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Wye Salmon Association
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River Wye E. coli Sampling 2022

Summary Report

1.0 Background

Escherichia coli (E. coli) is a type of faecal coliform bacteria that is commonly found in the intestines of animals and humans (Figure 1). Literature supports E. coli identification in surface water as a major indicator of faecal pollution (sewage or animal waste contamination) (Baudišová, 1997). Sewage and animal waste can contain many types of disease-causing organisms (USGS, 2018). Consumption of such organisms may result in severe illness for River Wye users such as swimmers, canoeists, fisherman; particularly children, those with compromised immune systems, and the elderly.

Total coliforms take into consideration all gram-negative, aerobic or *facultative anaerobic* bacteria, as well as E. coli. They are commonly used as an indicator for potable water (alongside E. coli) in the both the United Kingdom and United States; being widely distributed through nature as well as associations to the gastrointestinal tract of warm-blooded animals (USGS, 2018; Environment Agency 2021).

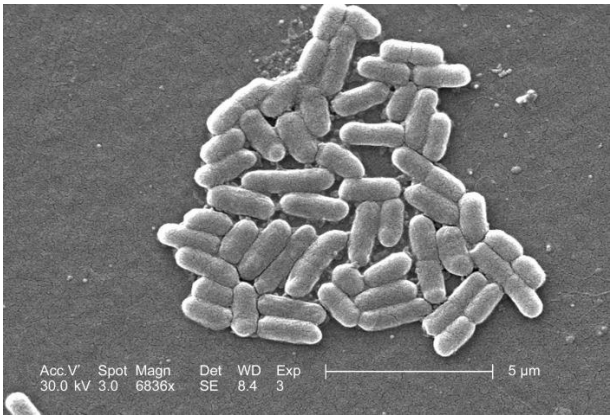

Figure 1. Image of Escherichia coli (E. coli) bacteria under magnification *(Image source is copyright free, 2023)*

2.0 Abstract

The study was devised by the Wye Salmon Association (WSA) to highlight potential bathing water quality issues at sites along the lower River Wye, Afon Gwy. The primary aim of the study was to measure levels of Escherichia Coli (E. coli) in the water and compare to UK/Environment Agency (EA) bathing water standards; with the intent of supplying the results to the local government and water authorities. As shown in figure 2 (a)(b) below, samples were collected above and below Eign (Hereford) and Wyesham (Monmouth) sewage treatments works (STWs) and sent to an accredited, independent laboratory (ALS Environmental) for micro E. coli analysis. A total of 20 samples were recorded and analysed during 2022, with some additional samples unrecorded due laboratory issues. Results were expressed in terms of colony-forming units per millilitre (CFU/ml) of fluid (HSE, 2022). Phosphate samples were also taken at each location using the Hanna HI-713 low range Phosphate checker, with results being recorded via the WSA EpiCollect5 database (titled- Wye Water Quality Monitoring). Data analysis (including univariate normality tests, correlation tests, scatter plots and linear models) using PAST 4.03 and Microsoft Excel was performed on both E.coli and Phosphate results to interpret the data and identify potential trends.

Figure 2. (a) Hereford Sampling Location Map 2022. HERE01 represents the sampling location at Hereford Rowing Club, above the STW (Lat 52.051696, Long -2.721832). HERE02 represents the sampling location near Eign Road, below the STW (Lat 52.048539, Long -2.700193).

Figure 2. (b) Monmouth Sampling Location Map 2022. MON01 represents the sampling location at the concrete groin situated above the STW (Lat 51.804223, Long -2.702329). MON02 represents the sampling location at another concrete groin, this one situated below the STW (Lat 51.799851, Long -2.700164).

3.0 Results

Table 1 provides the results for E.coli and Phosphate Monitoring across the sampling sites during 2022. The first set of results for Hereford samples on 17/12/21 were listed as "N/A" since they could not be taken at the time. There was a 13% increase in the mean results of Hereford samples from above to below the STW (71cfu/100ml for HERE01 and 80cfu/100ml for HERE02). Whilst the increase between mean results for Monmouth samples above to below the STW was 1000% (48cfu/100ml for MON01 and 528cfu/100ml for MON02). Excluding the row dated 17/12/21, the increase in E.coli levels between HERE02 and MON02 (sites below the STW) was 649% (or 8x).

Hereford Sites

An Anderson Darling test for normality was used for E. coli results at HERE01 (above) and HERE02 (below) (Table 1.). It was found that the data was normally distributed ($p>0.05$). This was followed by a paired T test for parametric data which suggested there was no significant difference between the E. coli levels at Hereford sites ($t= 0.27017$, $p=>0.05$).

Monmouth Sites

An Anderson Darling test for normality was used for E. coli results at MON01 (above) and MON02 (below) (Table 1.). It was found that the data was normally distributed ($p>0.05$). A paired T test for parametric data suggested there was no significant difference between the E. coli levels at the Monmouth sites, despite there clearly being a visible difference to the human eye ($t=-2.1599$, $p= >0.05$). However, a p value of 0.08 indicated there was still a difference between the results, but not large enough to be classed as "scientifically significant". Had there have been a larger dataset to analyse, the outcome of this test may have been different. This is also applicable to the t value.

Table 1. WSA E.coli Monitoring 2022 Results

		Location							
		HERE01		HERE02		MON01		MON02	
		Ecoli (cfu/100ml)	Phosphate (mg/l)	Ecoli (cfu/100ml)	Phosphate (mg/l)	Ecoli (cfu/100ml)	Phosphate (mg/l)	Ecoli (cfu/100ml)	Phosphate (mg/l)
Date	17/12/21	N/A	N/A	N/A	N/A	>100	0.1	>100	0.11
	27/02/22	43	0.18	140	0.17	130	0.15	530	0.19
	17/07/22	0	0.00	0	0.03	0	0.00	10	1.29
	11/09/22	30	0.06	40	0.00	2	0.00	>1000	0.51
	04/12/22	210	0.00	140	0.00	<10	0.00	>1000	0.11

***Note – A full list of ALS Environmental results and certifications for E.coli testing is available.*

Overall the results showed a clear difference between E.coli levels at the two Monmouth sites (Figure 3.), with E.coli being significantly higher below the STW (MON02) than above (MON01). However, the same cannot be said for the results recorded at Hereford sites (HERE01/HERE02), where a large distinction between levels of E. coli (and indeed phosphate) above and below the STW could not be made. Notably, E. coli levels were seen to peak during seasons typically associated with rainfall and declined during the seasons associated with dry weather (summer drought of 2022).

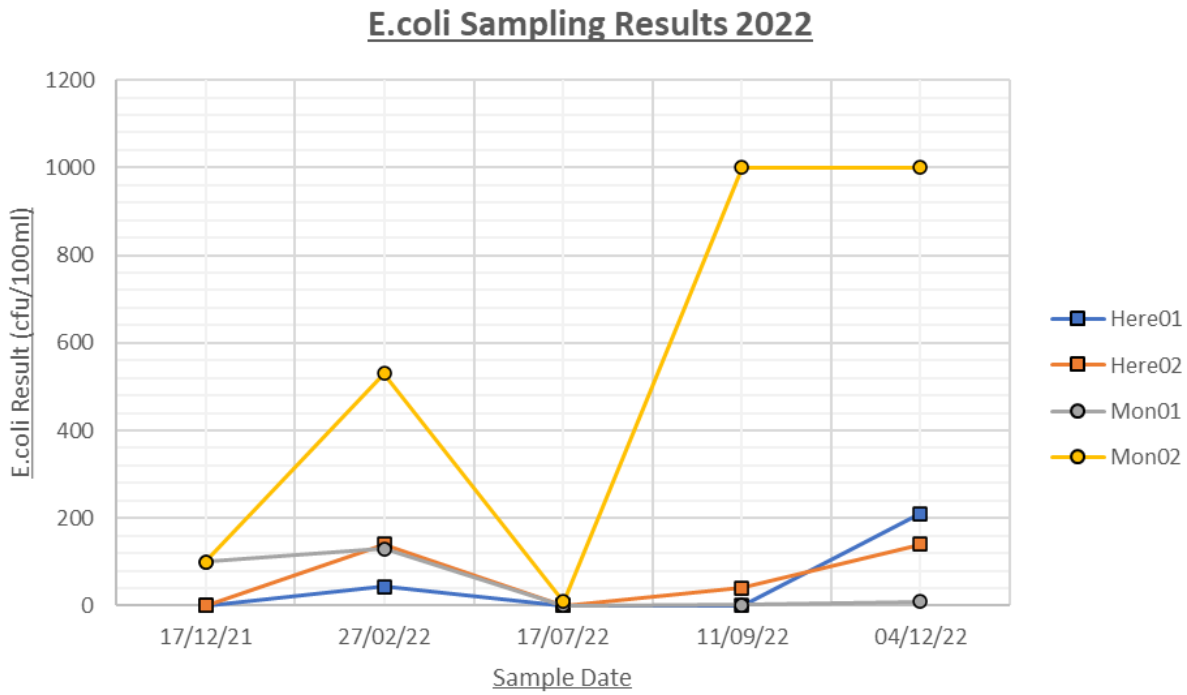

Figure 3. E.coli Sampling Results (cfu/100ml) over time at Monmouth and Hereford sampling locations.

E. coli vs Phosphate

An Anderson Darling test for normality was used for all E. coli and Phosphate results (Table 1.). It was found that the two rows of data were normally distributed ($p>0.05$). This was followed by Pearson's linear correlation, of which the results produced a value of r between 0 and 1. Therefore, there is positive correlation between the data i.e. when one variable changes, the other variable also changes in the same direction. This suggests that increased E. coli levels in the water corresponded with increased Phosphate levels. Furthermore, it can be said, and confirmed mathematically, that sites with low phosphate had low E. coli and vice versa.

A three-point average scatter plot (figure 4.) using the data on logarithmic scales was produced using PAST analytical software to confirm and visualise these trends. Additionally, an ordinary LS linear fit model was generated to further display the relationship between the two variables (figure 5). Positive correlation was displayed, however a low correlation coefficient and corresponding statistics proved this relationship to be not particularly strong. A larger dataset could produce stronger statistics in support of this argument.

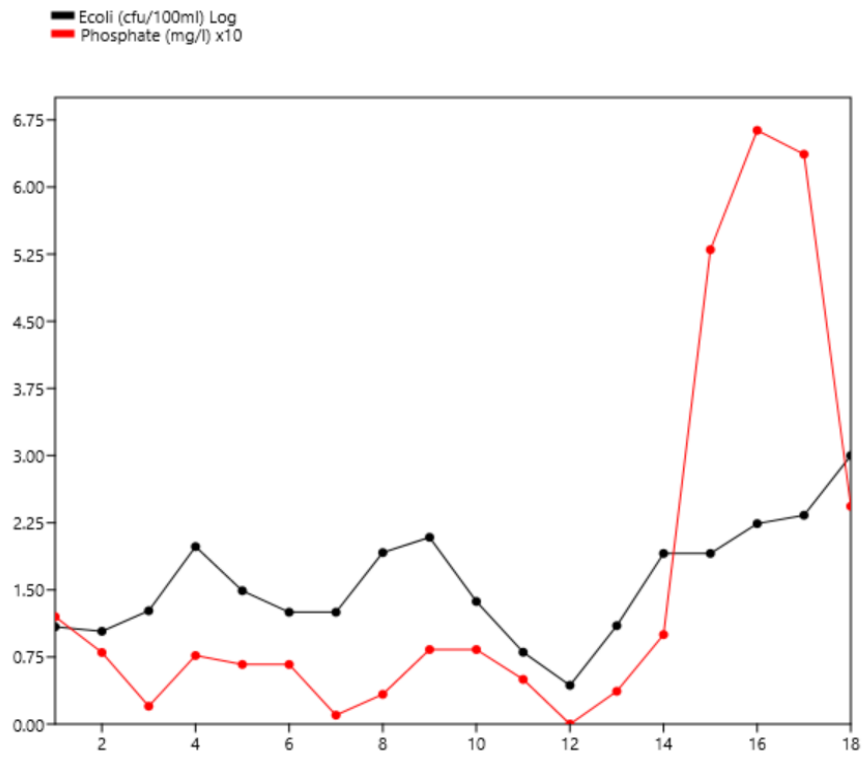

Figure 4. E.coli vs Phosphate. A three-point average scatter plot using logarithmic scales for E.coli and amplified scales for Phosphate (PAST 4.03).

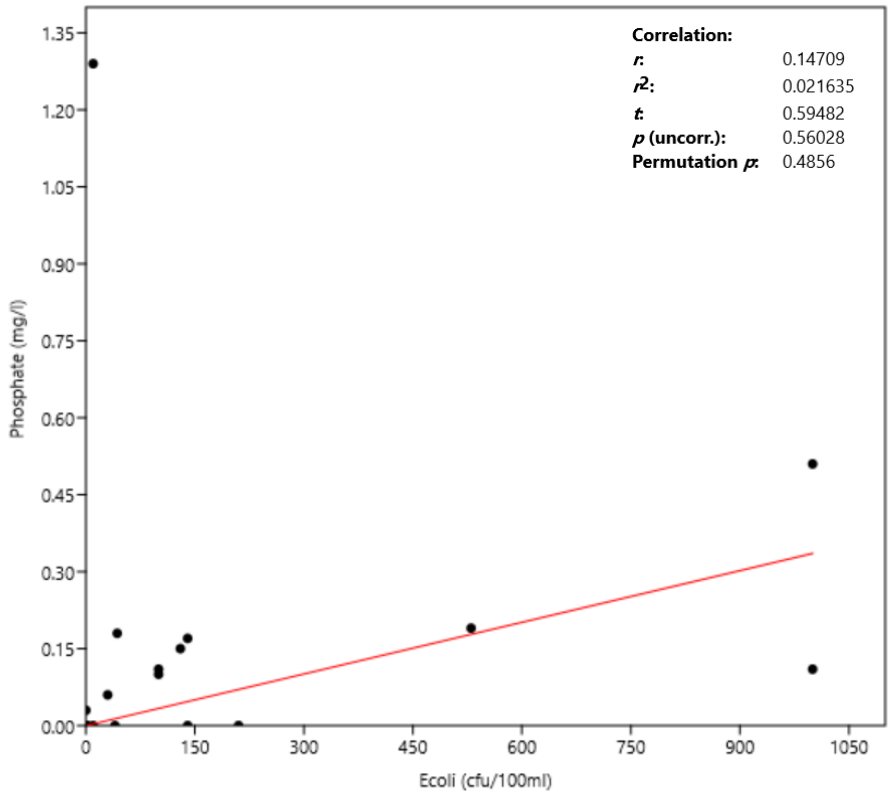

Figure 5. E.coli vs Phosphate. Ordinary LS Linear Fit Model (PAST 4.03). *An r vale of 0.14 indicates some correlation between the variables.*

4.0 Discussion & Conclusion

The study showed that E. coli levels below the STW's were higher than above. This was particularly the case at Monmouth. **Wyesham** works displayed consistently high readings below its outfall (taken at the appropriate mixing distance) that, at times, were **unsafe for public bathing**. On two out of five occasions, the E.coli and Total Coliform data **exceeded levels of 1000cfu/100ml below the works;** thus ranks as poor bathing water quality under EA classification (EA, 2021). On another occasion it exceeded 500cfu/100ml; ranking as sufficient bather water quality. However, Hereford results for E.coli (not total coliforms which were also particularly high) generally suggested water quality was suitable for bathing.

Although it was previously hypothesised there would be positive correlation between Phosphate and E. coli variables, only the three out of the five sites at Monmouth initially proved this to be correct. However, statistical analysis later confirmed there was an **overall positive correlation displayed between the two variables.** As they were present together in high quantities, and both being associated with faecal pollution (Baudišová, 1997; Mamera et al, 2022), it was accepted that the phosphate and E.coli **pollutants in Monmouth originated from the same source** (the Wyesham STW).

Further research into the high E. coli and Total Coliform results at the Wyesham works, revealed that there is neither a disinfection unit for bacteria, nor a phosphate scrubber installed. However, at Hereford there is believed to be such treatment. This suggests the **water authority do not have the appropriate measures to treat the water at Monmouth** so that it is safe for public exposure. Discussion with Natural Resources Wales (NRW) with regard the Wyesham works, suggested *Dwr Cymru are mostly compliant within their permits to discharge treated effluent*. However, WSA sources suggest their combined sewer overflows or outfalls (CSOs), are often opened during periods of increased pressure (i.e. heavy rainfall). Data from The Rivers Trust sewage map suggested that the **Monmouth CSO regularly spilled during 2021 (724 hours)**. If 2022 was a similar affair, this could well have been the primary cause for increased E.coli and Phosphate levels downstream. It therefore came as no surprise that **E.coli and Phosphate levels were highest during rainy seasons than dry seasons**. Further suggesting that inclement weather corresponds with an inability to treat large volumes of effluent for bacteria and phosphate, before it is discharged into the river system.

Some ALS lab results produced readings of "> - greater than X" or "< - Less than X" which made them difficult to interpret and perform analysis. For the example, with results >1000 it was uncertain as to how large the true figure might have been; as some studies of E.coli levels in surface waters have produced values into the tens of thousands (Frankenberger, 2023). The same can be said for values around >100, where values exceeding this figure are unsafe for human consumption. If a further study was to be conducted following the nature of this report, it must to ensure results include specific values as opposed to <> assumptions. Data must also be recorded over weekly timescales to produce more accurate interpretation and statistical analysis (unavailable to WSA due to resources). However, if further research did occur, it is without doubt it would greater magnify further water quality concerns in the region, as those highlighted above.

5.0 References

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