# WATER QUALITY AND OPERATIONAL LEARNINGS FROM THE CYANOBACTERIA INCIDENT IN GRAHAMSTOWN SOURCE

**Vikas Shah**, Treatment Engineer, Water Treatment Operations, Hunter Water Corporation
**Ashley Sneddon**, Manager Water Treatment Operations, Hunter Water Corporation
**Mark Coleman**, Senior Engineer, Water Planning, Hunter Water Corporation

## ABSTRACT

During February-May 2024, elevated levels of 2-methylisoborneol (MIB) (54.9 ng/L) and Microcystis (19,300 cells/mL) were detected in water supplied from Grahamstown Dam to Water Treatment Plant. Customer complaints to notify Hunter Water of an earthy taste in drinking water commenced at MIB concentrations of near 5 ng/L, which was below Australian Drinking Water Guideline value of 10 ng/L. Thirty-nine complaints were received until 28th March 2024. Hunter Water commenced dosing of powdered activated carbon (PAC). Alongside this, Hunter Water proactively issued a statement to local media informing that Hunter Water was aware of the presence of elevated levels of naturally occurring taste and odour compounds in its Grahamstown source and Hunter Water had started to dose PAC to remove these compounds from drinking water supplied to customers. Hunter Water also clarified that this was an aesthetic issue only and the drinking water supplied by Hunter Water was safe to drink. PAC dosing was ceased on 24th May 2024 after MIB levels of ~10 ng/L in raw and <5 ng/L in treated water were observed. The dosing of PAC was effective in removing earthy and musty taste and odour of MIB in drinking water supplied by Hunter Water.

## INTRODUCTION

Grahamstown Dam (182,000 ML capacity), Hunter Water's largest dam, is a broad, relatively shallow, man-made, off-river storage that is primarily used to store water extracted from the Williams River. Grahamstown Dam supplies raw water to Grahamstown Water Treatment Plant (WTP), Hunter Water's largest WTP, to supply drinking water to a population of 400,000 people in the Lower Hunter region of NSW. Grahamstown WTP uses conventional treatment processes which includes coagulation / flocculation, sedimentation, filtration, pH correction, disinfection, and fluoridation. A Powdered Activated Carbon (PAC) dosing facility is located at Grahamstown Dam immediately downstream of the raw water offtake and 5 km north of Grahamstown WTP.

Routine weekly algae monitoring locations within Grahamstown Dam catchment are the Dam's key northern (R2), middle (R12) and southern (R6) locations, Campvale Pump Station (R9) and Boags Hill at Seaham Weir (R1) (**Figure 1**). The raw water offtake is located near dam's key southern monitoring location R6.

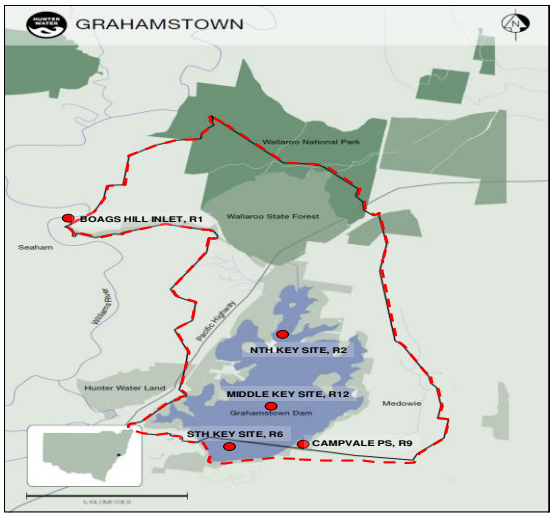


***Figure 1**: Key Routine Monitoring Sites in Grahamstown Dam Catchment*

Cyanobacteria can produce objectionable taste and odour compounds, such as 2-methylisoborneol (MIB), and toxins that can pose potential health hazards to freshwater systems and supply of safe

drinking water. Historical data show that presence of elevated MIB levels in Grahamstown source has been an uncommon occurrence (**Figure 2**). Historical water quality monitoring data show a gradual increase in relative abundance of cyanobacteria in Grahamstown raw water with several spikes in *Microcystis* levels with more frequent cyanobacteria blooms in recent years (**Figure 3**). In June 2021, algal scums were observed in Grahamstown Dam with elevated *Microcystis* levels (26,200 cells/mL; 2.28 $mm^3/L$) and presence of toxin, Microcystin-RR (0.04 µg/L Microcystin-LR toxicity equivalent). A significant water quality incident involving elevated levels of *Microcystis* and MIB concurrently in Grahamstown source has been a rare occurrence.

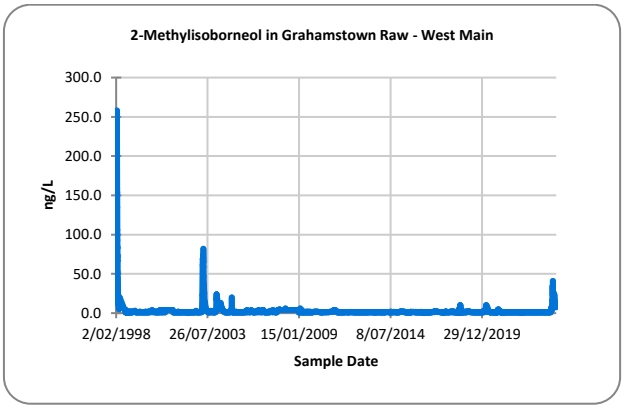


***Figure 2**: Historical MIB Levels in Grahamstown Raw*

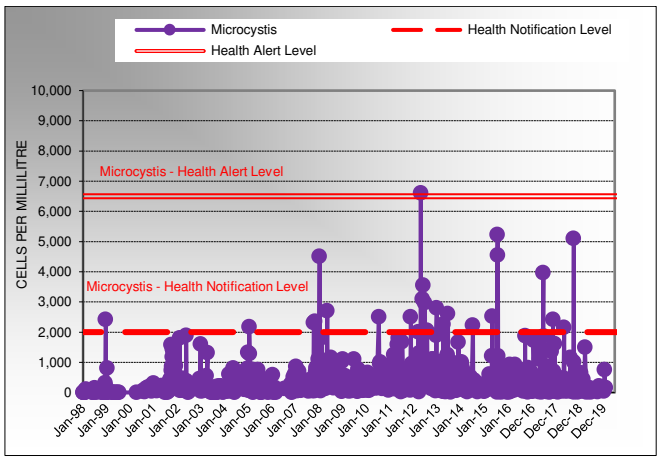


***Figure 3**: Historical Microcystis Levels in Grahamstown Raw*

## METHODOLOGY

In addition to routine weekly sampling for algae/cyanobacteria from three locations of Grahamstown Dam and Grahamstown raw, and MIB/geosmin in Grahamstown raw, Hunter Water commenced intense surveillance of Grahamstown raw and treated water for MIB with twice to thrice weekly samples from 4th March. In addition to routine monitoring, about 80 samples from Grahamstown Dam, raw and treated water were analysed for MIB, seven (7) Grahamstown raw samples were analysed for cyanobacteria and six (6) samples were analysed for algal toxins.

Sampling was conducted by sampling officers from Australian Laboratory Services Pty Ltd. (ALS) and testing was largely conducted in ALS laboratory located in Newcastle. Hunter Water provided a boat for the collection of samples from Grahamstown Dam by ALS sampling officers. Results of MIB and cyanobacteria were received generally on the same day of the sampling from ALS when requested by Hunter Water. A permanent sampler is installed upstream of PAC dosing facility to collect samples on MIB and cyanobacteria levels prior to PAC dosing to assist with optimisation of PAC dosing during an incident period.

Samples from Grahamstown Dam locations for algae/cyanobacteria analysis were collected at three different depths and then combined to a become a consolidated single sample. Surface sample was taken at about 1 m depth from top to allow the sample catcher to be submerged. The middle depth was chosen based on the depth sounder information and the bottom sample was collected within 0.5 m based on the readings from the boat's depth sounder. The rope used to close the catcher had 1 m markings on it to guide samplers to the correct depths.

All three routine locations of Grahamstown Dam were also sampled for the surveillance of MIB levels to better inform optimisation of PAC dosing. Sampling and analysis of raw water for cyanobacteria was undertaken at least twice a week whenever Microcystis had exceeded health notification level of 2,000 cells/mL until two consecutive samples returned a result below 2,000 cells/mL. Water samples from Grahamstown raw and/or treated water samples on 21st March, 25th March, 22nd April and 24th April were collected for the analysis of cyanotoxins and saxitoxins. Analysis of algal toxins in 24th April sample was completed on the same day by ALS laboratory given that the sample from 22nd April had returned elevated *Microcystis* count of 19,300 cells/mL.

## RESULTS AND DISCUSSION

MIB and *Microcystis* levels were increasing from February 2024 onwards. ADWG operational guideline limit for presence of total geosmin and MIB level in treated water is 10 ng/L, however, when MIB level in treated water exceeded 5 ng/L, customers notified Hunter Water of earthy/musty taste and odour.

Ongoing intense monitoring for MIB showed detections of 41 ng/L in Grahamstown raw, and 14.4 ng/L in Grahamstown treated water (highest during this incident) on 27th March 2024 with 11 customer complaints received by Hunter Water (**Figure 4**). On 28th March, Hunter Water received further 14 customer complaints with presence of elevated MIB of similarly levels in drinking water samples. In total, 39 complaints were received until 28th March 2024, which was valuable feedback from customers. Hunter Water commenced PAC dosing on 28th March with a target dose rate of 20 mg/L and issued a media release that PAC dosing had commenced to improve aesthetic water quality and the water was safe to drink. Prior to PAC dosed water was supplied to customers, Hunter Water had received 39 customer complaints for earthy/musty taste and odour.

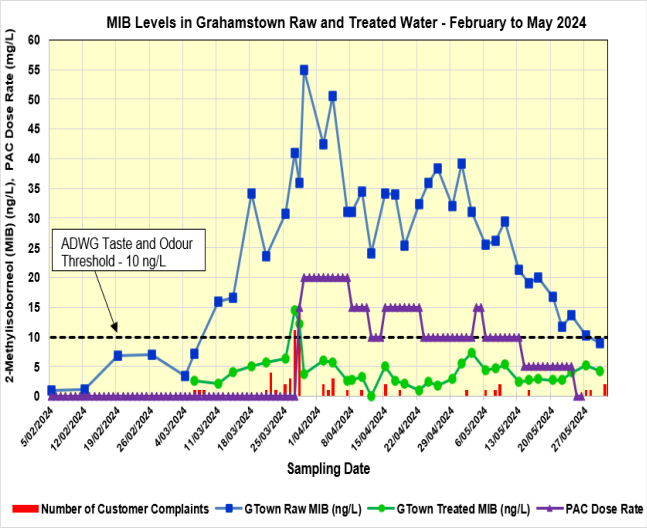


***Figure 4**: MIB Levels in Grahamstown Raw and Treated Water*

During the PAC dosing period of 28th March and 24th May 2024, Hunter Water received 21 intermittent customer complaints and accordingly PAC dosing rates were further reviewed against MIB levels and adjusted as necessary. During February to May 2024, average MIB levels in raw and treated water samples were 25 ng/L and 4 ng/L, respectively. Highest MIB level in Grahamstown raw water during this event was detected at 54.9 ng/L on 29th March. Geosmin was generally not present in vast majority of these samples and whenever present, it was observed in low levels.

Elevated levels of *Microcystis* were detected in Grahamstown raw on 21st March (7,240 cells/mL; 0.406 $mm^3/L$), 25th March (10,800 cells/mL; 0.606 $mm^3/L$) and 22nd April (19,300 cells/mL; 2.16 $mm^3/L$) exceeding ADWG health alert level trigger of 6,500 cells/mL. On 4th March (2,000 cells/mL; 0.112 $mm^3/L$), 14th March (2,100 cells/mL; 0.121 $mm^3/L$) and 2nd April (2,160 cells/mL) elevated levels of *Microcystis* were detected in Grahamstown raw that exceeded ADWG trigger of 2,000 cells/mL for health notification level (**Figure 5**).

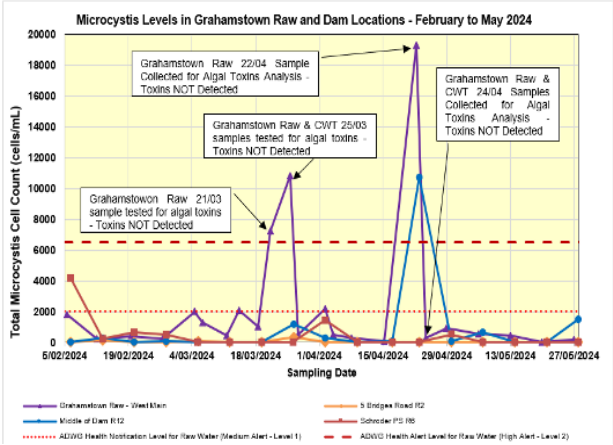


***Figure 5**: Microcystis Levels (Cell Count) in Grahamstown Dam and Raw Sampling Locations*

There were two significant rain events in Grahamstown Dam catchment area in April and May during this incident. Samples collected following these rain events showed lower MIB levels possibly due to increased dilution factor resulting in overall reduced adsorption of MIB to sediments and suspended solids. It is, however, noted that during other MIB incidents for Grahamstown Dam, higher levels of MIB were observed following significant rain events possibly due to noticeable run-off from Grahamstown Dam catchment entering the Dam and mixing the elevated levels of MIB from the bottom sediments throughout the entire water column. Thus, MIB levels can be unpredictable in water samples following significant rain events potentially due to complex environmental factors and processes impacting the sediments, ecosystem and water quality of the Dam.

WaterNSW was notified of these detections, who then notified other members of Regional Algal Coordinating Committee (RACC) of Hunter region. No algal scums were observed in Grahamstown Dam during this event by Hunter Water's Dams and Catchments Rangers during their surveillance visits. No algal toxins were detected in any of six (6) samples that were analysed for a wide range of cyanotoxins and saxitoxins (**Figure 5**). The results showed that *Microcystis* population in Grahamstown Dam was dominated by the non-toxigenic *Microcystis*. The continued non-detection of algal toxins meant this incident was ultimately classified as an aesthetic issue (Moderate incident due to elevated levels of MIB resulting in several customer complaints).

Assessment of *Microcystis* biovolume data in comparison to their corresponding cell count data informed that on average size of *Microcystis* cells were smaller than what has been assumed under the ADWG guideline values for *Microcystis* Health Notification (2,000 cells/mL; 0.2 $mm^3/L$) and Alert (6,500 cells/mL; 0.6 $mm^3/L$). Extrapolation of *Microcystis* cell count and biovolume data from this incident informed that corresponding cell counts for biovolumes of 0.2 $mm^3/L$ and 0.6 $mm^3/L$ were about 3,000 cells/mL and 9,000 cells/mL on average, respectively. Extrapolation of *Microcystis* cell count and biovolume data for 224 samples collected from Hunter Water's 20 routine monitoring locations during January 2023 to June 2024 informed that corresponding cell counts for biovolumes of 0.2 $mm^3/L$ and 0.6 $mm^3/L$ were about 4,000 cells/mL and 13,000 cells/mL on average, respectively. Given the possibility of variability in cell sizes of *Microcystis* population, it is envisaged that ADWG triggers based on cell biovolume would provide more accurate basis for triggering and responding to *Microcystis* blooms.

Known MIB producing cyanobacteria *Oscillatoriales*, *Pseudanabaena, Planktothrix* and *Phormidium* were observed in Grahamstown source during the MIB incident, which qualitatively correlated with

elevated MIB levels. MIB levels along with its extracellular fraction started to rise when multiple genera of known MIB-producing cyanobacteria were observed at once in Grahamstown raw and/or Dam sampling locations (**Figure 6**).

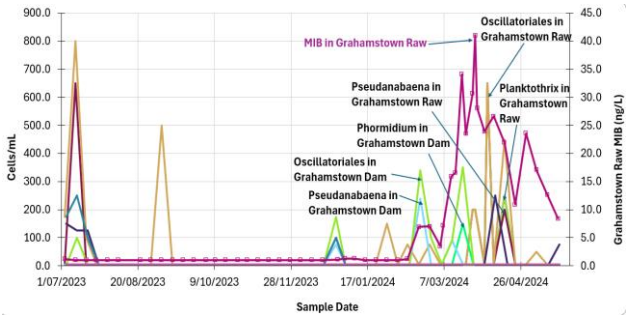


***Figure 6**: MIB-producing Cyanobacteria in Grahamstown Source*

There was no noticeable correlation between *Microcystis* and MIB levels in Grahamstown raw during this incident as MIB levels continued to vary between 1 to 54.9 ng/L, however *Microcystis* levels were generally consistently <2,000 cells/mL except for six samples with elevated levels.

Hunter Water conducted a thorough appraisal of treatment processes at Grahamstown WTP. The processes were optimised based on the monitoring results. The intracellular MIB was removed by conventional treatment processes and the extracellular MIB (about ~75% of total MIB) was adsorbed by PAC. Optimised treatment processes included an initial high PAC dose rate of 20 mg/L with a contact time of between 80 and 290 min; coagulation pH 6-6.5; increased alum dose; filters operated to maintain filtered turbidity <0.15 NTU and chlorine at treated water tank inlet maintained between 2.3 mg/L to 3 mg/L with chlorine exiting the plant 2.5 mg/L and Ct more than 150 min.mg/L. During 58 days of PAC dosing, a total of 62 tonnes of PAC was dosed with an average dose of 11.7 mg/L and target dose rate ranging from 20 mg/L early in event to 5 mg/L towards the end of the event.

Hunter Water's approach to the management of this "Moderate" incident involved development of plans based on the most likely and worst-case outcome. Due to the unprecedented scale of concurrent *Microcystis* and MIB levels, the management of the incident was challenging. There were uncertainties about the volatility in MIB levels as well as changes required to PAC dosing rates and whether toxins would be produced. Noticeable decrease in the customer complaints was noticed after PAC dosing had commenced i.e. the operational response was effective in addressing the aesthetic issue. The guidance literature for treatment of algal toxins (if detected) was helpful in that the chlorination is a robust barrier for the destruction of Microcystins (if detected in Grahamstown Raw) and that the oxidation of Microcystins can be achieved by maintaining a chlorine residual of 0.5 mg/L and a contact time of 30 minutes (equivalent to a chlorine contact time of 15 min.mg/L) while pH remains below 8.

To help understand the performance of algal cell removal rates through sedimentation tank and inform future upgrades for the treatment of algal solids and more efficient recovery of backwash water, samples from settled water flowing from sedimentation tank to filters, and backwash recovery water were collected during this incident. *Microcystis* was not detected in any of the settled water samples but was detected in low levels (45 cells/mL) in one of the backwash recovery water samples. Low levels of algal cells (up to 665 cells/mL representing 2% of algal cells detected in corresponding raw water samples) were detected in two out of three settled water samples when elevated levels of algae cells (up to 35,500 cells/mL) were present in raw water. Up to 28% of algae cell levels observed in raw water were detected in all three backwash recovery water samples.

Sentinel-2 satellite image of Grahamstown Dam provided by WaterNSW showed no obvious signs of high cyanobacteria biomass, which was reassuring given that monitoring of Grahamstown Dam locations consistently showed low levels of *Microcystis* despite having presence of the elevated levels in raw water samples (**Figure 7**). Hunter Water liaised with NSW Health as necessary and provided regular updates.

***Figure 7**: Sentinel-2 Satellite Image of Grahamstown Dam provided by WaterNSW*

## CONCLUSION

- The presence of elevated levels of both MIB and *Microcystis* in Grahamstown raw water during February to May 2024 was an uncharacteristic event for Grahamstown Dam. There was no noticeable correlation between *Microcystis* and MIB levels in Grahamstown raw.
- Customer complaints commenced at MIB concentrations near 5 ng/L, which is below ADWG guideline value of 10 ng/L.
- Hunter Water proactively managed the incident by commencing the PAC dosing, informing the customers about it by issuing a statement to local media and closely liaising with NSW Health on the ongoing steps being taken to manage the incident to keep the customer complaints to minimal.
- Dosing of PAC was effective in removing earthy and musty taste and odour of MIB in drinking water supplied by Hunter Water.
- MIB levels were not correlated with rain events.
- Known MIB producing cyanobacteria especially *Oscillatoriales* were observed in Grahamstown source during the MIB incident, which qualitatively correlated with elevated MIB levels.
- Total MIB levels along with its extracellular fraction started to rise when known MIB-producing cyanobacteria were observed together and/or levels of *Oscillatoriales* were elevated.
- Despite elevated levels of *Microcystis* observed, no algal toxins were detected in Grahamstown source. This finding signalled that *Microcystis* population was made up of the non-toxic genotype.
- Given the variability in cell sizes, ADWG triggers based on cell biovolume would provide more accurate basis for triggering and responding to algal incidents.
- Low levels of *Microcystis* observed at Grahamstown Dam routine sampling locations did not correlate with elevated levels of *Microcystis* observed in Grahamstown raw supplied from the Dam.

## KEY INITIATIVES

- Hunter Water will further investigate the potential option of triggering *Microcystis* blooms based on biovolume data instead of cell counts due to variability in cell sizes.
- Hunter Water has assessed options for additional treatment barriers at Grahamstown WTP for a severe algae bloom and considering installing lamella plates within the Stage 2 sedimentation tanks to increase the algal solids removal capacity from about 80% to 89-97%.

## REFERENCES


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