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Study on Chlorophyll-a Data for Jubilee River at Pocock’s Bridge and River Thames at Runnymede (2009-2013)

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Abstract

In this report, monitored data from two sampling sites of River Thames include various factor such as pH, chlorophyll-a and more. According to these data the close relationship between chlorophyll concentration and variables may be studied. Moreover, we can determine the root causes that may affect algal blooms by exploring the differences in chlorophyll concentrations between the two sites. The results showed that although nitrogen and phosphorus elements were likely to cause chlorophyll-a differences between the two sites, algal bloom events related to chlorophyll-a are affected by many factors.

Keywords: algal bloom events; chlorophyll-a; nitrogen; phosphorus;

1 Introduction

With the growing pressures from rapid development of industrialization process and ever-increasing population, water contamination has received growing global attention as one of the emerging global problems threatening a sustainable future. Therefore, the researches on representative river systems that closely linked to human’s economic activities, such as the River Thames and its tributaries, is of significant importance (Bowes et al., 2018).

The River Thames plays an essential role in the daily life of around 13 million inhabitants in the UK. It provides not only entertainment services including fishing,
swimming and boating but also most of the drinking water resources and it indirectly
disposes of agricultural and industrial wastes by receiving wastewater treatment
effluents for which the nitrate concentration has been continuously monitored since
1868 (Howden et al., 2010). In addition, the record of phosphorus concentration was
stretched back to 1936, which can be used to identify water quality and to develop new
protection policies for the government (Haygarth et al., 2014; Powers et al., 2016).

However, for water contamination events such as the harmful algal bloom (HAB),
the previous discontinuous monitoring data no longer meet the needs of researchers.
There was a strategic need to collect continuous data at multiple sites across the Thames
catchment for observing step changes in the water quality (Bowes et al., 2009), by the
continuous monitoring platform, namely Centre for Ecology and Hydrology (CEH).

The objective of this report is to explore the potential causes and early indicators of
the algal blooms in the River Thames by exploring the relationship between the
monitoring data of chlorophyll-α and other parameters provided by the Thames
Initiative research platform from March 2009 to February 2013. Meanwhile, this report
also provides some new basic analyses of the data, to help the government establish
mitigation or preventive measures of algal blooms in the future.

2 Data and methods

2.1 Data collection

In this report, the various data of the River Thames and its tributaries were monitored
at weekly intervals at two monitoring sites that are Jubilee River at Pocock’s Bridge
(JU) and Thames at Runnymede (TR) during the period from March 2009 to February
2013, including water temperature, pH, Gran alkalinity, suspended solids, phosphorus
concentrations, chlorophyll-α concentrations and major dissolved anions (fluoride,
chloride, bromide, sulphate) and cations (sodium, potassium, calcium, magnesium,
boron). These weekly water quality monitoring data are freely available from the UK
CEH Environmental Information Data Centre portal at
https://catalogue.ceh.ac.uk/documents/e4c300b1-8bc3-4df2-b23a-e72e67eef2fd and
the detail information on the locations of sites can be seen in Fig. 1.

**Figure 1.** Location of monitoring sites along the River Thames (Bowes et al., 2018).

### 2.2 Analysis Methods

Two quantitative methods used in this report were time-series and correlation/regression analysis respectively. The analysis method of time series is a set of data points index in time order. The main purpose of it is to obtain meaningful statistics, useful information and unique characteristic of the record data and to predict the trend in the impacts in the future (McDowall et al., 2019). Correlation and regression analysis are two different statistical measures based on multivariate distribution that can be described as a distribution of multiple variables. However, there are some differences between correlation and regression analysis. Correlation analysis is not only able to determine the association or the absence of the relationship between two variables but also to indicate the extent to which two variables change together by the correlation coefficient. On the other hand, regression normally is to predict the value of a dependent valuable based on the known value of an independent variable and is to predict the co-relationship or association of these (Zheng et al., 2017).
In this report, in order to explore what factors may lead to the increase of chlorophyll-\(a\) concentration, a time-dependent curve of temperature and chlorophyll-\(a\) concentration can be made respectively for observing the general trend of these two sites from March 2009 to February 2013. The reason is that these water quality monitoring data is continuous and in the case of uncertainty as to which one is the influencing factor, the time series figure might capture as much information as possible that includes outliers. Then, the seasonal variation in various variables can be built up using box plot. The reasons for it are to study more impact factors causing possibly the increase of chlorophyll-\(a\) concentration and to pick similar trends with the trend in chlorophyll-\(a\) concentration out to find what is the reason for the difference in chlorophyll-\(a\) concentration between two sites. After determining which variables might affect chlorophyll-\(a\) concentration, the most important factor causing the increase of chlorophyll-\(a\) can be studied by correlation plot, which plays an essential role in preventing and controlling algal blooms in future.

As for statistical tools used in this report, a script was written in python 3 (https://www.python.org/), data analysis was performed using Pandas software library (https://pandas.pydata.org/) in the Anaconda platform (https://www.anaconda.com/). In addition, Libraries Matplotlib (https://matplotlib.org/) and Seaborn (https://seaborn.pydata.org/) were used for data visualization.

3 Analysis and Discussion

The time series plots related to temperature for the Jubilee River at Pocock’s Bridge (JU) and Thames River at Runnymede (TR) are presented in Fig. 2 respectively. It shows that the significant seasonal variations in temperature can be found in these two sampling sites. In addition, the water temperature of these two monitoring sites follow a relatively consistent pattern of highest temperatures (around 20°C) in the August of each year and lowest temperatures around (5°C) can be observed during the period from December to February, which indicates the physical characteristics of two monitoring sites are similar and the data set from these sites is of good quality. Apart from this, the isolated data points like outliers can be seen from the March 2009 to February 2013 in the Fig. 2. However, these isolated points may be caused by non-seasonal factor such
as the weather changes rather than error as these outliers both appear at the same time in two sampling sites in Fig. 2c.

Figure 2. Water temperature time series data from March 2009 to February 2013, as (a) Jubilee River at Pocock’s Bridge (JU), (b) Thames at Runnymede (TR), (c) the temperature time series data combined JU and TR.

Moreover, the time series plots related to chlorophyll-α concentration for the Jubilee River at Pocock’s Bridge (JU) and Thames River at Runnymede (TR) are presented in Fig. 3. In comparison with Fig. 2, the Fig. 3 indicates that the trend in chlorophyll-α concentration over time seems to be slightly similar with temperature change from March 2009 to February 2013. Then, the peak of chlorophyll-α concentration is generally reached the May of each year, which is consistent with the timing of the algal
bloom (Lee et al., 2005). Therefore, the factors causing increase in chlorophyll-a concentration may related to seasonal variation.

![Graph of chlorophyll-a concentration time series data for two sites of Jubilee River at Pocock's Bridge (JU) and Thames at Runnymede (TR) from March 2009 to February 2013.](image)

**Figure 3.** Chlorophyll-a concentration time series data for two sites of Jubilee River at Pocock’s Bridge (JU) and Thames at Runnymede (TR) from March 2009 to February 2013.

After determining that there are seasonal variations in the chlorophyll-a concentration, the factor potentially caused increase in chlorophyll-a concentration can be detected by exploring whether other factors have seasonal variations similar to the chlorophyll-a concentration. Therefore, the seasonal variations in various variables such as water temperature, chlorophyll-a concentration, pH, total dissolved nitrogen concentration, mean daily river discharge and total dissolved phosphorus concentration are necessary to research detainly, presenting in Fig. 4.

Firstly, the seasonal variation in chlorophyll-a (Fig. 4b) indicates that highest concentration in spring and the lowest concentrations in autumn and winter in these two sites. Meanwhile, the chlorophyll-a concentrations from River Thames at Runnymede (TR) is dominant in all the seasons compared with it from Jubilee River at Pocock’s Bridge (JU). Therefore, the chlorophyll-a concentrations in spring and summer and this difference in the chlorophyll-a concentrations between two sites can be as the crucial study objects.

Secondly, as for pH (Fig. 4c) and water temperature (Fig. 4a) it is noticeable that the difference between the two sampling sites in each season is negligible, which trend is different in comparison with chlorophyll-a concentrations (Fig. 4b). Therefore, it may not be the direct reason for leading to difference in chlorophyll-a concentrations between these two sites.
Thirdly, the seasonal variation in mean daily river discharge (Fig. 4e) shows the highest discharge of TR and JU in winter around 110 m$^3$/s and 120 m$^3$/s respectively, which trend is completely different in comparison with chlorophyll-$a$ and thus it may not be a significant factor causing difference in chlorophyll-$a$ between two monitoring sites.

Finally, as can be seen from the Fig. 4 (d) and (f) the concentration differences in total dissolved nitrogen and total dissolved phosphorus between the two monitoring sites seems to be similar to that of chlorophyll-$a$. The concentrations of total dissolved nitrogen and total dissolved phosphorus in JU is less than TR in each season. Therefore, with the decrease in concentration of total dissolved phosphorus the chlorophyll-$a$ concentration may increase and then may lead to water contamination events such as the harmful algal bloom (HAB). In addition to this, the concentration of total dissolved nitrogen also affects chlorophyll-$a$ concentration to some extent, which is proved by previous research (Barica et al., 1980). As a result, total dissolved nitrogen and total dissolved phosphorus may play an essential role in the difference of chlorophyll-$a$ between Jubilee River at Pocock’s Bridge (JU) and River Thames at Runnymede (TR).
Figure 4. Seasonal variation in various variables in two sampling sites from March 2009 to February 2013, as (a) water temperature, (b) related to chlorophyll-a concentration, (c) pH, (d) related to total dissolved nitrogen concentration, (e) related to mean daily river discharge, (f) related to total dissolved phosphorous concentration.

The correlations of chlorophyll-a with various variables for River Thames at Runnymede and Jubilee River at Pocock’s bridge are presented in Fig. 5. As can be seen from the Fig. 5, it is noticeable that there is no direct linear relationship between chlorophyll-a concentration and these factors. Therefore, harmful algal bloom is a complex environmental problem, which cannot be resulted by single cause. However, these variables also may be crucial for algal bloom. For instance, Fig. 5a shows that the increase in chlorophyll-a normally occur in water temperature varied between 10°C and 20°C, which is consistent with the temperature required for algal bloom (Kaplan et al., 1989). In addition to this, lower mean daily river discharge might be a necessary condition for algal bloom events (Mitrovic et al., 2003). When the mean daily river
discharge is less than 50 m³/s, an irregular increase in chlorophyll-a concentration
between two sites can be observed in Fig. 5e. As for total dissolved phosphorus
concentration in Fig. 5f, increase in chlorophyll-a may lead to the lower concentration
ranged from 0 to 100 ug/L because algal bloom absorbs large amounts of phosphorus.
In addition, higher concentrations of total dissolved nitrogen do not cause chlorophyll-
a to rise, which is similar to total dissolved phosphorus (Kudela et al., 2008). Fig. 5d
indicates that the rise of chlorophyll-a generally occurs in the range of total dissolved
nitrogen concentrations from 5 mg/L to 8 mg/L. In conclusion, the single cause directly
leading to increase in chlorophyll-a cannot be found based on these data due to the
complexity of algal bloom.
Figure 5. The correlation between chlorophyll-a concentration and various variables at two sites from March 2009 to February 2013, as (a) related to water temperature, (b) related to chlorophyll-a concentration, (c) related to pH, (d) related to total dissolved nitrogen concentration, (e) related to mean daily river discharge, (f) total dissolved phosphorus concentration.

4 Results

Although the nitrogen and phosphorus may lead to the difference in chlorophyll-a concentration between Jubilee River at Pocock’s Bridge (JU) and River Thames at Runnymede (TR) according to the above analysis, the chlorophyll-a concentration is hard to be resulted by a single cause. In general, algal bloom events are caused by a...
variety of factors including pH, water temperature, river flow, nitrogen, phosphorus and more. However, among these factors, nitrogen and phosphorus have attracted the attention of many researchers in recent years (Smith et al., 1990). The reason is that with the growing pressures from ever-increasing population in recent decades, agriculture and industry have to make up the majority of human society, which result a great range of pollution that involve large amounts of nitrate into water system (Bowes et al., 2018). These nitrates from the pollution are closely associated with nitrogen and phosphorus concentrations, leading to eutrophication (Tyrrell et al., 1999) and this eutrophication leads to algal bloom events.

As for future, the governance of algal bloom events will be crucial in the worldwide. Therefore, study of how to prevent algal bloom is crucial for the government. From the above figures, the algal bloom events can be prevented by adjusting the average flow of river system through building up advanced water conservancy project. Furthermore, adjusting pH value using chemical methods is powerful way for the government to control algal bloom events because under aerobic conditions, the phosphate as a main factor leading to harmful algal bloom release increased with the increase of the pH value of water (Seitzinger et al., 1991). In addition to this, as long-term trends in rapid development of agriculture are consistent with increase in phosphorus loading to the river, the algal bloom problem might become a threat to human development. Therefore, the protection of water quality and the control of algal bloom events may take all of us including the government, scientists and public citizen. As for government, the sustainable development policy for water environment may need to be formulated and modified. As to scientists, advanced technology research of how can the root cause of algal bloom events be solved effectively and cheaply is imminent. At the same time, the awareness that is reduction of the emission of agricultural and domestic waste as much as possible should be raised in everyone’s mind and thus the persistent pollution may be reduced.

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