Microbial Water Quality in the Context of Urban Service Water Usage – Regulations, Barriers, and Solution Approaches

Qualité microbienne de l'eau dans le contexte de l'utilisation de l'eau dans les services urbains – Réglementations, obstacles et solutions possibles

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RÉSUMÉ

Le changement climatique, avec des périodes de sécheresse plus longues et une surchauffe urbaine, augmente la pression sur les ressources en eau urbaines et souligne l'importance de sources d'eau alternatives. Les cours d'eau captés dans les égouts pourraient en constituer une, mais des incertitudes subsistent quant à leur qualité microbiologique et à leur utilisation légale. L'influence des méthodes d'analyse sur l'évaluation de la qualité n'est également pas claire. Cette étude examine donc la qualité microbiologique de cours d'eau urbains intégrés au réseau d'égouts, à l'aide de méthodes établies basées sur des indicateurs fécaux (*E. Coli*, entérocoques) et d'un suivi innovant des sources microbiennes. À partir des résultats, l'utilisation légale a été déterminée pour trois cas d'utilisation : « irrigation des espaces verts urbains », « irrigation dans le jardinage urbain » et « utilisation pour des cours d'eau artificiels ». L'analyse visait aussi à déterminer si la contamination fécale provenait de sources humaines récentes. Les résultats montrent que les limites légales pour *E. Coli* et les entérocoques sont dépassées dans les trois cas d'utilisation, bien que le traçage des sources n'ait révélé aucune preuve de contamination humaine. Cela suggère que les méthodes d'évaluation et la législation doivent être adaptées aux progrès scientifiques afin d'intégrer de façon plus durable les ressources alternatives dans les stratégies de gestion de l'eau urbaine.

ABSTRACT

Climate change, characterised by longer periods of drought and urban overheating, intensifies the pressure on urban water resources and underscores the importance of alternative water sources. In-sewer captured streams could be a valuable water source, but uncertainties remain regarding their microbiological water quality and the resulting legal usability. Furthermore, the influence of analytical methods on water quality assessments is unclear. This study, therefore, examines the microbiological water quality of urban streams, which are integrated into the sewer system, using established faecal indicator-based methods (*E. Coli* and Enterococci) and innovative microbial source tracking. From the analysis results, the legal usability of the urban streams was derived for three use cases: “irrigation of urban greenery”, “irrigation in urban gardening”, and “utilisation for artificial streams”, and it was analysed whether the faecal contamination is due to recent human contamination. The analyses show that the legal limits for *E. Coli* and Enterococci in the urban streams are exceeded in all three use cases, despite microbial source tracking revealing no evidence of human contamination. The results suggest that existing assessment methods and legislation require adaptation to scientific advances in order to integrate alternative water resources more sustainably into urban water management strategies and meet the requirements of resource-efficient urban water management.

KEYWORDS

Faecal indicator bacteria, in-sewer captured streams, microbial source tracking, urban water resources, water quality standards

1 INTRODUCTION

Changes in the global climate and hydrosystem are predicted to significantly increase hydrological extremes, such as heavy precipitation events and prolonged droughts. Both events pose enormous challenges for urban areas in terms of water management (Borah, 2025). The European Union (EU) has thus introduced a range of policy instruments to support sustainable water use and urban resilience through the implementation of Blue-Green Infrastructure (BGI), recognising its crucial role in providing vital ecosystem services, including stormwater retention, improved water quality, biodiversity enhancement, and urban heat reduction. To reduce pressure on urban drinking water resources, a differentiated assessment of the available water resources in the city is necessary. While the use of stormwater is gaining attention in this context, the use of piped urban streams has been largely overlooked to date, despite their potentially superior water quality compared to stormwater. Against this background, the research project ProBACH (FFG, 2021) is investigating the possibilities of utilising piped streams for urban service water applications.

However, such alternative water resources can only be utilised if their use for the intended purpose is classified as harmless to human health (Voulvoulis, 2018). To this end, the EU has introduced strict regulatory frameworks to assess potential health risks, most notably Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the quality of bathing water (European Commission, 2006). The presented study thus aims to assess urban stream water quality against the applicable legal background and its legal usability for urban service water applications in the urban environment for three use cases: 1) irrigation of urban greenery, 2) irrigation in urban gardening, and 3) utilisation for artificial streams.

2 METHODS

2.1 Sampling Site

To assess urban stream water quality and legal usability, water samples were taken from four Viennese Forest streams – namely the Alserbach, Eckbach, Kräuterbach and Schreiberbach – located Northwest of Vienna, Austria. These streams previously fed into the Danube, but their historic utilisation as open sewers led to their integration into the combined sewer network, where they remain until today. For the purpose of this study, samples were taken before the streams entered the sewage system. The course of the streams examined and the location of the sampling points are depicted in Figure 1.

Sampling took place between June 27, 2024, and October 21, 2024, with each stream sampled once on three consecutive days. Sampling was always carried out in dry weather to rule out recent contamination from surface runoff.

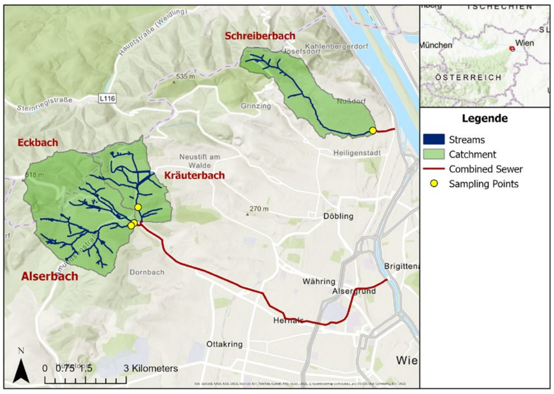

Figure 1: Overview of sampling site. The map illustrates the sampled Viennese Forest streams (blue), including their delineated catchments (green), the corresponding sampling points (yellow) and their underground course as part of the combined sewer system (red). Source: OpenStreetMap.

2.2 Laboratory analysis

Microbiological water quality analysis was conducted in accordance with the standards and protocols outlined in the relevant legal texts. Internationally established standards were applied, which are recognised worldwide as the benchmark for the microbiological analysis of water samples. Specifically, *E. Coli* was detected in accordance with ÖNORM EN ISO 9308-1:2017 10 15 (Austrian Standards International, 2017) and Enterococci in accordance with ÖNORM EN ISO 7899-2:2000 11 01 (Austrian Standards International, 2000).

As the use of faecal indicator bacteria (FIB) to assess microbial water quality has long been questioned in the scientific community, microbial source tracking (MST) has been used as an additional analysis method, allowing for more precise insights into the source of faecal contamination through the detection of host-specific markers in environmental DNA samples. In this case, MST was performed to analyse the presence of CrAssphage, a marker typically indicative of human faecal contamination. The analysis of the CrAssphage bacteriophage was performed according to the methodology of Sabar et al. (2022).

3 RESULTS

3.1 Laboratory results

All results and statistical evaluations of the cultivation-based analysis of FIB are presented in Table 3.

Tableau 1: Results of the microbiological water quality analysis of the urban stream water according to ÖNORM EN ISO 9308-1 and ÖNORM EN ISO 7899-2 (rounded to whole numbers, own illustration)

Indicator	Stream	Mean (n=3) [CFU/100 ml]	Standard deviation [CFU/100 ml]	Coefficient of variation [%]
E. Coli	Alserbach	1817	641	61
	Eckbach	1100	153	24
	Kräuterbach	1517	550	63
	Schreiberbach	2067	974	82
Entero-cocci	Alserbach	393	215	95
	Eckbach	607	169	48
	Kräuterbach	1338	1081	140
	Schreiber-bach	5450	2079	66

The mean *E. Coli* concentration varies between the streams, ranging from 1,100 colony-forming units (CFU) per 100 ml in the Eckbach to 2,067 CFU/100 ml in the Schreiberbach. The Schreiberbach similarly exhibited the highest mean value for Enterococci, at 5,450 CFU/100 ml, whereas the lowest mean value was found in the Alserbach, with a concentration of 393 CFU/100 ml.

The presence of the bacteriophage CrAssphage, which would indicate human contamination, was below the detection limit in all four samples. However, the positive control showed a clearly measurable CrAssphage concentration of 363,273 genome equivalents on average relative to the standard (copies/µl), which rules out measurement error and confirms the reliability of the measurement.

3.2 Assessment of use cases

Legal documents applicable in Austria and Germany were identified for each of the three use cases through a comprehensive literature review, prior to their application and comparison with the microbial water quality results observed in the Viennese Forest streams. The review revealed that rule sheet 407 from the Austrian Water and Waste Management Association (ÖWAV) and the German DIN 19650:1999-2 (DIN 19650:1999-2, 1999) are best suited to assess the usability of stream water for the use cases “irrigation of urban greenery” and “irrigation in urban gardening”. Considering the direct exposure to the water desired in the use case “utilisation for artificial streams”, this use case was assessed according to the Austrian Bathing Water Directive (BGBI. Nr. 59/2008). Comparison of the measured concentrations of FIB with the aforementioned regulatory guidelines indicated that all four streams would exceed the legal concentration threshold for the use case « irrigation of urban greenery », as the *E. Coli* and Enterococci concentrations are never simultaneously below their respective limits (see Fig. 2). Similarly, in the case of urban gardening, the average values for *E. Coli* and Enterococci exceed the limits for suitability classes 1 and 2, thus ruling out their use for growing fruit and vegetables for fresh consumption in large parts of the area. Only the Alserbach would be permitted for limited use as service water in suitability class 3 (fresh consumption up to two weeks before harvest).

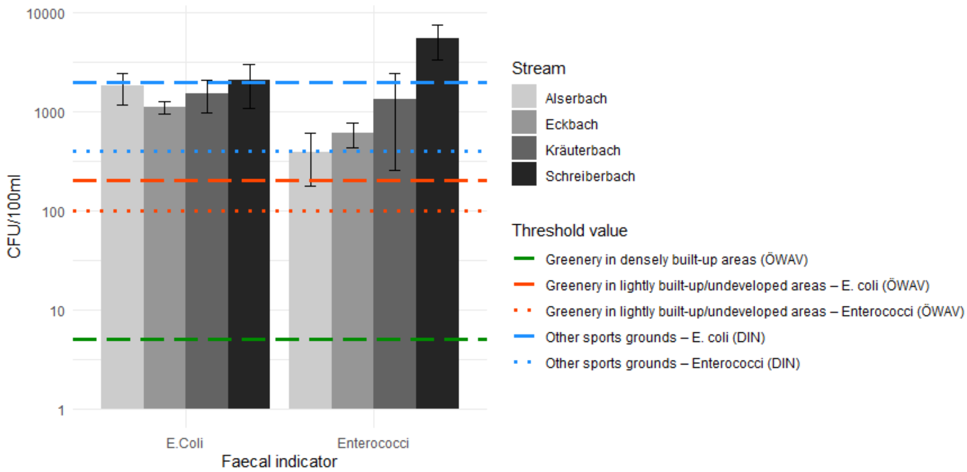

Figure 2: Microbiological threshold values for the irrigation of urban greenery according to ÖWAV RB 407(2016) and DIN 19650:1999-2 (DIN e.V., 1999) applied to the sampling results from the Viennese Forest streams (own illustration).

Assessing the use case "utilisation for artificial streams" through the lens of the bathing water directive (Federal Ministry of Health, 2009) shows that the water quality of these streams would have to be classified as 'poor' and would therefore not be available for this use case either.

4 DISCUSSION & CONCLUSION

A comparison of the water quality of the Vienna Forest streams with the requirements for different uses in urban areas has shown that, according to current guidelines and regulations, the Vienna Forest streams must generally be classified as unsuitable for use in urban areas. The analysis shows that for the three exemplary use cases – irrigation of urban green spaces, irrigation in urban gardening and use for artificial streams – the water quality required by law is in many cases higher than the water quality attributed to the streams in the Vienna Forest according to current methods. However, the results of the MST analysis indicate that there is no human contamination. Rather, it seems plausible that the detected *E. Coli* concentrations do not indicate recent faecal contamination of the water, but rather the presence of autochthonous bacterial populations in the Vienna Forest streams. This suggests that the current use of faecal indicators to assess microbiological water quality may not accurately reflect the actual risks posed by water resources. The resulting discrepancy between legal requirements and the current state of scientific knowledge might exclude potentially valuable water sources from sustainable use and, in particular, from efficient urban industrial water use and raise the question of the extent to which existing directives and regulations, in particular their methodology, are still compatible with current scientific findings.

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