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Hydrodynamic modelling of water quality impacts of petrol-powered boats on a drinking water reservoir

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Abstract: The risk posed by allowing petrol-powered boats for recreational use on a drinking water reservoir was assessed using three-dimensional hydrodynamic modelling. Chemical threats were identified and modelled for a number of different scenarios. The chemical risk was quantified and compared against the Australian Drinking Water Guidelines. Model outputs assisted in decision making regarding controls around recreational use of the reservoir.

Keywords: *Hydrodynamic modelling, drinking water, chemicals*

1. INTRODUCTION

This project assesses the risk to drinking water quality posed by allowing petrol-powered motor boats onto a large reservoir where recreational use of any kind is currently not permitted. Specifically, the focus was on quantifying the risk that a low volume leak or a high-volume spill of fuel and/or oils from a petrol-powered boat would have on drinking water quality. Three-dimensional hydrodynamic modelling was undertaken to determine the fate of a known volume of fuel and/or oil being accidently deposited directly into a drinking water reservoir. The use of modelling allows the risks associated with specific chemicals to be quantified and assessed against relevant health and aesthetic guidelines. It also provides the opportunity to test different scenarios in terms of, for example, spill location, time of year and volume, which may assist in decision making around how best to prevent or mitigate any impact to drinking water quality.

2. METHODOLOGY AND RESULTS

Chemicals typically found in petroleum products used in powered boats were identified and compared to the chemicals of concern outlined in the Australian Drinking Water Guidelines (ADWG) (2022) (Montano and Miller, 2022). This process resulted in a list of priority chemicals of impact and interest that also had a relevant guideline value for either health or aesthetics. The priority list of chemicals included polycyclic aromatic hydrocarbons (PAHs), mainly benzo(a)pyrene, and BTEX compounds (Benzene, Toluene, Ethylbenzene and Xylene). The PAH naphthalene was also included and as ADWG does not include a guideline for this chemical, the USEPA limits were used. Information regarding the physiochemical properties and environmental fate processes, i.e. half-life, for those chemicals was also compiled to assist in modelling their behaviour in water.

The reservoir used for this analysis was a drinking water reservoir that supplies water to Melbourne's south-eastern suburbs. There is currently no recreational access of any kind allowed either on the water or in the immediate catchment area. The reservoir is fed by rural and forested catchments and is filtered and disinfected before being supplied to consumers. It has a capacity of around 38 gigalitres, a maximum depth of 30 meters and water quality in the reservoir is generally considered very good. A three-dimensional hydrodynamic model was built for the reservoir using the modelling platform AEM3D, which is an updated version of the ELCOM model developed by the University of Western Australia (Hodges et al, 2000). The model was set up to show the fate of chemicals following a one-off low volume fuel leak of 1.5 L and a one-off high volume fuel spill of 100 L, assumed to be the volume of an entire tank of fuel, at three different locations and in both summer and winter conditions. The meteorological and operational conditions for the reservoir modelling were chosen to represent a reasonable worst-case in terms of dilution and mixing of surface water contamination. These conditions included a low reservoir level, wind direction towards the outlet tower and high inflow and outflow rates. The range of spill locations and reservoir boundary conditions resulted in 12 scenarios for each of summer and winter. Scenarios were run for 2 months, 1-month either side of the spill occurring.

To simulate a spill, chemicals at each location were added to the model at the surface, with the total mass of chemical introduced into one model cell as a concentration and assumed to be immediately completely mixed and diluted within that cell. From there the behaviour of the chemical is based on its density and the water movement within the reservoir. Solubility of the chemicals was not considered to ensure conservatism in the outcomes. Additionally, no consideration was given to the possible changes in surface hydrodynamics, specifically wind shear, that may occur given the addition of an oily film. Vertical transport of the chemicals within the water column was represented using Stokes law, which takes into consideration chemical density. Chemicals were assumed to act independently of the product they are in and of each other. They are also assumed to be inert in that they do not react with, nor are they consumed by or do they attach to, any constituents in the water or sediment. Chemical half-lives were converted into an exponential decay rate based on time and included in the model.

The chemical concentrations reported are the maximum chemical concentration observed in the profile at the outlet tower. The majority of the scenarios resulted in chemical concentrations being below the health guidelines for drinking water quality. The exceptions were for benzene, given a large volume spill at the closest location to the outlet tower and benzo(a)pyrene in 8 out of the 12 scenarios. In terms of the aesthetic guidelines, these were breached for all chemicals, excluding one, for high volume spills at the nearest location to the offtake.

The chemical of most concern is the polycyclic aromatic hydrocarbon (PAH) benzo(a)pyrene. Both large volume spills and small volume leaks at the closest location to the outlet tower resulted in concentrations at the outlet tower breaching health guidelines - in the case of the large volume spill the exceedance was over 100 times over the guideline value. Large volume spills at all three locations resulted in unacceptably high results at the outlet for benzo(a)pyrene. It is also worth noting that this chemical remains above the health guideline, for many of the scenarios, over a month after a spill occurs. The difference with this chemical compared to the others modelled is that it does not decay in the environment and so once in the water column will remain there until it is either removed through discharging water from the reservoir or diluted by fresh inflows. The health guideline is also very low due to its potential to increase the risk of certain types of cancer.

Predictably, the spill locations further away from the outlet tower resulted in lower chemical concentrations at the outlet due to more dilution and more time to decay before reaching the tower. The modelling can quantify the risk reduction afforded by not allowing petrol-powered boats to get within a certain distance from the outlet tower. This modelling can assist management in making decisions about allowing petrol-powered boats on to the reservoir and the necessary exclusions zones for certain types of recreation.

3. CONCLUSIONS

The outputs from the modelling formed part of the risk assessment and were used to help identify the minimum set of controls necessary in order to protect drinking water quality. Controls could include: exclusion of petrol-powered vessels from the reservoir; exclusion of petrol-powered vessels from specific zones of the reservoir, using on-water barriers; suitable rules, signage and surveillance; spill control and clean-up kits for land based spills; controlled access to the reservoir through a designated car park and boat ramp. If petrol-powered vessels with fuel tanks were permitted on the reservoir, then additional water treatment processes, designed to remove priority chemicals, may be necessary.

Decision-makers are able to use costs and effectiveness of controls to determine the most suitable outcomes taking into account overall project aims and budget.

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REFERENCES

Hodges BR, Imberger J, Saggio A & Winters KB (2000) Modeling basin-scale internal waves in a stratified lake, Limnology and Oceanography, 45(7), pp 1603-162

Montano L & Miller BM (2022) *Risk assessment of vessels with petrol outboards attached in drinking water*, University of New South Wales Water Research Laboratory (UNSW) report WRL TR 2022/09. 42 p. plus Appendices

NHMRC (2022) Australian Drinking Water Guidelines 6 2011: National Water Quality Management Strategy. Canberra: National Health and Medical Research Council

