Assessing the short-term effect of wildfire on peatland water quality through laboratory –based peat soil leaching studies

Yichen Wu and Charles-François de Lannoy*

Department of Chemical Engineering, McMaster University, 1280 Main St. W., Hamilton, Ontario L8S 4L8, Canada

Introduction

Boreal peatlands are expected to undergo more severe wildfires and droughts due to climate change. Peat soils experience complex physicochemical changes, leading to altered chemical compositions. Various types of pollutants, such as carbon-based pollutants and nutrients (i.e., N and P), can leach from peats into surface runoff following rainfall or flooding events, ultimately impacting downstream source waters, farming irrigation and drinking water treatment facilities. There is therefore an urgent need to understand the types and concentrations of the peat-derived pollutants following wildfires.

We hence performed lab-simulated peat smoldering at 2 different temperatures (250 and 300°C), and collected the pre- and post-heat treated peat leachates through a batch leaching test over a 2 day period. The leachates were filtered and characterized by different water quality parameters, such as chemical oxygen demand (COD), total carbon (TC), total nitrogen (TN), total phosphorus (TP) and total phenols. The concentrations were compared with United States surface water guidelines, European Union (EU) wastewater discharge limit and Canadian sewer discharge by-laws. Principal component analysis (PCA) was also used to conjecture possible pollutant leaching mechanisms. Partial least square regression (PLSR) model was used to predict the concentration of COD and total phenols in water based on other major parameters. Results of this study will largely benefit peatland environmental management and source water protection.

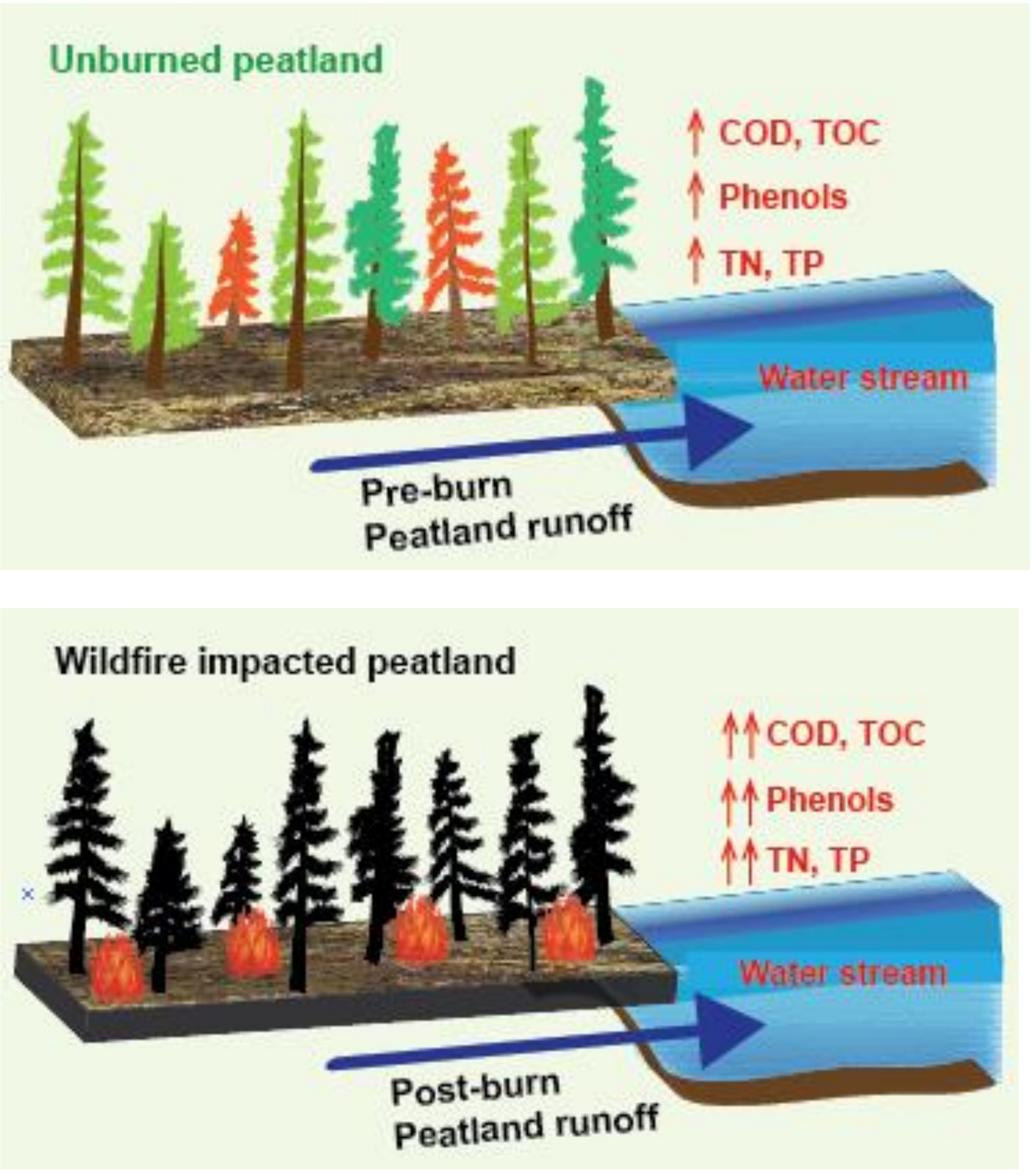
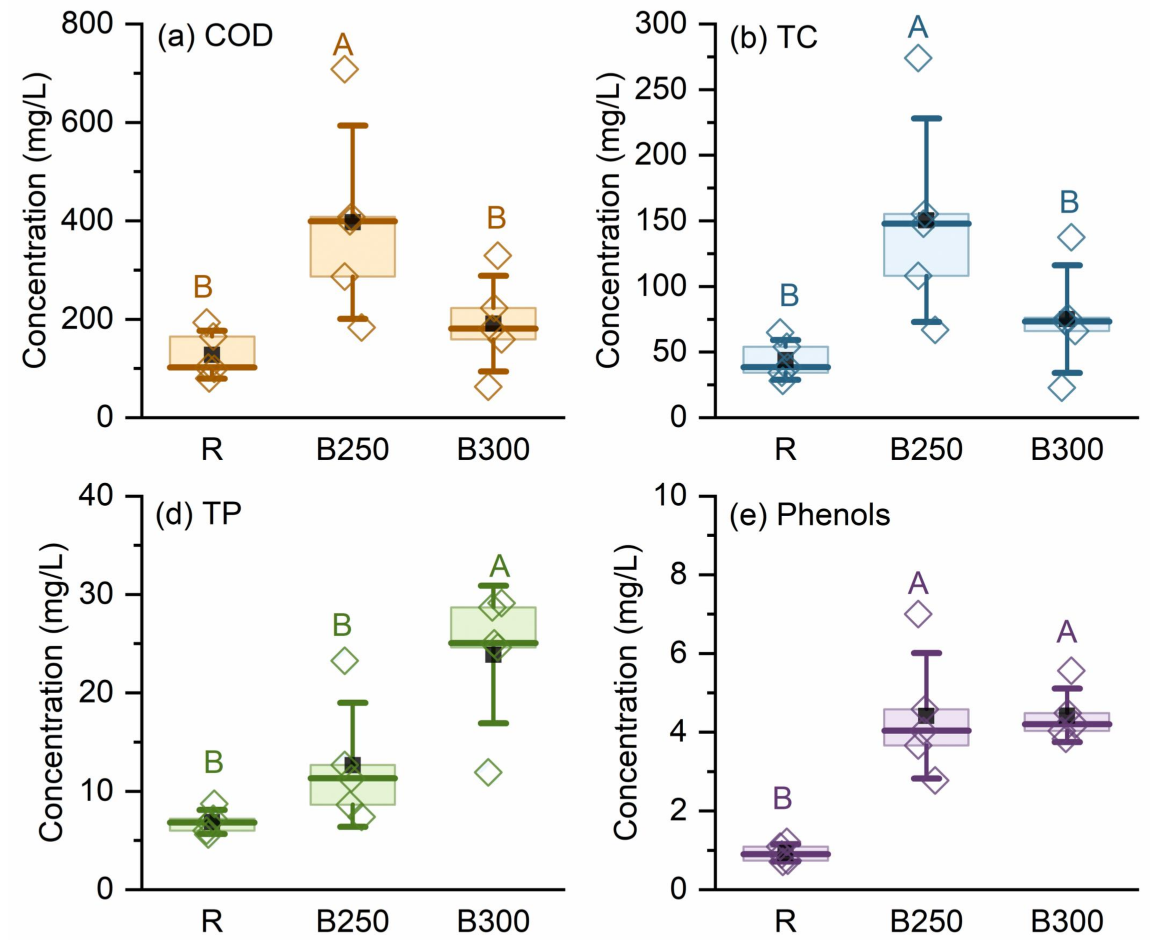


Figure 1 Climate impacted pre- and post-fire boreal peats and their contributions to leachate pollution.

Results



COD, TN and TP higher than EU wastewater discharge limit (125, 15 and 2 mg/L, respectively)

Phenols close to or higher than US EPA suggested water supply limit (1 mg/L)

Figure 2 Box plots with ANOVA post-hoc analyses indicating concentrations of (a) COD; (b) TC; (c) TN; (d) TP and (e) Phenols in pre- and post-heated peat soil leachates. R, B250 and B300 represent the leachates (n = 5 per treatment, as shown by the scattered open diamonds) extracted from raw peats, 250 and 300°C heat-treated peats, respectively. Mean values are shown in black solid squares. The top and bottom of the boxes indicates the upper and lower quartile, respectively. The horizontal lines in bold represent the median. The whiskers indicate the standard deviation. 1 mg/L aqueous pollution loading equivalents to 0.2 mg/g water-extractable amount from peat soil.

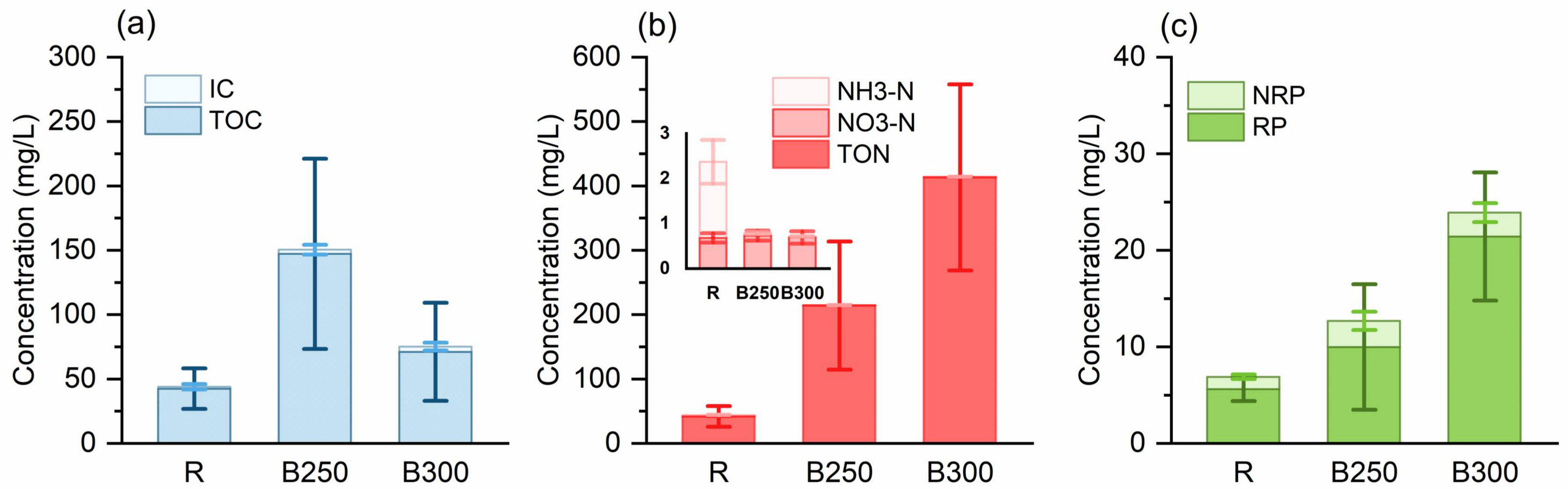


Figure 3 Stacked column charts indicating the average of sub-category pollutant concentrations of (a) TC; (b) TN; and (c) TP, of the extracts from R, B250 and B300, respectively. Error bars represent standard errors of the mean based on leachates from 5 peat cores per treatment, and 2 parallel tests per peat sample leachates.

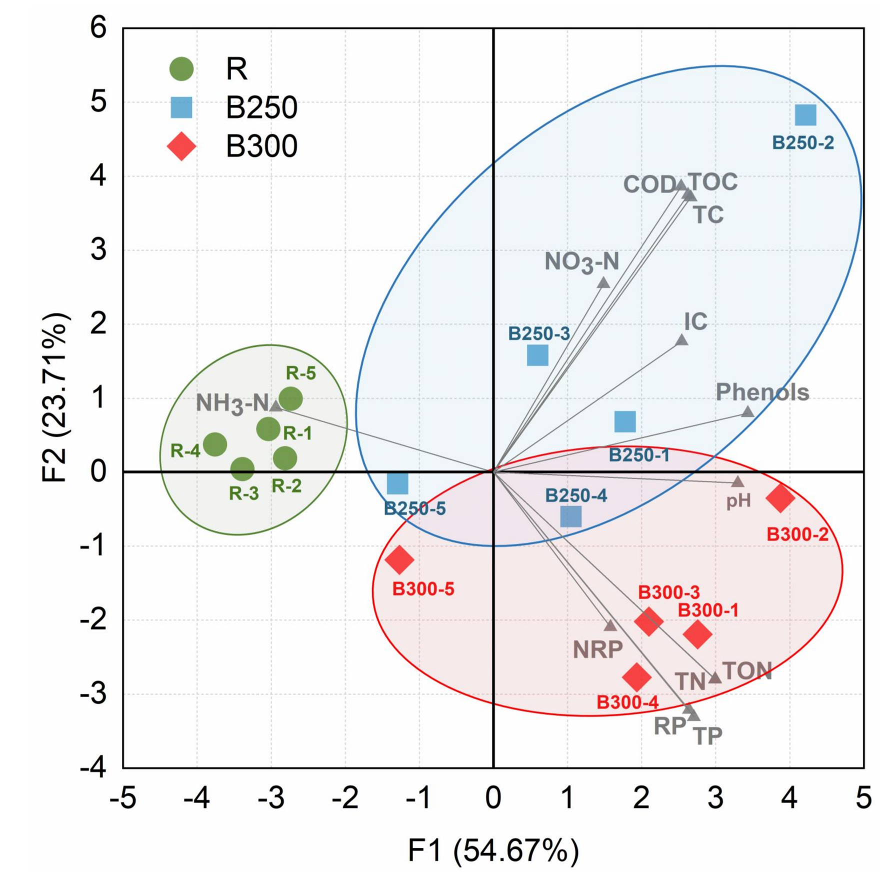
Substance	United States (mg/L)	European Union (mg/L)	Canada (mg/L)		
			Ottawa	Toronto	Hamilton
COD	5 - 90	125			
Total Phosphorus	0.025 - 0.05	2 (10000 - 100000 p.e.), 1 (> 100000 p.e.)	10 (0.4)	10 (0.4)	10
Total Nitrogen	2 - 10	15 (10000 - 100000 p.e.), 10 (> 100000 p.e.)			
Total Kjeldahl Nitrogen			100	100	100
Phenols	0.005		1 (0.008)	1 (0.008)	1 (0.02)

Note
US standard: site-specific values of water quality objectives for inland surface waters in California

EU standard: urban wastewater treatment plant discharge limit

Canadian standard: local by-law limits for sanitary and combined sewers discharge, and limits for storm sewer discharge (shown in brackets)

Table 1 Surface water and wastewater discharge guidelines for certain pollutants from US, EU and Canada.



250°C promoted the leaching of carbon-based pollutants

300°C promoted the leaching of nutrients

Modulated by different peat fire temperatures, pollutant leaching changes likely due to changes of peat chemical composition as well as pollutant mobility

Figure 3 PCA indicating F1 and F2 of water chemistry for leachates extracted from R, B250 and B300, respectively. Shaded green, blue and red colored areas indicate the clusters for R, B250 and B300 respectively. Vectors in grey refer to PC loadings of the corresponding variables.

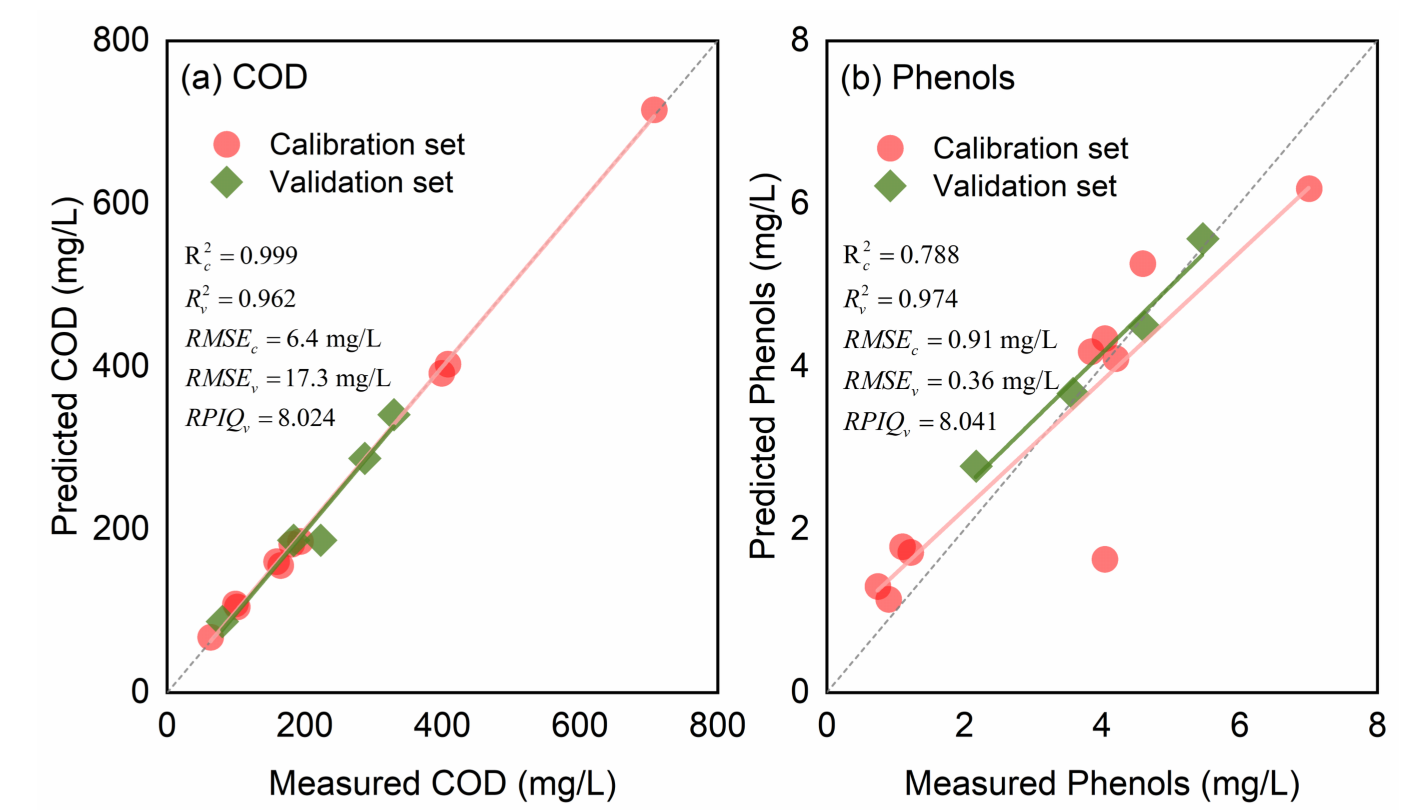


Figure 4 Goodness of fit of PLS model predictions for (a) COD and (b) phenols. The pink and green lines are the regression lines for the calibration set and validation set, respectively.

Conclusions

Leaching of pollutants from wildfire–impacted boreal peats potentially have significantly implications to downstream source waters, which are either directly used by humans or to be treated by water treatment processes prior to other use. The increased concentrations of DOM, for example, greatly impacts the denitrification in water treatment utilities, drinking water disinfection and residual chlorine monitoring. Results of this study will better guide land users to establish boreal area water management strategies in response to frequent fire regimes.

Acknowledgements

We would like to thank Patrick Deane and Sophie Wilkinson in Dr. Waddington's group for soil sample collection.