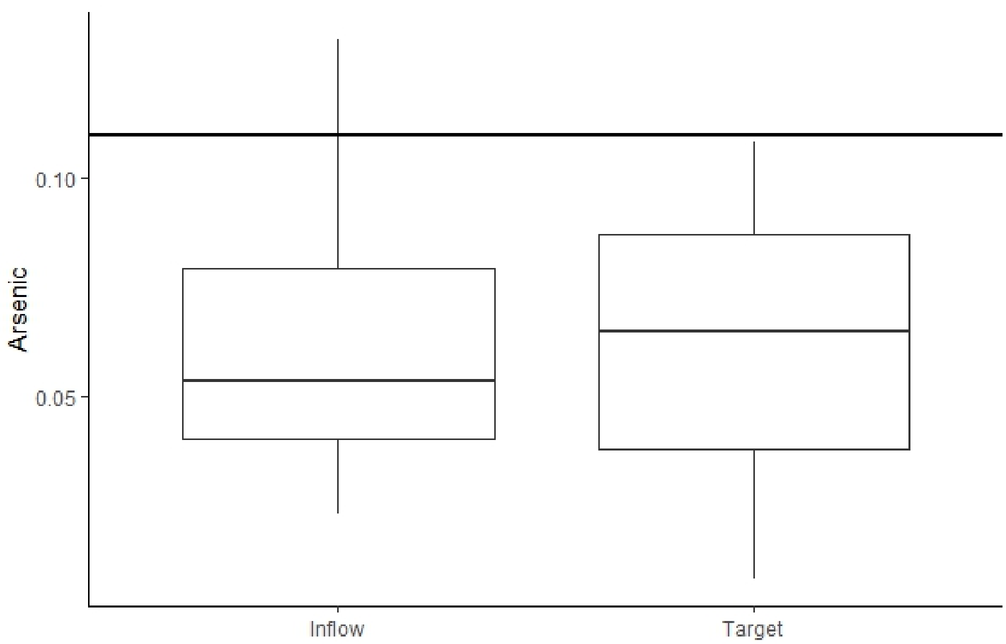





```
        Wilcoxon rank sum test with continuity correction

data:  pHBH by Flow
W = 3157, p-value = 2.893e-13
alternative hypothesis: true location shift is not equal to 0
```

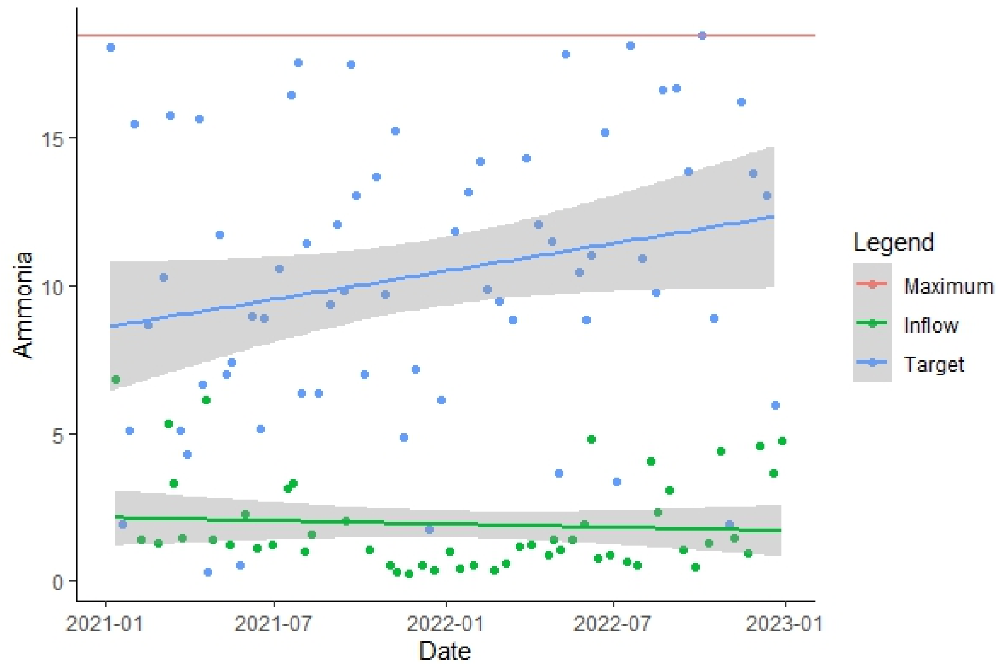
Arsenic (As)

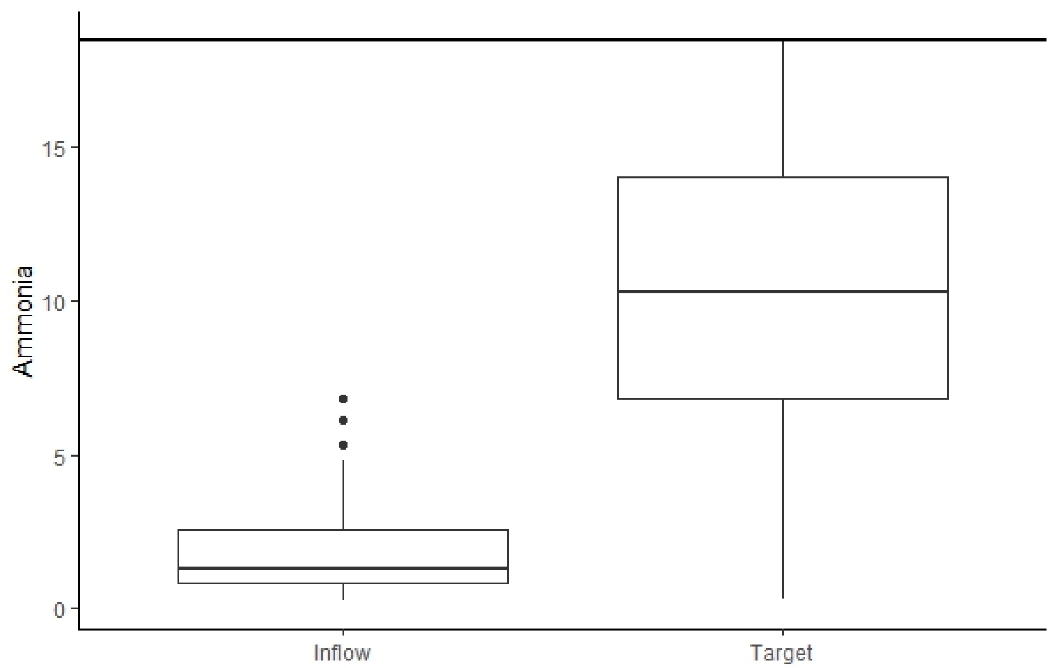





```
        Wilcoxon rank sum test with continuity correction

data:  AsBH by Flow
W = 1725, p-value = 0.7916
alternative hypothesis: true location shift is not equal to 0
```

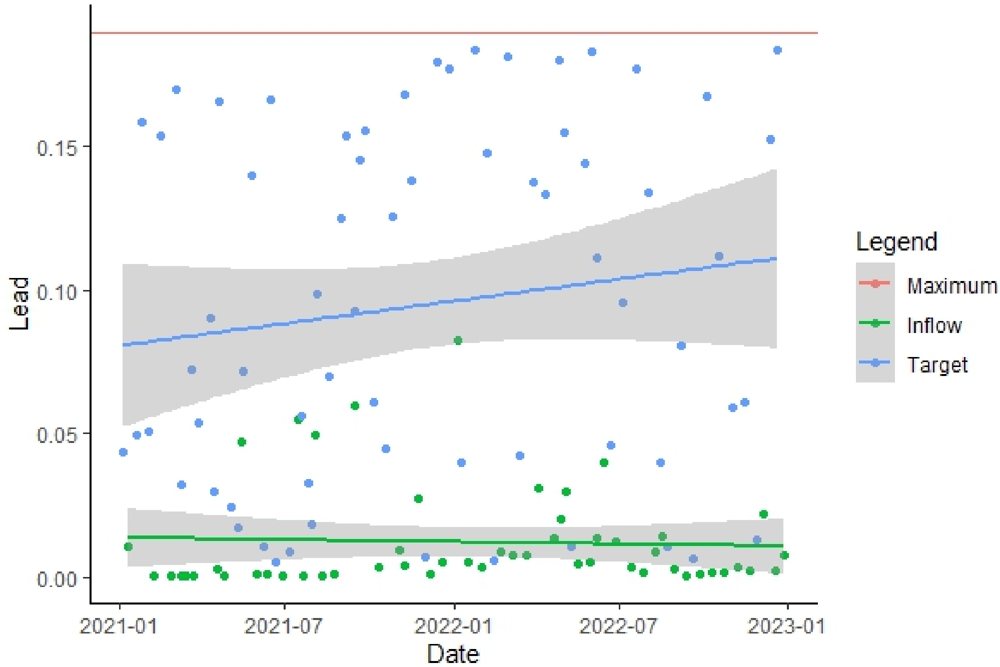
Ammonia (Am)

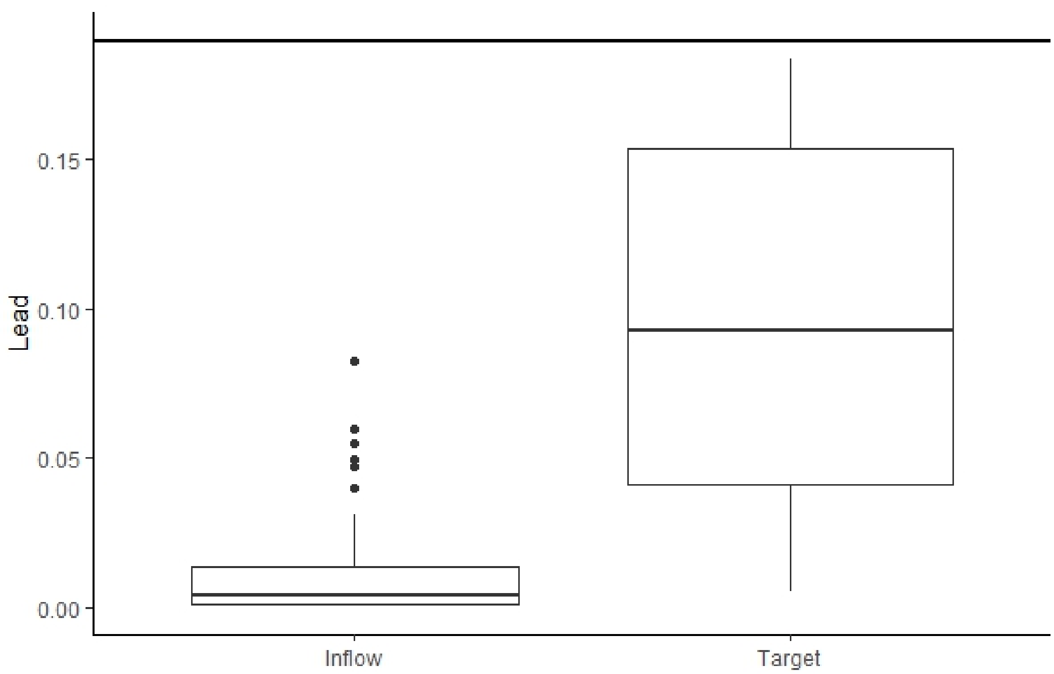





```
Wilcoxon rank sum test with continuity correction

data:  AmBH by Flow
W = 189, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

Lead (Pb)





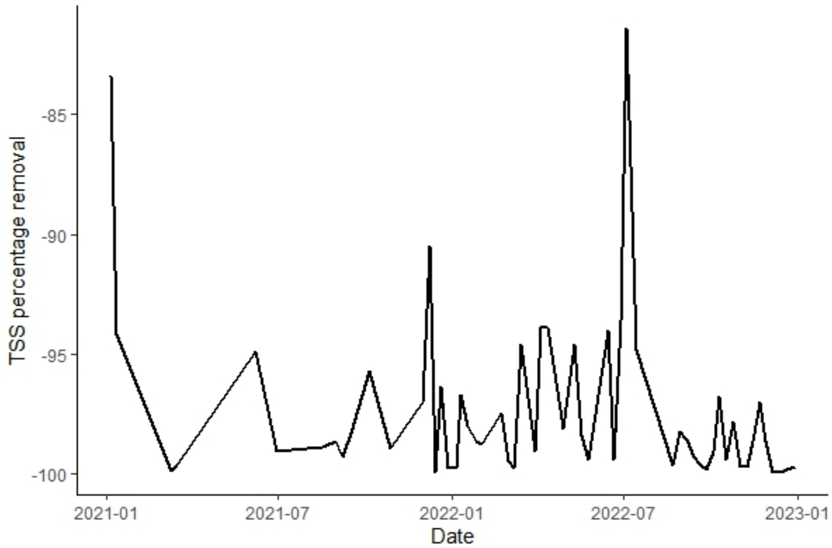

```
Wilcoxon rank sum test with continuity correction

data:  PbBH by Flow
W = 268, p-value = 1.654e-15
alternative hypothesis: true location shift is not equal to 0
```

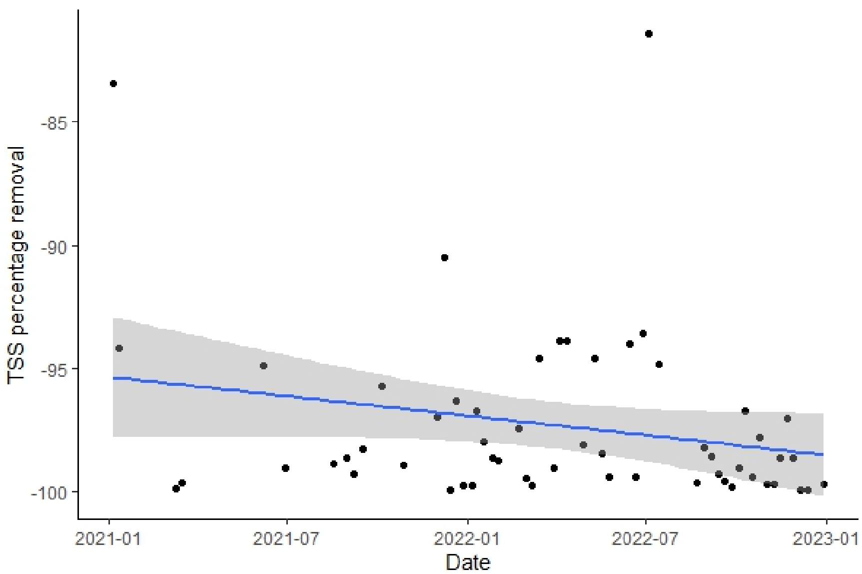
Change in percentage removal over time

Note that positive values mean that rather than removing that parameter during treatment, the concentration increased from the adit water to the effluent water.

Flame and Moth

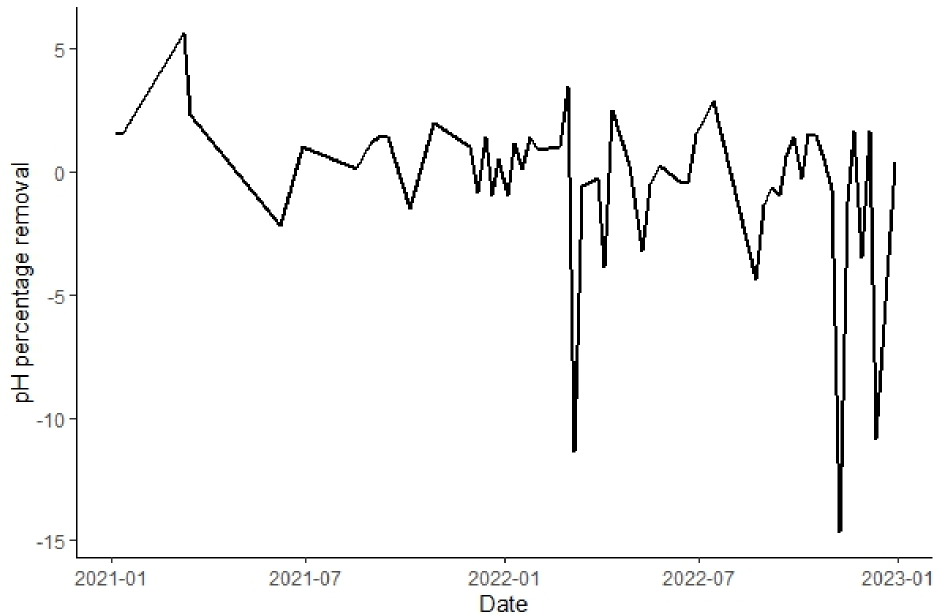
Total Suspended Solids (TSS)

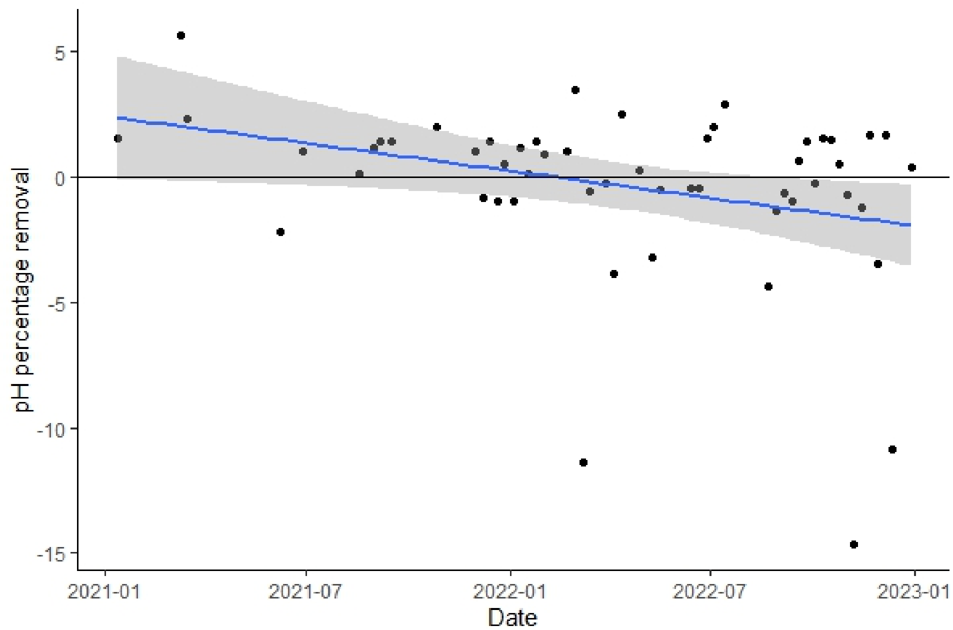





```
          Spearman's rank correlation rho

data:  HecR1$Day and HecR1$TSSFM
S = 63630, p-value = 0.02763
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.2696544
```

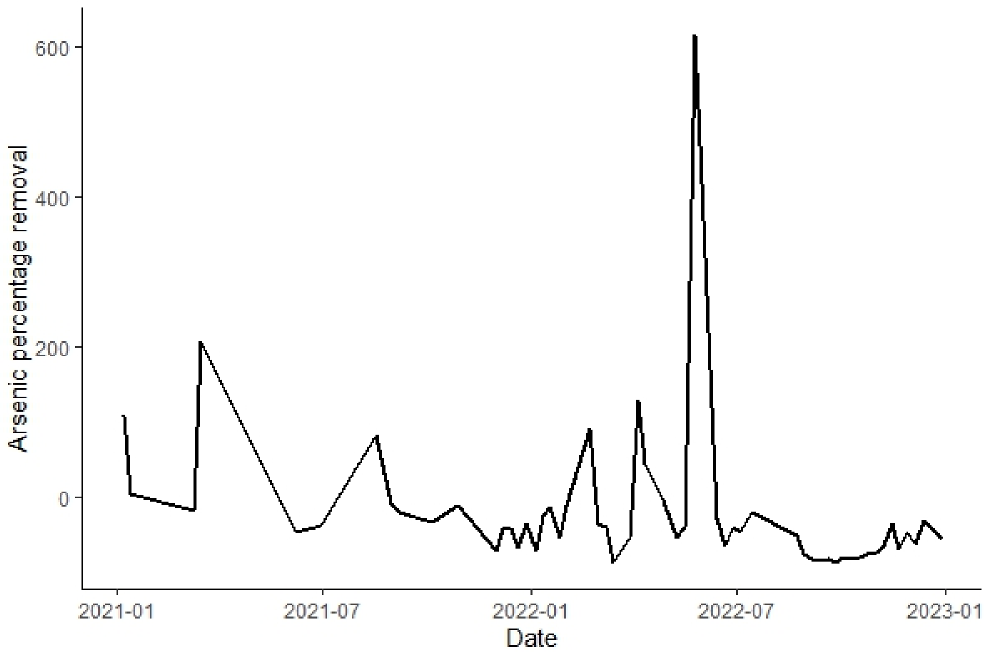
pH

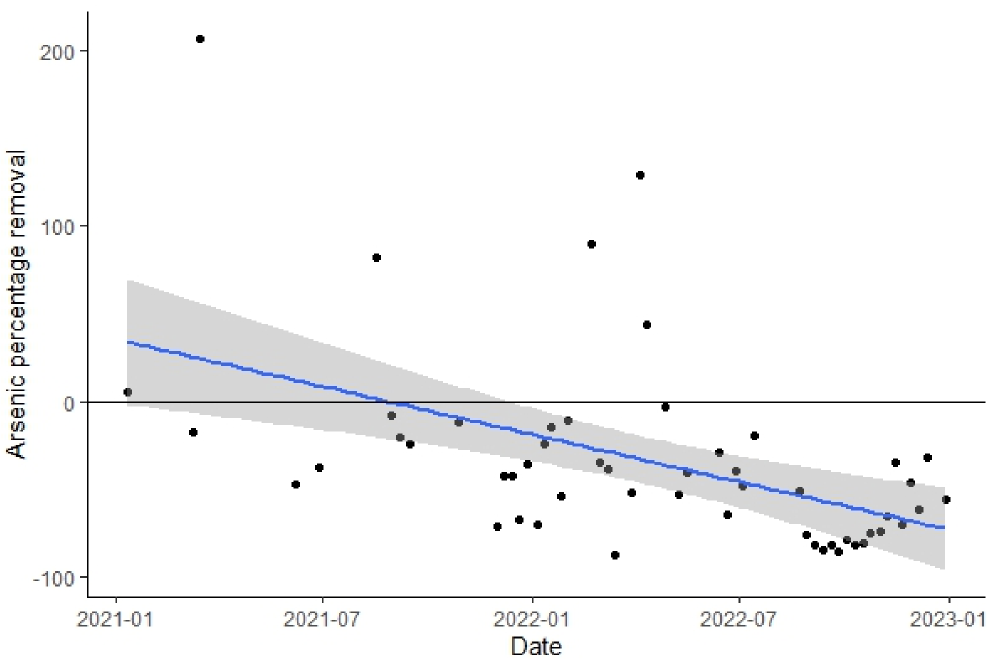





```
                Spearman's rank correlation rho

data:  HecR$Day and HecR$pHFM
S = 67584, p-value = 0.01648
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.2899242
```

Arsenic (As)

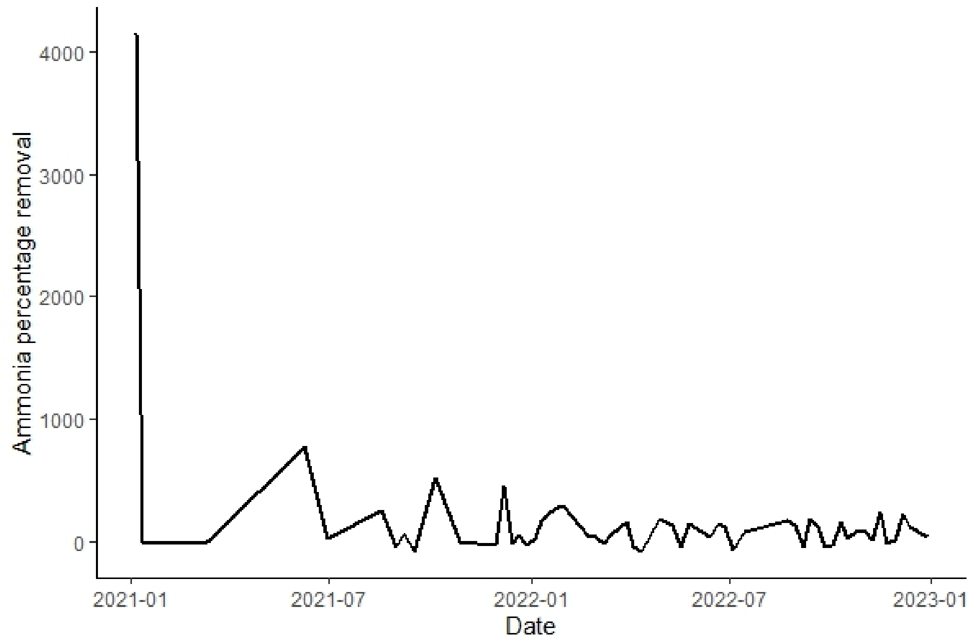


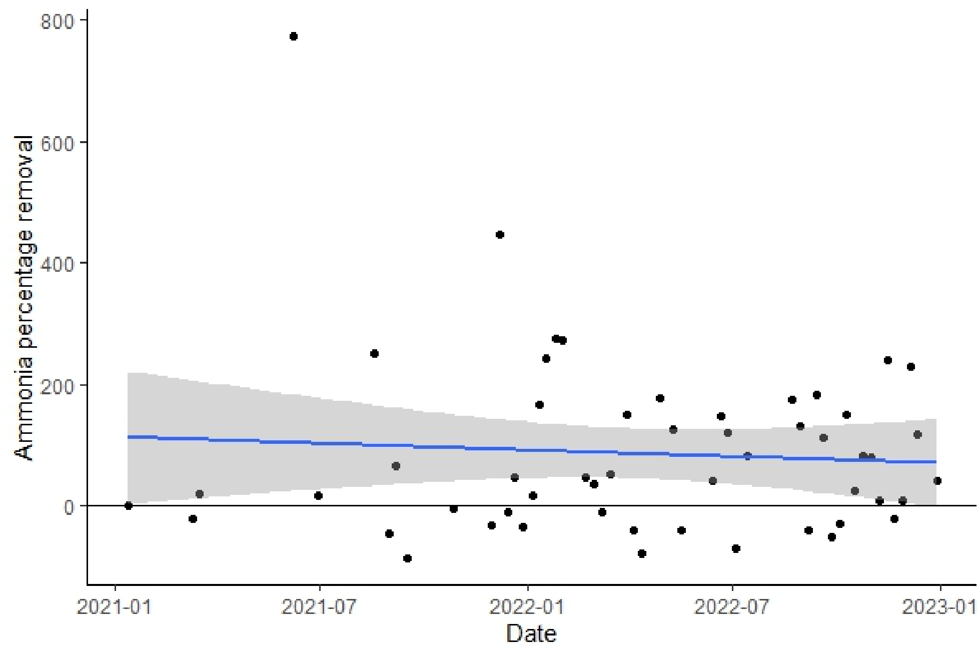


One outlier removed.

```
Spearman's rank correlation rho

data:  HecR$Day and HecR$AsFMx
S = 74630, p-value = 1.773e-06
alternative hypothesis: true rho is not equal to 0
sample estimates:
      rho -0.557875
```

Ammonia (Am)

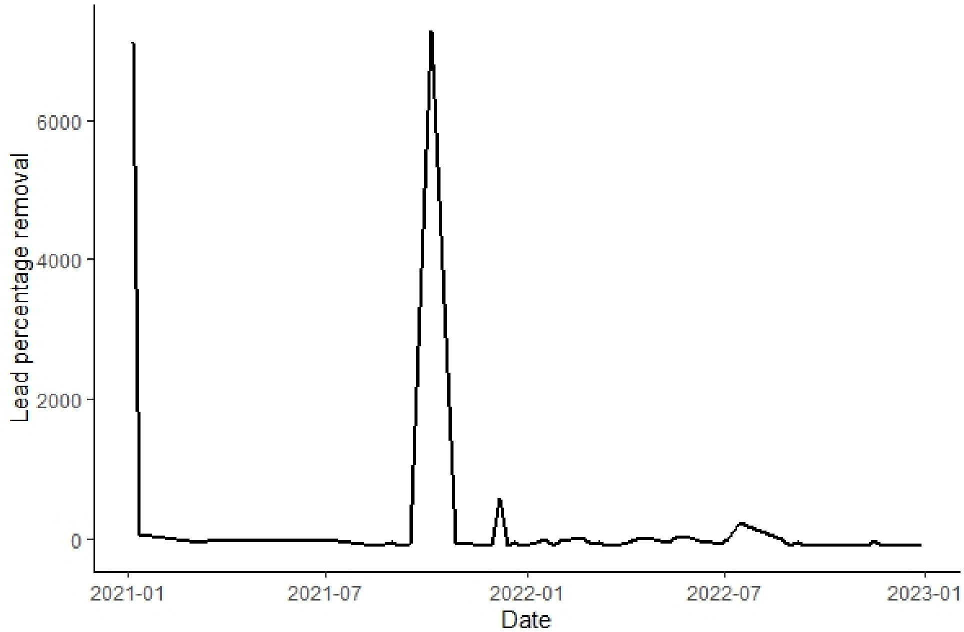


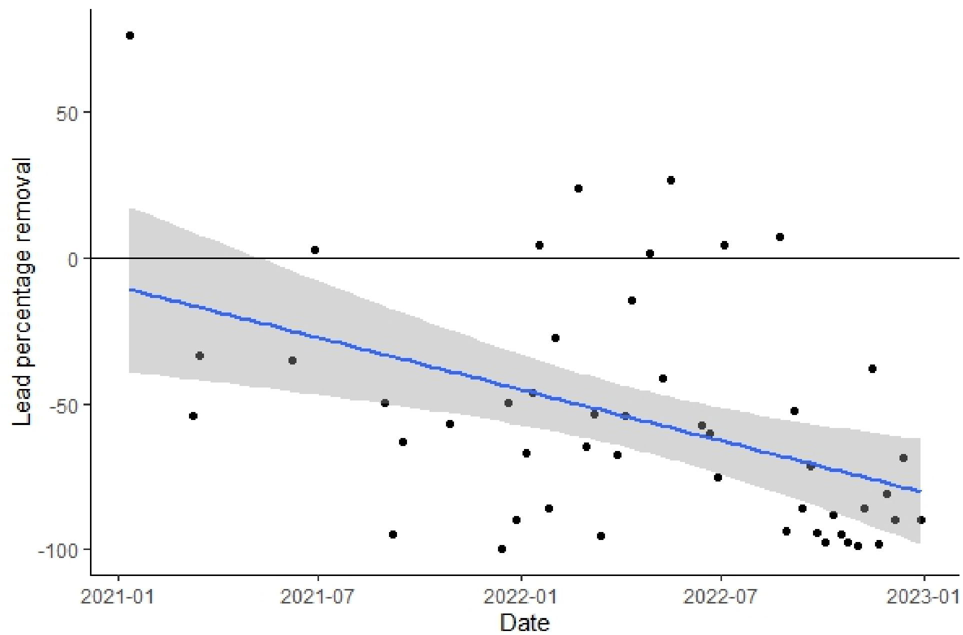


Two outlier removed.

```
Spearman's rank correlation rho

data:  HecR$Day and HecR$AmFMx
S = 45078, p-value = 0.9061
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho 0.01490385
```

Lead (Pb)



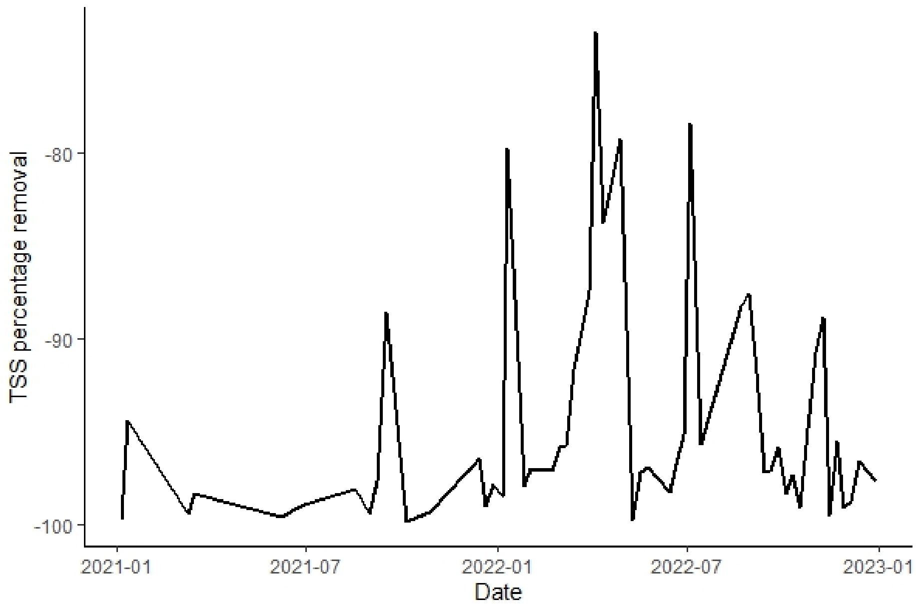


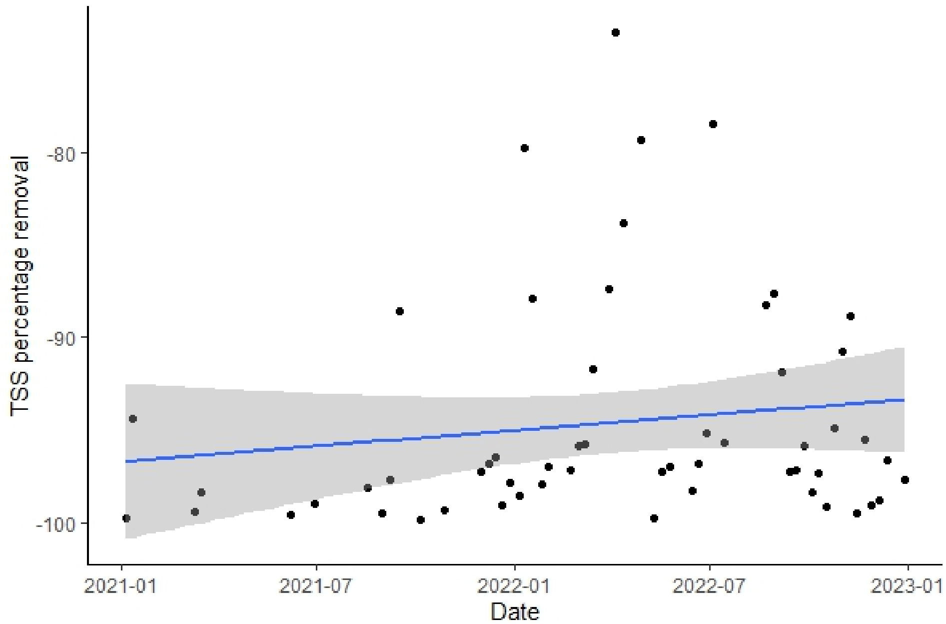
Five outlier removed.

```
                Spearman's rank correlation rho

data:  HecR$Day and HecR$PbFMx
S = 55673, p-value = 0.007055
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.3362297
```

Bermingham

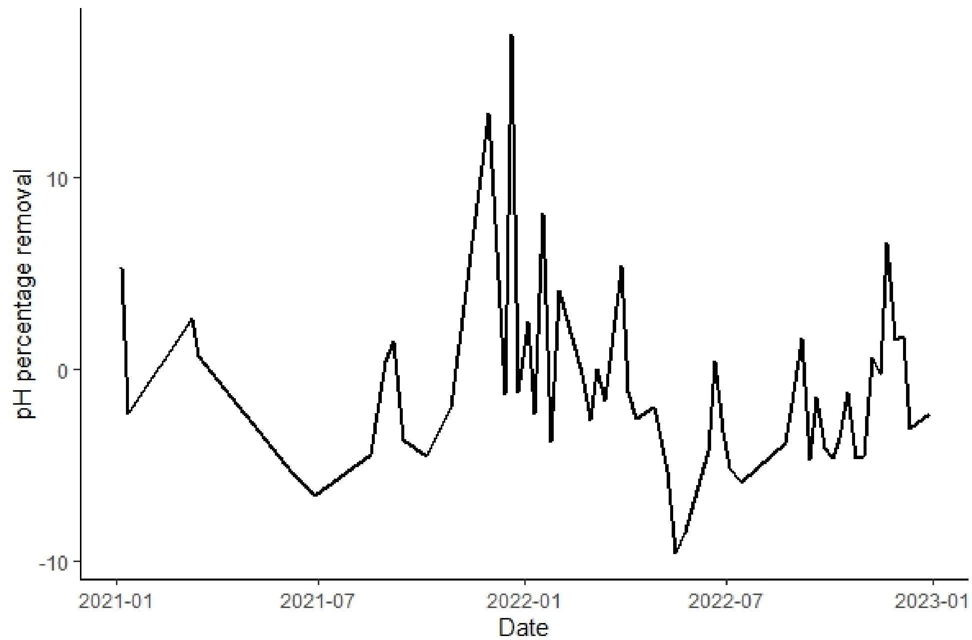
Total Suspended Solids (TSS)

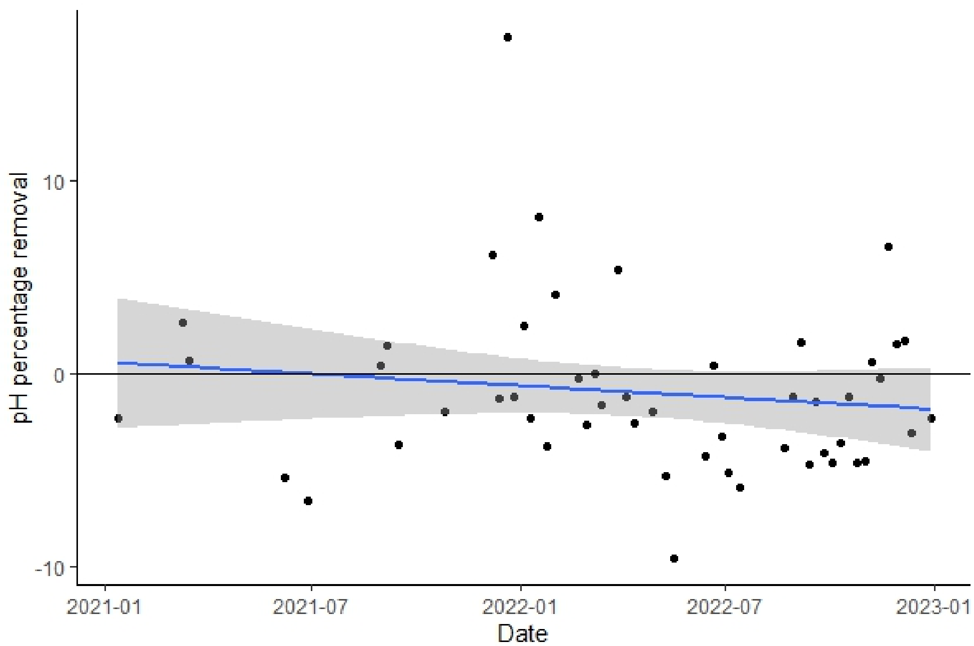





```
                    Spearman's rank correlation rho

data:  HecR$Day and HecR$TSSBH
S = 96712, p-value = 0.0001098
alternative hypothesis: true rho is not equal to 0
sample estimates:
     rho
0.383407
```

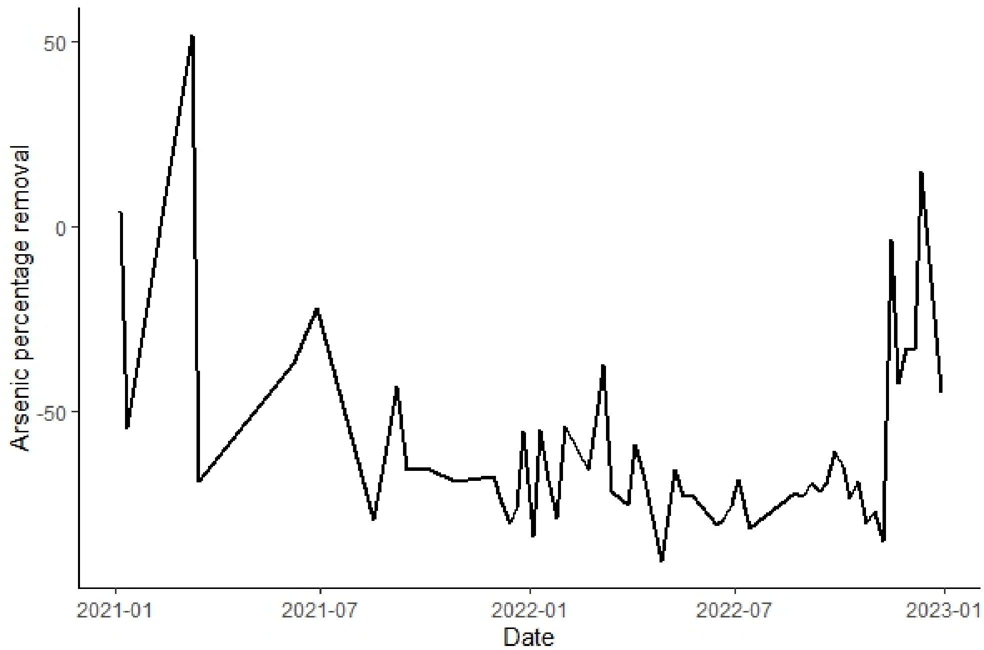
pH

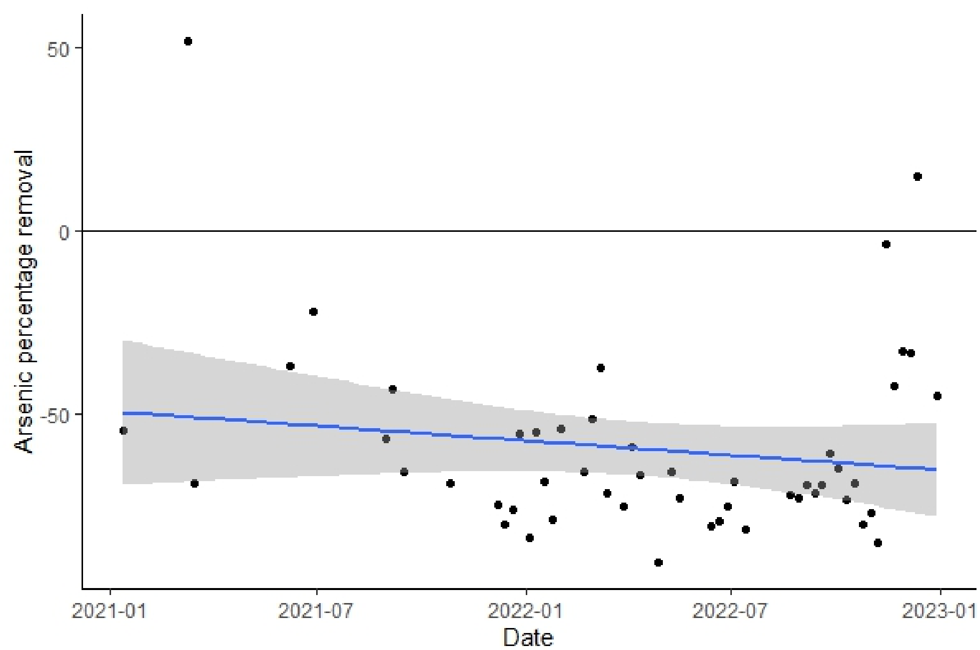





```
                    Spearman's rank correlation rho

data:  HecR$Day and HecR$pHBH
S = 176851, p-value = 0.2108
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.1275256
```

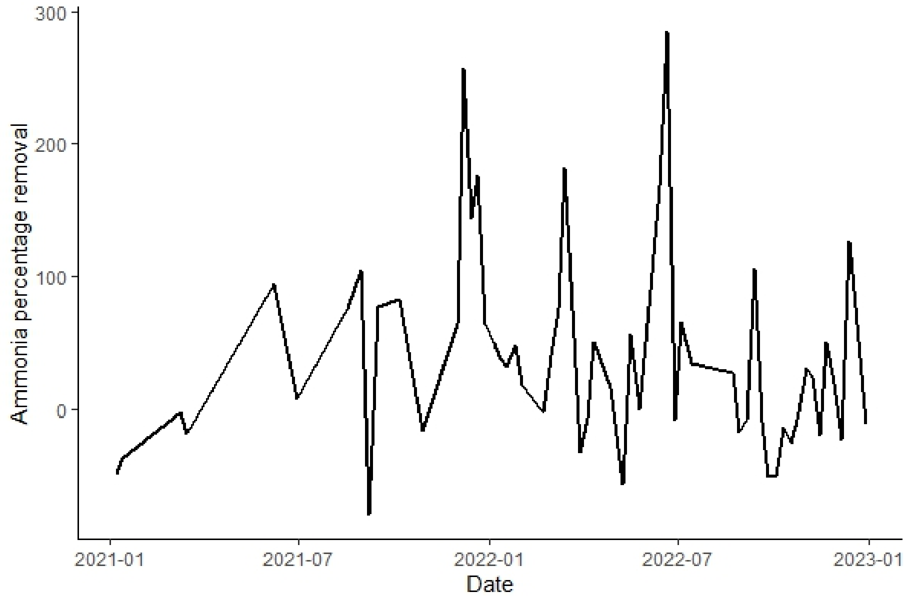
Arsenic (As)

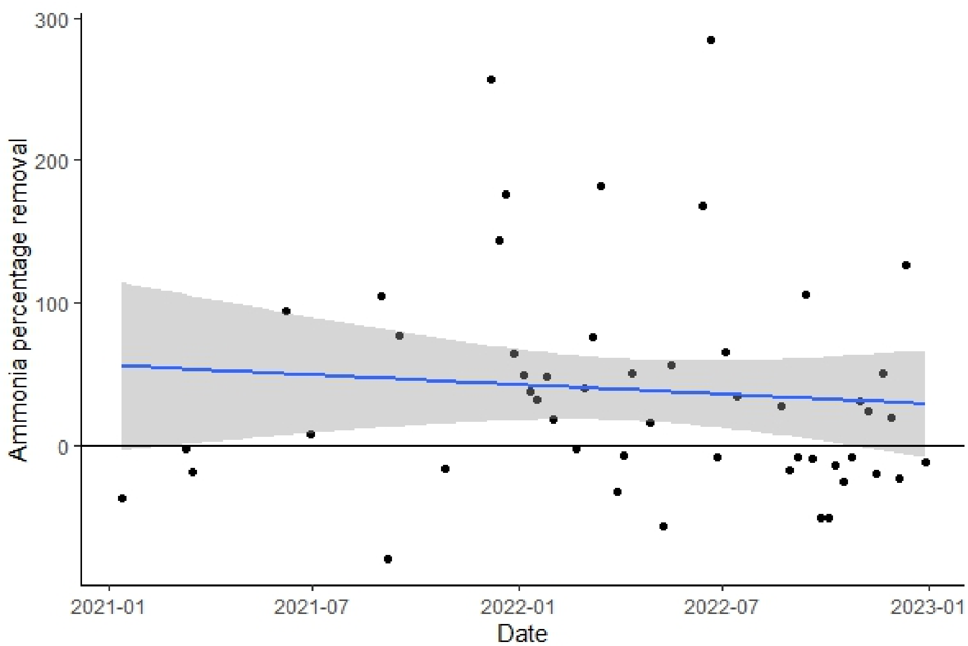





```
                Spearman's rank correlation rho

data:  HecR$Day and HecR$AsBH
S = 215556, p-value = 0.0001632
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.3742899
```

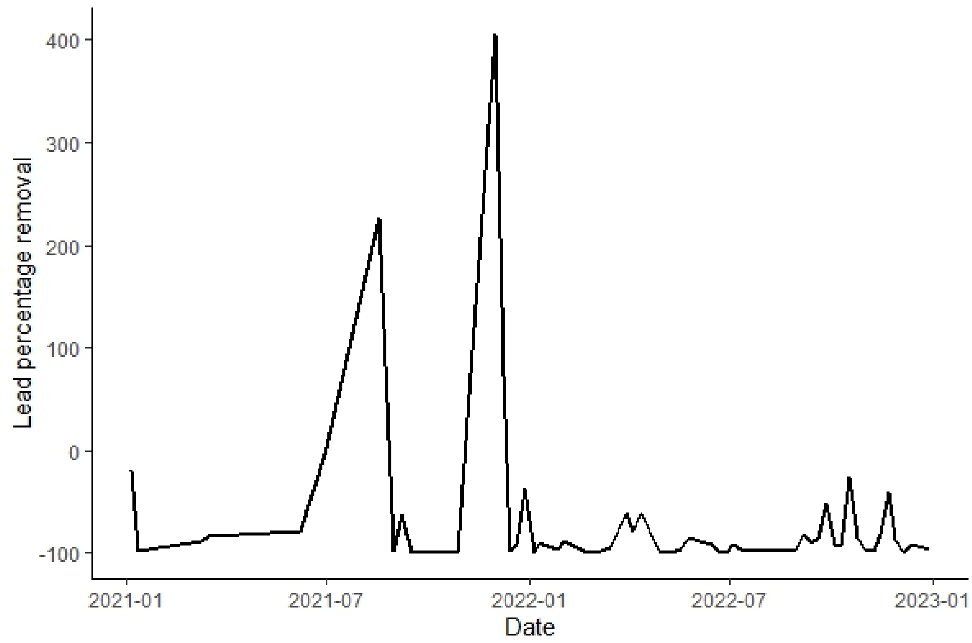
Ammonia (Am)

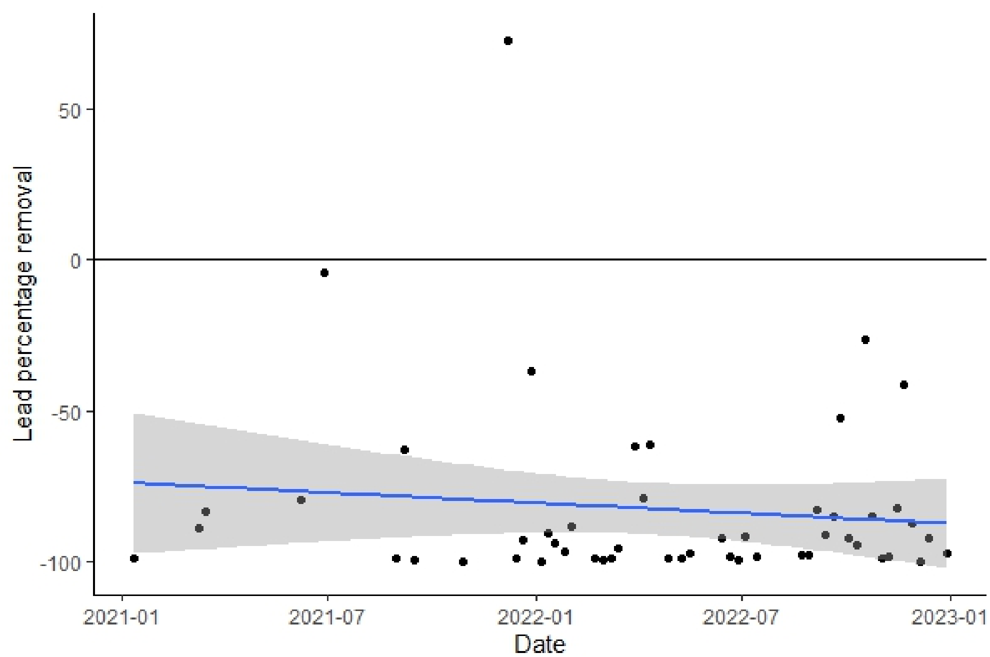





```
                Spearman's rank correlation rho

data:  HecR$Day and HecR$AmBH
S = 147222, p-value = 0.755
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
0.03204555
```

Lead (Pb)





Two outlier removed.

```
Spearman's rank correlation rho

data:  HecR$Day and HecR$PbBHx
S = 195568, p-value = 0.001171
alternative hypothesis: true rho is not equal to 0
sample estimates:
       rho
-0.3264254
```

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